PACIFIC COAST GROUNDFISH FISHERY MANAGEMENT PLAN

FOR THE CALIFORNIA, OREGON, AND WASHINGTON GROUNDFISH FISHERY

APPENDIX B
PART 2

GROUNDFISH ESSENTIAL FISH HABITAT AND LIFE HISTORY DESCRIPTIONS, HABITAT USE DATABASE DESCRIPTION, AND HABITAT SUITABILITY PROBABILITY INFORMATION

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LIFE HISTORIES, GEOGRAPHICAL DISTRIBUTIONS, AND HABITAT ASSOCIATIONS OF PACIFIC COAST GROUNDFISH SPECIES

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1. INTRODUCTION

The 1996 Sustainable Fisheries Act significantly amended the Magnuson-Stevens Act by requiring the Fishery Management Councils and the U.S. Secretary of Commerce, through the National Marine Fisheries Service (NMFS), to include provisions in fisheries management plans that describe, identify, conserve, and enhance essential fish habitat (EFH).

The appendix was originally prepared in 2005 for Amendment 19 to the groundfish fishery management plant (FMP) by a team led by Cyreis Schmitt (at the time, affiliated with the Northwest Fisheries Science Center), and the primary sources of information for the life history descriptions and habitat associations were both published reports and gray literature. Geographic information system (GIS) maps of species and life stage distributions generated in the format of ESRI ArcView GIS software were included. The appendix was intended to be a "living" document that could be changed as new information on particular fish species arose, without using the cumbersome FMP amendment process.

Much of the information about the life histories of groundfish species was compiled in 2005 by conducting literature searches using the Cambridge Scientific Abstracts Internet Database Service, and by reviewing recently completed summary documents, including the California Department of Fish and Game's Nearshore Fishery Management, a draft nearshore fishes synopsis in a section of the Oregon Department of Fish and Wildlife's Nearshore Fisheries Management Plan, and the book *The Rockfishes of the Northeast Pacific* by Love, et al. (2002).

The EFH regulations state that the Councils and NMFS should periodically review and revise the EFH components of FMPs, at least once every 5 years. Such review should include information regarding the description and identification of EFH, threats to EFH from fishing and non-fishing activities, and measures that could be taken to minimize those threats. In response to this requirement for periodic review, the updated life history descriptions are included in this report.

As part of a subsequent synthesis of new information on groundfish EFH (PFMC 2012), a new literature review was conducted by Dr. Joe Bizzarro, under contract with NMFS. Dr. Bizzarro's review was limited in scope and focused on a comprehensive updates of four FMP flatfish species (arrowtooth flounder, Dover sole, English sole, petrale sole) with general updates on other flatfishes, rockfishes, other rockfishes, roundfishes (gadiform and scorpaeniform), and elasmobranchs. These updates have been added to this appendix at the end of the relevant sections for each species or species group. Most of the available information, and certainly the most comprehensive, was obtained from directed studies. However, fishery–independent surveys provided general information on distribution and abundance patterns along the U.S. West Coast. More new spatial information was available when compared to trophic information, a situation that reflects the relative amount of scientific attention as well as the substantial contribution of newly published fishery–independent survey data.

The suite of species included in this version of the appendix differs from that in the 2005 version for two reasons. First, several species were designated as ecosystem component species by the Council in 2016, and have, therefore, been removed from this version. Second, several species of rockfishes that were not in the original version have since been found to occur within the geographic range of the groundfish FMP and are included in this appendix. Most, but not all, of these rockfishes are generally small, cryptic species that are not targeted by the fishery and have a paucity of habitat data.

This appendix contains EFH/life history descriptions for 80 of the 92 species in the plan. Information was insufficient to describe EFH for the remaining 12 species, although the information that was available was summarized in the general updates described above.

To organize the EFH/life history descriptions, the groundfish species were divided into sections based on taxonomic group, then sequenced alphabetically according to common name. A draft of each section was submitted to one or more experts on the respective species (see Acknowledgements), and their comments, corrections, additions, and changes were incorporated into the document.

Methane seeps. The role of methane seeps as EFH for groundfishes have recently garnered considerable scientific and public attention, as reflected in the number of public comments on the subject when the Council was considering Amendment 28 to the groundfish FMP. Recent surveys along the West Coast have identified a significant number of seeps (Embley, et al. 2017), and it is expected that many more will be found on future surveys. Although the precise relationships between methane seeps and Pacific Coast groundfishes are not well understood, the scientific literature suggests that these relationships are important.

The anaerobic oxidation of methane by bacteria at methane seeps increases the alkalinity in the sediment, leading to the precipitation of carbonate rock (Levin, et al. 2016). These areas of carbonate rock can be expansive and provide habitat for a variety of chemosynthetic and heterotrophic microbes and fauna, including siboglinid tube worm (Marlow, et al. 2014; Case, et al. 2015; Levin, et al. 2015). When seepage ceases, the carbonates attract diverse assemblages of background species, including deep-sea corals and sponges (Cordes, et al. 2008; Bowden, et al, 2013; Quattrini, et al. 2015). Therefore, methane seeps contribute to the formation of two of the Council's priority habitats for groundfishes: hard substrate and habitat-forming invertebrates.

The carbonates and empty siboglinid worm tubes have been observed to provide attachment points for egg capsules of invertebrates and fishes such as sculpins, sharks, rays, and skates (Drazen, et al 2003; Treude, et al. 2011). Grupe, et al (2015) found a variety of biogenic microhabitats near the Del Mar Seep off California, including microbial precipitated carbonate boulders, bacterial mats, and beds of vesicomyid clams, tube worms, and foraminifera. Several studies have documented groundfish associations with seeps and these habitats, including commercially important groundfish species. Sablefish (*Anoplopoma fimbria*) was the most abundant large demersal megafauna around the seeps surveyed by Levin, et al. (2003). The sablefish were observed stirring up and grabbing mouthfuls of sediment, suggestion that they consume bottom fauna at the seeps. Grupe, et al (2015) observed that densities of two commercially important council-managed species, longspine thornyhead (*Sebastolobus altivelis*) and Dover sole (*Microstomus pacificus*) increased in the center and periphery of the Del Mar Seep relative to off-seep transects. Longspine thornyhead was twice as abundant near the most active seep microhabitats when compared to habitats away from the seep. Seabrook, et al. 2019) provided the first evidence that a commercially harvested species, the tanner crab (*Chionoectes tanneri*) assimilating the chemosynthetic production from a seep off the coast of British Columbia. Similar associations of commercially-important fishes have been found elsewhere. For example, greater densities of the Patagonian toothfish were found at seeps than at other locations (Sellanes, et al. 2012). Baco, et al. (2010) report that commercial fisherman on the

Hikurangi Margin of New Zealand directly targeted demersal fishes associated with both active and inactive seeps.

In addition to directly providing a unique type of habitat that may be used by groundfishes, methane seeps are also recognized to interact with surrounding exosystems on the sea floor and in the water column, influencine elemental cyclicing and energy flux, habitat use, trophic interactions, and connectivity beyond the footprint of the seep itself (Levin, et al. 2016).

As the interest in methane seeps is a relatively recent development, they were not identified as groundfish habitat when the EFH descriptions were compiled for Amendment 19. However, it is expected that when these EFH descriptions are updated in the future, their role as EFH will be better understood and can be incorporated into the species-specific EFH descriptions. In the meantime, it is important to recognize that methane seeps likely represent an important type of habitat for, and important habitat-forming processes to, groundfishes and the fisheries they support. Consequently, the Council has taken the precautionary measure of designating methane seeps as EFH for Pacific Coast groundfishes.

Table 1. Common and scientific names of groundfish species managed under the Pacific Coast Groundfish Fishery Management Plan as of August 2016. * indicates a species that lacks a separate EFH/life history description.

Common Name	**Scientific Name**
FLATFISH (12 spp.)	
Arrowtooth Flounder	*Atheresthes stomias*
Butter Sole	*Isopsetta isolepis*
Curlfin Sole	*Pleuronichthys decurrens*
Dover Sole	*Microstomus pacificus*
English Sole	*Parophrys vetulus*
Flathead Sole	*Hippoglossoides elassodon*
Pacific Sanddab	*Citharichthys sordidus*
Petrale Sole	*Eopsetta jordani*
Rex Sole	*Glyptocephalus zachirus*
Sand Sole	*Psettichthys melanostictus*
Rock Sole	*Lepidopsetta bilineata*
Starry Flounder	*Platichthys stellatus*
ROCKFISH [a/] (70 spp.)	
Aurora Rockfish	*Sebastes aurora*
Bank Rockfish	*S. rufus*
Black Rockfish	*S. melanops*
Black-And-Yellow Rockfish	*S. chrysomelas*
Blackgill Rockfish	*S. melanostomus*
Blackspotted Rockfish*	*S. melanostictus*
Blue Rockfish	*S. mystinus*
Bocaccio	*S. paucispinis*
Bronzespotted Rockfish	*S. gilli*
Brown Rockfish	*S. auriculatus*
Calico Rockfish	*S. dallii*
California scorpionfish	*Scorpaena guttata*
Canary Rockfish	*S. pinniger*
Chameleon Rockfish	*S. phillipsi*
Chilipepper	*S. goodei*
China Rockfish	*S. nebulosus*
Copper Rockfish	*S. caurinus*
Cowcod	*S. levis*
Darkblotched Rockfish	*S. crameri*
Deacon Rockfish*	*S. diaconus*
Dusky Rockfish	*S. variabilis*
Dwarf-Red Rockfish*	*S. rufinanus*
Flag Rockfish	*S. rubrivinctus*
Freckled Rockfish*	*S. lentiginosus*
Gopher Rockfish	*S. carnatus*
Grass Rockfish	*S. rastrelliger*
Greenblotched Rockfish	*S. rosenblatti*

Common Name	**Scientific Name**
Greenspotted Rockfish	*S. chlorostictus*
Greenstriped Rockfish	*S. elongatus*
Halfbanded Rockfish*	*S. semicinctus*
Harlequin Rockfish	*S. variegatus*
Honeycomb Rockfish	*S. umbrosus*
Kelp Rockfish	*S. atrovirens*
Longspine Thornyhead	*Sebastolobus altivelis*
Mexican Rockfish	*S. macdonaldi*
Olive Rockfish	*S. serranoides*
Pacific Ocean Perch	*S. alutus*
Pink Rockfish	*S. eos*
Pinkrose Rockfish*	*S. simulator*
Puget Sound Rockfish	*S. emphaeus*
Pygmy Rockfish	*S. wilsoni*
Quillback Rockfish	*S. maliger*
Rainbow scorpionfish*	*Scorpaenodes xyris*
Redbanded Rockfish	*S. babcocki*
Redstripe Rockfish	*S. proriger*
Rosethorn Rockfish	*S. helvomaculatus*
Rosy Rockfish	*S. rosaceus*
Rougheye Rockfish	*S. aleutianus*
Semaphore Rockfish*	*S. melanosema*
Sharpchin Rockfish	*S. zacentrus*
Shortbelly Rockfish	*S. jordani*
Shortraker Rockfish	*S. borealis*
Shortspine Thornyhead	*Sebastolobus alascanus*
Silvergray Rockfish	*S. brevispinis*
Speckled Rockfish	*S. ovalis*
Splitnose Rockfish	*S. diploproa*
Squarespot Rockfish	*S. hopkinsi*
Starry Rockfish	*S. constellatus*
Stone Scorpionfish*	*Scorpaena mystes*
Stripetail Rockfish	*S. saxicola*
Sunset Rockfish*	*S. crocotulus*
Swordspine Rockfish*	*S. ensifer*
Tiger Rockfish	*S. nigrocinctus*
Treefish	*S. serriceps*
Vermilion Rockfish	*S. miniatus*
Whitespotted Rockfish*	*S. moseri*
Widow Rockfish	*S. entomelas*
Yelloweye Rockfish	*S. ruberrimus*
Yellowmouth Rockfish	*S. reedi*
Yellowtail Rockfish	*S. flavidus*
ROUNDFISH (6 spp.)	
Cabezon	*Scorpaenichthys marmoratus*

Common Name	**Scientific Name**
Kelp Greenling	*Hexagrammos decagrammus*
Lingcod	*Ophiodon elongatus*
Pacific Cod	*Gadus macrocephalus*
Pacific Whiting (Hake)	*Merluccius productus*
Sablefish	*Anoplopoma fimbria*
ELASMOBRANCHS (4 spp.)	
Big Skate	*Beringraja (Raja) binoculata*
Leopard Shark	*Triakis semifasciata*
Longnose Skate	*Raja rhina*
Pacific Spiny Dogfish	*Squalus suckleyi*

[a/] The category “rockfish” includes all genera and species of the family Scorpaenidae, even if not listed, that occur in the Washington, Oregon, and California area. The Scorpaenidae genera are *Sebastes, Scorpaena, Sebastolobus, and Scorpaenodes*.

2. HABITAT USE DATABASE

The Habitat Use Database (HUD) was developed by NMFS Northwest Fisheries Science Center (NWFSC) scientists as part of the 2005 Pacific Coast Groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005). Specifically, the HUD was designed to address the need for habitat-use analysis supporting groundfish EFH, habitat areas of particular concern (HAPC), and fishing and non-fishing impacts components of the EFH EIS. The 2005 database captured information on habitat use by Pacific Coast groundfishes covered under the FMP as documented in the updated EFH/life history descriptions found in this appendix. The groundfish EFH/life history descriptions are the product of a literature review that collected and organized information on the range, habitat, migrations and movements, reproduction, growth and development, and trophic interactions for each of the fishery management unit (FMU) species by life stage.

Thus, the scope of the 2005 HUD was narrow and specific, well integrated with the Amendment 19 EFH EIS, and provided a flexible and logically structured information base. The HUD provided information on habitat associations to the Habitat Suitability Probability (HSP) model (NMFS 2005). The HUD also provided distribution data (depth and latitude range) to the HSP model when fishery-independent distribution data from the West Coast Groundifsh Bottom Trawl Survey (WCGBTS) were insufficient for modeling.

The NWFSC made data updates and amendments, platform changes, and taxonomic additions to the database over the period from 2006 to present. Relevant new spatial and trophic information published between 2004 and 2011 was compiled for 91 species of groundfish during Phase 1 of the 5-year review of groundfish EFH. This information was then summarized for selected individual species and species groups in the Phase 1 report (PFMC 2012), and was used to update the EFH descriptions (Section X) and is being used to update the HUD. Similar to the 2005 EFH EIS, the revised HUD was then used to update the HSP models for a subset of FMP species where catch or fishery independent data are insufficient for modeling.

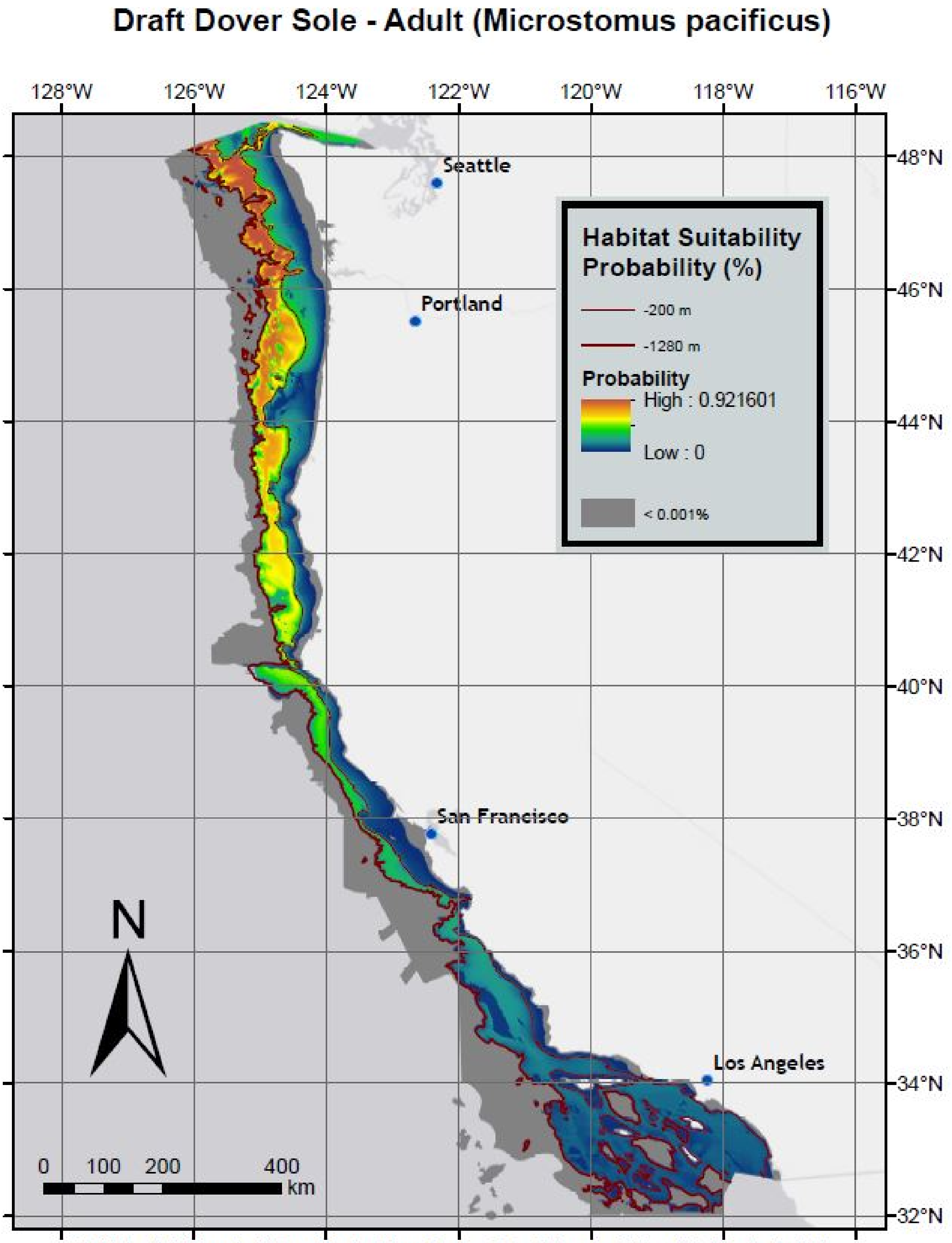
When the update is complete, the HUD will be curated by the NWFSC and housed on the NWFSC Fishery Regulation Assessment Model (FRAM) Data Warehouse (https://www.nwfsc.noaa.gov/data/map). The Data Warehouse will provide users with online tools to download or query the database.

3. HABITAT SUITABILITY PROBABILITY MODEL

A habitat suitability probability (HSP) model, termed the “EFH Model”, was developed in 2004 by NMFS and outside contractors (MRAG Americas Inc., et al. 2004). The model incorporated four basic variables (seafloor substratum type, depth, latitude, and location) to describe and identify EFH for each life stage of the 82 federally managed groundfishes and presents this information graphically as an HSP profile and map. Based on the observed distribution of a groundfish species/life–stage in the WCGBTS and HUD in relation to the input variables, locations along the West Coast were assigned a suitability value between 0 and 100 percent in the creation of the HSP profile. These scores and their differences among locations were used to develop a proxy for the areas that can be regarded as “essential.” The EFH Model provided spatially explicit HSP estimates for 160 of 328 groundfish species/life stage combinations, including the adults of all FMU species (PFMC 2011a). The remaining 168 species/life stages were not completed because of insufficient data. In 2005, when the HSPs of all modeled species/life stages were combined, all waters and bottom areas at depths less than 3,500 m were determined to be groundfish EFH.

The data used to determine HSP values exhibited some biases and limitations, and have been subject to continued refinement. Among the primary concerns regarding the validity of model outputs are the use of disparate data sets and data of variable quality. In response to these concerns and the significant amounts of new spatial information compiled during the Phase 1 review, the model was revised by the Oregon State University’s Active Tectonics and Seafloor Mapping Laboratory, through support by NOAA Fisheries, and, when the HUD update is complete, will be rerun for the adults of as many of the 92 species as possible, given the available data. Otherwise it will be run for juveniles and adults combined. These revisions are expected to improve the predictive capabilities of the HSP model.

The HSP values and maps for each species/life stage combination will be available online at the NWFSC FRAM Data Warehouse (https://www.nwfsc.noaa.gov/data/map). Figures 1 shows a draft of the HSP map for adult Dover sole as an example.



Habitat suitability probability map output from Oregon State University EFH model. Species/habitat association for substrate derived from NMFS Habitat Use Database.

Service Layer Credits: Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community

Figure 1. Draft HSP map for adult Dover sole, *Microstomus pacificus*.

4. MAJOR PREY TAXA

The regulations implementing the EFH provisions of the Magnuson-Stevens Fishery Conservation and Management Act (50 CFR 600) state that FMPs should list the major prey species for the fisheries in the fishery management unit and discuss the location of prey species' habitat [50 CFR 600.815(a)(7)]. Although the FMP contained information on groundfish prey species, there was no attempt to identify the major prey taxa. A preliminary attempt to identify the major prey of groundfishes was undertaken by the Essential Fish Habitat Review Committee (PFMC 2012). A more detailed analysis of major prey species was begun by NMFS (2013), and developed further by Bizzarro, et al. (2017), the results of which are summarized here. The reader is directed to Bizzarro, et al. (2017) for more detail.

Bizzarro, et al. conducted a meta-analysis of the feeding ecology of 18 important species from three functional groups (Table 2). Forty-seven prey categories (species or family) were grouped into 14 generalized categories (e.g., fishes, crustaceans, molluscs) for the diet composition analysis. When these 14 prey categories were analyzed, fishes represented the dominant prey taxon, making up almost one third of the diet of the selected groundfishes by weight or volume. These were followed by shrimps, crabs, and euphausiids. The analysis indicated that species-specific differences were the primary source of dietary variability, more so than life stage or functional group differences. The analysis showed that most species of groundfishes prey more heavily on fishes as they mature. Foraging habitats differed significantly among functional (benthic, demersal, pelagic) and taxonomic (flatfishes, rockfishes, roundfishes, and elasmobranchs) groups.

The EFH implementing regulations are silent on what constitutes a "major prey species", and syntheses of groundfish food habits literature are limited and highly generalized. Bizzarro, et al. (2017) developed a Major Prey Index (MPI) using five separate metrics of diet for the 18 species of groundfishes: 1) mean percent diet composition; 2) median percent diet composition; 3) prey-specific abundance; 4) minimum diet contribution; and 5) percent frequency of occurrence. These metrics were chosen because they are commonly used to summarize diet composition data and complement each other in collectively estimating prey importance. Highly correlated metrics were removed prior to analysis. Available data were insufficient to identify major prey to the species level referred to in the EFH regulations; therefore, the MPI identified "major prey taxa" for groundfishes.

The MPI for each prey taxon and the foraging habitat where they are found are shown in Table 3. Bizzarro, et al. (2017) defined major prey taxa as having an MPI score that was significantly higher than would be expected by chance (i.e., $P < 0.05$). Using this criterion, they identified the nine taxa with the highest MPI as major prey taxa (MPI > 0.707). Those taxa are: teleosts, euphausiids, brachyuran crabs, caridean shrimps, polychaetes, amphipods, crustaceans, copepods, and mysids. Not surprisingly, most of the prey taxa are demersal or benthic.

When interpreting these results, it is important to remember that: 1) this list represents the major prey taxa for groundfishes, in general, and does not represent the major prey for an individual species; and 2) the taxonomic resolution is generally low; 3) the MPI scores are based on diet information from only 18 of the 92 species of groundfishes (19%); and 4) while this list of major prey taxa uses a common approach to interpreting randomization tests, major prey taxa could be identified using different criteria. The authors noted that available diet composition data are too general to produce accurate estimates of prey for most species of Pacific coast groundfishes. Broad taxonomic categories, such as unidentified teleosts, may result in MPI values that underestimate the contribution of the species in that broad category. In the absence of higher-resolution data, a less conservative *P*-value of 0.10 may be considered more appropriate to designate major prey than the traditional 0.05 threshold, depending on the objectives and needs of the user. Non-statistical methods could also be used to identify major prey taxa. For instance, if major prey were defined as the 25% of prey taxa with the highest MPI score, there would be 12 major taxa.

The analysis by Bizzarro, et al. is a significant advancement in understanding the major prey of groundfishes that represents the best available scientific information and provides a basis for future work. However, the Council may consider whether or not the criterion (statistical significance, *P*<0.05) used in that study meets their needs, or whether another approach is required.

Table 2. Species of groundfishes, taxonomic group, and functional groups included in the meta-analysis by Bizzarro, et al. (2017).

Common name	Scientific name	Taxonomic group	Functional group
Black Rockfish	*Sebastes melanops*	Rockfishes	Demersal
Brown Rockfish	*Sebastes auriculatus*	Rockfishes	Demersal
Copper Rockfish	*Sebastes caurinus*	Rockfishes	Demersal
Darkblotched Rockfish	*Sebastes crameri*	Rockfishes	Demersal
Dover Sole	*Microstomus pacificus*	Flatfishes	Benthic
English Sole	*Parophrys vetulus*	Flatfishes	Benthic
Greenstriped Rockfish	*Sebastes elongatus*	Rockfishes	Demersal
Lingcod	*Ophiodon elongatus*	Roundfishes	Demersal
Longspine Thornyhead	*Sebastolobus altivelis*	Rockfishes	Benthic
Pacific Hake	*Merluccius productus*	Roundfishes	Pelagic
Pacific Spiny Dogfish	*Squalus suckleyi*	Elasmobranchs	Pelagic
Petrale Sole	*Eopsetta jordani*	Flatfishes	Benthic
Rosethorn Rockfish	*Sebastes helvomaculatus*	Rockfishes	Demersal
Sablefish	*Anoplopoma fimbria*	Roundfishes	Demersal
Sand Sole	*Psettichthys melanostictus*	Flatfishes	Benthic
Sharpchin Rockfish	*Sebastes zacentrus*	Rockfishes	Demersal
Starry Skate	*Raja stellulata*	Elasmobranchs	Benthic
Yelloweye Rockfish	*Sebastes ruberrimus*	Rockfishes	Demersal

Table 3. Major Prey index (MPI) values for 47 high-level prey taxa for 18 species of groundfishes, listed in order of descending MPI value. Major prey taxa are distinguished by bold type (from Bizzarro, et al. 2017).

Prey taxa (high level)	Foraging Habita	MPI
Teleosts (unid and other)	**Demersal**	**0.968**
Euphausiids	**Pelagic-Demersal**	**0.911**
Brachyuran crabs	**Benthic**	**0.887**
Caridean shrimps	**Benthic-Demersal**	**0.839**
Polychaetes	**Benthic**	**0.831**
Amphipods	**Benthic**	**0.823**
Crustaceans	**Benthic-Demersal**	**0.823**
Copepods	**Pelagic**	**0.774**
Mysids	**Demersal**	**0.710**
Pleuronectiform fishes (flatfishes)	Benthic	0.702
Jellyfish and other unid gelatinous zooplankton	Pelagic	0.637
Anomuran crabs	Benthic	0.629
Panaeid and sergettid shrimps	Benthic-Demersal	0.605
Shrimps, unid	Benthic-Demersal	0.573
Ehinoderms	Benthic	0.524
Rockfishes	Benthic-Demersal	0.524
Sculpins	Benthic	0.508
Myctophidae	Pelagic	0.500
Bivalves	Benthic	0.468
Engraulidae	Pelagic	0.419
Isopods	Benthic	0.419
Loligonidae	Demersal	0.403
Clupeidae	Pelagic	0.395
Gastropods	Benthic	0.379
Gadiformes	Demersal	0.371
Osmeriformes	Demersal	0.371
Scorpaeniformes, other and unid.	Demersal	0.355
Octopi	Benthic	0.347
Other decapods	Benthic-Demersal	0.339
Herrings	Pelagic-Demersal	0.339
Zoarcidae	Benthic	0.339
Hexagramidae	Demersal	0.331
Axiidae	Benthic	0.306
Ammodytidae	Pelagic-Demersal	0.274
Cephalopods, unid.	Demersal	0.266
Tunicates	Benthic	0.234
Squids, unid.	Pelagic-Demersal	0.218

Prey taxa (high level)	**Foraging Habita**	**MPI**
Invertebrates, unid	Benthic-Demersal	0.194
Bivalves or gastropods, unid.	Benthic	0.185
Squids (Oegopsina)	Pelagic-Demersal	0.177
Chondrichthyian fishes	Demersal	0.169
Cuttlefishes	Benthic-Demersal	0.113
Other marine worms (e.g., Nematoda, Sipuncula)	Benthic	0.113
Sardines	Pelagic	0.105
Poachers	Benthic	0.065
Crabs, unid.	Benthic	0.048
Agnathan fishes	Benthic	0.032

5. FLATFISHES

Of the 12 flatfish species covered by the FMP, 11 belong to the family Pleuronectidae, which are also called “right-eyed” flounders. The one exception is Pacific sanddab (*Citharichthys sordidus*), a member of the family Bothidae, also referred to as “left-eyed” flounders. Members of the Pleuronectidae have their eyes and dark pigmentation on the right side of their flat surface, although, starry flounder (*Platichthys stellatus*) tend to have eyes on either side of their head (Kramer, et al. 1995). Flatfish are oviparous and iteroparous with egg fertilization occurring externally (NOAA 1990).

Arrowtooth Flounder (Atheresthes stomias)

Range

Arrowtooth flounder range from the southern coast of Kamchatka to the northwest Bering Sea and Aleutian Islands to Santa Barbara, California (Allen and Smith 1988, M. Love[1], NOAA 1990). Densities are low south of Cape Blanco, Oregon (Dark and Wilkins 1994, Rickey 1995).

Fishery

Arrowtooth flounder have developed into an important commercial fishery in the 1990’s. The catch is made almost exclusively by deepwater trawl. Off of Oregon and Washington, it is the third most common commercially caught flatfish species, exceeded only by Dover sole and petrale sole (Oregon Department of Fish and Wildlife 2004, Bill Barss[2]). Arrowtooth flounder are not a recreationally important species, but they are occasionally caught incidentally to other groundfish species (NOAA 1990).

Habitat

Arrowtooth flounder is the dominant flounder species on the outer continental shelf from the western Gulf of Alaska to Oregon (NOAA 1990). Eggs and larvae are pelagic; juveniles and adults are demersal (Garrison and Miller 1982, NOAA 1990). Larvae are neritic in 200 m of water or less, but are occasionally found over depths of up to 3,100 m (Hart 1973, NOAA 1990). Juveniles and adults are sublittoral-bathyal from depths of 9–900 m (M. Love[3]), with larger fish tending to be found deeper (Dark and Wilkins 1994). Young juveniles are typically found in waters shallower than 200 m, while older juveniles and adults may be found from 50 to 500 m (NOAA 1990). In the Bering Sea and Gulf of Alaska, spawning occurs over depths of 110– 360 m (NOAA 1990). Spawning also may occur deeper than 500 m off Washington (Rickey1995). Brodeur, et al. (1995) found that arrowtooth flounder exhibit only weak depth-distribution patterns.

Juveniles and adults are most commonly found on sand or sandy gravel substrata, but occasionally occur over low-relief rock-sponge bottoms (NOAA 1990). In studies conducted in the Bering Sea, McConnaughey and Smith (2000) reported that arrowtooth flounder were most commonly found

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[2] B. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

[3] See note 1 above.

associated with sediment consisting of sand and mud, whereas Busby, et al. (in press) found them in a variety of sediment types ranging from silt to various mixtures of silt, mud, sand, gravel, and cobble. Jagielo, et al. (2003) compared densities of groundfish in "trawlable" and "untrawlable" areas off the northern Washington coast at depths of 90 and 148 m using visual observations made from a submersible. Trawlable bottoms were primarily mud, pebble, and mud-pebble (94%), whereas untrawlable bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). The density of arrowtooth flounder in trawlable areas was 49 times higher than the density found in the untrawlable areas. The association with mud and "soft" sediment was also reported by Demory, et al. (1976) and Barss, et al. (1977), who conducted trawl surveys off the coasts of Oregon and Washington. They compared the locations where arrowtooth flounder were collected to maps of sediment types prepared by other authors.

All life stages of the arrowtooth flounder occur almost exclusively in euhaline waters (NOAA 1990). Optimum conditions of egg incubation and survival were found at temperatures ranging from 3.7 to 6.8° C; larvae are best suited for temperatures of 6.6–8.0° C; juveniles may survive at sub-zero to 5.0° C; and adults are found from 0–9.0° C, but their optimal temperature range is 3–4° C (NOAA 1990, Zimmerman and Goddard 1996).

Migrations and Movements

Arrowtooth flounder exhibit a strong migration from shallow-water summer feeding grounds on the continental shelf to deep-water spawning grounds over the continental slope (NOAA 1990). Depth distribution may vary from as little as 50 m in summer to more than 500 m in the winter (NOAA 1990, Rickey 1995). Dark and Wilkins (Dark and Wilkins 1994) noted a tendency for arrowtooth flounder to move into deeper waters with increased age.

Reproduction

In Puget Sound, spawning occurs in the winter months (Garrison and Miller 1982). In the Gulf of Alaska, spawning occurs during spring and summer (Rickey 1995). The arrowtooth flounder is a batch spawner, and spawns off the coast of Washington between fall and winter (Rickey 1995).

Growth and Development

Fertilized eggs measure 2.5–3.5 mm in diameter (Garrison and Miller 1982, NOAA 1990). Embryonic development is indirect and external, and incubation time is unknown (NOAA 1990).

Larvae hatch at less than 9 mm and the yolk sac is absorbed by the time they reach 9.8 mm (Garrison and Miller 1982). Metamorphosis into a benthic fish occurs at a length of about 38.5 mm (Garrison and Miller 1982, NOAA 1990). Juveniles range in size from 38.5 mm to 43 cm, depending on geographical location (NOAA 1990).

Size and age at maturity varies a great deal; males may mature at 3–7 years and 31–42 cm, and females mature at 4–8 years and 37–43 cm (NOAA 1990). In Puget Sound, Rickey (1995) found that males mature as small as 28 cm and females as small as 36.8 cm. The species may live up to 20 years and reach 86 cm in length (Mecklenburg, et al. 2001).

Trophic Interactions

Larvae eat copepods, their eggs, and copepod nauplii (Brodeur, et al. 1995, Yang 1995, Yang and

Livingston 1985). Juveniles and adults feed on crustaceans (mainly ocean pink shrimp and krill) and fish (mainly gadids, herring, and pollock) (Hart 1973, NOAA 1990). Yang (1995) found that in the Gulf of Alaska, arrowtooth flounder greater than 20 cm long fed mainly on shrimp; fish 20–39 cm long preyed on herring and capelin; and those greater than 40 cm long fed mainly on pollock. In studies conducted in the Bering Sea, McConnaughey and Smith (2000) reported that arrowtooth flounder fed primarily on fish. Arrowtooth flounder exhibit two feeding peaks, at noon and at midnight (NOAA 1990).

In the North Pacific, the main predators of the arrowtooth flounder are the Pacific halibut, Orca whales, and possibly northern fur seals and Beluga whales (NOAA 1990).

Spatial Associations (updated September 2012)

The center of distribution for arrowtooth flounder is the western Gulf of Alaska and southern Bering Sea, but this species also commonly occurs along the U.S. West Coast. The results of fishery–independent surveys conducted by the NMFS-NWFSC between the Canadian border and southern California during May and October of 2000–2002, 2004, and 2005 were recently summarized (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). The 2004 and 2005 surveys captured a size range indicative of large juvenile (> 20 cm TL) and adult life stages (Keller, et al. 2007, 2008). These life stages were presumably also largely taken in earlier surveys but no measurements were provided. Arrowtooth flounder occurred in 17.3–21.5% of hauls conducted between 2000 and 2002 (n2000 = 325, n2001 = 334, n2002 = 427) at depths of 183–1280 m (Keller, et al. 2005, 2006a, 2006b). Its distribution was restricted to the outer continental shelf and continental slope (186–626 m) during 2000–2002 surveys with a mean capture depth of approximately 350 m. Changes in design between 2002 and 2004 surveys (minimum target depth range reduced to 55 m, southern extent of survey expanded from 34.5° N to 32.5° N) are probably responsible for observed differences in minimum depth ranges (52–1111 m, mean ~ 200 m) and frequency of occurrence during 2004 (36.0%, n2004 = 505) and 2005 (32.4%, n2005 = 675) surveys (Keller, et al. 2007, 2008). Along the West Coast, arrowtooth flounder abundance decreased from north to south, with the great majority of the population (> 90% of survey biomass in all survey years) located north of 43° N (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). Among groundfishes, arrowtooth flounder was typically among the top 15 most abundant species by biomass, and among the top 3 most abundant species between 47.5° N and the Canadian Border (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). Based on a subset of available West Coast survey information collected during 1999–2002 (n = 1159 tows), median depth of capture for arrowtooth flounder was 300 m, and the median latitude of capture was 45° N (Tolimieri and Levin 2006).

Arrowtooth flounder was extremely abundant in fishery–independent surveys conducted in continental shelf waters off Hecate Strait, British Columbia, ranking first and third among groundfishes by biomass during June 2002 (n = 96 tows) and May–June 2003 (n = 94 tows) (Choromanski, et al. 2004, 2005). The catch was composed of a wide range of juvenile– and adult–size individuals (male: 11–68 cm TL, n = 2623; female: 11–88 cm TL, n = 4914) (Choromanski, et al. 2004, 2005). During 2003, most individuals were caught between 108–126 m (depth range of tows = 18–146 m) (Choromanski, et al. 2004). Arrowtooth flounder occupied deeper waters during the winter (mean = 257 m) than during the summer (mean = 100 m) in this region (Pearsall and Fargo 2007). In continental shelf surveys (18–166 m) conducted sporadically during 1985–1987 among a variety of unconsolidated bottom types, arrowtooth flounder was the most abundant species by biomass on a silty sand, high current region (55–166 m) (Pearsall and Fargo 2007).

Recent fishery–independent survey results indicated that arrowtooth flounder was the most abundant groundfish in the Gulf of Alaska. During summer months (June–August) of 2007 (n = 820 tows) and 2009 (n = 823 tows), arrowtooth flounder biomass was overwhelmingly dominant among groundfishes with the highest densities occurring on the broad continental shelf of the western Gulf, especially around the Barren Islands and off northeast Kodiak Island (Von Szalay, et al. 2008, 2010). Mean weight of arrowtooth flounder generally increased with depth and (presumably) juveniles (< 30 cm TL) were relatively rare below 300 m. Distinct size modes corresponding to large juveniles or early adults typically occurred at depths of 100–500 m (Von Szalay, et al. 2008; Von Szalay, et al. 2010), with males distributed deeper than females (Von Szalay, et al. 2010).

High densities of large juvenile and adult arrowtooth flounder recently have been documented in the southern Bering Sea and eastern Aleutian Islands. Arrowtooth flounder was the most abundant flatfish and among the ten most abundant groundfishes (by biomass) in the Aleutian Island region in fishery–independent surveys conducted between May and August of 2002 (n = 417 tows), 2004 (n = 420 tows), 2006 (n = 358 tows), and 2010 (n = 417 tows) at depths of 1–500 m (Zenger 2004; Rooper 2008; Rooper and Wilkins 2008; Von Szalay, et al. 2011). Based on the combined results of these surveys, arrowtooth flounder was the dominant groundfish in the southern Bering Sea but catch rates were greatest in the eastern Aleutians. These results are consistent with those of Logerwell, et al. (2005) using data from NMFS surveys conducted during May–September 1980–2003. Mean length and weight increased with depth and individuals were larger in the eastern Aleutians than southern Bering Sea (Zenger 2004; Rooper 2008; Rooper and Wilkins 2008). Results of eastern Bering Sea surveys indicated that greatest catch rates were located between 600–800 m during May–August 2004 (n = 231), 2008 (n = 200), and 2009 (2000) (Hoff and Britt 2005, 2009, 2011). This center of distribution is generally deeper than that reported among other regions, although Von Szalay, et al. (2011) noted that arrowtooth flounder populations were concentrated in deeper water in the southern Bering Sea (301–500 m) than in the Aleutian Islands (201–300 m). No temperature or other information was available to explain the cause of the high observed catch rates in deep waters of the eastern Bering Sea. Based on a General Additive Model, year, depth, and bottom temperature explained 72% of variability in arrowtooth flounder CPUE in the eastern Bering Sea during spring and summer months of 1982–2004 (McConnaughey and Syrjala 2009). When backscatter data representing variable substrate types were included, model predictions only increased by 3.5% indicating that substrate type may not be an important predictor of arrowtooth flounder distribution.

Changing environmental conditions seem to be affecting the distribution and abundance of arrowtooth flounder in the Bering Sea. Warming temperatures have led to an overall increase in the Bering Sea Arrowooth Flounder population from 1982–2007 (Zador, et al. 2011). However, abundances generally have not increased in the most densely inhabited regions, and much of the recent population expansion appears to be driven by the increase in larger (adult) individuals caught on outer continental shelf north of Zhemchug Canyon (Zador, et al. 2011). Southeastern Bering Sea populations also showed a marked increase in abundance during recent warm years (2003−2005), indicating possible increased physical habitat suitability. The high numbers of small (juvenile) individuals found in the southeastern Bering Sea suggest that this region may be a nursery area (along with the outer shelf). Arrowtooth flounder movement patterns and geographic distribution appear to be strongly driven by temperature, and specifically the location of the cold pool and 0° C water. During years of large cold pools, distribution is restricted, which may increase density–dependent effects and curtailed population growth (Zador, et al. 2011). Arrowtooth flounder populations are expected to expand their distribution and abundance as the eastern Bering Sea warms (Zador, et al. 2011). This species is known to be a strong swimmer and has exhibited active migrations from the northeastern to northwestern Bering Sea (Orlov 2004). This westward movement has been attributed to a warming of the northwestern Bering Sea during the 1990s and the associated weakening of the Kamchatka Current (Orlov 2004).

Seasonal movements, spawning habitat, and distribution patterns of eggs and larvae recently have been described in the Gulf of Alaska. Arrowtooth flounder primarily spawned along the continental slope east of Kodiak Island from late January to March (Blood, et al. 2007). During peak spawning in January and February, mature–size females were concentrated along the continental slope southwest, south and east of Kodiak Island at depths of 190–340 m and as deep as 485 m (Bailey, et al. 2008). In early March and in April, most individuals had migrated towards Shelikof Strait. The monthly distribution of mature–size female arrowtooth flounder indicated a prompt migration away from the slope once spawning was complete (Bailey, et al. 2008). Early–stage eggs were found in tows that sampled to depths of ≥ 450 m. Larvae, which hatch between 3.9 and 4.8 mm standard length, increased in abundance with depth (Blood et al 2007). Larvae of increasing lengths were found inshore of eggs, demonstrating a shoreward movement with ontogeny. There also may be a downstream gradient over the shelf of increasing size, with the smallest larvae around Kodiak Island and the largest mean lengths between the Shumagin Islands and Unimak Pass. The mean depth of arrowtooth flounder larvae was ~30 m but there was an ontogenetic movement of larvae to the surface and early stage larvae were commonly found to 150 m (Bailey, et al. 2008). Arrowtooth flounder generally recruited to benthic environments of the inner and mid continental shelf during July–August (Bailey, et al. 2008).

Recently published spatial information concerning arrowtooth flounder is consistent with and expands upon prior knowledge. Previous findings, such as temperature tolerances of different life stages (McCain, et al. 2005), were utilized in some recent studies (e.g., Zador, et al. 2011) to build a more complete picture of spatial and temporal distribution patterns and to determine the main factors driving observed patterns. Most of the recently published spatial information on arrowtooth flounder was derived from Alaskan waters with West Coast contributions largely limited to the results of NMFS trawl surveys. However, a substantial amount of historic information is available from directed scientific research on the spatial associations of this species along the West Coast (McCain, et al. 2005).

Trophic Interactions (updated September 2012)

Several new studies are available that detail the food habits of arrowtooth flounder. All of these studies used benthic trawl gear deployed during daylight hours to collect specimens and stomach samples in the Gulf of Alaska (Yang 2004; Yang, et al. 2005; Yang, et al. 2006; Knoth and Foy 2008), eastern Bering Sea (Yang, et al. 2005; Lee, et al. 2010) and Hecate Strait, British Columbia (Pearsall and Fargo 2007). Data from the Gulf of Alaska were derived from Pavlof Bay (90–123 m; Augst 5–7 1995; Yang 2004), Chiniak and Marmot Bays off Kodiak Island (mostly <100 – 200 m, May and August 2002–2004; Knoth and Foy 2008), the central and western Gulf of Alaska (1999, 2001; Yang, et al. 2006) and throughout the Gulf of Alaska (May–September, 1990–2001; < 50–200 m; Yang, et al. 2005). In the Gulf of Alaska, arrowtooth flounder ate primarily fishes, with a greater proportion fishes noted among (presumably) adults (> 40 cm FL; Yang, et al. 2006, Knoth and Foy 2008). The dietary contribution of fishes (by weight) ranged from 43.5% (n = 465; Knoth and Foy 2008) to 73% (n = 1359; Yang, et al. 2006) in studies with large sample sizes (n > 100). Walleye Pollock was the primary prey species, contributing between 13.3% (2002–2004; Knoth and Foy 2008) and 31.4% (2001; Yang, et al. 2006) to diet composition by weight among identified fishes. Pacific Sand Lance and Capelin also were commonly ingested in the Gulf of Alaska (Yang, et al. 2005, 2006). Crustaceans, especially pandalid shrimps (%Weight (%W) = 7–12, Yang, et al. 2006) and euphausiids (%W = 17.7%; Knoth and Foy

2008), were also regularly consumed, especially by (presumably) juvenile specimens (< 40 cm FL; Yang, et al. 2006). A relatively low proportion of stomachs with prey items (53.8% (n = 80; Yang 2004) to 76.2% (Yang, et al. 2006)) were indicative of the episodic feeding of a piscivorous predator. In addition to the previously noted ontogenetic differences in diet composition, temporal dietary variability was documented in the Gulf of Alaska. In 2002 and 2003, Walleye Pollock was the dominant prey item of adult arrowtooth flounder in the western Gulf of Alaska, but its importance declined substantially in 2004 with an associated increased reliance on euphausiids and Pacific Sand Lance (Knoth and Foy 2008). The importance of euphausiids in the diet of arrowtooth flounder also decreased significantly from May to August, whereas the importance of capelin increased during the same time period. Temporal changes in feeding activity were more pronounced in smaller, likely juvenile, individuals (Knoth and Foy 2008). Temporal dietary variability was largely attributed to differences in local prey availability, suggesting that arrowtooth flounder is a generalist feeder. In addition, the prevalance of pelagic prey was interpreted to reveal that arrowtooth flounder feedsf mainly in the water column (Knoth and Foy 2008).

New studies conducted in the eastern Bering Sea also indicated piscivory by arrowtooth flounder. Fishes composed 72.2% of diet composition by weight during 1979–1985 in waters < 500 m (Lee, et al. 2010). Walleye Pollock (64%) dominated diet composition, followed by large zooplankton (20.1%) and shrimp (7.1%). Forage fishes composed a smaller proportion of diet (5.9%; Lee, et al. 2010) compared to the Gulf of Alaska population (Yang, et al. 2006; Knoth and Foy 2008). Capelin, for instance, constituted 1.0% of arrowtooth flounder diet composition in the eastern Bering Sea during 1970–2001, compared to 8.8% in the Gulf of Alaska during 1990–2001 (Yang, et al. 2005). Dietary overlap with Greenland Turbot was substantial during 1979–1985 (0.882) and trophic level was estimated at 3.93 (Lee, et al. 2010).

In the waters of Hecate Strait, British Columbia, fishes also were the primary prey taxa, although species composition varied. Pearsall and Fargo (2007) collected a size range representative of juvenile and adult arrowtooth flounder in trawl surveys conducted during June and September–October 1985, January 1986, and May–June 1987. Trawls were fished during daylight hours in four distinct regions at depths of 18–166 m and bottom types ranging from sandy silt to a mixture of coarse sand, gravel, pebbles, and cobbles. The great majority of stomach samples (n = 977) contained prey items (93.1%) (Pearsall and Fargo 2007). Based on %W, arrowtooth flounder in Hecate Strait fed mainly on fishes, with most unidentified (50.5%). Among identified prey taxa, Pacific Herring (12.9%), Pacific Sand Lance (9.8%) and lobsters (7.4%) contributed > 5% to diet composition (Pearsall and Fargo 2007). Adult–size arrowtooth flounder fed on a greater proportion of fishes than juvenile–size individuals and on a different species composition. Adults consumed a greater proportion of forage fish and herring whereas juveniles ate greater amounts of macrobenthos, as well as more euphausiids and shrimps (Pearsall and Fargo 2007). Pronounced temporal variability was reported in the relative contribution of prey taxa within and among regions. In general, however, a greater proportion of fishes was noted on a sand, gravel, pebbles, and cobbles habitat, whereas more shrimp and plankton were consumed on a sandy silt habitat with strong currents (Pearsall and Fargo 2007). Diet composition of juveniles and adults was similar and samples were pooled to estimate trophic level (between 3.8–4.0) and for interspecific comparisons. Arrowtooth flounder diet composition was most similar to that of of upper trophic level species such as dogfish (0.946), adult Pacific Cod (0.919), juvenile Pacific Cod (0.873), and Lingcod (0.824) (Pearsall Fargo 2007).

Seabirds, pinnipeds, and other fishes were reported as predators of arrowtooth flounder in recent studies. Common Murres (n = 15), Thick–Billed Murres (n = 76), Red–Legged Kittiwakes (n = 52), and Black–Legged Kittiwakes (n = 92) sampled on St. Paul and St. George Islands (Pribilof Islands) and Bogoslof Island (Aleutian Archipelago) during 1999–2000 all consumed (presumably) juvenile arrowtooth flounder. The relative dietary contribution differed among species and between short–term (stomach content analysis) and long–term (fatty acid analysis) feeding trends. Dietary contributions of arrowtooth flounder ranged from trivial amounts to nearly 30% (Iverson, et al. 2007). Based on 2760 scat samples collected on Kodiak Island during September 1999 to March 2005, juvenile and adult arrowtooth flounder (<16–70 cm TL) were the third most important species in the diet of Steller Sea Lions (%Number (%N) = 5.6, %Frequency of Occurrence (%FO) = 34.7). Arrowtooth flounder was more important to Steller Sea Lions diets in the summer as compared to the winter, and increased in dietary importance during 2000–2004 when Walleye Pollock numbers declined (McKenzie and Wynne 2008). Arrowtooth flounder also were important components of Pacific Cod diets (n = 1438) off Southeast Alaska during 1993–1999 (Trites, et al. 2007). The occurrence of arrowtooth flounder in Pacific Cod diet was similar among seasons, ranging from 13.2% (spring) to 20.3% (winter) (Trites, et al. 2007). Pacific Halibut (%W = 9.8, n = 152), Bocaccio (%W = 2.3%, n = 8), Rock Sole (%W = 0.5%, n = 347) and Pacific Sanddab (%W = 1.7%, n = 90) also consumed arrowtooth flounder (Pearsall and Fargo 2007).

Recent published information concerning arrowtooth flounder trophic interactions is consistent with and augments previous findings. A rather large body of information indicates a primarily piscivorous diet with a high proportion of Walleye Pollock in Alaskan waters. A previously reported dietary shift from crustaceans to small forage fishes between small and large juveniles (McCain et al 2005) was reinforced by recent studies (Yang, et al. 2006; Knoth and Foy 2008). Newly available information on arrowtooth flounder predators considerably augments prior documentation (McCain, et al. 2005).

Butter Sole (Isopsetta isolepis)

Range

Butter sole are found from the south Bering Sea and Aleutian Islands south to Ventura, southern California (Kramer, et al. 1995, Miller and Lea 1972).

Fishery

Butter sole are taken in the trawl fishery off Oregon (Hogue and Carey 1982) but are not of great commercial importance (Kramer, et al. 1995).

Habitat

Butter sole are common in shallow water, occasionally as deep as 425 m (Eschmeyer, et al. 1983, Allen and Smith 1988). They are found on muddy or silty bottoms (Kramer, et al. 1995). They are usually found in coastal waters within 18 km of shore, although they do occur in Puget Sound (Richardson, et al. 1980). They utilize shallow water off the Oregon coast as a site of benthic recruitment and early growth (Hogue and Carey 1982). An association with sandy sediment at shallow depths (< 55 m) was reported by Demory, et al. (1976) and Barss, et al. (1977) who conducted trawl surveys off the coasts of Oregon and Washington. They compared the locations where butter were collected to maps of sediment types prepared by other authors.

Migrations and Movements

No information.

Reproduction

Spawning takes place primarily in coastal areas rather than bays and estuaries and occurs from winter to spring (Richardson, et al. 1980). Spawning of butter sole occurs at the same time as English sole. The young of these species avoid competition for habitat by segregating: butter sole larvae move offshore and English sole larvae move into bays and estuaries (Richardson, et al. 1980). Off British Columbia, butter sole spawn at depths of 27.2–63.3 m (Levings 1968).

Their eggs are planktonic, spherical, and transparent (Richardson, et al. 1980). The specific gravity of fertilized eggs is 1.0208–1.0219 (Levings 1968). Butter sole eggs sink at salinities less than or equal to 26.61 ppt (Richardson, et al. 1980).

Growth and Development

Larvae and eggs are part of the zooplankton community. Either they float near-surface or in the surface layer, or like most flatfish, control their specific gravity so as to float somewhere below the surface (Rounsefell 1975). Early- and middle-stage eggs of butter sole co-occur with eggs of English sole, sand sole, and starry flounder (Richardson, et al. 1980). Larvae are abundant in nearshore coastal waters off Oregon and Washington in the winter and spring (Richardson, et al. 1980). Butter sole transformation from larval to juvenile form takes place at 18–23 mm (Richardson, et al. 1980). Settling time is restricted to May through August over a broad depth range, 9–60 m (Hogue and Carey 1982). Recently transformed benthic individuals of butter sole are usually found offshore for their first year of life rather than in the bay or nearshore habitats occupied by young and juvenile English sole (Richardson, et al. 1980).

Butter sole adults can reach a maximum size of 55 cm (Kramer, et al. 1995), but are usually under 30 cm (Eschmeyer, et al. 1983). The maximum age of butter sole is 11 years (Rounsefell 1975).

Trophic Interactions

Butter sole larger than 35 mm standard length feed mainly on amphipods, cumaceans, and decapods. Larger fish consume larger prey (Hogue and Carey 1982). In studies conducted in shallow waters (9–73 m) off the central coast of Oregon, Wakefield (1984) reported a wide variety of prey for butter sole, including polychaetes, mollusks, amphipods, and sea stars.

Curlfin Sole (Pleuronichthys decurrens)

Range

Curlfin sole (or curlfin turbot) are found along the Pacific coast of North America from the Bering Sea south to Punta San Juanico, Baja California (Fitch 1963, Kramer, et al. 1995, Miller and Lea 1972, Mecklenburg, et al. 2002).

Fishery

The curlfin sole is moderately important in the California trawl fishery (Kramer, et al. 1995) and is reported under the general grouping of "turbots." It comprises a minor incidental catch within other California commercial and sport fisheries (Sumida, et al. 1979). Landings off Oregon are also small, with total yearly landings rarely over 10,000 lbs (W. Barss[4])

Habitat

Curlfin sole have been taken between 7 and 349 m (Miller and Lea 1972), but most occur shallower than 90 m (Fitch 1963). They are found on soft bottoms (Eschmeyer, et al. 1983, Kramer, et al. 1995).

Migrations and Movements

No information.

Reproduction

Transparent eggs have been noted in curlfin sole ovaries from November to June. They spawn from late April to August (Fitch 1963). Eggs are pelagic with specific gravity equal to that of sea water (Fitch 1963). The eggs are spherical, ranging from 1.84 to 2.08 mm (Sumida, et al. 1979). Each egg is enclosed in a thin membrane that appears translucent because of a hexagonal pattern throughout its thickness. The yolk is clear and transparent and contains no oil globule (Fitch 1963).

Growth and Development

Curlfin sole eggs hatch slightly less than 7 days (160 hrs) after fertilization (Fitch 1963). Curlfin sole larvae are heavily pigmented, even at hatching (Sumida, et al. 1979). Newly hatched larvae measure 3.88 mm (Fitch 1963). Of flatfishes, curlfin sole are the largest at hatching and attain the largest size before transformation (Sumida, et al. 1979). In laboratory experiments, the left eye begins to migrate when larvae attain 10.5 mm standard length, but had not completed migration in a larva 21 mm standard length (Sumida, et al. 1979). The maximum size of adult curlfin sole is 37 cm (Eschmeyer, et al. 1983, Fitch 1963, Kramer, et al. 1995). The maximumweight of curlfin sole is 774 g (Fitch 1963). As adults, females are generally larger than male curlfin sole (Fitch 1963).

Trophic Interactions

Curlfin sole feed primarily on polychaete worms, nudibranchs, echiurid proboscises, crustacean (possibly crab) eggs, and brittle star fragments (Allen 1982, Fitch 1963). For curlfin sole from the central Oregon coast (73 m), the diet consisted entirely of polychaetes (Wakefield 1984).

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Dover Sole (Microstomus pacificus)

Range

Dover sole are distributed from the Navarin Canyon in the northwest Bering Sea and westernmost Aleutian Islands to San Cristobal Bay, Baja California (Hagerman 1952, Hart 1973, NOAA 1990).

Fishery

On the West Coast, Dover sole support a high-value commercial fishery (NOAA 1990, PMFC 1996). They are a major target of the deep-water trawl fishery. Dover sole are not a recreationally important species.

Habitat

Dover sole are a dominant flatfish on the continental shelf and slope from Washington to southern California. In the North Pacific, they are regarded as an inner shelf-mesobenthal species (Allen and Smith 1988). Adults are found in waters from 10 to 1600 m deep, with the highest abundance below 200–300 m (Love 1996). The majority inhabits waters deeper than 500 m (Allen and Smith 1988). Spawning occurs in waters 80–550 m deep at or near the bottom (Garrison and Miller 1982, Hagerman 1952, Hart 1973, Pearcy, et al. 1977). Hunter, et al. (1990) estimated that 86% of the spawning biomass of mature Dover sole off central California inhabit the oxygen minimum zone (OMZ) between 640 and 1010 m.

In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult Dover sole were most commonly found in habitat consisting of mud and sea urchins (*Allocentrotus*). They were evenly and sparsely distributed over mud bottoms. Jacobson, et al. (2001) analyzed data from eight bottom trawl surveys conducted on the upper continental shelf of the Pacific west coast, and reported that Dover sole 200–300 mm (total length) were collected at depths between 200 and 600 m, whereas larger sole were collected throughout the depth range of 200–1200 m. Jagielo, et al. (2003) compared densities of groundfish in “trawlable” and “untrawlable” habitat off the northern Washington coast over a depth range of 90 to 148 m using visual observations made from an occupied submersible. “Trawlable” bottoms were primarily mud, pebble, and mud-pebble (94%), whereas “untrawlable” bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). The density of Dover sole in “trawlable” areas was 3 times higher than the density found in the “untrawlable” areas.

Eggs are epipelagic; larvae are epi-mesopelagic. Juveniles and adults are demersal (Garrison and Miller 1982). Eggs are found primarily in the upper 50 m of the water column (Pearcy, et al. 1977). Larvae are found as deep as 600 m, but the majority are found from the surface to 50 m of depth, and up to 840 km offshore (Garrison and Miller 1982, NOAA 1990, Pearcy, et al. 1977). Juveniles are sublittoral-bathyal and found from 100 to 700 m deep; most are found deeper than 200 m (Hart 1973, NOAA 1990). Toole, et al. (1997) reported that the post-settlement nursery area for larvae was between 100 and 119 m in trawl studies conducted off the Oregon coast. Their data also suggested that larvae initially settle in deeper water and actively migrate inshore until the optimum nursery area is found.

Dover sole are an important flatfish of soft-bottom marine and inland sea environments (NOAA 1990). Dover sole populations spawn, rear, and grow in Puget Sound and off Vancouver Island. Summer feeding grounds of offshore populations may be in shallow-water bays, often as shallow as 55 m off British Columbia (Westrheim and Morgan 1963). Juveniles are often found in deep waters of the nearshore domain. Adults and juveniles show a high affinity toward soft bottoms of fine sand and mud.

All life stages of Dover sole are found in euhaline water at 4–15.5º C (NOAA 1990). Egg and larval development was found to be best at 8–10º C (Garrison and Miller 1982).

Migrations and Movements

Dover sole are considered to be a migratory species. In the summer and fall, mature adults and juveniles can be found in shallow-water (50–225 m) feeding grounds (Alton 1972). By late fall, the sole begin moving offshore into deep waters (300–1000 m) to spawn (Alton 1972, Barss and Demory 1988, Hunter, et al. 1990). Barss and Demory (1988) reported that adult males tend to be found deeper than 300 m during the entire year, suggesting that only adult females and juveniles make the seasonal migrations. Westrheim and Morgan (1963) found the movements to be onshore-offshore in nature, with little coastal north-south migration. Larvae are transported offshore and to nursery areas by ocean currents and winds. Juvenile fish move into deeper water with age, and begin seasonal spawning-feeding migrations upon reaching maturity (Hunter, et al. 1990); however, some data suggest that older, mature fish may remain in deep water and not make seasonal migrations into shallower areas (Hunter, et al. 1990).

Reproduction

Spawning occurs from January to August in the Gulf of Alaska, November to April off Oregon and California, and January to March in Puget Sound (Garrison and Miller 1982, Hart 1973, NOAA 1990, Pearcy, et al. 1977). In waters off central California, the average age and size of females at maturity are 7 years and 31.1 cm (Hunter, et al. 1990).

Dover sole are batch spawners; total fecundity of a 42.5-cm female is estimated at 52,000 eggs, whereas a 57.5-cm female was estimated to have 266,000 eggs (Hunter, et al. 1992, Yoklavich and Wolf 1990)

Growth and Development

Fertilized eggs average 2.0–2.6 mm in diameter (Pearcy, et al. 1977). Embryonic development is indirect and external. The eggs hatch in 40 days at 5º C; 24 days at 8º C; and 15 days at 12º C (Butler, et al. 1996).

Larvae hatch at about 6.5 mm (NOAA 1990). Metamorphosis may begin as early as 35– 48 mm; however, larvae are planktonic for up to two years, and metamorphosis may not begin until the sole has reached 100 mm (Butler, et al. 1996, Hart 1973, Markle, et al. 1992, Toole, et al. 1993). Settlement to benthic living occurs mid-autumn to early spring off Oregon, and February through July off California (Markle, et al. 1992). Juveniles grow to a size of 30–45 cm over the first four years of life (Hunter, et al. 1992). Adult females live to 53 years and males live to 58 years (Hunter, et al. 1990).

Trophic Interactions

Dover sole larvae eat copepods, eggs, and nauplii, as well as other plankton. Juveniles and adults eat polychaetes, bivalves, brittlestars, and small benthic crustaceans. Dover sole feed diurnally by sight and smell (Dark and Wilkins 1994, Gabriel and Pearcy 1981, Hart 1973, NOAA 1990).

Larvae are eaten by high seas pelagic fishes like albacore, jack mackerel, and tuna, as well as sea birds. Juveniles and adults are preyed upon by sharks, demersally feeding marine mammals, and to some extent by sablefish (NOAA 1990).

Dover sole compete with various eelpout species, rex sole, English sole, and other fishes of the mixed species flatfish assemblage (NOAA 1990).

Spatial Associations (updated September 2012)

A substantial amount of new information is available regarding the spatial associations of Dover Sole in the eastern North Pacific. Along the West Coast, this information is derived from fishery–independent surveys of NMFS–NWFSC and from directed scientific research. NMFS–NWFSC conducted surveys from the US/Canadian border to southern California between May and October of 2000–2002, 2004, and 2005 (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). The depth range of tows was expanded to include a shallower portion of the continental shelf during the 2004 and 2005 surveys (55–1280 m; 2000–2002: 183–1280 m) and the southern limit was extended (2000–2002: 34.5° N; 2004–2005: 32.5° N). Surveys captured a size range indicative of large juvenile (> 20 cm TL) and adult life stages. Dover Sole was caught at depths of 186–1241 m during 2000–2002 (#tows: n2000 = 325, n2001 = 334, n2002 = 427) with a mean capture depth of 549–581 m. A shallower depth range (52–1235 m) and mean depth of capture (359 m) observed during 2004 and 2005 (#tows: n2004 = 505, n2005 = 675) are presumably attributable to differences in survey depths. Dover Sole had the highest overall biomass among groundfish species for all surveys conducted during 2000–2005 (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). It was distributed throughout the survey region, but occurred in greatest abundance in continental slope and upper continental shelf regions (< 550 m). Dover Sole was especially abundant between 184–549 m (Keller, et al. 2007, 2008). In directed studies using NMFS trawl survey data derived from 1999–2002 (n = 1020 tows), Dover Sole was the second most common fish numerically and most common species by biomass (Tolimieri and Levin 2006; Tolimieri 2007). It numerically dominated hauls from 400–500 m (Tolimieri 2007) and inhabited progressively deeper depths on a gradient from north to south. For example, it was the most common species by biomass from 200–300 m at 40–43° N, and also the most common species at 700– 900 m at 34–37° N (Tolimieri and Levin 2006). The median latitude of capture was 41° N (Tolimieri and Levin 2006). The region from central California to the Canadian border represent the center of distirbution for this species in US waters; its abundance declined in the southern portion of the survey and was considerably less in the Gulf of Alaska (Tolimieri 2007; Von Szalay, et al. 2008, 2010, 2011).

Dover Sole were abundant in fishery–independent surveys conducted in continental shelf waters off Hecate Strait, British Columbia, ranking third and fourth among groundfishes by biomass during June 2002 (n = 96 tows) and May–June 2003 (n = 94 tows) (Choromanski, et al. 2004; 2005). The catch was composed of a wide size range suggestive of juveniles and adults (male: 15–52 cm TL, n = 3845; female: 13–68 cm TL, n = 4643) (Choromanski, et al. 2004; 2005). During 2003, most individuals were caught between 72–108 m (depth range of tows = 18–146 m) (Choromanski, et al. 2004). Dover Sole occupied deeper waters during March (mean = 334 m) than during the summer (mean = 163 m) in this region (Pearsall and Fargo 2007) in continental shelf trawl surveys (18–166 m) conducted sporadically during 1985–1987. These findings are consistent with those of Fargo and Westrheim (2007), who demonstrated that tagged adult Dover Sole (n = 852 recovered) migrated to deep water off the west coast of Queen Charlotte Island to spawn during winter months, with male migrations preceding those of females. Large juvenile– and adult–size Dover Sole (21.3–61.0 cm TL, n = 1824 measures) were relatively less abundant off the West Coast of Vancouver Island than in Hecate Strait, ranking 8th by biomass among groundfishes surveyed between 50–500 m (n = 165 tows) (Workman, et al. 2008).

Recent studies indicated that Dover Sole was extremely resilient to disturbance and low oxygen concentrations and reinforced its association with muddy habitats. Based on sampling conducted on Hecate Bank, Oregon during September 1988–2000 (67–360 m), Dover Sole was most abundant in mud– dominated seafloors from 200–360 m (n = 42 submersible dives) that included boulders, cobbles, and pebbles (Tissot, et al. 2007). Densities were ~5x greater on trawled mud seafloors of Coquille Bank, Oregon when compared to untrawled regions (Hixon and Tissot 2007). Trawling results in a general increase in sedimentation, turbidity, and the suspension of epibenthic invertebrates. Since Dover Sole primarily inhabit mud bottoms and use chemoreception to forage, all of these consequences are probably beneficial (Hixon and Tissot 2007). Dover Sole also do not seem to be adversely affected by low oxygen levels. In a recent study, conducted off the Oregon coast at depths of 50 m and 70 m (n = 17 tows), Dover Sole exhibited no significant effects of hypoxia (Keller, et al. 2010). Biomass of Dover Sole was not significantly related to dissolved oxygen concentration along the hypoxic gradient, and condition factors were actually somewhat higher in low oxygen waters (Keller, et al. 2010).

The early life history and reproductive movements of Dover Sole were recently investigated off central Oregon and in the Gulf of Alaska. Toole, et al. (2001) collected a complete size range of juveniles and adults (3–55 cm TL; mean = 13.2 cm TL) using a small–mesh shrimp trawl deployed off central Oregon (50–400 m) during 1989–1994. Dover Sole settled on the outer continental shelf and slope, moved inshore to nursery areas < 150 m and, after reaching ~20 cm TL, moved to progressively deeper water with ontogeny (Toole, et al. 2011). A massive amount of historic and contemporary data (1953–2006) were synthesized in two related studies conducted in the Gulf of Alaska that provided detailed descriptions of Dover Sole distribution and movement patterns. Adults were widely distributed from the inner shelf to outer slope during non–spawning months (n = 37,752 combined tows) but aggregated almost exclusively along the slope (310–500 m) in a few specific locations (off northern and southwestern Kodiak Island) when spawning (Bailey, et al. 2008; Abookire and Bailey 2007). Peak spawning season in the Gulf of Alaska was April to mid–June but extended from late January to July (Bailey, et al. 2008; Abookire and Bailey 2007). Spawning and egg concentrations tended to co–occur, indicating that adults maintained a protracted occupation in outer shelf spawning habitats (Bailey, et al. 2008). Eggs were mainly found from 200–1000 m (n = 10,776 tows) on the outer continental shelf and slope in accordance with spawning events (Abookire and Bailey 2007), but rose to epipelagic waters shortly thereafter (Bailey, et al. 2008). Mean depth of developing eggs and larvae was about 25 m, suggesting a comparative lack of directed, onshore movement with ontogeny (Bailey, et al. 2008). In accordance, all size categories of larvae (n = 10,776 tows) were distributed evenly across the shelf and into oceanic waters and data implied facultative settling of juvenile habitats (n = 13,347 combined tows) (Abookire and Bailey 2007; Bailey, et al. 2008). Small juveniles were found in bays and to a lesser extent scattered over the continental shelf, possibly indicating higher post–settlement mortality in offshore regions (Bailey, et al. 2008). Juveniles recruited to much shallower depths than those reported along the West Coast (Bailey, et al. 2008).

Dover Sole is a rather well–studied species throughout its range, in accordance with its high relative abundance, broad distribution, and commercial importance. New information concerning Dover Sole spatial associations are consistent with and expand upon prior knowledge (McCain, et al. 2005). Considerable advancements have been made in the determination of ontogenetic movements, especially as they relate to reproduction and early life history (Abookire and Bailey 2007; Bailey, et al. 2008; Toole, et al. 2011). New information concerning the impact of hypoxic conditions (Keller, et al. 2010) and trawling disturbance (Hixon and Tissot 2007) on distribution and abundance patterns of Dover Sole represents a major advancement in understanding the habitat requirements and physiological limitations of this species.

Trophic Interactions (updated September 2012)

Two studies have been recently published that describe the diet composition of Dover Sole. One of these studies provides historical information collected in Hecate Strait, British Columbia during June and September–October 1985, January 1986, and May–June 1987 (Pearsall and Fargo 2007). Trawl surveys were conducted during daylight hours in four distinct regions at depths of 18–166 m on bottom types ranging from sandy silt to a mixture of coarse sand, gravel, pebbles, and cobbles. The great majority of stomach samples (n = 305) contained prey items (98.4%). Juvenile and adults were distinguished but sample size of each group and sex were not reported. Based on pooled results using %W, Dover Sole in Hecate Strait fed mainly only benthic invertebrates, with polychaetes (54.3%) dominating diet composition. Echinoderms (18.4%), and cnidarians (11.9%) were of distant secondary importance, and crabs (5.1%) were the only other prey taxon that contributed more than 5% to diet composition. Fishes were not typically consumed by the study population (%W < 0.01%). Temporal and spatial results of this study were confounded by small and/or uneven sample sizes and cannot be uncoupled for comparisons. However, meiobenthos and secondarily macrobenthos constituted > 97% of the diet composition for each region and time period. Diet composition of juveniles and adults was extremely similar and samples were pooled for interspecific comparisons and to estimate trophic level (between 3.2–3.3). Dover Sole diet composition was most similar to that of adult (0.969) and juvenile (0.930). English Sole, and adult Rock Sole (0.878).

Diet composition of a small number of Dover Sole (n = 35) was estimated in the central and western Gulf of Alaska from trawl–derived samples collected during 1999 and 2001 (Yang, et al. 2006). Most stomach samples (91.4%) contained prey items. Among individuals with full stomachs, the average fork length (FL) was 44.4 + 1.7 cm (range = 34–60 cm FL), sizes that correspond to late juveniles and adults (Yang, et al. 2006). Among the sampled population, polychaetes were the most abundant prey taxon, constituting 49% of prey items by weight and 27% by frequency of occurrence. Brittle stars were of secondary importance (%W = 24, %FO = 25) and echiuran worms (%W = 5, %FO 22), gammarid amphipods (%W < 1, %FO = 22), and cumaceans (%W = < 1, %FO = 17) were frequently encountered but contributed modestly to total prey weight (Yang, et al. 2006).

Pinnipeds and Pacific Halibut were documented as predators of Dover Sole in recent publications. Dover Sole contributed trivially to the diet compositions of Pacific Halibut (%W = 0.01, n = 152); Pearsall, et al. 2007) and Steller Sea Lions (%FO = 0.2, %N < 0.1, n = 2760; McKenzie and Wynne 2008) in Hecate Strait and off Kodiak Island, respectively. Cumulative prey curves indicated that an adequate number of samples was collected for precise dietary estimates of the Steller Sea Lion study population. Dover Sole also was reported in the diet composition of Pacific Harbor Seals (%FO = 8.8) sampled in Alesa Estuary, Oregon during 1996–2002 (n = 3370) (Riemer and Mikus 2006). Juvenile Dover Sole (%FO = 70.6%, n = 339) were mainly consumed by Pacific Harbor Seals based on aged otoliths recovered from scat samples. The greatest overall contribution of Dover Sole to diet composition of Pacific Harbor Seals and the broadest observed age range occurred during summer months, coinciding with adult migrations to estuaries for spawning (Riemer and Mikus 2006).

Recent published information concerning Dover Sole trophic interactions was generally consistent and supported prior findings. Polychaetes, bivalves, brittlestars, and small benthic crustaceans have been previously reported as the main diet items of juvenile and adult Dover Sole (McCain, et al. 2005). These were also the main prey taxa reported in recent publication, although bivalves were of only minor dietary importance (Yang, et al. 2006; Pearsall and Fargo 2007). Fishes were extremely rare or absent in the diet of Dover Sole by all accounts. McCain, et al. (2005) reported that flatfishes, including English Sole, were among the main competitors of Dover Sole. This conclusion was supported by the results of Pearsall, et al. (2007). Marine mammals, but not Pacific Halibut, were previously reported as predators of Dover Sole (McCain, et al. 2005).

English Sole (Parophrys vetulus)

Range

English sole are found from Nunivak Island in the southeast Bering Sea and Agattu Island in the Aleutian Islands, to San Cristobal Bay, Baja California Sur (Allen and Smith 1988).

Fishery

English sole is an important commercial fish, captured primarily by bottom trawls. Most of this harvest is taken off the coasts of Washington, Oregon, and northern and central California. English sole are usually caught in relatively shallow water, less than 100 m deep (NOAA 1990). Along with starry flounder, sand sole, and Pacific sanddab, English sole forms the nearshore, mixed-species assemblage, based on commercial fishing strategies (Rogers and Pitkitch 1992). Females dominate the catch because males seldom grow to marketable size (Pedersen and DiDonato 1982). It is not an important recreational species, although it is caught on hook and line by boat, shore, and pier anglers.

Habitat

In the North Pacific, English sole is an inner-shelf mesobenthal species, occurring to 55 m (Allen and Smith 1988). In research survey data, nearly all occurred at depths of less than 250 m (Allen and Smith 1988). It is a member of the outer continental shelf community in southern California, the shallow sublittoral community in Puget Sound, and the intermediate depth Nestucca assemblage off Oregon (NOAA 1990).

Eggs and larvae are pelagic; juveniles and adults are demersal (Garrison and Miller 1982). Larvae are found primarily in waters less than 200 m deep (Laroche and Richardson 1979). Juveniles reside primarily in shallow-water coastal, bay, and estuarine areas (Ketchen 1956, Krygier and Pearcy 1986, Laroche and Holton 1979, Olson and Pratt 1973, Pearcy and Myers 1974, Rogers, et al. 1988, Toole 1980, Van Cleve and El-Sayed 1969, Westrheim 1955). Small juveniles settle in the estuarine and shallow nearshore areas all along the coast, but are less common in southerly areas, particularly south of Point Conception. As they grow, they move to deeper water. Large juveniles commonly occur out to depths of 150 m. Spawning occurs over soft-bottom mud substrata at depths of 50–70 m (Ketchen 1956).

Adults, spawning adults, and eggs have been found in Puget Sound, Hood Canal, Skagit Bay, and Grays Harbor in Washington, and in Santa Monica Bay, California. Adults are also common in San Pedro Bay, California. Larvae and juveniles occur in most estuaries between Puget Sound and San Pedro Bay, California (Emmett, et al. 1991). English sole uses nearshore coastal and estuarine waters as nursery areas (Krygier and Pearcy 1986, Rogers, et al. 1988).

English sole is a very important flatfish in shallow-water, soft-bottom marine and estuarine environments along the Pacific coast (Emmett, et al. 1991). Adults and juveniles prefer soft bottoms composed of fine sands and mud (Ketchen 1956) but also are reported to occur ineelgrass habitats (Peason and Owen 1992). An association with sandy sediment at depths less than 110 m was reported by Demory, et al. (1976) and Barss, et al. (1977) who conducted trawl surveys off the coasts of Oregon and Washington. They compared the locations where English sole were collected to maps of sediment types prepared by other authors. In Puget Sound, juveniles and adults prefer shallow (<12 m deep) muddy substrata (Becker 1984). Males show a preference for fine sediments (Becker 1988).

Eggs are neritic and buoyant, but sink just before hatching (Hart 1973). Eggs are mostly found in polyhaline waters at temperatures of 4–12º C, optimally at salinities of 25–28 ppt and 8– 9º C (Garrison and Miller 1982). Adults are found primarily in euhaline waters. Juveniles and larvae occur in polyhaline and euhaline waters. Optimum conditions for larval survival were found to be salinities of 25–28 ppt and temperatures of 8–9º C (Alderdice and Forrester 1968). No spawning occurs at temperatures below approximately 7.8º C (Jackson 1981). Temperatures around 18º C appear to be the upper thermal tolerance (reduced daily ration and growth) for juvenile English sole (Yoklavich 1982). The upper lethal limit for this species is 26.1º C (Ames, et al. 1978).

Migrations and Movements

Adults make limited migrations. Those off Washington show a northward post-spawning migration in the spring on their way to summer feeding grounds, and a southerly movement in the fall (Garrison and Miller 1982). Tagging studies have identified separate stocks based on this species' limited movements and meristic characteristics (Jow 1969). Tidal currents appear to be the mechanism by which English sole move into estuaries (Boehlert and Mundy 1987); larvae are transported to nearshore nursery areas (i.e., shallow coastal waters and estuaries) by these currents. Larvae metamorphose into juveniles in spring and early summer and rear until fall/winter at which time most emigrate to deeper waters (Olson and Pratt 1973). Although many post-larvae may settle outside of estuaries, apparently most will enter estuaries during some part of their first year of life (Gunderson, et al. 1990). Early- and late-stage larvae undergo diel vertical migrations (Misitano 1970, Misitano 1976). There is a general movement to deeper waters as fish grow (Ketchen 1956). Smaller fish tend to be restricted to shallow waters, with larger fish more abundant in deeper water (English 1967, Misitano 1970, Sopher 1974).

Reproduction

Spawning occurs from winter to early spring, depending on the stock: in Monterey Bay stocks, from January to May, peaking in March or April (Budd 1940); in Bodega Bay-Point Monterey stocks, from December to April, peaking in January or February (Villadolid 1927, cited in Garrison and Miller 1982); in Santa Monica Bay-Santa Barbara Channel stocks, from December to April; in Eureka-Oregon border stocks from October to May (Jow 1969); in Oregon stocks from January to April, peaking in February or March (Harry 1959); in Puget Sound stocks, from January to April, peaking in February or March (Smith 1936).

Five- to six-year-old females (36–38 cm in length) can produce about 1 million eggs, whereas large fish (43 cm long) may produce nearly 2 million eggs (Forrester 1969, Harry 1959, Ketchen 1947).

Growth and Development

Fertilized eggs are spherical and average 0.98 mm in diameter (Orsi 1968). Embryonic development is indirect and external. The planktonic eggs hatch in 3.5 days at 12º C, or 11.8 days at 4º C (Alderdice and Forrester 1968).

After hatching, larvae float with their yolk sac up. The yolk sac is absorbed in 9–10 days (Orsi 1968), with the planktonic larvae taking from 8–10 weeks to metamorphose to benthic living juveniles (Laroche, et al. 1982). Larvae are 2.0–2.8 mm total length at hatching (Orsi 1968) and grow to 18–26 mm before becoming juveniles (Garrison and Miller 1982, Misitano 1976). Juveniles range in size from 18 mm to about 26 cm long, depending on gender (Harry 1959).

Growth appears to be affected by upwelling (Kreuz, et al. 1982) and cohort abundance of age-1 fish (Peterman and Bradford 1987).

Some females mature as 3-year-olds and 26 cm long, but all females over 35 cm long are mature. Males mature earlier, beginning at 2 years and 21 cm in length. All males are mature at lengths of more than 29 cm (Harry 1959). In Puget Sound, all 2-year-old males are mature, but most females do not mature until they are 4 years old (Smith 1936). The maximum age of an English sole has been reported as 22 years (Munk 2001).

Trophic Interactions

Larvae are planktivorous. Larvae probably eat different life stages of copepods and other small planktonic organisms. Larvae appear to have a strong preference for appendicularians (Botsford, et al. 1989). Juveniles and adults are carnivorous, apparently feeding primarily during daylight hours (Becker 1984). Juveniles feed on harpacticoid copepods, gammarid amphipods, cumaceans, mysids, polychaetes, small bivalves, clam siphons, and other benthic invertebrates (Allen 1982, Becker 1984, Hogue and Carey 1982, Simenstad, et al. 1979). Small juvenile English sole concentrate their feeding on harpacticoid copepods and other epibenthic crustaceans until they reach approximately 50–65 mm in length, then they switch to feeding primarily on polychaetes (Toole 1980). Off Oregon, adult English sole feed on a variety of benthic organisms, but primarily polychaetes, amphipods, mollusks, cumaceans, ophiouroids, and crustaceans (Kravitz, et al. 1976, Wakefield 1984). English sole feed primarily by day, using sight and smell, and sometimes dig for prey (Allen 1982, Hulberg and Oliver 1979).

Larvae are probably eaten by larger fishes. A juvenile English sole's main predators are probably piscivorous birds such as great blue heron (*Ardia herodias*), larger fishes, and marine mammals. Adults may be eaten by marine mammals, sharks, and other large fishes. The English sole's sharp anterior anal spine may provide a defense against predators (Allen 1982).

English sole competes with slim sculpin, blackbelly eelpout, Pacific tomcod, spotted ratfish, Dover sole, and white croaker (Allen 1982, Jackson 1981). It occasionally interbreeds with starry flounder and produces a hybrid (Allen 1982, Eschmeyer, et al. 1983, Gabriel and Tyler 1980, Simenstad, et al. 1979).

Spatial Associations (updated September 2012)

Fishery independent surveys provided new information on distribution and abundance patterns of juvenile and adult English Sole along the U.S. West Coast. NMFS–NWFSC conducted surveys from the US/Canadian border to south of Point Conception, CA between May and October of 2000–2002 (#tows: n2000 = 325, n2001 = 334, n2002 = 427), 2004 (n = 505), and 2005 (n = 675) (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). The depth range of tows was expanded to include a shallower portion of the continental shelf during the 2004 and 2005 surveys (55–1280 m; 2000–2002: 183–1280 m) and more southern coverage (from 34.5° to 32.5° N). More recent surveys and presumably older surveys captured size ranges indicative of large juvenile (> 15 cm TL) and adult life stages (Keller, et al. 2007, 2008). English Sole was caught at depths of 188–382 m during 2000–2002 with a mean capture depth of 257– 271 m. A shallower depth range (52–404 m), mean depth of capture (123 m), and higher frequency of occurrence (2000–2002: 11.4–21.5%; 2004–2005: 46.9–47.0%) during 2004 and 2005 surveys can be attributed to differences in survey design. English Sole did not register among the top twenty most abundant groundfish by biomass during 2000–2002 (Keller, et al. 2005, 2006a, 2006b), but ranked 6th during 2004 (Keller, et al. 2007) and 16th during 2005 at depths of 55–183 m (Keller, et al. 2008). The bulk of English Sole biomass along the West Coast was distributed between 36–43° N (Keller, et al. 2007, 2008), with a median latitude of 39° N (Tolimieri and Levin 2006). In a directed study using NMFS trawl survey data derived from 1999–2002 between 33–47° N (n = 1159 tows), English Sole was the 24th most abundant fish species by biomass and was captured at depths of 200–500 m (median depth = 300 m) (Tolimieri and Levin 2006).

English Sole was abundant in fishery–independent surveys conducted in continental shelf waters off Hecate Strait, British Columbia, ranking third and second among groundfish by biomass during June 2002 (n = 96 tows) and May–June 2003 (n = 94 tows) (Choromanski, et al. 2004; 2005). The catch was composed of a wide size range of juveniles and adults (male: 11–48 cm TL, n = 6564; female: 11–53 cm TL, n = 8730) (Choromanski, et al. 2004; 2005). During 2003, most individuals were caught between 54– 72 m in a region of sandy silt with strong currents (depth range of tows = 18–146 m) (Choromanski, et al. 2005). In continental shelf trawl surveys (18–166 m) conducted sporadically during 1985–1987, English Sole occupied similar depths during May (mean = 90 m) and December (mean = 113 m), and was most abundant on fine to coarse sand habitats (Pearsall and Fargo 2007). In contrast to its high relative abundance in Hecate Strait, juvenile and adult English Sole (12.5–61.3 cm TL, n = 1334 measures) ranked only 16th among groundfishes surveyed between 50–500 m off the west coast of Vancouver Island (n = 165 tows) (Workman, et al. 2008).

A considerable amount of contemporary research has been devoted to the role of estuaries in the life history of English Sole. English Sole are believed to be carried to estuaries during periods of downwelling (Parnel, et al. 2008). Brown (2006a) demonstrated that juveniles collected in estuaries could be distinguish from those collected in nearby coastal regions off central California using multi–elemental analysis of otoliths. Specifically, Sr was considerably higher and Li was substantially lower in estuarine fish. These differences remained consistent over a large geographic region and among three very different oceanic years (1998–2000) (Brown 2006a). A companion study estimated that 45–57% of the adult English Sole population off central California used estuaries as juvenile nursery habitat (Brown 2006b). A similar conclusion was drawn from a study conducted in Oregon and Washington estuaries during 1985–1988 and June–August 1998–2000 (n = 800 tows) (Rooper, et al. 2004). Rooper, et al. (2004) suggested that the English Sole population on the Oregon–Washington shelf could potentially be supported solely by estuarine production, with production stabilized by the size of available nursery areas. Within estuaries, densities of age–0 individuals were much higher and more spatially variable shortly after settlement in June than in August (Rooper, et al. 2004). Spatial variability in estuary use also was reported by Chittaro, et al. (2009) between June 2006 (n = 130 fish) and August 2005 (n = 99 fish) using otolith microchemistry. However, observed spatial variability could not be explained by the density of recently settled fish, the available area of nearshore habitat, or measured environmental variables (e.g., temperature, salinity, dissolved oxygen) (Chittaro, et al. 2009). Based on trawl surveys (n = 431) conducted in Oregon and Washington estuaries during June and August 1998–2000, English Sole density anomalies were significantly higher at lower side channel sites (especially during June) than at other estuarine locations. Juvenile English Sole are thought to compete for space in estuaries with Pacific Sanddab, which are not as tolerant of the relatively warm water (13–17.5° C) found in side channels (Rooper, et al. 2006). Despite the conspicuous feeding behavior of English Sole, low predator densities and high turbidity allow juveniles to thrive in shallow, estuarine regions (Boersma, et al. 2008). Substrate type may not be an important determinant of English Sole distribution in estuaries, as a recent study conducted in Willapa Bay, WA found no statistical differences in abundance for individuals of unspecified maturity (n = 2128) among eelgrass, oyster beds, and mudflats (Hosack, et al. 2007).

English Sole show enhanced tolerance to low oxygen conditions. In a recent study, conducted off the Oregon coast at depths of 50 m and 70 m (n = 17 tows), no significant effects of hypoxia were noted (Keller, et al. 2010). Condition factors for English Sole was lower in low oxygen waters, but biomass was not affected (Keller, et al. 2010).

Recent scientific studies have greatly expanded the available information on English Sole distribution patterns and habitat associations, especially regarding the use of estuaries and their influence on population dynamics. Some integrated studies (e.g., Tolimieri and Levin 2006; Keller, et al. 2010) also have used survey data and knowledge gained from prior studies to better understand English Sole spatial associations in offshore waters. Newly acquired information, when comparable, is generally consistent with that reported by McCain, et al. (2005).

Trophic Interactions (updated September 2012)

New information concerning English Sole trophic interactions is limited to a single study, conducted in Hecate Strait, British Columbia during June and September–October 1985, January 1986, and May–June 1987 (Pearsall and Fargo 2007). Samples were collected from trawl surveys fished in four distinct regions at depths of 18–166 m on bottom types ranging from sandy silt to a mixture of coarse sand, gravel, pebbles, and cobbles. The great majority of English Sole stomach samples (n = 433) contained prey items (97.0%). Juvenile and adults were distinguished but sample size of each group and sex were not provided. Based on pooled results using %W, English Sole in Hecate Strait fed mainly on benthic invertebrates, with polychaetes (58.7%) dominating diet composition. Bivalves (10.2%), Pacific Sand Lance (8.2%), echiurans (7.1%), and echinoderms (6.2%) were of distant secondary importance, and no other prey taxon contributed more than 5% to diet composition. Although they were a relatively minor prey item when the overall diet was considered, Pacific Sand Lance dominated diet (84.1%) of a small number of English Sole (n = 11) collected during September–October 1985 on silty sand with high current activity. Temporal and spatial results of this study are confounded by small and/or uneven sample sizes and cannot be uncoupled for most comparisons. However, diet composition of English Sole collected during September–October 1985 (n = 62) and January 1986 (n = 125) was similar, and consisted mainly of polychaetes and other meiobethos. Juveniles and adults overlapped substantially in diet composition (0.989) and had similar estimated trophic levels (between 3.2–3.4). Diets of adult and juvenile English Sole also overlapped considerably with Dover Sole (0.969 and 0.930, respectively) and adult Rock Sole (0.873 and 0.886, respectively). The following predators of English Sole were indentified: Lingcod (8.5%, n = 25), Rock Sole (0.6%, n = 350), and Spiny Dogfish (0.2%, n = 799).

Recently published information concerning English Sole diet composition generally supports previous findings. Polychaetes have been consistently reported as the primary prey taxon for large juveniles and adults, with the remainder of the diet consisting mainly of other benthic invertebrates (McCain, et al. 2005; Pearsall and Fargo 2007). Amphipods and cumaceans were found to be common prey items in the diet of adult English Sole off Oregon (McCain, et al. 2005), but contributed little to the diet of juvenile and adult English Sole collected in Hecate Strait (Pearsall and Fargo 2007). Fishes were not indicated as prey items by McCain, et al. (2005) but Pacific Sand Lance were episodically ingested in large quantitites by some English Sole in Hecate Strait (Pearsall and Fargo 2007).

Flathead Sole (Hippoglossoides elassodon)

Range

Flathead sole are found on the Pacific coast of North America from Monterey Bay, central California northward through the Gulf of Alaska and across the Bering Sea (Alderdice and Forrester 1974, Eschmeyer, et al. 1983, Miller and Lea 1972, Allen and Smith 1988).

Fishery

In North American trawl catches, flathead sole is uncommon or incidental from Point Reyes, California to Cape Spencer, Alaska. They were of limited commercial use in the past, but are becoming more important (Kramer, et al. 1995).

Habitat

Flathead sole commonly inhabit the continental shelf of the North Pacific Ocean (Rose 1982). They inhabit water as deep as 1,050 m (Allen and Smith 1988), but usually occur in depths less than 366 m (Rose 1982). Flathead sole often occur in trace amounts in trawl samples off Washington and Oregon and are found more frequently as one moves northward (Rose 1982). Flathead sole are mesobenthic (Rounsefell 1975), with larger individuals occurring in deeper waters (Rose 1982).

Nursery areas along the northern Pacific coast are usually shallow (<100 m) estuaries, bays, and nearshore coastal areas (Holladay and Norcross 1995). In Kachemak Bay, Alaska, Abookire, et al. (2001) reported that juvenile flathead sole were collected at depths of 30–70 m, with highest CPUE values at greater than 50 m. The sediment at these depths consisted of sand (77–83%) and mud (17–23%). Previous work in this bay by Abookire and Norcross (1998) demonstrated that age-0 sole preferred mud and sediment containing equal proportions of mud and sand, where as age-1 sole were associated with these sediment types as well as sediments consisting primarily of sand. Young flathead sole are also frequently encountered in shallow depths of the inside waters of Puget Sound northward (Rose 1982). Age-0 and age-1 flathead sole are mainly captured deeper than 40 m (Holladay and Norcross 1995).

Flathead sole inhabit soft (Eschmeyer, et al. 1983), silty or muddy bottoms (Kramer, et al. 1995). They also occur on mud mixed with gravel or sand (Holladay and Norcross 1995). In studies conducted in the Bering Sea, McConnaughey and Smith (2000) reported that flathead sole were most commonly found associated with sediment consisting of sand and mud. An association with muddy and silty sediments was reported by Demory, et al. (1976) and Barss, et al. (1977) who conducted trawl surveys off the coasts of Oregon and Washington. They compared the locations where flathead sole were collected to maps of sediment types prepared by other authors

Newly spawned eggs are buoyant in salinities of 25–27 ppt or greater. Incubating eggs are euryhaline. Newly hatched larvae are buoyant in salinities of 17–18 ppt or greater. Total hatch and viable hatch are highest (>90%) at 25 ppt, 6° C, and 25 ppt, 7° C. Post-hatching flathead sole develop normally from 25 to 39.58 ppt and at temperatures from 5.5 to 10.65° C or greater (Alderdice and Forrester 1974).

Adult flathead sole occur in water 27–34 ppt (Alderdice and Forrester 1974). The preferred temperature range of adult flathead sole is 2–4° C (Paul, et al. 1995). Bottom temperatures during spawning season are from 6 to 8° C (Alderdice and Forrester 1974).

Migrations and Movements

Adult fish migrate from wintering grounds on the upper continental slope onto the shelf during the spring and summer (Rose 1982). In Auke Bay, southeastern Alaska, flathead sole larvae perform diel vertical movements, including nocturnal ascent, nocturnal descent, and nocturnal diffusion (Haldorson, et al. 1993). During the day, larvae concentrate at 5 -10 m. At twilight they appear to descend somewhat, but still have peak densities at 5–10 m (Haldorson, et al. 1993).

Reproduction

Eggs are fertilized externally and fecundity ranges from 72,000 to 600,000, varying with the size of the female (Rose 1982). Flathead sole spawn from May to June at 40–70 fathoms (Rounsefell 1975). The eggs of the flathead sole range from 2.75 to 3.75 mm in diameter (Rounsefell 1975).

Growth and Development

The larvae and eggs of the flathead sole are part of the zooplankton community. Either they float near-surface or on the surface layer or, like most flatfish, control their specific gravity so as to float somewhere below the surface (Rounsefell 1975).

Larger eggs occur when the water salinity is between 20 and 27.5 ppt (Alderdice and Forrester 1974). The eggs incubate for 7.2–20.9 days. Absorption of the yolk occurs at 6–17 days (Alderdice and Forrester 1974).

Flathead sole metamorphose and settle to the bottom beginning in late summer (Rose 1982). Larvae grow at 0.5 mm/day at lower temperatures and 1 mm at higher temperatures (Alderdice and Forrester 1974). Flathead sole larvae average 12–36 mm standard length (Brodeur, et al. 1995). Adults can grow to 56 cm (Kramer, et al. 1995).

Males and females may mature as young as 2–3 years in Puget Sound, but not until 6 years in the Bering Sea (NOAA 1990). Males live to 17 years and females to 21 years (NOAA 1990).

Trophic Interactions

Flathead sole feed on a wide variety of small mobile prey both on and off the bottom. Dominant prey items vary with area and season. They are opportunistic predators (Rose 1982) and are considered to be piscivorous feeders because they actively pursue prey (Rounsefell 1975).

Around Kodiak Island, Alaska, young flathead sole feed mostly on crustaceans. In order of importance, age-0 flathead sole preyed on amphipods, bivalves, mysids, and shrimp. Age-0 flathead sole in depths of 10–40 and 70–80 m consumed mainly gammarid amphipods; at depths of 50–60 m, they split their diet among *Caridea*, *Mysidea*, and *Gammaridea*; and at depths of 80–90 m, they consumed primarily *Bivalvia* (Holladay and Norcross 1995).

For one-year-old flathead sole off Kodiak Island, Alaska, their diet (in order of importance) consisted of mysids, shrimp, amphipods, and bivalves. Age-1 flathead sole in depths 20–40 and 50–60 m primarily consumed mysids; at depths of 10–20 and 40–50 m, they consumed nearly equal amounts of mysids and caridean shrimp; and in 80–90 m depths, mysids, amphipods, shrimp, and chaetognaths

were of similar importance in their diet (Holladay and Norcross 1995). Minimal dietary requirements of flathead sole ranges from 2.2 to 6.2% of body weight per day during its first year (Paul, et al. 1992).

Around the San Juan Islands in Washington, adult flathead sole prey upon mysids, fishes, shrimp, polychaetes, and clams. The most common fish in their diet is Pacific herring, *Clupea pallasi* (Miller 1970). Mysids are important contributors to the diet for all size groups, although primarily only in the summer and fall for larger sole. Shrimp are important in the diet of sole 180 mm and larger. Fishes and clams are important in the diet of sole 260 mm and larger.

Polychaetes were of some importance in the diet of medium-sized sole in the summer and early fall (Miller 1970). With the exception of larger fish, feeding decreases in the winter months (Miller 1970).

Pacific Sanddab (Citharichthys sordidus)

Range

Pacific sanddab are found from Cape Lucas, Baja California, to the eastern Gulf of Alaska (Barss 1976, Garrison and Miller 1982, Mecklenburg, et al. 2002).

Fishery

Pacific sanddab are taken commercially in the bottom trawl fishery (Love 1996). Off Oregon, they rank about fifth among the flatfish in annual landings (W. Barss[5]). Pacific sanddab are a targeted recreational species; they may be caught by hook and line from boats or piers (Arora 1951, Leos 1991).

Habitat

Pacific sanddab inhabit the shallow sublittoral zone of Puget Sound (Hart 1973), and the inner continental shelf along the West Coast (Alverson, et al. 1964, Barss 1976, Kravitz, et al. 1976). Adults are found in estuaries and coastal waters to as deep as 549 m (Miller and Lea 1972), but the highest abundance is found in waters less than 150 m deep (Hart 1973). Pearcy and Hancock (1978) found that sanddab off Oregon and Washington were most abundant between 37 and 90 m. In Puget Sound, adults may be found to 150 m, but are common in less than 20 m of water (Garrison and Miller 1982). Leos (1991) found adults in Monterey Bay.

Eggs and larvae are pelagic; juveniles and adults are demersal (Garrison and Miller 1982). Larvae may be found as far offshore as 724 km in the upper 200 m of the water column (Sakuma and Larson 1995). Juveniles are primarily found in shallow coastal waters, bays, and estuaries (Hart 1973).

Off Oregon, Pacific sanddab are numerically the most abundant species on sandy bottom habitats between 74 and 102 m (Pearcy 1978). These findings confirmed previous observation reported by Demory, et al. (1976) and Barss, et al. (1977). They conducted trawl surveys off the coasts of Oregon and Washington, and found that Pacific sanddab were associated with sandy sediment at depths less than 120 m. These investigators compared the locations where Pacific sanddab were collected to maps of sediment types prepared by other authors. Small juveniles less than 70 mm prefer substrata of silty sand, whereas adults prefer sand and coarser sediments and low-relief rock bottoms (Allen 1982, Pearcy and Hancock 1978), but are occasionally associated with mud (Love 1996).

Eggs are found in mostly in polyhaline waters at 4–12° C, optimally at 8–9° C (Garrison and Miller 1982). Adults are found in high salinity areas correlated with upwelling (Sakuma and Larson 1995, Sakuma and Ralston 1995). Larvae are found offshore in areas of lower salinity (Sakuma and Larson 1995). Pearcy (1978) and Sakuma and Larson (1995) reported that older fish occur in shallower water and nearer shore than younger fish.

Migrations and Movements

Pacific sanddab make limited migrations that are poorly studied and understood. Pearcy (1978)

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[5] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

reported that sanddab are absent from deep-water (195 m) trawls made off Oregon during the summer and fall, but present in the same areas in the winter and spring. This is thought to be a migration between winter-spring spawning grounds and summer-fall feeding grounds (Pearcy 1978). Coastal movements are minimal. Larvae are carried by wind and ocean currents as far offshore as 724 km (Sakuma and Larson 1995). Sakuma, et al. (1999) reported evidence suggesting that post-flexion sanddab larvae made diurnal vertical migrations through the pycnocline (mean depth 55 m) during the night and desending to to 80-90 m during the crepuscular periods and during the day, with highest catches occurring at night. .

Reproduction

Spawning occurs from late winter through summer, depending on stock and location. In Puget Sound, spawning begins in February and continues through spring, peaking in March and April (Garrison and Miller 1982, Hart 1973). Off California, spawning takes place July through September, peaking in August (Arora 1951, Garrison and Miller 1982). Female sanddab may spawn twice per season (Arora 1951, Garrison and Miller 1982, Hart 1973).

Growth and Development

Fertilized eggs are spherical, translucent and contain a single oil globule (Garrison and Miller 1982, Hart 1973). Eggs are 0.55–0.77 mm in diameter (Garrison and Miller 1982). Embryonic development is indirect and external. Larvae hatch at less than 5 mm (Garrison and Miller 1982) and are pelagic and planktonic. This pelagic stage may last up to 271 days (Sakuma and Larson 1995). Settlement to benthic living occurs at 20–39 mm (Sakuma and Larson 1995). Juveniles range in size from 20 mm to over 19 cm (Arora 1951, Hart 1973).

In Puget Sound, 50% of the species is mature by age 2 (both sexes) (Garrison and Miller 1982). In California, 50% of sanddab are mature by 19.1 cm and 3 years (Arora 1951, Hart 1973). Off Oregon, Pacific sanddab may reach 13 years of age (Barss 1976). Both sexes grow at the same rate for the first four years, after which females grow faster (Arora 1951).

Trophic Interactions

Juveniles and adults are carnivorous. Unlike many sympatric species, Pacific sanddab are mainly pelagic feeders; the only evidence of benthic feeding are annelid worms found in stomachs of some specimens (Pearcy and Hancock 1978). The main food items of large sanddab are crab larvae, squids, octopi, and northern anchovy (Pearcy and Hancock 1978). Smaller sanddab eat euphausiids, amphipods, copepods, shrimp, mysids, and some fish (Allen 1982, Kravitz, et al. 1976, Pearcy and Hancock 1978, Wakefield 1984). The diet of the sanddab is determined mainly by food availability; crab larvae are present only in certain months, and fish consumption is higher in the summer months (Pearcy and Hancock 1978). Pacific sanddab are often found with Dover sole, slender sole, and rex sole (Pearcy and Hancock 1978).

Petrale Sole (Eopsetta jordani)

Range

Petrale sole are found from Cape St. Elias, Alaska to Coronado Island, Baja California. The range may possibly extend into the Bering Sea, but the species is rare north and west of southeast Alaska and in the inside waters of British Columbia (Garrison and Miller 1982, Hart 1973).

Fishery

Landings of petrale sole off Oregon are second only to those of Dover sole among the flatfish, and they bring the highest price per pound among the trawl caught flatfish (W. Barss[6]). Most of the catch is made by deep-water demersal trawls at depths of 300–460 m (PMFC 1996). Petrale sole are not an important recreational species because of the great depths at which they are found, but they are caught incidentally with other species.

Habitat

Petrale sole is common on the outer shelf (100–150 m) (W. Wakefield[7]1) and is an important predator on the continental shelf from British Columbia to central California (NOAA 1990).

Eggs are pelagic; juveniles and adults are demersal (Garrison and Miller 1982). Larvae are neritic and epipelagic. Young juveniles are generally found between 18 and 82 m, and larger juveniles at 25–145 m. Adults are found from the surf line to 550 m, but their highest abundance is found in less than 300 m (NOAA 1990). Adults migrate seasonally between deep-water, winter spawning areas to shallower, spring feeding grounds (NOAA 1990). Larvae are often found in the upper 50 m of the water column far offshore (NOAA 1990). Spawning occurs over the continental shelf and continental slope to as deep as 550 m.

Spawning adults, as well as eggs, larvae, and juveniles, are found in Puget Sound and the waters around Vancouver Island (NOAA 1990, Pedersen 1975a and b).

Over a range of intertidal to 600 m (Love 1996), petrale sole are an important flatfish and benthic predator. They show an affinity to sand, sandy mud, and occasionally muddy substrata (NOAA 1990).

Eggs are found primarily in waters 4–10° C and salinities of 25–30 g/l (Garrison and Miller 1982). Optimum conditions for egg incubation and larval growth were 6–7° C and 27.5–29.5 ppt (Alderdice and Forrester 1971a). No egg hatching was found to occur below 4.3° C (Alderdice and Forrester 1971a). Adults and juveniles are found in euhaline waters.

Migrations and Movements

Petrale sole move from shallow summer feeding grounds to deep-water spawning grounds in the winter. There seems to be little north-south movement up and down the coast, but movements as

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[6] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

[7] W. Wakefield, NOAA Fisheries, NWFSC, NRS, 2032 SE OSU Drive, Newport, OR 97365. Person. commun., July 2003.

great as 628 km have been reported (Garrison and Miller 1982, Hart 1973). Eggs and larvae are transported from offshore spawning areas to nearshore nursery areas by oceanic currents and wind. Petrale sole tend to move into deeper water with increased age and size. Nine separate breeding stocks have been identified, although all stocks intermingle on summer feeding grounds (Alderdice and Forrester 1971a, Hart 1973, NOAA 1990). Of these nine, one occurs off British Columbia, two off Washington, two off Oregon, and four off California (NOAA 1990).

Reproduction

. The petrale sole is a broadcast spawner (NOAA 1990). In British Columbia, Washington and Oregon waters, the spawning season lasts from December to April, and peaks in February through March (Garrison and Miller 1982, Pearcy, et al. 1977). In California, spawning begins slightly earlier. Petrale sole spawn in the same area every year.

A 42-cm female petrale sole may produce 400,000 eggs, whereas a 57-cm female may produce as many as 1,200,000 eggs (Garrison and Miller 1982, NOAA 1990).

Growth and Development

Embryonic development is indirect and external. The planktonic eggs hatch in 13.5 days at 5.0° C, and 6 days at 8.5° C (Garrison and Miller 1982).

Larvae hatch at approximately 3 mm with a yolk sac. The yolk sac is gone by the time the larvae reach 5.7 mm, about 10–16 days (Garrison and Miller 1982). Larvae metamorphose into juveniles at 22 mm and six months of age, and settle to the bottom of the inner continental shelf (Pearcy, et al. 1977).

Petrale sole begin maturing at three years. Half of males mature by seven years and 29– 43 cm, and half of the females are mature by eight years and 44 or more cm (Pedersen 1975a and b). Near the Columbia River, petrale sole mature one to two years earlier (Pedersen 1975a and b). Their maximum age is around 35 years; the maximum length of females is 60–65 cm, and that of males is 40–45 cm (Munk 2001, Sampson and Lee 1999).

Trophic Interactions

Larvae are planktivorous. They prey on all stages of copepods (adults, eggs, and nauplii). Small juveniles eat mysids, sculpins, and other juvenile flatfishes. Large juveniles and adultseat shrimp and other decapod crustaceans, as well as euphausiids, pelagic fishes, ophiuroids, and juvenile petrale sole (Garrison and Miller 1982, Hart 1973, Kravitz, et al. 1976, NOAA 1990, Pearcy, et al. 1977, Pedersen 1975a and b).

Petrale sole eggs and larvae are eaten by planktivorous invertebrates and pelagic fishes. Juveniles are preyed upon (sometimes heavily) by adult petrale sole, as well as other large flatfishes. Adults are preyed upon by sharks, demersally feeding marine mammals, larger flatfishes, and pelagic fishes (NOAA 1990).

Petrale sole compete with other large sympatric flatfishesand share the same summer feeding grounds with lingcod, English sole, rex sole, and Dover sole (NOAA 1990).

Spatial Associations (updated September 2012)

New spatial information on Petrale Sole is somewhat limited and mainly derived from fishery independent surveys. NMFS–NWFSC conducted a survey along the U.S. West Coast between May and October of 2000–2002, 2004, and 2005 (Keller, et al. 2005, 2006a, 2006b, 2007, 2008). The 2004 and 2005 surveys (and presumably earlier surveys) captured a size range indicative of large juvenile (> 20 cm TL) and adult life stages (Keller, et al. 2007, 2008). Petrale Sole was infrequently captured during 2000– 2002, occurring in 3.6–7.3% of tows conducted during 2000 (n = 325 tows), 2001 (n = 334 tows), and 2002 (n = 427 hauls) at depths of 175–581 m (Keller, et al. 2005, 2006a, 2006b). Shallower tows were fished (from 55 m) during 2004 (n = 505) and 2005 (n = 675), however, and the depth profile shifted (52– 434 m) to reveal a greater reliance on shelf waters (mean depth of capture ~125 m) (Keller, et al. 2007; 2008). Based on a directed study using 2004 NMFS–NWFSC survey data (n = 252 tows) and ocenographic data, Petrale Sole was found to be most abundant at productive, northern latitudes (median latitude 45.7° N) (Juan–Jorda, et al. 2009). It was not, however, especially abundant in nearshore waters of Britisth Columbia, ranking 15th in biomass among groundfish surveyed in Hecate Strait during June 2002 (18–146 m; n = 94 tows) and 26th off Western Vancouver Isalnd during May–June 2006 (50–500 m; n = 165) (Choromanski, et al. 2004; Workman, et al. 2008). Petrale Sole exhibited a much wider and deeper distribution during winter months in Hecate Strait (mean = 302 m) when compared to summer moths (n = 108 m) (Pearsall and Fargo 2007). This species is negatively affected by hypoxic conditions, and abundance and physical condition declined significantly at oxygen concentrations < 1.0 ml/l (Keller, et al. 2010).

Other than the results of Keller, et al. (2010) concerning the effects of hypoxia, the new spatial information provided for Petrale Sole adds little to general body of knowledge regarding this species (McCain, et al. 2005). It does, however, provide area–specific information on distribution and abundance patterns that is useful for monitoring purposes.

Trophic Interactions (updated September 2012)

Recently published information concerning Petrale Sole trophic interactions is limited to a single study, conducted in Hecate Strait, British Columbia during June and September–October 1985, January 1986, and May–June 1987 (Pearsall and Fargo 2007). Samples were collected from trawl surveys fished in four distinct regions at depths of 18–166 m on bottom types ranging from sandy silt to a mixture of coarse sand, gravel, pebbles, and cobbles. The great majority of Petrale Sole stomach samples (n = 106) contained prey items (98.1%). Most samples were obtained during September–October 1985 (n = 55) and January 1986 (n = 45). No size or sex information was provided, but fishes represented a mixture of juveniles and adults. Based on pooled results using %W, Petrale Sole in Hecate Strait were largely piscivorous, with fishes accounting for 72.9% of diet composition. The primary prey taxon was Pacific Herring (47.2%). Unidentified fishes (21.1%) and mysids (19.4%) were of secondary dietary importance, and no other prey taxon contributed substantially to diet composition. Diet composition differed markedly between fish collected on fine to coarse sand in January 1986, and those collected on coarse sand, gravel, pebbles, and cobbles during September–October 1985. During the former collection, diet composition was largely composed of Pacific Herring (70.7%), whereas mysids and other epibenthic organisms (58.6%) were dominant during the latter collection. The relative weight of stomach contents also was greater during the former collection. Unfortunately, temporal and spatial results of this study cannot be uncoupled.

The prey taxa consumed by Petrale Sole in Hecate Strait were generally similar to those reported by McCain, et al. (2005) from a synthesis of several studies. However, whereas McCain, et al. (2005)

indicated a greater reliance on shrimp and decapods, fishes and mysids were the most important prey items in Hecate Strait (Pearsall and Fargo 2007). In addition, cannibalism was not noted by Pearsall and Fargo (2007) but was indicated to be a substantial source of mortality for juvenile Petrale Sole by McCain, et al. (2005). Yellowtail Rockfish was reported to be a predator of Petrale Sole in Hecate Strait, although the dietary contribution was trivial (0.25%). This interaction is noteworthy since it was not previously demonstrated (McCain, et al. 2005).

Rex Sole (Glyptocephalus zachirus)

Range

Rex sole are found from the western Bering Sea southward to Cedros Island, Baja California (Eschmeyer, et al. 1983, Love 1996, Miller and Lea 1972).

Fishery

Rex sole are not usually caught by sport fishers (Eschmeyer, et al. 1983, Love 1996), but they are an important food fish and are trawled for commercially (Eschmeyer, et al. 1983). Among flatfish species in the commercial trawl fishery off of Oregon, landings of rex sole rank about fourth (W. Barss[8]).

Habitat

Rex sole is a middle shelf-mesobenthal species, occurring in depths from 0 to 850 m. In survey catches, most (96%) occurred from 50 to 450 m (Allen and Smith 1988). Rex sole are probably the most widely distributed sole on the continental shelf and upper slope off Oregon, occupying a large bathymetric range with diverse sediments (Pearcy 1978). They can occur in water as shallow as 18 m (Eschmeyer, et al. 1983) and occur in Puget Sound (Becker and Chew 1987).

Off Oregon, young-of-the-year rex sole are most abundant at a depth of 200 m (Pearcy 1978). Juveniles (40–60 mm standard length) are common in beam trawls on the outer edge of the continental shelf (150–200 m) during winter months off Oregon (Pearcy, et al. 1977). In studies of Heceta Bank, Pearcy (1978) reported that adult rex sole were most abundant at 55–150 m and intermediate-sized rex sole (75–150 mm) inhabited shallower water of the inner shelf (Pearcy 1978). In Kachemak Bay, Alaska, Abookire, et al. (2001) reported that juvenile rex sole were collected at depths of 30–70 m, with highest CPUE values at greater than 50 m. The sediment at these depths consisted of sand (77–83%) and mud (17–23%).

Rex sole do not appear to have specific spawning sites, but appear to spawn between 100 and 300 m (Pearcy, et al. 1977). Larvae are widely distributed offshore, most abundantly 46– 211 km with a peak around 46 km (Pearcy, et al. 1977). Juvenile rex sole settle to the bottom mainly on the outer continental shelf during the winter when they are longer than 50 mm standard length (Pearcy 1978). Rex sole may utilize the outer continental shelf-upper slope region for a nursery during early benthic life (Pearcy, et al. 1977).

Rex sole are cold-temperate, upper-slope and outer-shelf flatfish (Stull and Tang 1996, NMFS, et al. 1998). They have pelagic eggs and larvae. When inactive, rex sole are buried in the sediments (Stull and Tang 1996). Rex sole are abundant on sandy, muddy, and gravelly bottoms along much of their range (Love 1996, NMFS, et al. 1998, Eschmeyer, et al. 1983). They also occur in complexes of mud and boulders (Love 1996).

Migrations and Movements

Rex sole move inshore in the summer and make offshore spawning movements in the winter (Love 1996). They undergo a modest ontogenetic movement from the shelf to upper-slope habitat (Vetter,

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[8] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

et al. 1994). The maximum movement of a recaptured tagged rex sole was 54 km, suggesting only limited movement (Hosie and Horton 1977).

Reproduction

Off Oregon, 50% of male rex sole mature at 16 cm (3 years), and females mature at 24 cm (5 years) (Hosie and Horton 1977). Spawning off northern Oregon occurs from January to June, with a peak in March through April (Hosie and Horton 1977, Castillo 1995). Two females, 24 and 59 cm total length, yielded fecundity estimates of 3,900 and 238,000 ova, respectively (Hosie and Horton 1977).

Growth and Development

The pelagic larval stage of rex sole usually lasts for about 1 year (Pearcy, et al. 1977). Females grow faster, are larger, and live longer than males (Hosie and Horton 1977, Love 1996). Rex sole are a slow-growing species and live to 24 years (Eschmeyer, et al. 1983, Love 1996). They can grow to 61 cm (Mechlenburg, et al. 2002).

Trophic Interactions

Rex sole feed almost exclusively on benthic invertebrates (Pearcy and Hancock 1978, Stull and Tang 1996). Small (<15 cm standard length) rex sole feed mainly on amphipods and other crustaceans. Large (15–45 cm standard length) rex sole prey chiefly on polychaetes. Rex sole less than 20 cm standard length prey primarily on euphausiids, decapod crab larvae, copepods, *Oikopleura*, and ostracods. Mollusks form only a minor part of rex sole diet. Euphausiids are principal prey only during summer, and cumaceans and *Oikopleura* are more common during the winter (Pearcy and Hancock 1978). In Puget Sound, they feed primarily on *Capitella* spp. (Becker and Chew 1987). Rex sole are nocturnal feeders (Becker and Chew 1987).

Rock Sole (Lepidopsetta bilineata and L. polyxystra)

Range

Three species of rock sole are currently recognized: an Asian species (*Lepidopsetta mochigarei*), in and near the Sea of Japan; a northern species (*L. polyxystra*), from Puget Sound to the Kuril Islands; and a southern species (*L. bilineata*), from Baja California to the far southeasterly extreme of the Bering Sea (Orr and Matarese 2000). All three of these species have similar habitat associations, but their life histories differ slightly (J. Orr[9]). The remainder of this chapter will deal with *L. bilineata and L. polyxystra*.

Fishery

L. polyxystra are among the most abundant groundfish species in the Bering Sea (NMFS 1999). Rock sole are commonly taken by recreational anglers from boats, but most of this catch is incidental to other benthic fishes.

Habitat

Adult rock sole are found intertidally to as deep as 732 m, but they are uncommon below 300 m (Love 1996, Horton 1989). Juveniles and adults are demersal and found primarily in shallow water bays and over the continental shelf (Alton and Mearns 1976, Forrester and Thomson 1969, Horton 1989). They overwinter on the edge of the continental slope at depths of 125–275 m (Horton 1989) and occupy the shelf during the summer at depths of 18–80 m. In Puget Sound, rock sole are uncommon below 55 m and spawning occurs in shallow water (Garrison and Miller 1982).

Eggs are demersal and adhesive (Horton 1989). Larvae are pelagic and primarily found in the upper 30 m of the water column (Haldorson, et al. 1993, Hart 1973, Horton 1989), although Orr and Matarese (2000) reported that “larvae were collected over depths less than 1000 m.” Small juveniles settle all along the coast, with a much higher occurrence further north. Juveniles move into deeper waters with increased size. Eggs occur in polyhaline to euhaline waters, from sub-zero temperatures to 15° C (Garrison and Miller 1982, Horton 1989). Adults are found almost exclusively in euhaline waters. Juveniles and larvae occur in polyhaline to euhaline waters. Larval development was most successful at 6° C (Horton 1989). Temperatures above 18° C inhibit egg and larval growth, as well as adult feeding, and the upper lethal limit is 24.9° C (Horton 1989).

Adults and juveniles of L. bilineata and polyxystra prefer sandy or gravel substrata on the coast of the contiguous U.S., and also show an affinity to steep rock slopes in Puget Sound (Garrison and Miller 1982, Hart 1973, Horton 1989). Garrison and Miller (1982) also reported that rock sole occur over soft bottoms. Pettila (1995) reported finding eggs of *L. bilineata* in sandy gravel of upper intertidal areas of Puget Sound. Spawning occurs over a variety of substrata, from rocky banks to sand and mud (Garrison and Miller 1982, Horton 1989).

Studies conducted in Alaskan waters likely involved *L. polyxystra.* In Kachemak Bay, Alaska, Abookire, et al. (2001) reported that juvenile rock sole were collected at depths of 10–40 m, with highest CPUE values at less than 20 m. The sediment at these depths consisted of at least 95% sand. Previous work in this bay by Abookire and Norcross (1998), demonstrated that age-0 sole preferred

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[9] J. W. Orr, NOAA NMFS WASC, 7600 Sand Point Way, NE, Seattle, WA 98115. Person. commun. March 2003.

sand, whereas age-1 sole were associated with sand as well as sediments consisting of mixed sand and mud, mixed sand and gravel, and gravel. In studies conducted in the Bering Sea, McConnaughey and Smith (2000) reported that rock sole were most commonly found associated with sediment consisting of sand and mixtures of sand and mud. Orr and Matarese (2000) reported that *L. polyxystra* collected from the continental shelf were commonly found "at depths of 200 m and less, to as deep as 575 m."

Migrations and Movements

Rock sole are sedentary (Garrison and Miller 1982, Horton 1989). They undergo a movement to deeper waters in the winter to spawning grounds, and a post-spawning migration to summer feeding grounds in the shallow waters over the continental shelf (Alton and Mearns 1976, Forrester and Thomson 1969, Hart 1973). Haldorson, et al. (1993) reported that larvae migrate from 5–10 m during the day to 30 m at night, most likely following the peak abundances of copepod nauplii. Larvae are transported by wind and tidal currents. Immature rock sole reside in shallow waters in the winter and move to shallower waters in coastal areas in the spring and summer (Orr and Matarese 2000). Rock sole (mainly *L. polyxystra*) also move into deeper water with increased size (Shvetsov 1978).

Reproduction

Spawning occurs from winter through early spring, depending on location of the stock. In Puget Sound, spawning occurs from December to April, peaking in March. In southern California, spawning occurs from November to March, peaking in February. In the Bering Sea, spawning occurs from March to June, peaking in April (Garrison and Miller 1982, Hart 1973, Horton 1989, Love 1996, Shvetsov 1978).

A 35-cm fish may produce 400,000 eggs per year, whereas a 46-cm fish may produce up to 1,300,000 eggs per year (Garrison and Miller 1982, Horton 1989).

Growth and Development

Fertilized eggs are spherical and 0.87–1.00 mm in diameter (Horton 1989). Embryonic development is indirect and external. The eggs hatch in 6.4 days at 11° C, 9–18 days at 6.5– 8.0° C, and 25 days at 2.9° C (Alton and Mearns 1976). Larvae hatch at 3.4–5.0 mm with a yolk sac that is absorbed in 10–14 days (Alton and Mearns 1976). Metamorphosis occurs at 17–20 mm (Garrison and Miller 1982, Horton 1989). Juveniles range from 17 mm to 33 cm, depending on gender (Webber and Shippen 1975).

Rock sole females mature at 4–5 years and 33–36 cm. Males mature at 3–4 years and 30 cm (Forrester and Thomson 1969, Garrison and Miller 1982, Hart 1973). In Puget Sound, female rock sole mature in 3–4 years at 32–33 cm, and males mature at 2 years (Garrison and Miller 1982). After 2–3 years, females grow faster than males and reach a larger average size. Growth of both sexes decreases after 8 years. Female rock sole may live up to 18 years at 49 cm fork length, and males up to 17 years at 40 cm fork length (Forrester and Thomson 1969, Levings 1967).

Trophic Interactions

Larvae are planktivorous. Juveniles and adults are carnivorous, feeding during the daylight hours (Onate 1991). Juveniles consume mobile prey, such as cumaceans, carideans, and gammarid amphipods. Adults feed on more sedentary foods, such as polychaetes, echiuroids, mollusks, echinoderms, benthic fishes, and urochordates (Onate 1991, Wakefield 1984). In studies conducted off Oregon, brittlestars were the primary prey organism, followed by polychaetes and mollusks (Wakefield 1984). Polychaetes may constitute up to 62% of an adult rock sole’s diet (Lang 1992). Depending on the season, clam siphons may be consumed almost exclusively (Hart 1973). Diet variation results as much from food availability as it does from prey preference (Lang 1992).

Larvae are probably eaten by larger fishes, including other rock sole, and perhaps sea birds. Juveniles are eaten by larger fishes, including rock sole (Alton and Mearns 1976). Adult rock sole may be eaten by sharks, marine mammals, and larger fishes (Horton 1989).

Sand Sole (Psettichthys melanostictus)

Range

Sand sole occur from Redondo Beach, southern California to as far north as the Alaskan Peninsula and the Bering Sea (Garrison and Miller 1982, Mecklenburg, et al. 2002).

Fishery

Sand sole are of minor commercial importance off the West Coast, although they occur in relatively high abundance. Sand sole are captured by means of demersal trawl and, among flatfish species in the Oregon commercial fishery, their landings rank approximately sixth (W. Barss[10]). Sand sole are not targeted recreationally, but are taken incidentally to other fish species.

Habitat

Sand sole are considered an inner shelf-outer shelf species. Adults and older juveniles occur between 1 and 325 m, but nearly all occur at depths shallower than 150 m (Sommani 1969, Hart 1973, Allen and Smith 1988, Rogers and Millner 1996). Eggs, larvae, and small juveniles are pelagic; older juveniles and adults are demersal (Haldorson, et al. 1993). Larvae are generally found in the upper 10 m of the water column of waters less than 200 m deep (Garrison and Miller 1982, Haldorson, et al. 1993). Small juveniles may remain pelagic for some time, and in Puget Sound usually occur in 5–20 m of water (Garrison and Miller 1982). Adults and older juveniles are found as deep as 183 m, but do not occur in high densities below 73 m (Kramer, et al. 1995) Spawning occurs over sandy and muddy substrata in water 20–30 m deep (Garrison and Miller 1982).

Adults are found year-round in some estuaries, and spawning adults, eggs, and larvae are found winter-spring in Puget Sound, Bellingham Bay, and East Sound (Hart 1973, Sommani 1969). Larvae and juveniles occur in most estuaries along the West Coast. Sand sole show a high affinity to shallow waters with sandy and muddy substrata all along the Pacific coast (Garrison and Miller 1982, Hart 1973, Sommani 1969).

Eggs are pelagic and float up just before hatching (Hart 1973, Sommani 1969). Egg and larval development is fastest between 4 and 12° C (Garrison and Miller 1982). Adults are found from sub-zero temperatures to as warm as 16° C (Sommani 1969). All life stages are found in euhaline water (Haldorson, et al. 1993).

Migrations and Movements

Sand sole are not considered to be a migratory species. Adults may move into shallow nearshore waters in early winter to spawn, then move south and offshore in the summer to feed (Rogers and Millner 1996). Adults and demersal juveniles tend to move to deeper waters with increased size and age (Garrison and Miller 1982). Larvae and small juveniles are transported to estuaries and shallow nearshore bays by tidal currents (Haldorson, et al. 1993).

Reproduction

Spawning occurs in winter and spring. In Puget Sound, the spawning season is January through April,

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[10] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

peaking in February. In Bellingham Bay, spawning peaks in March. In northern British Columbia, spawning peaks in late April. On the west coast of Vancouver Island, spawning peaks in July (Garrison and Miller 1982, Hart 1973, Sommani 1969). A 28-cm female may produce 900,000 eggs, while a 37-cm fish may produce 1,400,000 eggs.

Growth and Development

Fertilized eggs are spherical and 1.00 mm in diameter (Hart 1973, Sommani 1969). Embryonic development is indirect and external. The planktonic eggs hatch in 6–7 days at 1.5° C, 5 days at 7–9° C, and 3.5 days at 12° C (Garrison and Miller 1982, Hart 1973). Larvae hatch at 2.8 mm and float with their yolk sacs up (Sommani 1969). The yolk sac is absorbed in 10–12 days. Larvae begin metamorphosis into juveniles between 23 and 27 mm (Hart 1973). Juveniles range in size from 23 mm to 24 cm, depending on gender.

Sommani (1969) reported that all females were mature by age 3 and males by age 2. These ages correspond to 20 cm for males, and 28 cm for females (Hart 1973). After 2 years, females begin to grow more rapidly than males. Sand sole may attain 10 years of age (B. Barss[11]).

Trophic Interactions

Larvae and small juveniles feed on copepods, their eggs, and nauplii. Juveniles feed on small crustaceans such as mysids and crangons, worms, and mollusks (Barry, et al. 1996, Hart 1973, Sommani 1969, Hogue and Carey 1982). Adults feed mainly on speckled sanddabs, herring, anchovies, crustaceans, worms, and mollusks (Barry, et al. 1996, Hart 1973, Rogers and Millner 1996, Sommani 1969). Large adults eat more mobile prey; crabs and fish may make up to 80% of their diet (Barry, et al. 1996). Wakefield (1984) reported that the primary food items for sand sole collected at depths of 9 and 22 m off the central Oregon coast were mysids and fish.

Eggs and larvae are preyed upon by small fishes and sea birds. Juveniles are preyed on by larger fishes. Adults are eaten by larger fishes, sharks, and marine mammals (Barry, et al. 1996).

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[11] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

Starry Flounder (Platichthys stellatus)

Range

Starry flounder are found in the western Bering Sea and north of the Bering Strait south to Avila Beach, central California (M. Love[12]). They are common in Puget Sound (Garrison and Miller 1982, Hart 1973, NOAA 1990).

Fishery

Starry flounder are a modestly important commercial flatfish species (W. Barss[13]). Starry flounder are captured by bottom trawl. They are not generally targeted recreationally, but they are taken quite often by anglers fishing from boats or steep rocky banks.

Habitat

Starry flounder is an important member of the inner continental shelf and shallow sublittoral communities (NOAA 1990). Older juveniles and adults are found from 120 km upstream to the outer continental shelf at 375 m, but most adults are found in less than 150 m (NOAA 1990). Richardson, et al. (2000) reported finding significant numbers of starry flounder in the Fraser River, B.C, as far as 70 km upstream. Most juvenile and adult starry flounder were collected in the tidally influenced section (<7 km), whereas most flounder from the upper reaches were juveniles (length <100 mm). Most spawning occurs in estuaries or sheltered inshore bays (Orcutt 1950), in less than 45 m of water.

Eggs and larvae are epipelagic; juveniles and adults are demersal (Garrison and Miller 1982). Eggs occur at or near the surface over water 20–70 m deep (Conley 1977, Garrison and Miller 1982, Hart 1973). Larvae are found in estuaries and up to 37 km offshore. Juveniles are found in estuaries and the lower reaches of major coastal rivers (Hart 1973, Orcutt 1950). Adults also occur in estuaries or their freshwater sources year-round in Puget Sound (Garrison and Miller 1982).

Juveniles prefer sandy to muddy substrata and adults prefer sandy to coarse substrata, including gravel (Cailliet, et al. 2000, NOAA 1990). These findings confirmed previous observation reported by Demory, et al. (1976) and Barss, et al. (1977). They conducted trawl surveys off the coasts of Oregon and Washington, and found that starry flounder were associated with sandy sediment at depths less than 60 m. These investigators compared the locations where starry flounder were collected to maps of sediment types prepared by other authors. Eggs are found in polyhaline to euhaline waters; juveniles are found in mesohaline to fresh water; adults and larvae are found in euhaline to fresh water (Conley 1977, Garrison and Miller 1982, Orcutt 1950). All life stages can survive and grow at temperatures between 0° C–12.5° C (NOAA 1990).

Migrations and Movements

Starry flounder is not considered to be a migratory species. However, adults move inshore in late winter-early spring to spawn and offshore and deeper in the summer and fall, but these coastal movements are generally less than 5 km (Conley 1977, NOAA 1990). Some starry flounder have shown movements of greater than 200 km (Conley 1977), but this is not considered typical. Adults

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[12] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.

[13] W. Barss, Oregon Dept. of Fish and Wildlife, 2040 SE Marine Science Dr., Newport, OR 97365. Pers. commun., March 2004.

and juveniles are known to swim great distances up major coastal rivers (>120 km), but not following any migratory trend. Larvae may be transported by oceanic currents great distances.

Reproduction

Spawning occurs annually in a short time frame in winter and spring, with the exact timing depending on location. In California, starry flounder spawn from November to February, peaking in December (Garrison and Miller 1982, Orcutt 1950). In Puget Sound, spawning occurs from February to April, peaking in March (Garrison and Miller 1982, Hart 1973). In British Columbia and the Gulf of Alaska, spawning occurs from February to May, peaking in early April (Hart 1973).

In the Bering Sea, females of 38–48 cm produced between 900,000 and 2,500,000 eggs (NOAA 1990). In California, a 56-cm fish had 11,000,000 eggs (Orcutt 1950).

Growth and Development

Fertilized eggs are spherical and between 0.89 and 1.01 mm in diameter (Hart 1973, NOAA 1990). Embryonic development is indirect and external. Eggs hatch in 2.8 days at 12.5° C, 4.6 days at 10.0° C, and 14.7 days at 2.0–5.4° C (Garrison and Miller 1982, Hart 1973, Policansky and Sieswerda 1979).

Larvae hatch at 1.93–2.08 mm and float with their yolk sacs up (Garrison and Miller 1982, Hart 1973, Policansky and Sieswerda 1979). The yolk sac is gone in 4–5 days, by the time the larvae reaches 6 mm (Garrison and Miller 1982). Metamorphosis to the benthic juvenile form occurs at 10–12 mm (Garrison and Miller 1982, Policanski 1982). Sexually immature juveniles range in size from 10 mm to 45 cm, depending on gender (Conley 1977, Hart 1973, Love 1996, Orcutt 1950).

Females begin maturing at 24 cm and 3 years, but some may not mature until 45 cm and 4–6 years (Garrison and Miller 1982, Hart 1973, Love 1996, Orcutt 1950). Males begin maturing at 2 years and 22 cm, but some may not reach maturity until 4 years and 36 cm (Garrison and Miller 1982, Hart 1973, Love 1996). After 2 years, females grow faster than males and reach larger sizes. Maximum age is reported as 21 years (NOAA 1990).

Trophic Interactions

Larvae are planktivorous. Juveniles and adults are carnivorous. At 5–12 mm, larvae eat copepods, eggs, and nauplii, as well as barnacle larvae and diatoms (Hart 1973, Policansky and Sieswerda 1979). Small juveniles feed on copepods, amphipods, and annelid worms (McCall 1992). Barry, et al. (1996) reported that adult starry flounder in Elkhorn Slough, California, fed on 87 different taxa of prey over one year, yet mollusks and infaunal worms made up more than 65% of their diet. Large fish fed on a wider variety of items, including crabs and other more mobile foods. In other areas, clams and benthic fishes are an important part of the starry flounder's diet (NOAA 1990). Starry flounder do not feed during spawning or coldwater periods (NOAA 1990).

Larvae are eaten by larger fish and herons. Juveniles and adults are eaten by larger fishes, sharks, and by pinnipeds and other marine mammals (NOAA 1990). Wading and diving seabirds such as herons and cormorants feed on juvenile starry flounder (Haugen 1992).

Starry flounder probably competes with other soft-bottom benthic fishes of estuaries and shallow nearshore bays. It occasionally interbreeds with the English sole to produce a hybrid (NOAA 1990).

Other Flatfish Group Summary Information
(Updated September 2012)

New literature on spatial associations and trophic interactions of the Other Flatfishes group consisted of 66 publications, with several publications providing information for multiple species. Most Other Flatfishes were well studied, with rex sole (41 publications), flathead sole (38 publications), and rock sole (31 publications) foremost among them. Curlfin sole (10 studies) and sand sole (12 publications) were referenced least among the accumulated literature, with most relevant information contained in survey reports. Data on Pacific and speckled sanddabs and southern and northern rock sole were occasionally pooled because of uncertain identification (e.g., Love and York 2005; McKenzie and Wynne 2008) or for convenience during multi–species analyses (e.g., Hoff 2006; Gaichas and Francis 2008). To avoid confusion, the current designation of "rock sole" should be changed to the proper common name of "southern rock sole" in accordance with American Fisheries Society guidelines. Data summaries from fishery–independent surveys provided a great deal of general information on distribution and abundance patterns along the U.S. West Coast (e.g., Keller, et al. 2005, 2007, 2008) and throughout Canadian (e.g., Choromanski, et al. 2004, 2005; Workman, et al. 2008) and Alaskan waters (e.g. Hoff and Britt 2005; Rooper 2008; von Szalay, et al. 2010). In addition, many directed studies provided information on a wide variety of topics related to EFH (e.g., habitat associations, physiological tolerances, trophic relationships), at various levels of detail. Much more new spatial information was available when compared to trophic information, and no new diet composition information was produced along the West Coast.

Spatial Associations (updated September 2012)

Contemporary spatial information about other flatfishes was substantial and diverse. Fishery-independent surveys provided information on distribution and abundance patterns of juveniles and adults, but additional information on eggs and larvae was also available. In the Gulf of Alaska, integrated data sets were used to determine spawning locations and distribution patterns of eggs and larvae of rex sole (Abookire and Bailey 2007; Bailey, et al. 2008) and flathead sole (Porter, et al. 2005). In the northern California Current, Pacific sanddab was among the most abundant ichthyoplankton species surveyed, and rex sole was also commonly observed (Phillips, et al. 2009). Habitat associations were determined for several species of Other Flatfishes. Pacific sanddabs were found predominantly in muddy, benthic habitats off central California (Anderson and Yoklavich 2007) but were also commonly encountered in pelagic sampling off Oregon and Washington (Brodeur, et al. 2009), and in association with heavily encrusted oil platform beams off Southern California (Love and York 2006). Starry flounder exhibited no preference among mud, oyster, and eelgrass habitats in Willapa Bay, Washington (Hosack, et al. 2006) and preferred sand to cobble, and cobble to bedrock (Thedinga, et al. 2008); however, sample sizes were low for both studies. Patterns of estuary nursery use and evidence for habitat partitioning was provided for sand sole, starry flounder, and Pacific sanddab in the Pacific Northwest (Rooper, et al. 2005). Early juvenile starry flounder typically occupy upper regions of estuaries, and this distribution pattern is facilitated by the development of a strong low-salinity tolerance during early ontogeny (Wada, et al. 2007).

Trophic Interactions (updated September 2012)

Contemporary information on trophic interactions was available for all members of the Other Flatfishes group but the great majority of this information was derived from Canadian and Alaskan waters. For example, diet composition studies were limited to those conducted off British Columbia (Pearsall, et al. 2007) and in Alaskan waters (Yang 2004; Yang, et al. 2004, 2005). In Hecate Strait, British Columbia, diet composition, seasonal and spatial dietary variability, and dietary overlap were evaluated for flathead sole, Pacific sanddab, rex sole, rock sole, and sand sole (Pearsall, et al. 2007). In the Gulf of Alaska, diet composition was determined for flathead sole, rex sole, and rock sole (Yang, et al. 2006) based on small sample sizes, and flathead sole and rock sole were lumped in an "other flatfish" group to investigate predation on capelin (Yang, et al. 2005). Stellar sea lions were found to prey on several species of Other Flatfishes off Kodiak Island, but only rock sole (combined) contributed more than a trivial proportion to diet by percent frequency of occurrence (Trites, et al. 2007; McKenzie and Wynne 2008). Similarly, harbor seals in the Umpqua River (Oregon) frequently consumed rex sole, and ate butter sole, Pacific sanddab, and starry flounder less commonly. In California waters, Pacific sanddab was a minor prey item of California sea lions (Weise and Harvey 2008; Orr, et al. 2011). A large number of predator (n = 4) and prey (n = 44) linkages were determined for flathead sole based on benthic food web modeling in the Gulf of Alaska, and rex sole (1 predator link, 13 prey links) was also an importance source of energy flow in this region. The longnose skate was found to be a major predator of mall flatfishes in the Gulf of Alaska, including flathead sole, rex sole, and rock sole (Gaichas, et al. 2010).

6. ROCKFISHES

The West Coast FMP includes fifty-three species of rockfish (genus *Sebastes*) and two species of thornyhead (genus *Sebastolobus*). Some species are localized latitutinally along certain sections of the coastline, for example, Mexican rockfish (*S. macdonaldi*) and calico rockfish (*S. dallii*) are commonly found only off southern California. Other species, such as dusky rockfish (*S. variabilis*) and yellowmouth rockfish (*S. reedi*) are restricted to the northern waters off Oregon and Washington. Other species are widely distributed along the coastline, including copper rockfish (*S. caurinus*) and canary rockfish (*S. pinniger*). Similarly, some species are restricted to shallow depths (< 30 m), examples include grass rockfish (*S. rastrelliger*) and kelp rockfish (*S. atrovirens*); whereas others are found primarily at depths (30- 200 m) over the Continental shelf, such as greenspotted rockfish (*S. chlorostictus*) and squarespot rockfish (*S. hopkinsi*), or over the Continental slope (> 200 m), such as aurora rockfish (*S. aurora*) and longspine thornyheads (*Sebastolobus altivelis*) (Love, et al. 2002).

All rockfish species, with the exception of the *Sebastolobus* spp., are viviparous, a process by which embryos derive energy both from yolk and from their mothers. Larvae are released through a phenomenon known as parturition. The larvae and young juveniles are pelagic, occupying a wide range of depths over a wide range of time intervals. The *Sebastolobus* spp are oviparous and are characterized by single spawning events (Love 1996, Pearson and Gunderson. 2003).

Aurora Rockfish (Sebastes aurora)

Range

Aurora rockfish are found from Langara Island, British Columbia to Isla Cedros, Baja California (Gillespie 1991, Kramer and O'Connell 1995, Love, et al. 2002).

Fishery

Aurora rockfish are a minor component of trawl catches from deep, soft-bottom habitats (Moser, et al. 1985), and are sometimes taken in sablefish traps (Eschmeyer, et al. 1983). They are only occasionally taken in sport fisheries (Lea 1992).

Habitat

Aurora rockfish are common offshore (Eschmeyer, et al. 1983) and occupy upper slope habitats (Moser, et al. 1985). They range in depth from 125 to 893 m (Lauth 1999), with nearly 96% occurring from 300–500 m (Allen and Smith 1988, Orr, et al. 2000). Larvae are pelagic (NMFS, et al. 1998) and occur from 110 to 170 km from shore (Kendall and Lenarz 1987). In a study conducted in the California Bight, Moser, et al. (2000) reported that aurora rockfish larvae collected by plankton tows were almost exclusively in waters over the continental shelf at depths less than 200 m. Adults and juveniles are found in soft- and hard-bottom habitats on the continental slope/basin (NMFS, et al. 1998, Love, et al. 2002).

Migrations and Movements

No information.

Reproduction

Aurora rockfish spawn during March through May off northern and central California and in June off British Columbia (Kendall and Lenarz 1987). Larvae are about 4.0 mm long at birth (Moser, et al. 1985).

Growth and Development

Aurora rockfish transform from pelagic larvae to pelagic juveniles at about 13 mm standard length, and they transform from pelagic juveniles to benthic juveniles at about 38 mm standard length (Moser, et al. 1985). They settle to benthic habitats at about 3–4 months of age (Moser, et al. 1985). The estimated age of a 17.6 mm standard length pelagic juvenile is 68 days, a 25.3 mm standard length pelagic juvenile is about 76 days, and a 26.8 mm standard length pelagic juvenile is about 80 days (Moser, et al. 1985). Adults grow to 41 cm (Kramer and O'Connell 1995), and have been aged up to about 75 years (Love, et al. 2002).

Trophic Interactions

No information.

Bank Rockfish (Sebastes rufus)

Range

Bank rockfish are found from Queen Charlotte Sound, British Columbia, to central Baja California, most commonly from Fort Bragg southward (Love 1992a, Love, et al. 2002).

Fishery

Bank rockfish are important to commercial fisheries and occasionally taken in recreational fisheries off California (Lea 1992).

Habitat

Bank rockfish occur offshore (Eschmeyer, et al. 1983) at a maximum depth of 247 m (Orr, et al. 2000), although adults prefer depths beween 31 and 247 m (Orr, et al. 2000). Observations of commercial catches indicate juveniles occupy the shallower part of the species range (Love, et al. 1990). Pelagic juveniles are found over a wide depth range, 25–80 m (Lenarz, et al. 1991).

Some adult bank rockfish form aggregates in midwater over hard bottoms (Love 1992a), over high relief, or on bank edges (Love, et al. 1990) and along the ledges of canyons (Sullivan 1995). They also frequent deep water over muddy or sandy bottoms (Miller and Lea 1972, Piner, et al. 2000). Adults are also found on rocky reefs, among boulder fields, cobble, mixed mud-rock bottoms, non-rocky shelf, and canyons along the continental slope/basin (Love and Watters 2001, NMFS, et al. 1998). Juveniles are paradmersal, occupy the shallower part of the adult range, and prefer mixed mud and rock habitats (NMFS, et al. 1998, Love, et al. 2002).

Migrations and Movements

No information.

Reproduction

Spawning ranges from December to May (Love, et al. 1990). Peak spawning in the southern California Bight is January; in central and northern California it is February. Off California, bank rockfish are multiple brooders (Love, et al. 1990). Egg numbers range from 65,000 eggs per brood for a 37-cm female to a maximum of 607,000 eggs per brood for a 49.6- cm female (Love, et al. 1990).

Growth and Development

Females grow to a larger maximum size (50 cm) than males (44 cm), but grow at a slightly slower rate (Cailliet, et al. 1996). They have been aged to 85 years (Love, et al. 2002). Males reach first maturity at 28 cm, 50% maturity at 31 cm, and 100% at 38 cm. Females reach first maturity at 31 cm, 50% at 36 cm, and 100% maturity at 39 cm (Love, et al. 1990).

Trophic Interactions

Bank rockfish are midwater feeders, eating mostly gelatinous planktonic organisms such as tunicates, but also preying on small fishes and krill (Love 1992a).

Black Rockfish (Sebastes melanops)

Range

Black rockfish are found from southern California (Hunington Beach) to the Aleutian Islands (Amchitka Island), and they occur most commonly from San Francisco northward (Miller and Lea 1972, Phillips 1957, Stein and Hassler 1989, Mecklenburg, et al. 2002).

Fishery

Black rockfish are important in the ocean sport and commercial fisheries (Boettner and Burton 1990, Dunn and Hitz 1969, Stein and Hassler 1989). Black rockfish are commonly taken by trollers and trawlers fishing in shallow waters overlying the continental shelf off California, Oregon, and Washington (Alverson, et al. 1964). They are also taken incidentally by commercial salmon trollers, especially from June to August (Dunn and Hitz 1969). Recent catches have been greatest by sport anglers, followed by the commercial handline jig, trawl, and salmon troll fisheries.

Habitat

Black rockfish occur from the surface to 366 m, but are most common at depths shallower than 55 m (Love, et al. 2002). Off Oregon, they are most common in waters from 12 to 90 m (Oregon Dept. of Fish and Wildlife 2002). Off California, black rockfish make up the kelp-rockfish assemblage along with the blue, olive, kelp, black-and-yellow, and gopher rockfishes, and they are distinguished, to some degree, from offshore species (Hallacher and Roberts 1985). However, they can occur far offshore (Dunn and Hitz 1969). Juveniles occur well up in the water column, usually near or in such shelter as kelp or pilings, though they may live in deeper waters in the winter (Stein and Hassler 1989). Adults are also usually observed well up in the water column (Hallacher and Roberts 1985). In the water column, the frequency of black rockfish occurring closer (<0.5 m) to vertical *Macrocystis* fronds is significantly greater than that expected had they been randomly distributed (Carr 1991).

Black rockfish larvae and young juveniles (<40–50 mm) are pelagic (Boehlert and Yoklavich 1983, Laroch and Richardson 1980) and larvae have been collected as far as 266 km offshore of the Oregon coast (Love, et al. 2002). Young-of-the-year settle nearshore, generally in the shallower portions of the kelp beds (6–12 m), where they frequent the sand-rock interface, seagrass beds, kelp canopy, midwater column, and high-relief rock. They have also been found on artificial reefs and in bays, estuaries, and tide pools (Dewees and Gotshall 1974; Gascon and Miller 1981, 1982; Grossman 1982; Yoshiyama, et al. 1986; Stein and Hassler 1989; Love, et al. 1991; Moser and Boehlert 1991; Love 1996; Ven Tresca, et al. 1996; Bloeser 1999). When benthic, juvenile black rockfish inhabit waters less than 20 m and can occur over sandy bottom (Laroch and Richardson 1980). As described by Stein and Hassler (1989), juveniles in the kelp beds of Monterey Bay, California, live both in the canopy and on the bottom, often associated with kelp holdfasts and sporophylls. They are recruited to the bottom primarily in June. Off Oregon, age-0 juveniles occur seasonally from June to October. The June transition from pelagic to benthic habitat is marked by a distinct inshore movement to estuaries, tide pools, and nearshore depths of less than 20 m. In nearshore areas of central California, post-pelagic newly settled black rockfish were first observed at the seaward, sand-rock interface of nearshore reefs in depths of 6–20 m. They are associated with crevices, sand channels among the rocks, or depressions in the reef (Ven Tresca, et al. 1996). Small juveniles occur in three habitats: pelagic individuals offshore at less than 60 mm standard length in summer; nearshore on bottom at 40– 70 mm standard length in June; and in estuaries at 35–92 mm standard length from April to October, often in eelgrass.

Larger juveniles up to 15 cm may live in rocky holes. Black rockfish use low-rock and high-rock substrata during the summer recruitment period (Carr 1991).

Juvenile black rockfish may inhabit intertidal eelgrass beds from March to October in Yaquina Bay, Oregon (Boehlert and Yoklavich 1983).

Adults inhabit the midwater and surface areas over high-relief rocky reefs. They are found in and around kelp beds, boulder fields, pinnacles, and artificial reefs (Ebeling, et al. 1980a; Grossman 1982; DeMott 1983; Hallacher and Roberts 1985; Bodkin 1986, 1988; Love 1996; Starr 1998; Bloeser 1999). In the central portion of their range from Oregon to southeast Alaska, they will often form schools of thousands of individuals, often in association with reefs and with other species including yellowtail, dusky, silvergray and blue rockfishes (Oregon Dept. of Fish and Wildlife 2002).

The abundance of black rockfish in shallow water declines in the winter and increases in the summer (Stein and Hassler 1989). Densities of black rockfish decrease with depth during both the upwelling and non-upwelling seasons (Hallacher and Roberts 1985, PMFC 1996). Off Oregon, larger fish seem to be in deeper water (20–50 m) (Stein and Hassler 1989). Black rockfish are also found in the Strait of Juan de Fuca (Clemens and Wilby 1961).

Migrations and Movements

Black rockfish off the northern Washington coast and outer Strait of Juan de Fuca exhibit no significant movement. However, fish appear to move from the central Washington coast southward to the Columbia River, but not into waters off Oregon. Also, movement displayed by black rockfish off the northern Oregon coast is primarily northward to the Columbia River (Culver 1986). Black rockfish form mixed-sex, midwater schools, especially in shallow water (Hart 1973, Stein and Hassler 1989). In the summer, schools of feeding black rockfish are commonly seen at the surface along the kelp-lined shores of the western Juan de Fuca Strait, particularly near Duncan Rock (about 2.8 km north-northwest of Cape Flattery) (Dunn and Hitz 1969). Schools of black rockfish occur above shallow water British Columbia reefs only from June to September (Stein and Hassler 1989).

In kelp beds, larger adult black rockfish seem to migrate outside the kelp diurnally, returning before dusk; juveniles and small adults remain in the kelp and also tend to be closer to the bottom at night (Stein and Hassler 1989). Black rockfish may travel up to 600 km, but they usually remain in one area (Stein and Hassler 1989).

Reproduction

Black rockfish have internal fertilization and annual spawning (Stein and Hassler 1989). Parturition occurs from February to April off British Columbia, January to March off Oregon, and January to May off California (Boehlert and Yoklavich 1983, Houk 1992a, Stein and Hassler 1989). Spawning areas are unknown, but spawning may occur in offshore waters because gravid females have been caught well offshore (Dunn and Hitz 1969, Hart 1973, Stein and Hassler 1989).

Growth and Development

Age of 50% maturity for black rockfish off California is estimated at 7 years (P. Reilly[14]). Black

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rockfish can live to about 50 years of age (Love, et al. 2002). Off California, males may be sexually mature at 3 years (250 mm); all are mature by 10 years (430 mm). Females off California may mature at 5 years (300 cm); all are mature by 11 years (480 mm). Off Oregon, males may mature in 5 years, and females in 6 years. The maximum length attained by the black rockfish is 65 cm (Lea, et al. 1999). After age 7, females are larger than males of the same age (Stein and Hassler 1989).

Trophic Interactions

Black rockfish larvae feed on nauplii, invertebrate eggs, and copepods (Sumida, et al.1985, Moser and Boehlert 1991). Off Oregon, black rockfish primarily prey on pelagic nekton (anchovies and smelt) and zooplankton such as salps, mysids, and crab megalops (Steiner 1978). Juveniles feed on copepods, zoea, other crustaceans (such as carangids and mysids), barnacle cypriots, fish larvae, and juvenile polychaetes (Gaines and Roughgarden 1987). Adults prey on small fishes (including juvenile blue and other rockfishes), euphausiids, and amphipods during upwelling periods; during non-upwelling periods they primarily consume invertebrates, such as crustaceans, polychaetes, cephalopods, chaetognaths, and jellyfish (Washington, et al. 1978; Rosenthal, et al. 1982; Bodkin 1988; Houk 1992a; Love 1996; Bloeser 1999; Lea, et al. 1999).

During the summer months when recruitment of juvenile *Sebastes* is relatively high, juvenile rockfish are the primary prey of adult black rockfish (Hobson, et al. 2000). Most feeding probably occurs during the day or at twilight (Stein and Hassler 1989). Black rockfish feed almost exclusively in the water column (Culver 1986). Black rockfish have a dietary overlap with black-and-yellow rockfish, gopher rockfish, and kelp rockfish (Hallacher and Roberts 1985) and probably other species of *Sebastes* (Lea, et al. 1999). Black rockfish are known to be eaten by lingcod and yelloweye rockfish (Stein and Hassler 1989).

Larval black rockfish are subject to predation by siphonophore and chaetognaths (Yoklavich, et al. 1996). Juveniles fall prey to other rockfishes, lingcod, cabezon, salmon, marine birds, and porpoise (Miller and Geibel 1973; Baltz 1976; Follet and Ainley 1976; Morejohn, et al. 1978; Roberts 1979; Ainley, et al. 1981; Stein and Hassler 1989; Love, et al. 1991; Houk 1992a,1992b; Ainley, et al. 1993; Eldridge 1994). Adults are subject to predation by large rockfish, lingcod, sharks, salmon, dolphin, pinnipeds, marine birds, and possibly river otters (Merkel 1957; Morejohn, et al. 1978; Antonelis and Fiscus 1980; Rosenthal, et al. 1982; Stevens, et al. 1984; Houk 1992a,1992b; Love 1996; Casillas, et al. 1998; Bloeser 1999).

Black rockfish occur with blue and olive rockfishes in the water column and with black- and-yellow rockfish near and on the bottom (Burge and Schultz 1973; Houk 1992a); however, no published studies are available on competition. Although black rockfish may occur with blue rockfish, particularly in central and northern California, they are not considered to be competitors because their diets share little in common. Black rockfish are commonly associated with other nearshore fish species, particularly other rockfishes. A statistical technique, cluster analysis, was used to partition commercial passenger fishing vessel catch data from 1987 to 1992 in the Monterey area based on the frequency of occurrence of species in the sampled catch.

Interestingly, no other schooling rockfish was closely associated statistically with black rockfish; but three benthic species (gopher, China, and brown rockfishes) showed an affinity to the same habitat and depth range (Sullivan 1995).

Black-and-Yellow Rockfish (Sebastes chrysomelas)

Range and Special Features

Black-and-yellow rockfish are morphologically indistinguishable from gopher rockfish (*S. carnatus*), but they have different color patterns and inhabit different depths (Love, et al. 2002). Narum, et al. (2004) conducted microsatellite DNA studies of the two species, and reported that divergence between the two species was low relative to other distinctly different rockfish species, "suggesting that the two morphs represent reproductively isolated incipient species". Black-and-yellow rockfish are found from Cape Blanco, Oregon to central Baja California and are common central California southward to about Point Conception (Love 1996, Love, et al. 2002).

Fishery

Black-and-yellow rockfish are commonly taken by recreational fishers, divers, and charter vessels (Love, et al. 2002). They are commonly caught by fishers from shore. Black-and- yellow rockfish are taken commercially pimarily in central California in the live-fish fishery (Love, et al. 2002).

Habitat

Black-and-yellow rockfish are considered a kelp-forest or inshore rockfish species (Hallacher and Roberts 1985). Black-and-yellow rockfish occur from the intertidal zone down to 37 m (Miller and Lea 1972), but are most common in waters less than 18 m (Love 1996) in kelp beds and rocky areas (Miller and Lea 1972).

Pelagic juveniles spend only a short period in the nearshore water column (Love, et al. 2002). Juvenile black-and-yellow rockfish live in the surface kelp canopy (Hoelzer 1987), and near drift algae (Caselle 1999). Young initially occupy the surface and mid-depth portions of the water column in very close proximity with the *Macrocystis* canopy. Gradually they migrate down the kelp stipes and assume a demersal existence in close proximity to benthic algal cover, in sandy areas near low-relief rock formations (Cailliet, et al. 2000), and in cracks and crevices within the rocky substratum. Once assuming a bottom residence, young apparently sequester in cracks and holes (Hallacher and Roberts 1985), sometimes in artificial reefs (Cailliet, et al. 2000).

Adult black-and-yellow rockfish defend a shelter hole, which they inhabit during turbulent days, and a feeding area, where they rest in more exposed positions during calm days and at night (Larson 1980c). They spend most of their time sheltering in rocky holes and crevices, or perching on the bottom in the open (Larson 1980b). They can associate with artificial reefs (Cailliet, et al. 2000).

Migrations and Movements

Adults are demersal, sedentary residents (Hopkins and Larson 1990). Black-and-yellow rockfish are more active at dusk than during the daytime and are more active during the summer than winter (Larson 1980b). They are territorial and antagonistic encounters included simple chases, often accompanied by displays, sounds, and biting by the resident fish (Larson 1980b). Black-and-yellow rockfish defend their territories from all but very small fish (Larson 1980c). If artificially or naturally displaced up to 1.2 km from their home site, they have the ability to find their way back home and can do so relatively quickly (Matthews 1988). Some movement may also occur with the pursuit of better habitat (Matthews 1988).

Reproduction

Black-and-yellow rockfish reach sexual maturity at 3–4 years, at sizes of 135 mm standard length or greater (Larson 1980b). Mating occurs from late January to early February. Females then carry eggs internally until hatching, which occurs from March to May (Larson 1980b).

Growth and Development

Planktonic larvae settle in their adult habitats in early summer (Larson 1980b). Black- and-yellow rockfish grow to 39 cm (Miller and Lea 1972) and have been aged to 21 years (Lea, et al. 1999).

Trophic Interactions

Juvenile black-and-yellow rockfish pick zooplankton out of the water and fall prey to a variety of predators, including birds (Hoelzer 1987). Small black-and-yellow rockfish eat zooplankton such as copepods and crab larvae (Love 1996) and larger ones eat crabs, shrimp, and occasionally fish and octopi (Hopkins and Larson 1990, Larson 1980b, Larson 1980c, Love 1996). Black-and-yellow rockfish have a high similarity in diet with Sebas*tes melanops, S. atrovirens*, and *S. carnatus*, owing to their common predation on juvenile rockfishes (Hallacher and Roberts 1985). Prey items for larval black-and-yellow rockfish include nauplii, invertebrate eggs, and copepods (Sumida, et al. 1985, Moser and Boehlert 1991). Both juveniles and adults consume crustaceans, but the adults also eat mollusks and fish (Love 1996, Lea, et al. 1999). The adults are nocturnal feeders, ambushing their prey between dawn and dusk (Ebeling and Bray 1976, Ebeling, et al.1980a, Allen 1982, Hallacher and Roberts 1985). Predators of the adult black-and-yellow rockfish include sharks, dolphins, and seals (Morejohn, et al. 1978, Antonelis and Fiscus 1980), while juveniles are prey of birds, porpoises, and fishes, including rockfishes, lingcod, cabezon, and salmon, (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al.1981, Hoelzer 1987, Love, et al. 1991, Ainley, et al. 1993). Larvae are taken by siphonophore and chaetognaths (Yoklavich, et al. 1996).

Blackgill Rockfish (Sebastes melanostomus)

Range

Blackgill rockfish are distributed from central Vancouver Island, British Columbia to Punta Abreojos, Baja California (Love 1996, Moser and Ahlstrom 1978, Love, et al. 2002).

Fishery

Blackgill rockfish are unusual in the sport catch, but are a mainstay of the commercial rockfish catch in southern and central California, taken by trawl, gill net, and hook and line (Love, et al. 1990, Love 1996). Blackgill rockfish are also caught on longlines on banks and to a much lesser degree on mud (Cross 1987). Blackgills are sometimes captured in sablefish traps (Eschmeyer, et al. 1983).

Habitat

Adult blackgill rockfish are found offshore at a maximum depth of 768 m (Eschmeyer, et al. 1983, Orr, et al. 2000). In the northern part of their range, adults are found from 230 to 550 m, while off southern California, mature fish are rarely taken shallower than 275 m (Love 1996). Orr, et al. (1998, 2000) reported common depths at 250–600 m, whereas Allen and Smith (1988) reported collecting them at 125–625 m, with nearly 95% occurring from 250 to 600 m. Juveniles are found in water at least 180 m deep (Love 1996).

Blackgill rockfish usually inhabit rocky- or hard-bottom habitats, along steep drop-offs, such as the edges of submarine canyons, and over seamounts (Love 1996). Blackgill rockfish are rarely taken more than 9 m above the bottom (Love 1996). Larvae inhabit the upper mixed layer, 5–220 km from shore (Kendall and Lenarz 1987), and are seldom taken below 100 m. Larvae transforming to pelagic juveniles (at about 16 mm) live in midwater over coastal basins during the summer (Moser and Ahlstrom 1978). Pelagic juveniles (approximately 30 mm in length) migrate or are carried shoreward at a depth of about 200 m (Moser and Ahlstrom 1978), and, as determined by trawl collections, they are commonly associated with flat bottoms rather than rocky bottoms (Love and Butler 2001).

Migrations and Movements

Blackgill are considered an aggregating species (Love 1996).

Reproduction

Blackgill rockfish spawn from January to June (peaking in February) off southern California, and in February off central and northern California (Love 1996, Love, et al. 1990, Moser and Ahlstrom 1978). They produce only one brood per year (Love, et al. 1990). Half of all blackgill rockfish mature at 34 cm (7–8 years); all are mature at 38 cm (Love, et al. 1990, Love 1996). The fecundity of at 41.5-cm female is 152,072 eggs and that of a 53.0-cm female is 769,152 eggs (Love, et al. 1990).

Growth and Development

Larvae are extruded at a length of 4.5 mm. Juveniles are approximately 3.5 months old at the time of settling to benthic habitat (Moser and Ahlstrom 1978). The largest blackgill rockfish on record is 61 cm (Eschmeyer, et al. 1983, Love 1996, Love, et al. 1990), and they are reported to live to about 87 years (Love, et al. 2002).

Trophic Interactions

Blackgill rockfish primarily prey on such planktonic prey as euphausiids and pelagic tunicates, as well as small fishes (e.g., juvenile rockfishes and hake, anchovy, and lantern fishes) and squid (Love, et al. 1990).

Blue Rockfish (Sebastes mystinus)

Range

Blue rockfish are found from Punto Santo Tomas, Baja California to at least Sitka, Alaska (Love, et al. 2002, Miller and Lea 1972).

Fishery

Blue rockfish is a popular species for recreational anglers, especially off Oregon and California (Miller and Geibel 1973). Small catches are made in commercial fisheries with a variety of methods, including midwater trawl, hook and line, and traps, although catches are increasing with a new fishery for live rockfish.

Habitat

Blue rockfish range in depth from tide pools to 549 m (Orr, et al. 2000), but adults are usually taken over rocky depths of 25 to 90 m (Houk 1992b, Love, et al. 2002). They are not caught in large numbers south of the Channel Islands or north of Eureka, California (Houk 1992b). Blue rockfish adults show a strong affinity for kelp forests (Lea 1992). North of Point Conception, they will school with olive and black rockfish; south of Point Conception they are found schooling with kelp bass, olive rockfish, blacksmith, and halfmoon (Oregon Dept. of Fish and Wildlife 2002).

Larvae and early-stage juveniles are pelagic (Moser 1996), whereas older juveniles, subadults, and adults are semi-demersal or demersal (Love and Ebeling 1978). Larvae live in the surface waters for several months. In the spring, young-of-the-year blue rockfish begin to appear in the kelp canopy, shallow rocky areas, and nearshore sand-rock interface, while some remain pelagic. In nearshore areas of central California, post-pelagic newly settled blue rockfish are first observed at the seaward, sand-rock interface of nearshore reefs in depths of 6–20 m. They are associated with crevices, sand channels among the rocks, depressions in the reef, or tide pools (Ven Tresca, et al. 1996, Love 1996). Young blue rockfish (3.5–4 cm) settle in nearshore rocky habitats (Love, et al. 2002). Juveniles appear, often in massive swarms, in the kelp canopy and shallow rocky areas by April or May (Houk 1992b, Carlisle, et al. 1964, Feder, et al. 1974, Ebeling and Bray 1976, Yoshiyama, et al. 1986, Bodkin 1988, Carr 1991, Love, et al.1991, Moser and Boehlert 1991, Danner, et al. 1994, Karpov, et al. 1995, Love 1996, Ven Tresca, et al. 1996).

Adults inhabit the midwater and surface areas around high-relief rocky reefs, within and around the kelp canopy, and around artificial reefs (Love, et al. 1991, Carlisle, et al. 1964, Turner, et al. 1969, Burge and Schultz 1973, Feder, et al. 1974, Ebeling and Bray 1976, Ebeling, et al.1980a, Stephens, et al. 1984, Allen 1985, Hallacher and Roberts 1985, Bodkin 1986, Bodkin 1988, Love 1996, Starr 1998). Adult blue rockfish are common in kelp beds where food is plentiful and protection from predators is provided by the kelp, but they also occur on deeper rocky reefs between 30 and 91 m deep. In kelp beds, they form both loose and compact aggregations. Under dense kelp canopies, they sometimes aggregate in shoals or schools from the surface to the bottom. More commonly, the distribution does not extend to the entire water column.

Migrations and Movements

As described by Houk (1992b), in inshore kelp bed areas, blue rockfish form loose-to- compact aggregations. They can also often be found as solitary, wandering individuals moving in and about the kelp or swimming along with other rockfish species, such as olive, black, and kelp rockfishes. Under dense kelp canopies, they will sometimes form a column as wide as 4 m and as deep as 25 m. In deeper waters, they form dense aggregations that may extend from the surface to the bottom, but are usually in the mid-depth levels from 18 to 36 m.

Blue rockfish are not considered to be a migratory species (Lea, et al. 1999). Love, et al. (1991) report that movements that do occur are most likely related to changes in water temperature or water turbulence. Early life history stages are generally found in shallower water than adults, suggesting a movement toward deeper water with age. Diel movements have been noted, with the fish moving slightly off the bottom during the day to feed (Love, et al. 1991).

Reproduction

In southern California, mating begins in November and continues through early spring (Love, et al. 1991). A 25-cm female may give birth to as many as 50,000 larvae, and a 32.5-cm female may give birth to as many as 300,000 larvae (Garrison and Miller 1982). Hart (1973) reported that fecundity may be as high as 524,000 larvae, but it was not specified if this was over a whole breeding season or in a single birthing event. Blue rockfish may give birth twice in a breeding season (Love, et al. 1991).

Growth and Development

Embryonic development is internal, and larvae are born at about 3.5 mm (Garrison and Miller 1982). Larvae are considered juveniles after acquiring a full complement of meristic characters, but specific lengths or ages for this were not found. Wyllie Echeverria (1987) estimated that 50% of males are mature at age 5 and 50% of females at age 6. Nearly all are mature by age 11 (P. Reilly[15]). Females tend to be larger than males after maturation, and females and males can live as old as 41 and 44 years, respectively (Lea, et al. 1999, Love, et al. 2002).

Trophic Interactions

Tunicates, hydroids, jellyfishes, salps, crustaceans such as krill and pelagic red crab, and larval and juvenile fishes of many species are the main prey items of the blue rockfish (Gotshall t al. 1965, Hart 1973, Love and Ebeling 1978, MacGregor 1983). Algae are also a significant component of their diet during the summer months (Hobson, et al. 2000). Juvenile blue rockfish prey heavily on all life stages of calanoid copepods and euphausiids (Hallacher and Roberts 1985), and on plankton such as tunicates, salps, and hydroids, and on crustaceans such as krill and pelagic red crab. In shallow waters over reefs and in kelp beds, they feed on macro- plankton, algae, smaller fishes (young-of-the-year rockfishes), and crustaceans.

The blue rockfish competes with other species of rockfishes for space and food; two of the main competitors in southern California are the kelp bass and olive rockfish (Love and Ebeling 1978).

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Bocaccio (Sebastes paucispinis)

Range

Bocaccio are found in the Gulf of Alaska off Krozoff and Kodiak Islands, south as far as Punta Blanca, Baja California (Chen 1971, Miller and Lea 1972). They are generally most abundant between Oregon and northern Baja California (Love, et al. 2002).

Fishery

In the commercial fishery, bocaccio are caught primarily in bottom trawls. Bocaccio are a recreationally sought-after species by anglers from boats, jetties, and piers, with the latter two types of structures yielding primarily young-of-the-year (M. Love[16]). They are important to the party-boat fishery off California and northern Baja California (M. Love[17]).

Habitat

The bocaccio is classified as a middle shelf-mesobenthal species (Allen and Smith 1988). Orr, et al. (2000) reported bocaccio to be found as deep as 475 m, and were most common between 50 and 250 m.

Sakuma and Ralston (1995) categorized bocaccio as both a nearshore and offshore species. Larvae and small juveniles are pelagic; large juveniles and adults are semi-demersal (Garrison and Miller 1982). Juveniles frequently settle out over rocky areas associated with algae or on to sandy areas with eelgrass or drift algae (Love, et al. 2002). Larvae and small juveniles are commonly found in the upper 100 m of the water column, often far from shore (MBC Applied Environmental Sciences 1987). In a study conducted in the California Bight, Moser, et al. (2000) reported that bocaccio larvae collected by plankton tows were almost exclusively in waters over the continental shelf at depths less than 200 m. Larvae have been collected as far as 480 km from shore, and are often located close to the water surface (Moser 1967, Love, et al. 2002). Young-of-the-year are most often found in shallow coastal waters over rocky bottoms associated with algae (Sakuma and Ralston 1995). Young-of-the-year in central California are first observed associated with the giant kelp canopy, but are also seen throughout the water column (Ven Tresca, et al. 1996).

Juvenile and subadult bocaccio are more common in shallower water than adults.Wilkins (1980) reported finding younger bocaccio at depths less than 183 m in trawl surveys on the West Coast. A similar finding was reported by Yoklavich, et al. (2000) using submersibles to quantify and characterize rockfishes in Soquel Submarine Canyon, Monterey Bay, California, except that their cut-off depth was 175 m. Wilkins (1980) also reported that bocaccio from more northern latitudes (37º07'–40º16' N) were larger than those from more southern latitudes (34º09'– 37º07' N). Juvenile bocaccio have been reported in 8–20 m in Diablo Canyon (Love, et al. 1990). Nelson (2001) reported finding high densities of young-of-the-year among kelp canopies.

Adults have two primary habitat preferences: some are semi-pelagic, forming loose schools above rocky areas; and some are non-schooling, solitary benthic individuals (Yoklavich, et al. 2000). Young and adult bocaccio also occur around artificial structures, such as piers and oil platforms (MBC

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[16] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.
[17] Ibid.

Applied Environmental Sciences 1987). Benthic juveniles and adults are usually found around vertical relief; over sand-mud bottoms with little relief (MBC Applied Environmental Sciences 1987); and in areas with mixtures of rocks and boulders, rock ridges, and rocks and boulders among mud (Yoklavich, et al. 2000). Solitary bocaccio have been found in association with large sea anemones, as well as under ledges and in crevices of isolated rock outcrops (Yoklavich, et al. 2000).

Larval stages of bocaccio are found in euhaline waters, and may congregate in local areas of high salinity (Sakuma and Ralston 1995). Bocaccio reportedly occur in typical marine waters with salinities of 31–34 ppt, temperatures of 6–15.5° C and dissolved oxygen concentrations of 1.0–7.0 ppm (MBC Applied Environmental Sciences 1987).

Migrations and Movements

Lea, et al. (1999) classified bocaccio as a "nonmoving species," although their conclusions were based on a limited amount of data. Starr, et al. (2001) implanted acoustic transmitters in 16 adults using underwater procedures, and 10 spent only 10% of a two-month period in the 12-km^2 study area, whereas, the remaining fish remained in the study area most of the time. The authors suggested that some bocaccio may move large distances. The tagged adults made frequent small vertical movements, indicating that they were at the top or just above rock habitats during the day, and down in the lower reaches of these habitats at night. Young-of-the-year bocaccio recruit into shallow water during their first year of life (Hart 1973), then move into deeper water with increased size and age (Garrison and Miller 1982). Subadults probably wander from one rocky area to another (M. Love[18]).

Reproduction

Bocaccio are viviparous (Garrison and Miller 1982, Hart 1973). Love, et al. (1990) reported the spawning season to be protracted and last almost year-round (>10 months). Parturition occurs during January to April off British Columbia and Washington, November to March off northern and central California, and October to March off southern California (MBC Applied Environmental Sciences 1987). In California, bocaccio may become pregnant in October, give birth in November, and prepare immediately for a second brood to be born in March (Moser 1967). Two or more broods may be born in a year in California (Moser 1967, Love, et al. 1990). The spawning season is not well known in northern waters.

Although age-at-size calculations were not given, a 38.1-cm female may give birth to 20,000 young, while a 77.5-cm specimen may give birth to 2.3 million young (Garrison and Miller 1982, Hart 1973). MacGregor (1986) estimated that a female produces 339 eggs/gram of body weight.

Growth and Development

Mature eggs measure about 0.55 mm in diameter (Garrison and Miller 1982). Eggs develop for 40–50 days in the ovary, hatch, and yolkless larvae are released about one week later at 4–6 mm (Garrison and Miller 1982, Hart 1973). Larvae remain pelagic for up to 150 days (Sakuma and Ralston 1995). Metamorphosis to a semi-demersal juvenile stage occurs near 30 mm total length (Garrison and Miller 1982, Hart 1973).

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[18] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.

Males mature at 3–7 years with 50% mature in 4–5 years. Females mature at 3–8 years with 50% mature in 4–6 years (MBC Applied Environmental Sciences 1987). They are difficult to age, but are suspected to live as long as 50 years (Love, et al. 2002).

Trophic Interactions

Larval bocaccio often eat diatoms, dinoflagellates, tintinnids, and cladocerans (Sumida and Moser 1984). Copepods and euphausiids of all life stages (adults, nauplii, and egg masses) are common prey for juveniles (Sumida and Moser 1984). Adults eat small fishes associated with kelp beds, including other species of rockfishes, and occasionally small amounts of shellfish (Sumida and Moser 1984). Bocaccio probably locate prey by sight and feed mostly at night (MBC Applied Environmental Sciences 1987).

Bocaccio are eaten by sharks, salmon, other rockfishes, lingcod, and albacore, as well as sea lions, porpoises, and whales (MBC Applied Environmental Sciences 1987).

Bocaccio directly compete with chilipepper, widow, yellowtail, and shortbelly rockfishes for both food and habitat resources (Reilly, et al. 1992).

Bronzespotted Rockfish (Sebastes gilli)

Range

Bronzespotted rockfish occur from Punta Colnett, Baja California, Mexico to Eureka, California (Love, et al. 2002, R.N. Lea[19]).

Fishery

Bronzespotted rockfish are only occasionally taken in commercial and recreational fisheries off California (Lea 1992).

Habitat

Bronzespotted rockfish were historically relatively common in deeper waters of southern California, from 200 to 290 m (Miller and Lea 1972, R.N. Lea[20]). Adults are collected at depths of 75–413 m and inhabit high-relief rocky outcrops (Love, et al. 2002). A few young-of-the-year have been seen in a boulder field at 252 m (Love, et al. 2002).

Migration and Movements

No information.

Reproduction

No information.

Growth and Development

A single adult measured at 61.2 cm and an estimated age of 47 years has been reported (Love, et al. 2002).

Trophic Interactions

No information.

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[19] California Department of Fish and Game, 20 Lower Ragsdale Drive, Suite 100, Monterey, CA 93940. Pers. Commun., Sept. 2004

[20] Ibid.

Brown Rockfish (Sebastes auriculatus)

Range

Brown rockfish are found from San Hipolito, Baja California to southeastern Alaska (Eschmeyer, et al. 1983, Matthews 1990b, Miller and Lea 1972, Stein and Hassler 1989, Love, et al. 2002). They are most common in south and central Puget Sound, and from central California to southern California (Love, et al. 2002, R.N. Lea[21]).

Fishery

Brown rockfish are commonly taken by recreational fishers in Puget Sound, Washington, and off central to southern California (Mason 1995, Love, et al. 2002). They are also caught from private boats, piers, and shore; divers also take a few. Brown rockfish are a valuable hook- and-line species for the commercial live-fish fishery along the central California coast (Stein and Hassler 1989, Love, et al. 2002,).

Habitat

Brown rockfish are common in shallow water (Matthews 1990a, 1990b) and occur from the surface to 135 m (M. Love[22]). However, they are most common in waters less than 53 m and the young are widely distributed in shallow water bays (Love 1996, Miller and Lea 1972, Love, et al. 1996). Pelagic juveniles are found over a wide depth range, 50–90 m (Lenarz, et al. 1991). Juveniles usually live in shallower water than adults (Love 1996). Sub-adult and adult brown rockfish are more-or-less residential, though they may migrate into somewhat deeper water in the winter (Gascon and Miller 1981, Stephens, et al. 1994, Palsson 1998). Brown rockfish use inland seas as nursery grounds (Stein and Hassler 1989) and they are common in Puget Sound (Hart 1973). There, brown rockfish initially settle at 18–25 mm total length to shallow, vegetated habitats such as beds of kelp or eelgrass (West, et al. 1994). Off California, young brown rockfish recruit to hard substrata, low relief (<1 m) reefs, patches of drift algae on the bottom, and on the walls of submarine canyons (Love, et al. 1991 and 2002).

Brown rockfish are bottom dwellers, frequently living on low-profile hard bottom (Lea 1992, M. Love[23]). They aggregate near sand-rock interfaces and rocky bottoms of artificial and natural reefs over a fairly wide depth range, in eelgrass beds, near oil platforms and sewer pipes, and even around old tires (Love 1996, Matthews 1990b). Off California, some fish frequent sewer outfalls (Stein and Hassler 1989).

In Puget Sound, highest densities are reported on natural reefs, rock piles, and artificial reefs in water less than 30 m (Matthews 1990b); however, Miller and Borton (1980) reported that brown rockfish were found almost exclusively in the Main Basin in central Puget Sound. In California they are primarily found on sandy, low-relief areas (Matthews 1990b). Adults occupy higher-relief portions and young-of-the-year occupy lower-relief portions (West, et al. 1994).

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[21] R.N. Lea, California Department of Fish and Game, 20 Lower Ragsdale Drive, Suite 100, Monterey, CA 93940. Pers. Commun., Sept. 2004

[22] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.

[23] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.

Brown rockfish maintain small home ranges on high-relief rocky reefs and display strong reef fidelity that is not affected by season. On artificial reefs in Puget Sound, they maintain small home ranges (most within 30 m^2). In the summer, artificial reefs become less suitable and considerable off-reef movement occurs. On low-relief reefs, they maintain considerably larger home ranges (most within 400 m^2 and some up to 1500 m^2). The low-relief reefs are only inhabited during the summer and brown rockfish only return to low-relief reefs in the summer coincident with peak algal cover (Matthews 1990a). Because brown rockfish inhabit shallow water, they are exposed to a relatively broad range of seasonal temperature variations, of at least 10° C–17° C (Stein and Hassler 1989). Their capacity for acclimation is higher than that of rockfishes living below the thermocline and they can tolerate higher temperatures to at least 22° C (Stein and Hassler 1989). Occurrence in inland seas and oceanic waters suggests a relatively broad salinity tolerance (Stein and Hassler 1989).

Migrations and Movements

Movements of greater than 3 km are rare for brown rockfish (Mason 1995, Matthews 1990a) and they are said to have a strong homing tendency (Love 1996). Juveniles gradually move into deeper water as they mature (Love 1996).

Reproduction

Brown rockfish mate in March and April in Puget Sound (Stein and Hassler 1989). In Puget Sound, they are carrying young in May and probably give birth in June (Hart 1973). Off Oregon, spawning occurs in May and June; the spawning season is longer off central California, at least from December to July (Love 1996). Also, off California females spawn more than once per season (Love 1996). In Puget Sound, they spawn once per year (Stein and Hassler 1989). A 31-cm female brown rockfish produces approximately 52,000 young and a 48-cm female produces 339,000 (Hart 1973).

Growth and Development

Brown rockfish are 5–6 mm in length at birth (Stein and Hassler 1989). Brown rockfish can grow to a length of 55 cm (Hart 1973, Love 1996). Brown rockfish measuring 52 cm have been aged at 18 years (Love 1996). Males and females probably grow at the same rate and mature at similar ages and lengths (Love 1996). However, other evidence indicates that females grow larger than males, and both species may live as long as 34 years (Love, et al. 2002). Off Oregon, 50% of brown rockfish mature at 31 cm (5 years) and all are mature at 38 cm (10 years) (Love 1996).

Trophic Interactions

Brown rockfish eat small fishes, crabs, shrimp, isopods, and polychaetes (Love 1996, Stein and Hassler 1989). As juveniles they feed on small crustaceans, amphipods, and copepods, but at approximately 13 cm, shift to crabs and small fish (Gaines and Roughgarden 1987, Love, et al. 1991). An adult brown rockfish (over 30 cm) will feed on larger fish, shrimp, crabs and other crustaceans, and polychaetes (Carlisle, et al. 1964, Quast 1968c, Feder, et al. 1974, Washington, et al. 1978, Buckley and Hueckel 1985, Stein and Hassler 1989, Love 1996, Holbrook, et al. 1997). Little is known about predation on larval brown rockfish, but it is thought to be similar to that of other nearshore rockfish species. In general, predation most likely lessens as individuals grow. Birds, dolphins, seals, sharks, lingcod, cabezon, and salmon have been observed to feed on juvenile and adult brown rockfish (Merkel 1957, Miller and Geibel 1973, Morejohn, et al. 1978, Roberts 1979, Antonelis and Fiscus 1980, Ainley, et al. 1981, Stein and Hassler 1989, Love, et al. 1991, Ainley, et al. 1993).

Calico Rockfish (Sebastes dalli)

Range
Calico rockfish are found from Sebastian Viscaino Bay, Baja California, northward to San Francisco (Miller and Lea 1972); they are most common south of Pt. Conception (R.N. Lea[24]).

Fishery
Calico rockfish are not important commercially, but they are taken in recreational fisheries for nearshore rockfish in southern California (Lea et al 1999).

Habitat
Calico rockfish are common throughout southern California (Miller and Lea 1972) Adults can be found from depths of 18–256 m (Miller and Lea 1972), but prefer water 60–89 m deep (Love, et al. 1990). Calico rockfish are benthic (Love, et al. 1990). At rest, calico rockfish seek crevices or are exposed (Stull and Tang 1996) on the bottom, rarely swimming more than 2 m above the bottom (Turner, et al. 1969). Adults often live at sand-rock interfaces (Turner, et al. 1969), especially rocky shelf areas where there is a mud-rock or a sand-mud interface. Adults are also associated with areas of high- and low-relief, including artificial reefs (Richards 1986, Love, et al. 1990, Carlisle, et al. 1964, Murie, et al. 1994, Love 1996, Starr, et al. 1998, Bloeser 1999, Yoklavich, et al. 2000). Juvenile calico rockfish are found in areas of soft sand-silt sediment, at sand-rock interfaces, and on artificial reefs over a wide depth range, including intertidally (Carlisle, et al. 1964, Love, et al. 1991, Love, et al. 2002, Moser and Boehlert 1991, Mearns, et al. 1980). Young-of-the-year (35–65 mm standard length) occur in San Pedro Bay in late July (Mearns, et al. 1980).

Calico rockfish are a warm-temperate species and are more abundant during warm water years (17° C or warmer) (Mearns, et al. 1980). They enter small embayments, such as King Harbor, Redondo Beach, California only as far as the bottom wedge of seawater penetrates (Shode, et al. 1982).

Migrations and Movements

No information.

Reproduction

Calico rockfish are single brooders and release their pelagic larvae from January through May with a peak in February in the Southern California Bight (Love, et al. 1990). An 11.6-cm female spawned 3,878 larvae and a 15.5-cm female spawned 18,000 larvae (Love, et al. 1990).

Growth and Development

For males, length at first maturity is 7 cm, half are mature at 9 cm, and all are mature at 14 cm. For females, length at first maturity is 9 cm and all are mature at 10 cm (Love, et al.1990). The maximum

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[24] California Department of Fish and Game, 20 Lower Ragsdale Drive, Suite 100, Monterey, CA 93940. Pers. Commun., Sept. 2004

length for calico rockfish is 20 cm (Love, et al. 1990, Miller and Lea 1972). They have been aged to 12 years, but some may live longer (Love, et al. 2002).

Trophic Interactions

Juvenile calico rockfish feed on zooplankton such as copepods, barnacle cypriots, and larval fish (Gaines and Roughgarden 1987, Love, et al. 1991). Adults feed on larger crustaceans, such as euphausiids, copepods, and crabs; and on fishes, gammarid amphipods, bivalves, and cephalopods (Love 1996, Oregon Dept. of Fish and Wildlife 2002). As larvae, calico rockfish are preyed upon by siphonophore and chaetognaths (Yoklavich, et al. 1996). Adult calico rockfish are preyed upon by lingcod, cabezon, salmon, and larger rockfish species. Sea birds and dolphins have also been known to feed on calico rockfish (Morejohn, et al. 1978, Rosenthal, et al. 1982, Stevens, et al. 1984, Rosenthal, et al. 1988, Bloeser 1999, Allen 1982, Stull and Tang 1996).

Calico rockfish probably compete with other foraging rockfish species and other finfishes with similar food habits. They may also compete with other fish and with other calico rockfish for favorable habitat because they are a residential, non-schooling species (Wallace and Tagart 1994).

California Scorpionfish (Scorpaena guttata)

Range

The California scorpionfish is found from Monterey Bay south to Uncle Sam Bank, in southern Baja California (Miller and Lea 1972).

Fishery

The California scorpionfish forms a part of the commercial fishery for live fish in California. Catch is made predominantly by hook and line, although they are taken incidentally by trawl and round haul nets. California scorpionfish are a moderately important part of the sport fishery in southern California; they are taken primarily from party and private vessels, occasionally from piers and jetties, mostly from Pt. Mugu southward (Love 1992b).

Habitat

California scorpionfish are benthic fish. They are found in the intertidal zone (infrequently) to as deep as 183 m (Love, et al. 1987, Miller and Lea 1972, Love 1996). Allen (1982) reported highest catch rates at 50 m. They are commonly found in both sandy and rocky areas and also on muddy bottoms (Allen 1982, Love, et al. 1987), and in association with rocky reefs, often lodged in crevices (Love, et al. 1987). Although it is commonly a solitary species, it aggregates near prominent features, such as rocks and boulders (Allen 1982, Cailliet, et al. 2000) and can be associated with artificial reefs, kelp beds, sewer pipes, and wrecks (Love 1992b, Cailliet, et al. 2000). Juveniles settle on rocky bottoms, including artificial reefs (Cailliet, et al. 2000). Very young fish live in shallow water, hidden away in habitats with dense algae and bottom-encrusting organisms (Love 1992b).

Migrations and Movements

California scorpionfish make extensive spawning migrations in late spring and early summer, when most adults move to 4–110 m depths, forming large spawning aggregations on or near the bottom. Spawning occurs in the same areas year after year, and it is likely that the same fish return repeatedly to the same spawning ground. When spawning ends, the aggregations disperse and many (though not all) of the fish move into shallower waters (Love 1992b).

Tagging studies have found movements of up to 190 km, possibly to follow the ridgeback prawn, a potential food source (Love, et al. 1987).

Reproduction

The California scorpionfish is oviparous. Spawning runs from May through September, and peaks in July (Love, et al. 1987). During spawning, California scorpionfish aggregations rise up off the bottom, sometimes approaching the surface (Love 1992b). Eggs are laid as a single layer in a floating gelatinous mass (Love, et al. 1987) that float near the surface (Love 1992b). Eggs are approximately 1.2 mm in diameter and slightly ovoid when extruded (Orton 1955).

Growth and Development

Larvae hatch from eggs 58–72 hours after extrusion (Orton 1955) and are approximately 2.0 mm long (Orton 1955). Females begin to outgrow males by three years. Both sexes reach 50% maturity by two years, females at 18 cm and males at 17 cm (Love, et al. 1987). Females live to 21 years, whereas males rarely live longer than 15 years (Love, et al. 1987).

Trophic Interactions

The main food items of the California scorpionfish are juvenile cancer crabs, small fishes such as the northern anchovy, octopus, isopods, the ridgeback prawn and shrimp (Love, et al.1987, Love, et al. 1987).

Canary Rockfish (Sebastes pinniger)

Range
Canary rockfish are found between Punta Colnett, Baja California, and the western Gulf of Alaska (Boehlert 1980, Boehlert and Kappenman 1980, Mecklenburg, et al. 2002, Love 1996, Miller and Lea 1972, Richardson and Laroche 1979).

Fishery
Canary rockfish are a major constituent of the commercial trawl fishery off Oregon and Washington (Boehlert 1980, Gunderson and Lenarz 1980, Love 1996). Off California, canary rockfish are caught both in the sport fishery and commercial longline fishery. They are moderately important in the party and private vessel sport fishery, from central California northward (Boehlert 1980, Love 1996).

Habitat
Canary rockfish are considered a middle shelf-mesobenthal species (Allen and Smith 1988). There is a major population concentration of canary rockfish between lat. 44°30' and 45°00' N off Oregon (Richardson and Laroche 1979).

Canary rockfish have a depth range from the surface (juveniles) to 425 m (Boehlert 1980, Hart 1973, Love 1996, Mecklenburg, et al. 2002), but primarily inhabit waters 50-250 m deep (Orr, et al. 2000). Larvae and juveniles are pelagic (Boehlert and Kappenman 1980, Richardson and Laroche 1979). Larvae can be captured over a wide area, from 13 to 306 km offshore, and pelagic juveniles occur mostly beyond the continental shelf (Richardson and Laroche 1979).

Canary rockfish inhabit shallow water when they are young, and deep water as adults (Mason 1995). Adults have two primary habitat preferences: some are semi-pelagic, forming loose schools above rocky areas; and some are non-schooling, solitary benthic individuals (Stein, et al. 1992). Adult canary rockfish are associated with pinnacles and sharp drop-offs (Love 1996). They are also found near, but usually not on the bottom, often associating with yellowtail, widow, and silvergray rockfish (Love 1996). Canary rockfish are most abundant above hard bottoms (Boehlert and Kappenman 1980), and they have been observed among mixtures of mud and boulders (Love, et al. 2002). In the southern part of its range, the canary rockfish appears to be a reef-associated species (Boehlert 1980). On Heceta Bank, near Oregon, they were commonly found in boulder and cobble fields in association with rosethorn, sharpchin, yelloweye, and pygmy rockfish (Stein, et al. 1992). In studies conducted off Southeast Alaska using an ROV, Johnson, et al. (2003) reported finding canary rockfish primarily associated with complex bottoms composed of rocks and boulders, and a few individuals were seen near soft sediments. Jagielo, et al. (2003) compared densities of groundfish in “trawlable” and “untrawlable” habitat off the northern Washington coast over a depth range of 90 to 148 m using visual observations made from an occupied submersible. “Trawlable” bottoms were primarily mud, pebble, and mud-pebble (94%), whereas “untrawlable” bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). The density of canary rockfish in “untrawlable” areas (0.36 ave. no./hectare) was somewhat similar to the density found in the “trawlable” areas (0.41 ave. no./hectare).

Young-of-the-year rockfish can also be found in tide pools (Love 1996), and can be associated with artificial reefs, and in interfaces between mud and rock (Cailliet, et al. 2000). In central California, young-of-the-year canary rockfish are first observed near the bottom at the seaward, sand-rock interface and farther seaward in deeper water (18–24 m) (Carr 1991). Their first appearance generally occurs shortly after the first upwellings of the spring (Carr 1991). They are often seen hovering above sand or small rock piles (Ven Tresca, et al. 1996), and are seldom associated with kelp beds, although some young-of-the-year are associated with floating algae (Carr 1991).

Migrations and Movements

Canary rockfish are densely aggregating fish (Love 1996). Juveniles descend into deeper water as they mature (Love 1996). Canary rockfish move into deeper water with age and also are capable of major latitudinal movements (up to 380 nautical miles) (Lea, et al. 1999). Juveniles have been reported to be associated with rocky sandy areas during the day, and with sand flats during the night (Love, et al. 2002).

Reproduction

Off California, canary rockfish spawn from November to March and from January to March off Oregon, Washington, and British Columbia (Hart 1973, Love 1996, Richardson and Laroche 1979). A wide range in larval sizes over a broad time span indicates that canary rockfish may have protracted and variable spawning (Richardson and Laroche 1979).

The age of 50% maturity of canary rockfish is 9 years; nearly all are mature by age 13 (P. Reilly[25]). Maximum age has been estimated as 60 years (Adams 1992) to 84 years (Munk 2001).

Growth and Development

The mean length of newly extruded canary rockfish larvae is 3.66 mm standard length (Richardson and Laroche 1979). The transformation to pelagic juvenile occurs at sizes greater than 12.5 mm standard length. Transformation to benthic juveniles occurs after 59.4 mm, during June to August (Richardson and Laroche 1979). Canary rockfish growth does not vary with latitude (Boehlert and Kappenman 1980). The maximum length canary rockfish grow to is 76 cm (Miller and Lea 1972, Boehlert and Kappenman 1980, Hart 1973, Love 1996).Off California, about 50% of the population is mature at 35.6 cm (5 or 6 years). A 48.3- cm long female carries approximately 260,000 young and a female 53.3- to 66-cm long carries about 1,900,000 young (Hart 1973). Canary rockfish can live to be 75 years old. A 10-year-old canary rockfish is approximately 50 cm standard length (Love 1996). After age 11, females grow faster than males and mature at a larger size, but males live longer (Boehlert 1980, Boehlert and Yoklavich 1984, Love 1996).

Trophic Interactions

Canary rockfish juveniles and adults primarily prey on crustaceans, primarily planktonic euphausiids and mysids, and occasionally on fish (Love 1996, Lea, et al. 1999). Canary rockfish feeding increases during the spring-summer upwelling period when euphausiids are the dominant prey and the frequency of empty stomachs is lower (Boehlert, et al. 1989).

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[25] P. Reilly, California Department of Fish and Game, 20 Lower Ragsdale Drive, Moterey, California 93940. Pers. commun., July 2003.

Chilipepper (Sebastes goodei)

Range

Chilipepper are found from Magdalena Bay, Baja California, to as far north as Pratt and Durgin Seamounts in the Gulf of Alaska; however, they are most commonly found between Cape Mendicino and northern Baja California (Allen and Smith 1988, Mecklenburg, et al. 2002, Love, et al. 2002).

Fishery

Chilipepper are one of California's most important rockfishes; a major contributor to sport and commercial fisheries. The commercial catch is primarily taken by trawl and hook and line. Adult chilipepper are taken by recreational anglers fishing from boats, whereas, juveniles are sometimes caught from piers.

Habitat

Allen and Smith (1988) define chilipepper as a middle-shelf mesobenthal to outer-shelf species. Chilipepper have been taken as deep as 425 m, but nearly all in survey catches were taken between 50 and 250 m (Orr, et al. 2000). They are considered to be a parademersal species.

Adults and older juveniles usually occur over the shelf and slope; larvae and small juveniles are generally found near the surface. In California north of Point Conception, age-0 chilipepper are found from the surface to 8 m around inshore rocky reefs during the summer (MBC Applied Environmental Sciences 1987). Larvae and juveniles are associated with kelp canopies, but not as frequently as other rockfish species (Love, et al. 1990). Pelagic juveniles are primarily found in 30–50 m of water (Love, et al. 1990), and recruitment into deep (12 m) sand bottoms with pockets of drift algae has been noted off of southern California (Love, et al. 2002). Juvenile chilipepper have been reported in 8–20 m in Diablo Canyon (Love, et al. 1990).

In California, chilipepper are most commonly found associated with deep, high-relief rocky areas and along cliff drop-offs (Love, et al. 1990). They are occasionally found over flat, hard substrata (Love, et al. 1990). Adults form schools over areas with boulders and rock structures (Love, et al. 2002).

Chilipepper are found in water with salinities of 32–34 ppt, temperatures of 5–25° C, and at dissolved oxygen levels of 1.0–6.8 ppm (MBC Applied Environmental Sciences 1987).

Migrations and Movements

Movements and migrations of chilipepper rockfish are poorly understood (M. Love[26]). However, movements of up to 2.4 km per day have been recorded (Love 1981). Chilipepper may move as far as 45 m off the bottom during the day to feed (Love 1981). Chilipepper also school by sex just prior to spawning (MBC Applied Environmental Sciences 1987).

Reproduction

Chilipeppers are viviparous (Reilly, et al. 1992). In California, fertilization of eggs begins in October. Spawning occurs from September to April (Oda 1992); peak spawning is December to January (Love,

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[26] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. commun., July 2004.

et al. 1990).

Chilipepper may spawn multiple broods in a single season (Love, et al. 1990). A 30-cm female may give birth to as many as 29,000 larvae (Hart 1973). Hart (1973) also found that a 52- to 56-cm female may give birth to as many as 538,000 young, but Love, et al. (1990) found this number to be significantly too high.

Growth and Development

Eggs develop internally for 40–50 days (Reilly, et al. 1992). Larvae are extruded at 4.7–5.8 mm in length (Sakuma and Laidig 1995). Larvae are considered to be juveniles typically around 22–26 mm in length (Sakuma and Laidig 1995). Females of the species are significantly larger, reaching lengths of up to 59 cm (M. Love[27]). Males are usually smaller than 40 cm (Dark and Wilkins 1994).

Males mature at 2–6 years of age and 50% are mature at 3–4 years. Females mature at 2– 5 years with 50% mature at 3–4 years (MBC Applied Environmental Sciences 1987). Females may attain an age of about 27 years, whereas the maximum age for males is about 12 years (MBC Applied Environmental Sciences 1987).

Trophic Interactions

Larval and juvenile chilipepper eat all life stages of copepods and euphausiids, and are considered to be somewhat opportunistic feeders (Reilly, et al. 1992). In California, adults prey on large euphausiids, squid, and small fishes such as anchovy, lanternfishes, and young hake (Hart 1973, Love, et al. 1990).

Off southern California, chilipepper are found with widow rockfish, greenspotted rockfish, and swordspine rockfish (Love, et al. 1990). Juvenile chilipepper compete for food with bocaccio, yellowtail rockfish, and shortbelly rockfish (Reilly, et al. 1992).

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[27] M. Love, University of California Santa Barbara, Santa Barbara, CA 93106. Pers. Commun., July 2004.

China Rockfish (Sebastes nebulosus)

Range

China rockfish occur from Kodiak Bay, western Gulf of Alaska, southward to Redondo Beach (southern California) on the mainland and San Nicolas Island offshore (Mecklenburg, et al. 2002, M. Love[28]).

Fishery

China rockfish are moderately important in the sport catch. They are taken by party and private vessels from central California to southeastern Alaska and are occasionally speared by divers (Love 1996). China rockfish are valuable to the commercial rockfish fishery with most of the catch by hook-and-line gear (Love 1996).

Habitat

China rockfish occur both inshore and along the open coast (Eschmeyer, et al. 1983) from 3 to 128 m (Eschmeyer, et al. 1983, Hart 1973, Love 1996). They are most commonly found in waters between 18 and 92 m (Orr, et al. 2000). The juveniles are pelagic, but the adults are sedentary, associated with rocky reefs or cobble. They are residential (Lea, et al. 1999), and generally are found resting on the bottom or hiding in crevices (Love 1996) and kelp beds (California Dept. Fish and Game 2003). China rockfish are a sedentary and probably territorial species (Eschmeyer, et al. 1983, Love 1996). They occupy progressively deeper waters in the southern portion of their range (Oregon Dept. of Fish and Wildlife 2002). China rockfish commonly inhabit the dens of large Pacific octopus (Love, et al. 2002).

Off southeastern Alaska, juvenile and adult China rockfish occur in semi-protected habitats, but seem to prefer high-energy or more exposed environments. Divers and ROVs frequently observe them around high-relief rocky reefs, submerged wave-cut platforms, and boulder fields (Johnson, et al. 2003). Juvenile China rockfish inhabit shallow subtidal waters during summer and early fall (Rosenthal, et al. 1982) and are associated with kelp beds (NMFS, et al. 1998).

Migrations and Movements

They remain close to home crevices and take shelter when disturbed (Hart 1973, Love 1996). Tagging studies indicate that they probably move little as adults (Lea, et al. 1999).

Reproduction

Spawning occurs from January to July throughout most of its range, with a January peak (Love 1996). Lea, et al. (1999) observed parturition occurring in April and May off central California.

Growth and Development

Male and female China rockfish mature at the same size: half are mature at 28 cm and all are mature at 30 cm (Love 1996). Off central California, Lea, et al. (1999) reported that the smallest sexually mature female was 26 cm, and the smallest sexually mature male was 34 cm. China rockfish grow to 45 cm (Kramer and O'Connell 1995, Love 1996) and reach an age of 78 years (Munk 2001).

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Trophic Interactions

China rockfish larvae are planktivores. They eat invertebrate eggs and nauplii, and copepods as their primary prey (Sumida, et al.1985, Moser and Boehlert 1991). Juveniles eat crustaceans, such as barnacle cypriots (Gaines and Roughgarden 1987, Love, et al. 1991). Prey taxa of the China rockfish off southeastern Alaska include brittle stars, rock crabs, decorator crabs, brachyuran crab larvae, caridean shrimp, hermit crabs, and fish. Most observed feeding was directed toward the bottom as China rockfish forage on sedentary invertebrates comprising the living turf (Rosenthal, et al. 1988). Off Oregon they consume crustaceans, particularly decorator or spider crabs, and rock crabs (Rosenthal, et al. 1988). Off California, China rockfish consume crustaceans (primarily brachyuran crabs), octopi, abalones, chitons, fishes, and brittle stars (Lea, et al. 1999). China rockfish are dietary specialists and have the greatest dietary similarity with quillback rockfish (Rosenthal, et al. 1988).

Predators of China rockfish larvae include siphonophore and chaetognaths (Yoklavich, et al. 1996). Juveniles are prey of birds, porpoises, and fishes, including rockfishes, lingcod, cabezon, and salmon (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1981, Love, et al. 1991, Ainley, et al. 1993). Predators of adult China rockfish include sharks, dolphins, seals, lingcod, and possibly river otters (Fitch and Lavenberg 1971, Morejohn, et al. 1978, Antonelis and Fiscus 1980, Stevens, et al. 1984).

China rockfish are likely to compete with other demersal species such as kelp greenling, cabezon, and lingcod; and other rockfishes such as grass, quillback, copper, black and yellow, gopher, and vermilion, all of which also inhabit rocky areas (California Dept. Fish and Game 2001).

Copper Rockfish (Sebastes caurinus)

Range

Copper rockfish are found from the western Gulf of Alaska, east of Kodiak Island, southward to central Baja California (Mecklenburg, et al. 2002, Love 1996, Matthews 1990c, Stein and Hassler 1989). They are relatively abundant in Puget Sound (Bargmann 1977), common throughout the San Juan Islands and the Strait of Juan de Fuca (Matthews 1990b), and are abundant in southern California (M. Love[29]).

Fishery

Copper rockfish are moderately important in the recreational catch from southern California northward to at least southeastern Alaska; adults are commonly taken by party and private vessels and young are occasionally taken from piers, jetties, and rocky shores (Love 1996). Copper rockfish are part of the commercial catch off California, taken primarily by hook and line, and, previously, gill nets (Love 1996).

Habitat

Adult copper rockfish occur in nearshore waters, reportedly from the surface to 183 m (Eschmeyer, et al. 1983, Stein and Hessler 1989), and are somewhat shallower during upwelling (Stein and Hessler 1989). They are common in Puget Sound (Buckley and Hueckel 1985, Quinnel and Schmitt 1991). They are usually found in waters shallower than 20 m in British Columbia, and less than 23 m in Puget Sound, but occupy deeper waters in the southern portions of the range (Oregon Dept. of Fish and Wildlife 2002). Larval and small juvenile copper rockfish are pelagic for several months to a year, and are frequently associated with surface waters containing surface-forming kelp such as *Macrocystis* sp., *Cystoseira* sp., and *Nereocystis* sp. After several months, at about 4 cm, the juveniles settle to the bottom on rocky reefs as well as sandy areas in shallow habitats, up to about 6 m (Love 1996), and are referred to as benthic juveniles (Carlisle, et al. 1964; Dewees and Gotshall 1974; Gascon and Miller 1981, 1982; Richards, et al.1986; Buckley and Hueckel 1985; Stein and Hassler 1989; Matthews 1990b; Love, et al. 1991; Moser and Boehlert 1991; Carr 1991; West, et al. 1994; Ven Tresca, et al. 1996; Love 1996). Copper rockfish may use bays as nursery areas (Dewees and Gotshall 1974, Stein and Hassler 1989). Juvenile copper rockfish that migrate from surface habitats to benthic habitats are considered habitat generalists (Matthews 1990b). Young-of-the-year copper rockfish initially occupy a greater diversity of habitats off British Columbia than off California; kelp forests and eelgrass beds are an especially important habitat during this phase (Murphy, et al. 2000, Haldorson and Richards 1986). In the Georgia Basin, small young-of-the-year copper rockfish are first observed in August through October in cobble, near the base of rock piles, or under pieces of bark or fronds of kelp lying on the bottom (Patten 1973, Love 1996, Love, et al. 1991). Benthic macrophytes and crevices in rocky areas are also important habitats (Buckley 1997). In central California, juveniles are closely associated initially with the surface and mid-depth of *Macrocyctis* kelp beds, although older young-of-the-year are frequently associated with drift algae near the bottom (Carr 1991). These older young-of-the-year are also commonly located in habitats of sand and low rock formations during both the summer and winter months (Carr 1991). Off British Columbia, juveniles have been found riding in gooseneck barnacles on flotsam (Stein and Hessler 1989).

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Adult copper rockfish are also common in rocky areas and on rock-sand bottoms in shallow water (Eschmeyer, et al. 1983, Haldorson and Richards 1986, Stein and Hessler 1989). Copper rockfish are almost never observed on an exclusively sand bottom (Patten 1973, Stein and Hessler 1989). They are found on or near natural rocky reefs, boulder fields, artificial reefs, oil platforms, and rock piles; they are typically found directly on the bottom, closely associated with reefs or kelp bed areas (Lea 2001, Matthews 1990c, Love, et al. 2002). In a study off British Columbia (Murie, et al. 1994), copper rockfish were observed within 3 m of quillback rockfish 92% of the time. They have been sighted sharing caves with giant Pacific octopus (Love 1996). Copper rockfish hide in rock interstices in the winter but not in the summer (Patten 1973). Fish within rock piles are inactive and maintain contact, even curving their bodies around rocks (Patten 1973). From July to October, when bull kelp is most dense, few copper rockfish are seen in the rock interstices, but they are always within 1 m of the rocks' perimeter (Patten 1973). On high-relief rocky reefs, they maintain small home ranges (most within a 30-m^2 area), yet returned to their home sites when experimentally displaced up to 6.4 km in an underwater tag-resighting study (Mathews 1990c).

On low-relief reefs, they have larger home ranges (Mathews 1990c). These low-relief reefs are only inhabited by copper rockfish during the summer, coincident with the densest kelp cover; in fall and winter when algal cover is reduced, low-relief reefs appear quite barren (Matthews 1990a). Copper rockfish do not seem to defend their territories. They assess habitat quality on the presence of structure, protective cover, mates, and food, not on presence of predators (Matthews 1990a). When copper rockfish and quillback rockfish are located on the same reef, quillback rockfish generally occupy the deeper depths (Matthews 1987). Copper rockfish also avoid warm water by living in deeper depths off southern California (usually below 55 m) than farther north. Conversely, off British Columbia, they are found in quite shallow water, mostly less than 18 m (Love 1996).

Migrations and Movements

Copper rockfish may move inshore to release their young (Matthews 1990a). Once adults find a good reef, many do not seem to move about much (Stein and Hassler 1989, Love 1996, Lea, et al. 1999). Tagging studies indicate that copper rockfish show little movement once they have settled to the bottom. Movement of up to 1.6 km has been noted, but the majority of tagged and recaptured copper rockfish are from the locality where they were originally taken (Miller and Geibel 1973, Hartmann 1987, Lea, et al. 1999). In northern waters, copper rockfish probably withdraw in winter deep within crevices to avoid storms (Love 1996).

Reproduction

Off central California, male copper rockfish may be sexually mature at 3 years of age (30 cm); all are mature by 7 years (40 cm). All females are mature off central California by 8 years (41 cm). In Puget Sound, Washington, sexual maturity occurs at age 4, but occasionally at age 3 (Stein and Hassler 1989). Copper rockfish spawn once per year. In Puget Sound, Washington, eggs mature by February. Fertilization occurs from March to May off Washington. Egg production ranges from 15,000 eggs in a 24-cm female to 640,000 in a female 47 cm long (Hart 1973, Stein and Hassler 1989). Parturition occurs from April to June in Puget Sound (Matthews 1990b), from February to April south of British Columbia, and from March to July in southeastern Alaska (Love 1996). Gravid females were observed in February and March off the central California coast (Lea, et al. 1999).

Growth and Development

Young are pelagic as larvae and measure 5–6 mm in length at birth; they remain pelagic until 40–50 mm standard length (Stein and Hassler 1989). Copper rockfish are slow-growing and live to 55 years (Matthews 1990b). They can grow to 66 cm in length (Love, et al. 2002). In Humboldt Bay, California, fish are 110–155 mm long as underyearlings, 138–196 mm at age one year, 172–231 mm at age two, and 220–300 mm at age three (Stein and Hassler 1989). Growth rates are highest during the summer, coinciding with high feeding rates and upwelling (Stein and Hassler 1989).

Trophic Interactions

Copper rockfish are opportunistic carnivores. Juvenile copper rockfish feed primarily on planktonic crustaceans. Larger crustaceans form a major part of their diet as they grow; these include *Cancer* crabs, kelp crabs, and shrimp. Squid of the genus *Loligo* and octopi are also important food items. Crustaceans, followed by fish and mollusks, are the most important food groups of adult copper rockfish in terms of volume, number, and frequency of occurrence. Off British Columbia, they feed on herring, kelp perch, pile perch, squat lobsters, coonstriped shrimp, and to a lesser extent mysids (Murie 1995). Fishes, which include young-of-the-year rockfishes, cusk-eels, eelpouts, and sculpins, are important forage for larger individuals (Carlisle, et al. 1964, Burge and Schultz 1973, Prince and Gotshall 1976, Washington, et al. 1978, Buckley and Hueckel 1985, Rosenthal, et al. 1988, Stein and Hassler 1989, Matthews 1990a, Murie 1995, Love 1996, Holbrook, et al. 1997, Lea, et al. 1999). In Humboldt Bay, juvenile Dungeness crabs were the most important individual food item in terms of volume and frequency of occurrence (Prince and Gotshall 1976). Demersal crustaceans are important prey throughout all seasons, increasing in occurrence from winter to fall (Murie 1995).

Generally, copper rockfish rely less on reef-associated food organisms as their age (size) increases (Stein and Hassler 1989). Copper rockfish feed during the day and at night (Prince and Gotshall 1976, Stein and Hassler 1989). In Humboldt Bay, northern anchovy comprises the largest portion of fish in the copper rockfish diet; shiner perch is also important. Smaller copper rockfish (<45 mm standard length) in the kelp canopy eat primarily calanoid copepods, with some harpacticoids and zoea. Fish 110–115 mm eat small crustaceans such as amphipods, shrimp, caprellids, isopods, and pinnixid crabs. Copper rockfish 1–3 years old eat juvenile Dungeness crab and anchovies, with fish increasing and crustaceans decreasing as the fish grow (Stein and Hassler 1989).

As juveniles and adults, copper rockfish are preyed upon by a variety of fishes including other rockfishes, lingcod, cabezon, salmon, several species of birds, and marine mammals (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1981, Stein and Hassler 1989, Love, et al. 1991, Ainley, et al. 1993, Haldorson and Richards 1986).

Cowcod (Sebastes levis)

Range

Cowcod occur from Ranger Bank and Guadalupe Island, Baja California to Newport, Oregon (Love, et al. 2002). Most of the preferred habitat for cowcod is located in the Southern California Bight (Barnes 2001).

Fishery

Cowcod have some commercial importance and are prized by sport fishers (Lea 1992, Love, et al. 1990).

Habitat

Cowcod range from 21 to 366 m (Butler, et al. 2003, Miller and Lea 1972). Adults are commonly found at depths of 152–244 m (Orr, et al. 2000) and juveniles are most often found in 20–100 m of water (Allen 1982, Butler, et al. 1999, Butler, et al. 2003, Love, et al. 1990). MacGregor (1986) found that larval cowcod are almost exclusively found in southern California and may occur many miles offshore. In studies conducted in the California Bight, Moser, et al. (2000) reported that cowcod larvae collected by plankton tows were almost exclusively in waters over the continental shelf adjacent to the northern Channel Islands at depths of less than 200 m.

Adult cowcod are primarily found over high-relief rocky areas (Allen 1982); they are generally solitary, but occasionally aggregate (Love, et al. 1990). Juveniles recruit to soft bottom habitats and to habitats consisting of low-relief rocks and sedimentary outcrops bounded by mud and sand, commonly at depths of 40 to 224 m (Love, et al. 2002). Solitary subadult cowcod have been found in association with large white sea anemones on outfall pipes in Santa Monica Bay (Allen 1982), as well as submarine canyons under ledges and in crevices of isolated rock outcrops surrounded by mud (Yoklavich, et al. 2000). Yoklavich, et al. (2000) suggest that adults may excavate semi-consolidated mudstone to create desirable habitats. Juveniles occur over sandy and clay bottoms and near oil platforms (Butler, et al. 2003, Love, et al. 2002).Solitary juveniles have been observed resting within a few centimeters of soft-bottom areas where gravel or other low relief was found (Allen 1982).

Migrations and Movements

Although the cowcod is considered as generally not migratory; it may move to some extent to follow food (Love 1980).

Reproduction

Large female cowcod may produce up to three broods per season (Love, et al. 1990). Spawning peaks in January in the southern California Bight (MacGregor 1986). A 45.5-cm female may produce up to 181,000 young per brood, and an 80-cm female may give birth to nearly two million young (Love, et al. 1990).

Growth and Development

Cowcod grow to 94 cm (Miller and Lea 1972, Allen 1982). The length at 50% maturity for both sexes occurs at 43–44 cm in the southern California Bight (Love, et al. 1990). Extruded larvae are about 5.0 mm (MacGregor 1986). They live to an age of at least 55 years (Love, et al. 2002).

Trophic Interactions

Juveniles eat shrimp and crabs, and adults eat fish, octopus, and squid (Allen 1982).

Darkblotched Rockfish (Sebastes crameri)

Range

Darkblotched rockfish are found from Santa Catalina Island off southern California to an area southeast of Zhemchug Canyon in the eastern Bering Sea (Miller and Lea 1972, Richardson and Laroche 1979) and Tanaga Island in the Aleutian Islands (Allen and Smith, 1988).

Fishery

Darkblotched rockfish are an important component of the commercial groundfish trawl fishery (Nichol and Pikitch 1994, Weinberg 1994). For this fishery, they comprise the deep- water assemblage, along with shortspine thornyhead, Pacific Ocean perch, and splitnose and redbanded rockfishes (Weinberg 1994).

Habitat

Off Oregon, Washington, and British Columbia, darkblotched rockfish is primarily an outer-shelf/upper-slope species (Richardson and Laroche 1979). Distinct population groups have been found off the Oregon coast between lat. 44º30' and 45º20' N (Richardson and Laroche 1979). Darkblotched rockfish are found offshore and in Juan de Fuca Strait and Haro Strait.

Pelagic juvenile darkblotched rockfish are found over a depth range of 20–45 m (Lenarz, et al. 1991). Adults occur in depths of 25–910 m and 95% are between 50 and 400 m (Allen and Smith 1988, M. Love[30]). Weinberg (1994) analyzed the results of groundfish surveys conducted between 1977 and 1992 in the coastal waters of Oregon and Washington. Using recurrent group analysis, he found that redbanded rockfish occurred in the same group as darkblotched and splitnose rockfish, shortspine thornyhead, and Pacific Ocean perch. This group was most commonly collected at depths of 155–366 m. Off central California, young darkblotched rockfish recruit to soft substrata, low-relief (<1 m) reefs (Love, et al. 1991), and oil platforms (Love, et al. 2002). Off Oregon, benthic juveniles are taken at depths of 55–200 m, nearer to shore than larvae or pelagic juveniles (Richardson and Laroche 1979). The greatest numbers of larvae and pelagic juveniles are found 83–93 km offshore in water 900–1300 m deep (Richardson and Laroche 1979), although Love, et al. (2002) stated that pelagic juveniles have been collected off of Oregon in water depths of 55–200 m. Eschmeyer, et al. (1983) reported this species to be associated with soft bottoms, whereas Love, et al. (2002) state that adult darkblotched rockfish are frequently observed associated with mud near cobble or boulders. Submersible observations of Soquel Canyon in Monterey Bay, California also revealed that adult darkblotched rockfish are associated with rocks, boulders, and cobble surrounded by mud (Yoklavich, et al. 2000).

Migrations and Movement

Darkblotched rockfish migrate to deeper waters with increasing size and age (Rogers, et al. 2000). Darkblotched rockfish make limited migrations after they have recruited to the adult stock (Gunderson 1997).

Reproduction

Insemination of female darkblotched rockfish occurs from August to December, fertilization and

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parturition occur from December to March off Oregon and California, primarily in February off Oregon and Washington (Hart 1973, Nichol and Pikitch 1994, Richardson and Laroche 1979). Females attain 50% maturity at a greater size (36.5 cm) and age (8.4 years) than males (29.6 cm and 5.1 years) (Nichol and Pikitch 1994). Off Oregon, fecundity ranges from about 20,000 to nearly 500,000 oocytes, depending on the size and age of the fish (Nichol and Pikitch 1994). In a reproductive study of darkblotched rockfish off Oregon (Nichol and Pikitch 1994), sampled fish ranged from 6 to 66 years of age.

Growth and Development

Larvae can be as small as 8 mm at extrusion (Richardson and Laroche 1979). Transformation from pelagic larvae to pelagic juveniles occurs at approximately 16 mm (Richardson and Laroche 1979). Transformation from pelagic to benthic habitat occurs between 40 and 60 mm (Richardson and Laroche 1979). Adults can grow to 58 cm (Love, et al. 2002) and have been aged to 105 years (Love, et al. 2002).

Trophic Interactions

Adults in a California study fed extensively on macroplanktonic organisms, primarily euphausiids, but occasionally on Crangon shrimp, squid, amphipods, small salps, and small octopi (Allen 1982). Infrequently, small fish such as anchovy appear in their diet (Phillips 1964). Pelagic young are food for albacore and Chinook salmon (Hart 1973, Love, et al. 2002).

Dusky Rockfish (Sebastes variabilis) and Dark Rockfish (S. ciliatus)

Range

The two distinct forms of dusky rockfish, that were previously recognized as the light- colored form, commonly found in deep water along the continental shelf, and the dark-form, commonly in shallow waters (Love, et al. 2002), were recently reclassified as two species: *S. variabilis* (dusky rockfish) and *S. cilliatus* (renamed as dark rockfish), respectively, based on morphological evidence (Orr and Blackburn 2004). Dark rockfish are distributed from Johnstone Strait, British Columbia, through southeast Alaska to the Bering Sea (Orr and Blackburn 2004). The range of dusky rockfish (the light form) is from the western Bering Sea to the central coast of Oregon (Orr and Blackburn 2004).

Fishery

Dusky rockfish are caught almost exclusively with otter trawls (NMFS, et al. 1998) in offshore waters, whereas, dark rockfish are frequently caught in nearshore waters with jigs (Orr and Blackburn 2004).

Habitat

Dark rockfish are found nearshore (5–160 m) (Orr and Blackburn 2004), and usually off the bottom (Eschmeyer, et al. 1983). Dusky rockfish are found from depths of 12–675 m, and most commonly at depths of 100–300 m in boulder-rubble substrata (Love, et al. 2002).

Juvenile dark rockfish are found associated with rocks and among algae. Adult dark rockfish are commonly found in semi-protected areas with kelp beds and rocky reefs. Dark and dusky rockfish adults have been observed in common schools over rocky areas in relatively shallow areas (Love, et al. 2002). From submersible dives in the Gulf of Alaska, dusky rockfish have been observed associated with rocky areas and in areas with extensive sponge beds (NMFS, et al. 1998).

Migrations and Movements

Dusky rockfish are among the most highly concentrated of the rockfish species in the Gulf of Alaska; outside these concentrations, this species is rarely captured (NMFS, et al. 1998).

Reproduction

Female and male dusky rockfish in the western Gulf of Alaska were reported to be reproductively mature during the summer, but during the same time period dark rockfish were found to be immature (Orr and Blackburn 2004).

Growth and Development

Dusky rockfish can reach 59 cm in length (Orr and Blackburn 2004). Maximum ages are 49–59 years (NMFS, et al. 1998). The maximum length of dark rockfish was reported to be 47 cm (Orr and Blackburn 2004).

Trophic Interactions

The most prominent prey for dusky rockfish appears to be euphausiids, although larvae, ephalypods, shrimp, and hermit crabs are also eaten (NMFS, et al. 1998).

Flag Rockfish (Sebastes rubrivinctus)

Range

Flag rockfish are found from Heceta Bank, Oregon to central Baja California (Love, et al.2002, Klingbeil and Knaggs 1976, Love 1996, Miller and Lea 1972). Flag rockfish reported north of Oregon may have been misidentified and are probably redbanded rockfish (Love 1996, Miller and Lea 1972).

Fishery

Flag rockfish are a moderately important sportfish, in both party- and private-vessel catch, along both central and southern California. They are occasionally taken by hook-and-line commercial fishermen (Love 1996).

Habitat

Flag rockfish occur at depths up to 302 m (Orr, et al. 2000, Love 1996, Miller and Lea 1972), and are most common between 30 and 183 m (Orr, et al. 2000). Young flag rockfish are found in the shallower part of their range (Love 1996). Pelagic juveniles are commonly found near the water surface often associated with drifting algae mats and plant debris, often many miles from the coast (Love, et al. 2002). They first appear in August and leave the kelp mats in January and February (Love 1996). Juveniles are also associated with rocky reefs (California Dept. Fish and Game 2003).

Adult flag rockfish are solitary, bottom-dwelling reef fish, although they are sometimes found in small congregations. They are often found among large white anemones. Almost any hard bottom seems acceptable to the flag rockfish; for example, they commonly live near sewer outfalls off southern California and have been detected in submarine canyons (California Dept. Fish and Game 2003).

Migrations and Movements

No information.

Reproduction

Flag rockfish spawn from March to June off southern California, July to August off northern California, and from April to May off Oregon (Kendall and Lenarz 1987).

Growth and Development

Half of all flag rockfishes mature by 38 cm (Love 1996). A 41-cm flag rockfish is probably about 18 years old and a 32-cm fish is probably about 12 years old (Love 1996). Adults can grow to a maximum of 44 cm, but 41 cm is more common (Love 1996, Love, et al. 2002).

Trophic Interactions

Flag rockfish eat mostly bottom dwellers, such as crabs, shrimp, and occasionally fish and octopus (Love 1996).

Gopher Rockfish (Sebastes carnatus)

Range

Gopher rockfish are morphologically indistinguishable from black-and-yellow rockfish (*S. chrysomelas*), but they have different color patterns and inhabit different depths (Love, et al. 2002). Gopher rockfish are common and range from Cape Blanco, Oregon, to Punta San Roque, Baja California (Love, et al. 2002, Knoph 1983, Miller and Lea 1972), but they are most common from about Mendocino County to Santa Monica Bay, Los Angeles County (Love 1996).

Fishery

Anglers catch a fair number of gopher rockfish from charter boats and skiffs (Knoph 1983), and they are taken by spear fishers (Lea, et al. 1999). When blue rockfish (mid-water dwelling species) are low in skiff catches, gopher rockfish (bottom-dwelling species) reach their highest contributions to catches in the vicinity of Santa Cruz and Monterey (Mason 1995). They are also important to the live-fish fishery in central California (Love, et al. 2002).

Habitat

Gopher rockfish generally occur in waters less than 30 m deep (Carr 1991), but range from intertidal to about 86 m (Love, et al. 2002, Knoph 1983, Weinberg, et al. 2002). They are most commonly found between 12 and 37 m (Orr, et al. 2000, Love 1996).

Gopher rockfish are shallow-water benthic rockfish that inhabit rocky reefs, kelp beds, and sandy areas near reefs (Love 1996, Eschmeyer and Herald 1983). They spend the majority of their time during the day in rocky shelters (Larson 1980a) and at night (and to a lesser degree during the day) perching on the bottom in the open (Larson 1980b). Home ranges of gopher rockfish consist of a primary shelter hole and a larger, feeding area in which they often rest in more exposed positions. The home range size increases with fish size and depth (Larson 1980b). Both the young-of-the-year and adults rest on the bottom.

Young gopher rockfish are demersal and prefer low-relief rock or sand bottoms. They are closely associated with algae and are distributed equally among drift algae and *Macrocystis*. During and after fall storms, they shift to crevices within high-relief rock and are less associated with algae (Carr 1991).

Larvae and young juveniles are pelagic, but as the juveniles mature, they will settle on rocky reefs or into the kelp canopy. Planktonic larvae initially occur in the surface canopy in late May and increase in density through July. By July, individuals at mid-depth and on the bottom are larger. En route to the bottom, small juveniles may inhabit the kelp canopy (Ven Tresca, et al. 1996). As density decreases in the surface canopy, it increases at mid-depth and on the bottom, indicating a gradual movement from surface to bottom in a 1-month period (Carr 1991).

Adults aggressively defend their territories in rocky reefs dominated by the giant kelp (*Macrocystis pyrifera*).

Migrations and Movements

In one study (Matthews 1988), gopher rockfish moved 1.2 km from a natural reef to an artificial reef in pursuit of a better habitat. In another tagging study conducted off central California, gopher rockfish were primarily residential; however, individuals exhibited movements of up to 2.04 km over the reef system on which they were tagged (Lea, et al. 1999). However, movements of more than 3 km are rare (Mason 1995).

Reproduction

Gonadal development begins in late November and mating occurs in late January and early February; spawning occurs from March to May (Larson 1980a).

Growth and Development

Larvae are planktonic and they settle in late June (Larson 1980a). Metamorphosing juveniles first appear inshore during mid- to late June (Larson 1980a). Gopher rockfish reach sexual maturity in 3–4 years at sizes of 135 mm standard length or greater (Larson 1980b). Gopher rockfish can live to be more than 30 years old (Mason 1995).

Trophic Interactions

Gopher rockfish larvae are diurnal planktivores, preying on nauplii eggs, invertebrate eggs, and copepods during daylight hours (Sumida, et al. 1985, Moser and Boehlert 1991). They are prey to siphonophore and chaetognaths (Yoklavich, et al. 1996). Juveniles are also daytime feeders, and eat crustaceans such as calanoid copepods, shrimp, brachyurans, including *Cancer* sp., barnacle cypriots, and algal-associated prey (Carr 1991, Prince and Gotshall 1976, Gaines and Roughgarden 1987, Love, et al. 1991, Lea, et al. 1999). Their predators include fishes such as rockfish, lingcod, cabezon, and salmon, as well as birds and porpoises (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1981, Love, et al. 1991, Ainley, et al. 1993). Juveniles living in the surface canopy fall prey to a variety of predators, including birds (Hoelzer 1987). In deeper waters, juvenile gopher rockfish are the primary prey of adult gopher rockfish, probably because preferred food (crabs and shrimp) is less abundant in the deeper water (Hallacher and Roberts 1985). Adult gopher rockfish are nighttime predators that ambush their prey (Ebeling and Bray 1976, Ebeling, et al. 1980). Prey items for adults include crustaceans (particularly *Cancer* sp. crabs, caridean shrimp, anomurans), fish (especially juvenile rockfish), and mollusks (Love 1996; Lea, et al. 1999; Larson 1980a and b). Their predators include sharks, dolphins, and seals (Morejohn, et al. 1978, Antonelis and Fiscus 1980).

Gopher rockfish, because of their nature, will have a tendency to discourage kelp rockfish from bottom territories and black-and-yellow rockfish from the deeper portions of its vertical distribution (Larson 1980a, Hallacher and Roberts 1985). Gopher rockfish probably compete for food and space with cabezon, lingcod, greenlings, and other rockfish such as China, quillback, copper, and vermilion, based on the fact that they live in the same area.

Grass Rockfish (Sebastes rastrelliger)

Range

Grass rockfish are found from Playa Maria Bay, Baja California to Yaquina Bay, Oregon (Eschmeyer, et al. 1983, Miller and Lea 1972, Russo 1990), although they are most common south of southern Oregon (Miller and Lea 1972, Love, et al. 2002).

Fishery

Throughout coastal California, grass rockfish are a relatively common part of the shore, pier, and small-vessel catch, and are also taken by divers. Party vessels fishing near shore for bass and shallow-water rockfish also catch substantial numbers. Grass rockfish have become an important component of the live-fish fishery (Lea, et al. 1999).

Habitat

The grass rockfish is a common, shallow-water rockfish (Eschmeyer, et al. 1983). Among rockfishes, they have one of the shallowest and narrowest depth ranges. They are found from the intertidal zone to 56 m (Orr, et al. 2000), frequently less than 15 m (Eschmeyer, et al. 1983, Miller and Lea 1972, Russo 1990), and are commonly found from the intertidal to 6 m (Miller and Lea 1972, Eschmeyer and Herald 1983, Love 1996). Tide pools usually contain only juveniles (Love 1996). . Young-of-the-year grass rockfish appear in shallow water during the spring and summer (Love 1996) and recruit to hard substrata, including artificial reefs (Love, et al. 1991). Adults and older juveniles are most commonly found in kelp beds off California (Kendall and Lenarz 1987).

Grass rockfish are common in nearshore rocky areas, along jetties, in kelp, and in eelgrass (Eschmeyer, et al. 1983, Miller and Lea 1972, Russo 1990). Around reef structures, adults may be found hiding in crevices (Carlisle, et al. 1964, Turner, et al. 1969, Feder, et al. 1974, Grossman 1982, Larson and DeMartini 1984, Allen 1985, Love 1996, Laidig and Sakuma 1998, Love and Johnson 1998, Starr 1998, Bloeser 1999).

Migrations and Movements

This species is considered residential, moving less than 1 m from their home range (Miller and Geibel 1973).

Reproduction

Both sexes of grass rockfish begin to mature at 22 cm and are fully mature at 28 cm; these lengths correspond to ages 2 to 5 years for males and 3 to 5 years for females (Love and Johnson 1998). Larvae are released from January to March, with the peak release occurring in January, and fecundity ranges from 80,000 eggs in a 26 cm (TL) female to 760,000 eggs in one 46.5 cm (TL) long (Love and Johnson 1998).

Growth and Development

Adult grass rockfish can grow to a maximum of 56 cm total length (Miller and Lea 1972, Eschmeyer, et al. 1983, Russo 1990, Lea, et al. 1999) and can live to be at least 23 years of age (Love, et al. 2002).

Trophic Interactions

Larval grass rockfish are daytime feeders that prey upon nauplii eggs, invertebrate eggs, and copepods (Sumida, et al. 1985, Moser and Boehlert 1991). Juveniles and adults prey upon crustaceans, but the adults also eat other fishes (such as juvenile surfperches, white croaker, and midshipmen) (Holbrook and Schmitt 1988), crabs, shrimp, cephalopods, and gastropods (Love 1996, Lea, et al. 1999). The adults are nighttime feeders (Holbrook and Schmitt 1988, Love 1996).

Larvae are eaten by siphonophore and chaetognaths (Yoklavich, et al.1996). Predators of juveniles include birds, porpoises, and fishes, including rockfishes, lingcod, cabezon, and salmon (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1993, Love, et al. 1991). The adults are prey of sharks, dolphins, and seals (Morejohn, et al. 1978, Antonelis and Fiscus 1980).

Greenblotched Rockfish (Sebastes rosenblatti)

Range

Greenblotched rockfish are found from Ranger Bank, Baja California, to Punta Delgada, northern California, although they are most common southward from Central California (Love, et al. 2002, Miller and Lea 1972).

Fishery

Greenblotched rockfish are uncommon in the commercial and recreational fishery of California (Lea 1992).

Habitat

Greenblotched rockfish occupy a depth range of 55-491 m (Love, et al. 2002, Miller and Lea 1972), although adults prefer depths of 61-396 m (Orr, et al. 2000). Juvenile greenblotched rockfish are generally shallower than adults (Love, et al. 1990). Larvae are pelagic; juveniles and adults are benthic (Love, et al. 1990). Adults and older juveniles are usually found near high- relief rocks, caves, and crevices, and occasionally found in mixtures of mud and rock, mud and boulders, oil platforms, and mud and cobble, with the fish lying on mud (Love, et al. 1990, Love, et al. 2002). In one study (Allen 1982), greenblotched rockfish were observed resting in a hole along the mud wall of Redondo Canyon.

Migrations and Movements

No information.

Reproduction

A 32-cm female greenblotched rockfish produces approximately 30,600 eggs and a 47- cm female produces 655,000 eggs (Love, et al. 1990). Greenblotched rockfish spawn multiple broods that is two or more times per season. Smaller mature females are most likely single brooders (Love, et al. 1990). Greenblotched rockfish spawn from December to July, and the peak spawning month is April (Love, et al. 1990).

Growth and Development

Size at first maturity of male greenblotched rockfish is 23 cm; half are mature at 30 cm; and all are mature at 32 cm. Size at first maturity of females is 16 cm; half are mature at 28 cm, and all are mature at 34 cm (Love, et al. 1990). There is no size difference between male and female greenblotched rockfish, which can grow to 48 cm (Eschmeyer, et al. 1983, Love, et al. 1990, Miller and Lea 1972). In one study (Love, et al. 1990) greenblotched rockfish were aged to 50 years.

Trophic Interactions

Juvenile and adult greenblotched rockfish prey upon planktonic prey such as euphausiids and pelagic tunicates, as well as small fishes (e.g., hake, anchovies, and lanternfishes), and squid. Off Southern California, Allen (1982) reported that juveniles (<6.4 cm) almost exclusively preyed upon copepods and amphipods; small fish (6.4–16.1 cm) consumed primarily shrimp, and larger fish (18.4–37.7 cm) consumed mainly fish and squid.

Greenspotted Rockfish (Sebastes chlorostictus)

Range

Greenspotted rockfish range from Copalis Head, Washington, southward to southern Baja California and are abundant as far north as Monterey Bay, California (Eschmeyer, et al. 1983, Love, et al. 2002, Miller and Lea 1972).

Fishery

Greenspotted rockfish are important in commercial and sport catches (Love, et al. 1990). They are taken from party and private vessels in southern and central California.

Habitat

Greenspotted rockfish are common, benthic inhabitants in waters 90–363 m deep (Love, et al. 2002, Miller and Lea 1972). Adult greenspotted rockfish prefer waters 49-201 m deep (Orr, et al. 2000 and small fish (primarily juveniles) prefer depths between 30 and 89 m (Love, et al.1990).

Greenspotted rockfish spend most of their time on or near the bottom, often in caves and crevices. Juveniles are often associated with rock outcrops (Love, et al. 2002), and are also associated with soft-bottom habitats (California Dept. of Fish and Game 2003) and oil platforms (Love, et al. 2002). Adult greenspotted rockfish are mostly caught over high-relief rocky reefs (Love, et al. 1990), but they are also common on soft bottoms (Eschmeyer, et al. 1983), such as sand or mud (Mason 1995). They are frequently observed on mud near rock outcrops, and less frequently near oil platforms (Love, et al. 2002). Yoklavich, et al. (2000) used submersibles to quantify and characterize rockfish in Soquel Submarine Canyon, Monterey Bay, California. They found greenspotted rockfish associated with a variety of habitat types, including cobble- mud, pebble-mud, boulder-mud, rock-mud, and rocky ridge. Solitary greenspotted rockfish were commonly found in association with large sea anemones, as well as under ledges and in crevices of isolated rock outcrops (Yoklavich, et al. 2000). The only habitat types that had few greenspotted rockfish were mud, and mixed rocks and boulders.

Migrations and Movements

Greenspotted rockfish do not undergo extensive migrations or movements as they are sedentary creatures which rarely venture a few feet above the rocks they inhabit (Love 1996). Starr, et al. (2001) implanted acoustic transmitters in 6 adults using underwater procedures, and 2 spent 90% of a two-month period in a 1.6-km^2 area, whereas the remaining fish remained in this area most of the time, but did not move further than 3 km from the site of tag-and-release.

Reproduction

Spawning occurs in April off Oregon, from April to September off northern and central California, and from April to July off southern California (Wyllie Echeverria 1987). Spawning peaks in May off northern and central California, and in April off southern California (Love 1996). Male rockfish may mate more than once per season (Wyllie Echeverria 1987).

Greenspotted rockfish are known to be multiple brooders, that is, females spawn two or more broods per season. Smaller mature females are single brooders (Love, et al. 1990). The minimum number of eggs per female is 41,000 (from a 27.6-cm female) and the maximum number of eggs per female is 760,000 (from a 39-cm female) (Love, et al. 1990).

Growth and Development

Greenspotted rockfish reach a maximum size of 47.2 cm (Eschmeyer, et al. 1983, Love 1996, Love, et al. 2002, Miller and Lea 1972). Greenspotted rockfish can reach more than 21 years of age (Lea, et al. 1999).

Trophic Interactions

They are benthic feeders that prey primarily on planktonic euphausiids and pelagic tunicates, as well as small fishes (e.g., juvenile rockfishes and hake, anchovies, and lanternfishes) and squid (Love, et al. 1990).

Greenstriped Rockfish (Sebastes elongatus)

Range

Greenstriped rockfish are found from Cedros Island, Baja California to Green Island in the Gulf of Alaska; however, they are most common between British Columbia and Punta Colnett in northern Baja California (Eschmeyer, et al. 1983, Hart 1973, Love, et al. 2002).

Fishery

Greenstriped rockfish are of importance to recreational and commercial fishers (Love, et al. 1990). They are commonly caught on baited hooks, but are most often trawled (Eschmeyer, et al. 1983). Although not considered a good food fish, greenstripes are commonly used by southern Californian fishers as bait for cowcod and bocaccio (Eschmeyer, et al. 1983).

Habitat

Greenstriped rockfish is a deep-water species that can inhabit waters 52– 828 m (Lauth 1999, Hart 1973, Murie, et al. 1994), although it is commonly encountered inshore and offshore (Love 1996). About 95% of greenstriped rockfish in survey catches occurred in 100–250 m (Orr, et al. 2000). In studies conducted in British Columbia, Richards (1986) reported that the highest densities of greenstriped rockfish were at depths greater than 81–100 m.

Recruitment of juvenile greenstriped rockfish to soft bottom habitats occurs in shallower depths, primarily in 60-100 m (Love, et al. 1990, Johnson, et al. 2001). In Monterey Bay, young- of-the-year have been observed primarily at the interface between fine sand and clay, but they were also seen within sand-cobble patches, along sand-mud bottoms that surround rock outcrops, and near offshore oil platforms (Love, et al. 2002). Juveniles have also been observed associated with artificial reefs and oil platforms (Cailliet, et al. 2000).

Greenstriped rockfish are widely distributed on rocky as well as soft bottoms (Eschmeyer, et al. 1983, Love, et al. 1990). They are associated with both high- and low-relief reefs (Love, et al. 990). They co-occur with greenspotted rockfish on deep reefs (P. Reilly[31]). In a studies conducted by Murie, et al. (1994) and Richards (1986) using submersibles to observe rockfish behavior off British Columbia, greenstripe rockfish were most often seen perched on sand-mud substrata at depths less than 80 m, and were associated with sand-mud and complex high-relief areas at depths of more than 80 m. In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult greenstripe rockfish were most commonly found in habitat consisting of boulders, cobble, demosponges, and brittlestars (*Ophiacantha*). They occurred in patches of one to several individuals sitting on the bottom near small isolated clusters of rock surrounded by mud. In some cases, they were evenly and sparsely distributed over mud bottoms. Jagielo, et al. (2003) compared densities of groundfish in “trawlable” and “untrawlable” off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. “Trawlable” bottoms were primarily mud, pebble, and mud-pebble (94%), whereas “untrawlable” bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and

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[31] P. Reilly, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814. Pers. commun., July 2003.

boulder-cobble (89%). The density of greenstriped rockfish in “untrawlable” areas (3.76 ave. no./hectare) was somewhat similar to the density found in the “trawlable” areas (5.65 ave. no./hectare).

Migrations and Movements

Greenstriped rockfish are primarily sedentary.

Reproduction

Greenstriped rockfish are multiple brooders, that is, they spawn two or more times per season (Love, et al. 1990). The peak spawning month for greenstriped rockfish off the southern California Bight is April (ranging from January to July). Off central and northern California, May is the peak spawning month (ranging from May to July) (Love, et al. 1990). Greenstriped rockfish can spawn up to 250,000 eggs per year (Love, et al. 1990). Young greenstripe rockfish are probably also born in late spring and early summer off Oregon, Washington, and British Columbia (Hart 1973).

Growth and Development

Newly released greenstriped rockfish larvae are about 5 mm in length (Hart 1973). Adults can grow to 38 cm (Eschmeyer, et al. 1983, Hart 1973, Love, et al. 1990). Males live to a maximum of 37 years, and females to 28 years (Love, et al. 1990). Off California males grow faster and females grow slower than in other areas of their range (Love, et al. 1990). There is no size difference between the sexes once they are finished growing (Love, et al. 1990). Males reach the size of 50% maturity at 18 cm total length and 100% maturity at 26 cm total length; females reach the size of 50% maturity at 19 cm total length and 100% maturity at 25 cm total length (Love, et al. 1990).

Trophic Interactions

Juvenile and adult greenstriped rockfish prey upon planktonic prey such as euphausiids, copepods, and pelagic tunicates, as well as small fishes (e.g., hake, anchovies, and lanternfishes), shrimp, and squid (Allen 1982).

Harlequin Rockfish (Sebastes variegatus)

Range

Harlequin rockfish have been reported from the central Oregon coast to the southeastern Bering Sea and the Aleutian Islands (Love, et al. 2002, Hart 1973, Mecklenburg, et al. 2002). Recently their southern range was extended with one specimen taken off La Push, Washington, and one off Newport, Oregon (Orr and Baker 1996). Catches reported off the Cobb Seamount (Pearson, et al. 1993) and Bodega Bay (Allen and Smith 1988) are questioned (Allen and Smith 1988, Love, et al. 1996).

Fishery

No information.

Habitat

Harlequin rockfish inhabit the inner shelf-mesobenthal (outer shelf) zone at depths up to 558 m (Allen and Smith 1988); adults are generally found in waters 100-350 m deep (Allen and Smith 1988, Orr, et al. 2000, Love, et al. 1996, Quast 1971), whereas, juveniles are found in waters as shallow as 6 m (Love, et al. 2002). Adults are found over high-relief substrata, including seamounts (Love, et al. 2002).

Migrations and Movements

Harlequin rockfish are a sedentary benthic species. However, the idea that harlequin rockfish may have moved from nearshore areas to the Cobb Seamount (520 km away), either in the pelagic larval state, or as juveniles or adults has been suggested by Pearson, et al. (1993).

Reproduction

No information.

Growth and Development

The maximum size attained by the harlequin rockfish is 37 cm (Love, et al. 1996). It takes a harlequin rockfish over 10 years to reach a length of 25 cm (Feldman and Rose 1981). The average age of harlequin rockfish caught off the Cobb Seamount by Pearson, et al. (Pearson, et al. 1993) was 15 years old. Munk (2001) reported that harlequin rockfish from the coastal waters of British Columbia reach the age of 43 years.

Trophic Interactions

No information.

Honeycomb Rockfish (Sebastes umbrosus)

Range
Honeycomb rockfish are found from Point Pinos (Monterey County, central California) to Punta San Juanico, Baja California (Eschmeyer, et al. 1983, Love, et al. 1996, Miller and Lea 1972). They tend to most abundant between Point Dume, California to Punta San Roque (southern Baja California) (Love, et al. 2002).

Fishery
Honeycomb rockfish are taken in the sport fishery, primarily off southern California (Lea 1992).

Habitat
The honeycomb rockfish is rare north of Point Conception, but is common in southern California (Eschmeyer, et al. 1983, Miller and Lea 1972). The honeycomb rockfish is a shallow- water species, found on or near the bottom, most often between 45 to 60 m (Love, et al. 2002). However, they range in depth from 30 to 270 m (Chen 1971, Eschmeyer, et al. 1983, Love, et al. 2002).

Young recruit to hard substrata and high-relief reefs (>1 m) (Love, et al. 1991), and in some cases to soft bottoms (California Dept. Fish and Game 2003), at depths between 27 and 54 m (Love, et al. 2002). Young-of-the-year honeycomb rockfish have been found settling to the bottom in the La Jolla Submarine Canyon as early as October (Chen 1971).

Migrations and Movements
Adult movement is probably not extensive.

Reproduction
Honeycomb rockfish spawn from March to July, probably peaking in April (Chen 1971).

Growth and Development
Honeycomb rockfish usually do not get much larger than 20 cm. They mature in 3–5 years and may begin to mature as early as 10 cm standard length. There is no size difference between the sexes (Chen 1971).

Trophic Interactions
No information.

Kelp Rockfish (Sebastes atrovirens)

Range

Kelp rockfish are found from Albion in northern California to Bahia San Carlos in central Baja California (Love, et al. 2002), but are abundant from northern California to Arrecife Sacramento in central Baja California (Eschmeyer, et al. 1983, Love 1996, Miller and Lea 1972).

Fishery

Kelp rockfish are commonly caught by recreational anglers fishing at shallow depths in kelp beds and occasionally from piers and rocky shores (Eschmeyer, et al. 1983, Love 1996, Mason 1995). As an example, kelp rockfish are more abundant in skiff catches at Monterey than at Santa Cruz because Monterey has a more abundant kelp forest (Mason 1995). Kelp rockfish are important in the sport-diver catch, particularly from Santa Barbara to central California (Love 1996). Infrequently, commercial fisheries take kelp rockfish in traps and gill nets (Love 1996), but kelp rockfish are becoming important in the live-fish fishery off California.

Habitat

Kelp rockfish inhabit shallow waters. Most live at depths of 18-24 m (Love, et al. 2002) although they occur from 3 to 58 m (Eschmeyer, et al. 1983, Love, et al. 2002). As adults, kelp rockfish are primarily residential (Mason 1995) in kelp forests and are considered parademersal (Hallacher and Roberts 1985).

Older kelp rockfish frequently occur on or near the bottom in kelp beds and rocky areas (Eschmeyer, et al. 1983, Mason 1995) and also in midwater areas around giant kelp plants (Love 1996). Juveniles and adult kelp rockfish apparently prefer rocky habitats and are predominately associated with *Macrocystis* plants (Carr 1991). During the day, kelp rockfish are usually right in the algal blades, sometimes sitting on them, often upside down (Love 1996). With the onset of fall storms that remove the *Macrocystis*, proportionally fewer individual kelp rockfish are associated with *Macrocystis* and individuals are more evenly distributed among all substratum types (Carr 1991).

Although adult kelp rockfish prefer kelp and other algae, they have been observed living in rocky areas without algae (Love 1996), including artificial reefs (Cailliet, et al. 2000). However, in a study conducted by Holbrook, et al. (1990), kelp rockfish were absent from reefs lacking *Macrocystis*. Their conclusion was that kelp rockfish require a threshold of *Macrocystis* before occupying a reef, maybe because a low density of kelp does not provide enough resources to a population.

Juvenile kelp rockfish settle out of plankton into kelp beds in the summer from April to August (earliest in southern California and Baja California). Kelp rockfish larvae reach their peak abundance in September (Carr 1991). Carr (1991) reported that over 70% of kelp rockfish larvae are less than 0.5 m away from *Macrocystis* fronds; nearly all of these were tucked amongst the fronds.

Young-of-the-year first settle in the fronds of kelp beds, which provide a nursery area and a refuge (Diaz and Hamann 1987, Nelson 1992). As they grow, they spread out away from the canopy (Carr 1991, Love 1996, Ven Tresca, et al. 1996). For example, they are occasionally found associated with drift algae (Caselle 1999). Nelson (2001) reported that the young-of-the- year use three different microhabitats in the canopy prior to movement to the bottom. These associations with microhabitats appear to reduce the threat of predation. The surface-to-bottom transition also corresponds to increasing size (Carr 1991). They gradually migrate down the kelp stipes and assume a parademersal existence in close proximity to benthic algal cover, and cracks and crevices within the rocky substratum (Hallacher and Roberts 1985).

Young kelp rockfish initially occupy the surface and mid-depth portions of the water column in very close proximity with the *Macrocystis* canopy for the first 16 weeks after their recruitment to the nearshore regions of central California (Hallacher and Roberts 1985, Nelson 1992).

Migrations and Movements

Kelp rockfish is a shallow-water species, which is less likely to undertake movements than species inhabiting deeper waters (Mason 1995). They do not make extensive seasonal migrations (Mason 1995). However, during winter storms they may migrate into slightly deeper water or retire to rock caves, otherwise they rarely move from place to place (Love 1996).

Juvenile kelp rockfish first appear in the *Macrocystis pyrifera* canopy, within which they make a series of microhabitat shifts preparatory to making a downward migration to the kelp holdfasts.

Reproduction

Kelp rockfish are ovoviviparous and their eggs are fertilized internally (Yoklavich, et al. 1996) Spawning ranges from late winter through summer (Love 1996, Moreno 1993), usually from May to June (Carr 1991).

Growth and Development

Larvae of the kelp rockfish are planktonic. Kelp rockfish grow to a maximum of 42 cm (Eschmeyer, et al. 1983, Love 1996, Miller and Lea 1972) and live to a maximum of 15 years (Lea, et al. 1999). The length at 50% sexual maturity is 26 cm (4–5 years) and 100% sexual maturity is 30 cm (6–7 years) (Love, et al. 2002).

Trophic Interactions

Kelp rockfish are carnivorous and eat a variety of prey, most of which are free-swimming (Love 1996). They are most active at night and will sometimes chase food slightly away from the plant habitat (Love 1996). Older kelp rockfish prey primarily on benthic invertebrates and small fishes that colonize the substrata; they ambush these prey a short distance from kelp fronds (Diaz and Hamann 1987, Holbrook, et al. 1990). An index of relative importance shows that their diet is dominated by caridean shrimp and amphipods (Diaz and Hamann 1987); tunicates, cephalopods, and gastropods are also important (Oregon Dept. of Fish and Wildlife 2002). Adult kelp rockfish also commonly prey on juvenile rockfishes (Hallacher and Roberts 1985). Kelp rockfish larvae are zooplanktivores, preying on nauplii and invertebrate eggs as well as copepods (Sumida, et al. 1985, Moser and Boehlert 1991). Juveniles (25 mm to maturity) are also planktivores, feeding on crustaceans such as gammarid amphipods, barnacle larvae, and juvenile fishes (Oregon Dept. of Fish and Wildlife 2002). Larvae are preyed upon by siphonophore and chaetognaths (Yoklavich, et al. 1996). The juveniles are prey of birds, pinnipeds, porpoises, lingcod, cabezon, salmon, and other rockfish (Miller and Geibel 1973, Morejohn, et al. 1978, Love, et al. 1991, Ainley, et al. 1993). Nelson (2001) reported that young-of-the-year bocaccio are a major predator of young-of-the-year kelp rockfish. Predators of adult kelp rockfish include sharks, dolphins, and seals (Morejohn, et al. 1978, Antonelis and Fiscus 1980).

The kelp rockfish is excluded from bottom areas of kelp beds by the territorial gopher rockfish (Hallacher and Roberts 1985).

Longspine Thornyhead (Sebastolobus altivelis)

Range

Longspine thornyhead are found from the southern tip of Baja California to the Aleutian Islands (Eschmeyer, et al. 1983, Jacobson and Vetter 1996, Love 1996, Miller and Lea 1972, Smith and Brown 1983), but are abundant from southern California northward (Love 1996).

Fishery

A substantial commercial trawl fishery exists for both longspine and shortspine thornyheads, much of which developed quite recently and is centered around central California and northward (Love 1996). They are harvested by a deep-water bottom trawl fishery that also targets Dover sole and sablefish (Jacobson and Vetter 1996). Thornyheads also have been caught in great numbers in trawls over seamount summits, at depths of 531–810 m (Alton 1986). They are not taken in sport fisheries (Love 1996) because thornyheads occur too deep.

Habitat

Juvenile and adult longspine thornyheads are demersal and occupy the sediment surface (Smith and Brown 1983). They inhabit the continental slope and are dominant over their depth range (Wakefield and Smith 1990). Off Oregon and California, the depth range of longspine thornyhead is 201–1755 m (Orr, et al. 2000, Love, et al. 2002), but they most commonly occur between 600 and 1000 m in the oxygen minimum zone (OMZ) (Eschmeyer, et al. 1983, Smith and Brown 1983, Wakefield and Smith 1990, Jacobson and Vetter 1996). Longspine thornyhead are specialists of the OMZ. They spend part of their pelagic larval and entire benthic juvenile and adult phases in the OMZ (Jacobson and Vetter 1996).

Spawning occurs at 600–1000 m and eggs rise to the surface to develop and hatch. Larvae and small juveniles are pelagic for 18–20 months (Jacobson and Vetter 1996). Thornyhead larvae have been taken in research surveys up to 560 km off the California coast (Cross 1987, Moser, et al. 1993). Most were more than 32 km offshore. Juvenile longspines settle on the continental slope at about 600–1200 m (Jacobson and Vetter 1996).

Longspine thornyheads live on soft bottoms, preferably sand or mud (Eschmeyer, et al.1983, Jacobson and Vetter 1996, Love 1996), or in muddy areas associated with rocks and sponges (Love, et al. 2002). They are also associated with seamounts (Alton 1986). Juveniles (<5.1 cm long) occur in midwater (Eschmeyer, et al. 1983). After settling at depths ranging from 600 to 1,200 m (Wakefield 1990), longspine thornyhead are completely benthic (Jacobson and Vetter 1996).

Migrations and Movements

Jacobson and Vetter (1996) and Vetter and Lynn (1997) report that longspine thornyheads exhibit no ontogenetic migration pattern and their mean size is similar at all depths. In contrast, Wakefield and Smith (1990) report that longspine thornyheads display ontogenetic migration where eggs from the bathyal bottom rise to surface and juveniles return to the bottom. Genetic studies by Stepien, et al. (2000) did not demonstrate significant geographic isolation among longspine thornyhead populations, suggesting that eggs and larvae are retained locally by currents and gyres.

Juveniles can accelerate rapidly in random directions for short distances. However, adults lay lethargically on the bottom and can be approached in a submersible within a few centimeters before they swim away for several meters and then resume resting quietly on the bottom (Smith and Brown 1983). Longspine thornyheads neither school nor aggregate (Jacobson and Vetter 1996).

Reproduction

Length at maturity for individuals caught along the West Coast was 17.83 cm (Pearson and Gunderson 2003). Annual fecundity ranges from 20,000–450,000 eggs per season (Love 1996). Females release eggs in gelatinous masses that float to the surface where, after hatching, the larvae undergo rapid development to a feeding larval stage (Smith and Brown 1983, Wakefield and Smith 1990). Along the West Coast, longspine thornyhead spawn between January and April at 600–1000 m (Jacobson and Vetter 1996, Wakefield and Smith 1990, Pearson and Gunderson 2003). Floating egg masses can be seen at the surface in March, April, and May (Wakefield and Smith 1990). Wakefield (1990) reported that approximately 90% of the spawning populations reside in "a stratum bounded by the 500 and 1,100 m isobaths."

Growth and Development

Longspine thornyhead can grow to 38 cm (Eschmeyer, et al. 1983, Jacobson and Vetter 1996, Miller and Lea 1972) and live more than 40 years (Jacobson and Vetter 1996). A longspine measuring 30 cm correlates to 25–45 years in age (Jacobson and Vetter 1996).

Physical conditions on the slope and low influx of carbon from photosynthesis in overlying waters result in a low metabolism and slow growth rates (Jacobson and Vetter 1996). Longspine thornyhead reach the onset of sexual maturity at 17–19 cm total length (10% of females mature) and 90% are mature by 25–27 cm (Jacobson and Vetter 1996).

After hatching, longspine thornyhead have a protracted pelagic stage and juveniles reportedly spend 20 months in midwater (Love 1996) before they settle as a benthic juveniles at approximately 55 mm in length. The smallest demersal juveniles are 42 mm and the largest pelagic juveniles are 56 mm (Wakefield and Smith 1990). After about 1 year of life as a demersal juvenile, they reach 80 mm in length (Wakefield and Smith 1990).

Trophic Interactions

Longspine thornyhead are sit-and-wait predators (Jacobson and Vetter 1996). They consume fish fragments, crustaceans, bivalves, and polychaetes, and occupy a tertiary consumer level in the food web. Pelagic juveniles prey largely on herbivorous euphausiids and occupy a secondary consumer level in the food web (Love 1996, Smith and Brown 1983).

Longspine thornyhead are common items in shortspine thornyhead stomachs. Cannibalism in newly settled longspine thornyhead may occur because juveniles settle directly onto adult habitat (Jacobson and Vetter 1996). Sablefish commonly prey on longspine thornyhead (Alton 1986).

Mexican Rockfish (Sebastes macdonaldi)

Range

Mexican rockfish occur from Point Sur, California, southward as far as Cape San Lucas, Baja California, and eastward in the Gulf of California (MacGregor 1986, Moser, et al. 1977, Love, et al. 2002).

Fishery

Mexican rockfish are occasionally taken in sport and commercial fisheries off California (Lea 1992).

Habitat

Adult Mexican rockfish are found at depths of 76–350 m (Moser 1972, Love, et al. 2002, Love[32]). Larvae and juveniles (60–100 mm) are found in 80–100 m of water (Moser, et al. 1977). Larval Mexican rockfish have been captured as far as 185 km offshore (MacGregor 1986). Adults are commonly found at 91-238 m, inhabit rock outcrops, and have been observed near deep oil platforms (Love, et al. 2002, Orr, et al. 2000).

Migrations and Movements

No information.

Reproduction

Mexican rockfish spawn in highest densities beginning in April, but the peak spawning time is later in the southern parts of its range (MacGregor 1986).

Growth and Development

Larvae are extruded at approximately 4–5 mm (Moser, et al. 1977). Larvae become pelagic juveniles by 15 mm and are demersal by about 60 mm (Moser 1972, Moser, et al. 1977).

Trophic Interactions

No information.

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[32] M. S. Love, University of California at Santa Barbara, Person. Commun. June 2004.

Olive Rockfish (Sebastes serranoides)

Range

Olive rockfish occur from southern Oregon to Islas San Benito in central Baja California (Miller and Lea 1972, Love, et al. 2002). They are abundant from Santa Barbara northward to about Mendocino County, northern California (Eschmeyer, et al. 1983, Love 1996, Love and Westphal 1981), and around the Northern Channel Islands (Love 1996). Olive rockfish appear to be very rare off much of both southern California and Baja California.

Fishery

Olive rockfish are important in the party- and private-vessel sport fishery (Eschmeyer, et al. 1983, Love 1980, Love 1996). Divers also spear a substantial number and juveniles are readily taken from piers. Occasionally olive rockfish are found in the commercial fishery, taken primarily by hook and line (Love 1996).

Habitat

Olive rockfish occur from surface/intertidal waters to 174 m deep (Eschmeyer, et al. 1983, Love 1980, Love 1996). Most commonly they occur in waters less than 30 m (Eschmeyer, et al. 1983).

Olive rockfish co-occur with blue rockfish and kelp bass in areas of reef and giant kelp (Love and Ebeling 1978). On some reefs, olive rockfish are the most abundant species (Love 1996). They are most common in southern and central California from surface waters to depths of about 75 m (Love 1980). Olive rockfish also occur along the Monterey Canyon ledge (Sullivan 1995).

Adult olive rockfish are a midwater fish, almost always living over hard, high relief (such as reefs, wrecks, oil platforms, or pipes) (Love 1996). They often form schools in association with blue and yellowtail rockfish (Oregon Dept. of Fish and Wildlife 2002). Young-of-the-year and adults are primarily found hovering off the bottom (Carr 1991). Sometimes olive rockfish are observed well off the bottom, in or near kelp or over rocky reefs (Eschmeyer, et al. 1983).

Olive rockfish prefer clear-water areas of dense kelp (Love and Ebeling 1978) and are rarely caught or seen over sandy substrata. Kelp beds may provide "bridges" from one reef to another (Love 1980). Olive rockfish distribution is fairly even over all rocky substrata, although significant selection is exhibited toward low-rock substratum (Carr 1991).

The larval stage of olive rockfish is planktonic (Moser 1996c). When young-of-the-year olive rockfish settle out of the plankton, they are most commonly found in and around kelp beds, drifting kelp mats, oil platforms, surfgrass, artificial reefs, and other structures at depths as shallow as 3 m (Limbaugh 1955, Carlisle, et al. 1964, Mitchell and Hunter 1970, DeMartini 1981, Carr 1983, Larson and DeMartini 1984, Kendall 1991, Danner, et al. 1994, Love 1996, Ven Tresca, et al. 1996, Bloeser 1999, Cailliet, et al. 2000, Love 2001). During the day, young fish aggregate in the water column, occasionally with blue and black rockfish. They spend the night near or on the bottom, sheltering under algae or among rocks. Young olive rockfish also are found under drifting kelp mats. Young-of-the-year tend to aggregate in areas of reduced water movement where drift algae accumulate and young recruit to both kelp-only and rock-only substrata in the lower third of the water column (Carr 1991) in June (Kendall and Lenarz 1987). Recently settled individuals form aggregations at mid-depths along the shoreward margins of *Macrocystis* beds. Older juveniles aggregate near the bottom along the outer edge of the kelp bed and disperse over adjacent *Dictyopterus* beds at night (Love, et al. 1991).

Migrations and Movements

Olive rockfish are active, fast-swimming, streamlined predators, usually found in the water column, but occasionally hovering over or resting upon rocky substrata (Love and Westphal 1981). They often form single or multispecies aggregations of thousands of individuals (Love 1980). Individual olive rockfish may be found in schools of blue rockfish (Love 1996).

Olive rockfish spend most of their time anywhere from 0.5–12 m or so above the substrata, and have even been seen breaking the surface chasing small fishes (Love 1996). However, they are mostly a sedentary fish (Love 1996) and tagging studies show that they tend to spend their entire life near the same reef (Watters 1992). Lea, et al. (1999) reported movements of less than 1.8 km in tag-and-release studies. During the day, olive rockfish are found midwater next to kelp plants; they descend to the bottom at night (Love 1996). The movement patterns of olive rockfish may be limited by the presence or absence of kelp beds (Love 1980). It has been shown that the abundance of olive rockfish decreases as beds of *Macrocystis* are removed (Bodkin 1988).

Reproduction

The age at first maturity ranges from 3 to 8 years, most maturing by age 6 (Love and Westphal 1981, Love 1996). Olive rockfish spawn once per season, usually from January to March (with a peak in January or February) (Love and Westphal 1981, Love 1996). Fecundity ranges from 30,000 to 490,000 eggs (Love and Westphal 1981).

Growth and Development

Olive rockfish larvae are pelagic for 3–6 months before they settle out (Love and Westphal 1981). Beginning in April, newly settled olive rockfish appear in kelp beds (Love 1996). They can grow to 61 cm (Eschmeyer, et al. 1983) and live to be 25 years old (Love 1996, Watters 1992). Females grow faster than males, beginning at age 5 when 50% of males are mature (Love and Westphal 1981).

Trophic Interactions

Larval olive rockfish are planktivorous and are known to feed on nauplii, invertebrate eggs, and copepods (Love 1978, Sumida, et al. 1985, Moser and Boehlert 1991). Juveniles feed on crustaceans (such as calanoid copepods, zoea larvae, and barnacle cypriots), juvenile fishes, polychaetes, octopi, and squid (Limbaugh 1955, Hobson and Chess 1976, Roberts 1979: Singer 1982, Gaines and Roughgarden 1987, Love, et al. 1991). Adults and subadults rockfish feed primarily on midwater organisms rather than on substrata-orientated prey. They also feed more on moving prey and so may forage more widely than other species of rockfish (Love 1980).

Major prey of the olive rockfish include fishes (particularly juvenile rockfishes), octopi, squid, and planktonic organisms, such as copepods and crab larvae (Love 1996), although polychaetes are sometimes consumed (Limbaugh 1955; Miller 1960b; Quast 1968a, 1968c; Feder, et al. 1974; Hallacher 1977; Love 1978; Love and Ebling 1978; Roberts 1979; Hobson et al 1981; Hallacher and Roberts 1985; Bodkin 1988; Watters 1992; Love 1996; Holbrook, et al. 1997; Lea, et al. 1999). Olive rockfish prefer fish prey over plankton, and the fish consumed include juvenile blacksmith, anchovy, pipefish, blue rockfish, olive rockfish, adult topsmelt, and anchovy (Love and Ebeling 1978). Small individuals prey primarily on plankton (Love and Westphal 1981). Individuals of all sizes ingest tiny prey such as ostracods, cladocerans, and small copepods. During the winter, copepods and zoea larvae are important (Love and Ebeling 1978). Olive rockfish also ingest parasitic copepods (Love and Ebeling 1978). Larger juveniles and adults are nocturnal, pursuing prey primarily after sunset (Love 1996, Love and Ebeling 1978).

Larval olive rockfish are known to be preyed upon by siphonophore and chaetognaths (Yoklavich, et al. 1996). Juveniles fall prey to other rockfishes, lingcod, cabezon, salmon, albacore, birds, and porpoise (Miller 1960b, Miller and Geibel 1973, Baltz 1976, Morejohn, et al. 1978, Roberts 1979, Ainley, et al. 1981, Love, et al. 1991, Ainley, et al. 1993). Adults are preyed on by sharks, dolphin, and pinnipeds such as seals and sea lions (Morejohn, et al. 1978, Antonelis and Fiscus 1980).

Olive rockfish are known to compete with the kelp bass for food and shelter in southern and central California where their ranges overlap (Feder, et al. 1974). Though olive rockfish have been associated with surfperches and bocaccio (Carlisle, et al. 1964), and are frequently observed among schooling blue rockfish (Burge and Schultz 1973), no information on competition among them was found. However, Hallacher and Roberts (1985) suggested that blue rockfish may have feeding strategies that limit trophic competitiveness with olive rockfish, whereas, bocaccio and olive rockfish have somewhat more similar feeding strategies.

Pacific Ocean Perch (Sebastes alutus)

Range

Off the coast of North America, Pacific ocean perch are found from La Jolla (southern California) to the western boundary of the Aleutian Archipelago (Eschmeyer, et al. 1983, Gunderson 1971, Ito 1987, Miller and Lea 1972), but are common from Oregon northward (Eschmeyer, et al. 1983). They are also distributed from Honshu, Japan to Cape Navarin in the Bering Sea (but not in the Sea of Okhotsk) (Allen and Smith 1988). The species appears to be most abundant in northern British Columbia, the Gulf of Alaska, and the Aleutian Islands (NMFS, et al. 1998).

Fishery

The Pacific Ocean perch has been one of the most important commercial rockfishes for the bottom trawl fishery in the eastern North Pacific (Eschmeyer, et al. 1983, NOAA 1990). Recreationally, it is not an important species (NOAA 1990).

Habitat

Pacific Ocean perch primarily inhabit waters of the upper continental slope (Dark and Wilkins 1994) and are found along the edge of the continental shelf (Archibald, et al. 1983). Pacific Ocean perch occur from 25 to 825 m deep, but trawl surveys found 96.8% of occurrences at 55–350 m (Orr, et al. 2000). They are often found along submarine canyons, depressions (NOAA 1990), pinnacles (Carlson and Strady 1981), and seamounts (Poltev 1999). During the summer, Pacific ocean perch primarily inhabit waters 180–220 m in depth, but during the winter, they inhabit waters deeper than 275 m (Archibald, et al. 1983). They have also been found at 55– 640 m (Eschmeyer, et al. 1983) Weinberg (1994) analyzed the results of groundfish surveys conducted between 1977 and 1992 in the coastal waters of Oregon and Washington. Using recurrent group analysis, he found that Pacific Ocean perch occurred in the same group as darkblotched, redbanded, and splitnose rockfish, and shortspine thornyhead. This group was most commonly collected at depths of 155–366 m.

Larvae and juveniles are pelagic; subadults and adults are benthopelagic. Larvae are released at dusk, 20–30 m off the bottom in depths of 360–400 m, and rise to midwater depths of 215–275 m (NOAA 1990). Spawning generally occurs among seamounts and other steep areas that are associated with circulation patterns that limit their distribution (Poltev 1999). Larvae initially occur at mesopelagic depths over the continental slope, later rising to epipelagic depths. Juveniles are epipelagic, and those carried far offshore may remain pelagic for 2–3 years. Juveniles carried into shallow waters become demersal more quickly, and remain shallower than 250 m (NOAA 1990).

Juveniles are confined to shallow portions of the bathymetric range to as shallow as 37 m over hard bottoms of the shelf break (Carlson and Straty 1981). Most fish 10 years or younger are found over rough or rocky bottoms of the shallow and intermediate portion of the bathymetric range, indicating that segregation of recruits into shallow-water and deep-water components does not occur until age 11 (Gunderson 1974).

Adults are usually found below 122 m (Eschmeyer, et al. 1983). Subadults and adults are benthopelagic; adults primarily inhabit waters of the upper continental slope and are found along the edge of the continental shelf. During summer, Pacific Ocean perch inhabit waters 180–220 m deep;

in winter, they are found in waters deeper than 275 m. In Alaskan waters, adults are found primarily offshore along the continental slope in depths of 180–420 m (NMFS, et al. 1998).

Brodeur (2001) conducted studies in Pribilof Canyon in the Bering Sea, and reported adults in areas covered with silt and clusters of sea whips (*Halipteris willemoesi*) at depths of 180–220 m during the night. During the day, these fish were higher in the water column (150–175 m), feeding on zooplankton.

Throughout its range, adult Pacific Ocean perch is generally associated with gravel, rocky, or boulder-type substratum found in along gullies, canyons, pinnacles (Carlson and Strady 1981), seamounts (Poltev 1999), and submarine depressions of the upper continental slope (Ito 1987, NOAA 1990). Krieger and Sigler (1995) report adults also occur on smooth substrata in groups of 2–200 fish. All life stages occur in euhaline waters at temperatures of 2.5– 6.5° C (NOAA 1990), although investigations of Pacific ocean perch in the British Columbia- Oregon area indicate that adults prefer temperatures of 5–8° C (Scott 1995 and Poltev 1999).

Most of the population occurs in patchy, localized aggregations and adults may aggregate over the smooth bottom of the continental slope (NMFS, et al. 1998).

Migrations and Movements

Pacific ocean perch winter and spawn in deeper water (>275 m), then move to feeding grounds in shallower water (180–220 m) in the summer (June through August) to allow gonads to ripen (Archibald, et al. 1983, Gunderson 1971, NOAA 1990). Adults form large schools 30 m wide, to 80 m deep, and as much as 1,300 m long (NOAA 1990). They also form spawning schools (Gunderson 1971). Juvenile Pacific Ocean perch form ball-shaped schools near the surface or hide in rocks (NOAA 1990).

At ages of 1–3 years, they may move to progressively deeper waters of the continental shelf; older juveniles are often found together with adults at shallower location of the continental slope in the summer months (NMFS, et al. 1998).

Migrations and movements are probably related to summer feeding and winter spawning (NMFS, et al. 1998). In Alaskan waters, adults inhabit shallower depths (180–250 m) in the summer and in the fall migrate farther offshore to depths of approximately 300–420 m (NMFS, et al. 1998). In the northeast Pacific, juveniles make seasonal depth migrations (Westerheim 1970). On the west coast of Vancouver Island, older juveniles spend summer and fall at approximately 160–200 m, then travel down to 200–240 m in winter and spring (Love, et al. 1991).

Reproduction

Fertilization is internal (NOAA 1990), with insemination of females occurring from September to October off British Columbia and Washington (Archibald, et al. 1983, Gunderson 1971). Parturition apparently takes place months after mating, primarily from January to April off Washington (Gunderson 1971, NOAA 1990), although a few fish release larvae in August and October (Love, et al. 2002). Females are reported to release larvae at dusk at depths between 20 and 30 m off of the bottom (Love, et al. 2002).

Fecundity ranges from 10,000 eggs at 23 cm to 300,000 eggs at 45 cm, with a possible maximum of over 500,000 eggs. Males mature at 4–13 years and females at 5–15 years, mostly in 5–9 years for both (NOAA 1990).

Growth and Development

Larvae are 5–8 mm standard length at parturition and the larval period lasts several weeks. Juveniles range up to 22–35 cm, depending on gender and region (NOAA 1990). Pacific Ocean perch are slow-growing and long-lived; growth is slower for males (Beamish 1979, Eschmeyer, et al. 1983, Leaman 1987, NOAA 1990). The maximum age in Alaskan waters has been estimated at 98 years (Munk 2001). Largest size is about 54 cm and 2 kg (Archibald, et al. 1983, Beamish 1979, Eschmeyer, et al. 1983, Ito 1987, Mulligan and Leaman 1992, NOAA 1990, Richards 1994).

Trophic Interactions

Pacific Ocean perch are carnivorous. Larvae eat small zooplankton. Small juveniles eat copepods, and larger juveniles feed on euphausiids and calinoid copepods (Poltev 1999). Adults eat euphausiids, calinoid copepods, mysids, shrimp, squid, and small fishes. The zooplankton prey tend to be bathypelagic (cold-stenothermic), which may partially explain why adults are found in temperatures between 5 and 8° C. Juveniles in southeastern Alaska were found to feed predominantly on copepods and euphausiids in roughly equal proportions, with other food types being of incidental importance. Feeding intensity was low in March and April (Carlson and Haight 1976). Adults occurring shallower than 150 m feed during the day; those at greater depths move toward the surface to feed at dawn and dusk. Immature fish feed throughout the year, but adults feed only seasonally, mostly April to August (NOAA 1990). Predators of Pacific Ocean perch include sablefish and Pacific halibut. Other predators may include Pacific cod and arrowtooth flounder. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other large demersal fish (NMFS, et al. 1998).

Pink Rockfish (Sebastes eos)

Range

Pink rockfish occur from southern Baja California, near Isla Guadalupe northward to the central Oregon coast (Love, et al. 2002).

Fishery

Pink rockfish are taken in commercial fisheries and occasionally in sport fisheries off California (Lea 1992).

Habitat

Pink rockfish are common in waters, from 45 to 366 m (Love, et al. 2002). Adults have been observed in boulder fields, resting on soft bottom sediments (Love, et al. 2002). Adults have also been reported near rocky bottoms on the shelf, slope, and in canyons; whereas, juveniles have been reported inhabiting primarily soft bottom sediments (California Dept. of Fish and Game 2003).

Migrations and Movements

No information.

Reproduction

No information.

Growth and Development

Adult pink rockfish grow to 56 cm (Miller and Lea 1972, Love, et al. 2002).

Trophic Interactions

No information.

Quillback Rockfish (Sebastes maliger)

Range

Quillback rockfish are found from the northern Channel Islands in southern California to the Gulf of Alaska (Miller and Lea 1972). They are common in the Strait of Georgia, San Juan Islands, and Puget Sound, and from southeastern Alaska to northern California (Clemens and Wilby 1961, Hart 1973, Love 1996, Matthews 1990a, Love, et al. 2002).

Fishery

Quillback rockfish are important in the sport and commercial fisheries (Hart 1973, Murie 1995). From Oregon to southeastern Alaska, quillback rockfish are an important part of the inshore sport fishery and are taken by party and private vessels and divers (Love 1996).

Habitat

Quillback rockfish are a common, shallow-water benthic species (Matthews 1990a). They are taken from subtidal depths to 275 m (Hart 1973, Love 1996), but they occur mainly from 9 to 147 m (Orr, et al. 2000). Young quillback rockfish occur along the shores at depths less than 60 m and adults usually in deeper waters to 140 m (Clemens and Wilby 1961, Richards 1986).

Quillback rockfish are solitary reef-dwellers, living close to or on the bottom (Love 1996, Matthews 1988, Rosenthal, et al. 1988). Occasionally they will rise up 9–12 m in the water column (Love 1996). In Puget Sound, they occupy a wide variety of habitats, having the highest densities on shallow (<30 m) reefs (Matthews 1990a). Quillback rockfish live among rocks or sometimes on coarse sand or pebbles next to reefs, particularly in areas with a lot of flat-bladed kelp (Love 1996). They are either found perched on rock or kelp or wedged into crevices and holes, and are rarely seen out in the open or unstructured areas of reefs (Matthews 1988). When quillback rockfish and copper rockfish are located on the same reef, quillback rockfish generally occupy the deeper depths (Matthews 1987). Adults tend to associate with high-relief substrata, and young-of-the-year tend to associate with low-relief substrata. In British Columbia, young fish are frequently associated with sponge beds (Richards 1986). Young-of-the-year tend to be on the most complex areas of low-relief reefs (West, et al. 1994) and use eelgrass/sand habitat as temporary habitat (Matthews 1990b). Young settle at 18–25 mm total length to shallow, vegetated habitats such as beds of kelp and eelgrass (West, et al. 1994). Densities on low-relief reefs and sand/eelgrass increased during the summer coincident with peak plant cover (Matthews 1990a). Buckley (1997) hypothesized that prior to settlement, the pelagic larval and juvenile stages are located in mid-water habitats. Eventually they are thought to settle out on sandy/muddy habitats at “moderate depths” (Buckley 1997). These benthic juveniles (18–25 mm total length) gradually settle in shallow waters along the shores, and are associated with a variety of habitats, including drifting aggregates of benthic macrophytes, established bull kelp (*Nereocysis luetkeana*) beds, natural rock configurations, and artificial reefs (West, et al. 1994).

The larvae of quillback rockfish are planktonic (Moser 1996). After about 1–2 months in the plankton, they begin to settle near shore.

Donnelly and Burr (1995) reported the results of trawls conducted in all the basins in Puget Sound, except Hood Canal, as well as a site in the Georgia Basin. Over 100 fish species were collected between 1983 and 1988. During the winter, spring, and summer months, quillback rockfish were among the 10 most common species collected at depths greater than 100 m. Jagielo, et al. (2003) compared densities of groundfish in "trawlable" and "untrawlable" off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. "Trawlable" bottoms were primarily mud, pebble, and mud-pebble (94%), whereas "untrawlable" bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder- cobble (89%). Although low densities (0.27 ave. no./hectare) of quillback rockfish were found in the "untrawlable" areas, this species was not collected in the "trawlable" areas.

Migrations and Movements

On high-relief rocky reefs in Puget Sound, quillback rockfish maintain small home ranges (within 30 m^2). Off-reef movement occurs during the summer. During the fall and winter, they remain on artificial reefs. On low-relief rocky reefs, they maintain considerably larger home ranges (400–1500 m^2). Quillback rockfish only inhabit low-relief reefs during the summer and only return from displacements in the summer coincident with peak algal cover. They move from artificial reefs to low-relief reefs during the summer and return to artificial reefs in the fall when kelp disappears on low-relief reefs. Returns to original reefs when artificially displaced indicate site fidelity. Quillbacks can return to their home sites when experimentally displaced up to 6.4 km. Quillback rockfish are not territorial of their home range. They may use navigation or olfactory cues to relocate home sites. They maintain small home ranges during the day, night, and high currents (Matthews 1988, Rosenthal, et al. 1988, Matthews 1990a). Female quillback rockfish probably move to other habitat to release larvae because no pregnant individuals were observed in these studies (Matthews 1988).

Tagging studies in central California and Washington have shown quillback to be residential (no movement other than diurnal) or to show movement of less than 9.6 km (Miller and Geibel 1973, Love 1978, Gascon and Miller 1981, Lea, et al. 1999). They have also demonstrated homing ability and specific diurnal movement patterns (Matthews 1990b, 1990c; Matthews, et al. 1986).

Reproduction

Mating probably occurs in March in Puget Sound and parturition in May (Matthews 1990b). Over their geographic range, they spawn from April to July, with a peak early in the season (Love 1996, Matthews 1988).

Growth and Development

Quillback rockfish can grow to 61 cm (Clemens and Wilby 1961, Hart 1973, Love 1996) and live to 90 years (Munk 2001). Growth rates differ along its range; off southeastern Alaska a 12-year-old is approximately 31 cm, and 50% of quillback rockfish mature at 31 cm; whereas off California a 12-year-old would only be 18 cm, and 50% mature at 23 cm (Love 1996).

Trophic Interactions

Quillback rockfish consume a wide range of prey taxa, but are more dietary generalists than other rockfish species (Rosenthal, et al. 1988). Off British Columbia, quillback rockfish feed on herring and demersal and pelagic crustaceans. They feed primarily during mid-day and are inactive, sheltering in holes and crevices, during the night (Murie 1995).

As planktonic larvae, quillback rockfish are known to consume nauplii, invertebrate eggs, and copepods (Sumida, et al. 1985, Moser and Boehlert 1991). After they settle in the shallow, nearshore areas, they remain zooplanktivorous and feed on crustaceans such as barnacle cypriots, shrimp, and calanoid copepods (Hueckel and Stayton 1982, Gaines and Roughgarden 1987, Love, et al. 1991, Murie 1995). As adults their habit is more benthic, and they are known to feed on a variety of prey such as crustaceans, small fish including rockfishes and flatfishes, bivalves, polychaetes, and fish eggs such as from lingcod (Washington, et al. 1978, Rosenthal, et al. 1982, Huekel and Stayton 1982, Rosenthal, et al. 1988, Murie 1995, Love 1996). In Puget Sound, quillback rockfish principally prey upon brachyuran crabs, gammarid amphipods, euphausiids, and calanoid copepods (Hueckel and Slayton 1982, Matthews 1990a, Rosenthal, et al. 1988).

Quillback rockfish larvae are subject to predation by siphonophore and chaetognaths (Yoklavich, et al. 1996). As juveniles, they are preyed upon by fishes, including larger rockfishes (such as yelloweye), lingcod, cabezon, and salmon. Various marine birds and pinnipeds take juvenile quillback as well (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1981, Rosenthal, et al. 1982, Love, et al. 1991, Ainley, et al. 1993). Adults are also subject to predation by larger fishes including some sharks, as well as pinnipeds, and possibly river otters (Antonelis and Fiscus 1980, Stevens, et al. 1984, Rosenthal, et al. 1988, Morejohn, et al. 1978, Bloeser 1999).

Redbanded Rockfish (Sebastes babcocki)

Range

Redbanded rockfish range from the Bering Sea (Zhemchug Island) and Aleutian Islands (Amchitka Island) to San Diego, California (Hart 1973, Eschmeyer, et al. 1983, Love, et al. 2002, Miller and Lea 1972). They are uncommon south of San Francisco (Hart 1973, Eschmeyer, et al. 1983).

Fishery

Off California, they are occasionally taken in sport and commercial fisheries (Lea 1992).

Habitat

Redbanded rockfish can occur as shallow as 49 m and as deep as 625 m (Love, et al. 2002) and most (97%) occur from 150 to 400 m (Allen and Smith 1988, Orr, et al. 2000). Adults and juveniles occur over soft substrata (Eschmeyer, et al. 1983, Rosenblatt and Chen 1972, California Dept. of Fish and Game 2003), although in one study off British Columbia (Matthews and Richards 1991), redbanded rockfish occurred over untrawlable habitat. Moreover, Love, et al. (2002) state that they are associated with hard-bottom substrata, generally in crevices between boulders, although occasionally they are observed over mixtures of mud, cobble, and pebbles.

Weinberg (1994) analyzed the results of groundfish surveys conducted between 1977 and 1992 in the coastal waters of Oregon and Washington. Using recurrent group analysis, he found that redbanded rockfish occurred in the same group as darkblotched and splitnose rockfish, shortspine thornyhead, and Pacific Ocean perch. This group was most commonly collected at depths of 155–366 m.

Migrations and Movements

No information.

Reproduction

Off Oregon, redbanded rockfish give birth to young March through September (Love, et al. 2002). Off Oregon, 50 % of the males and females mature at 23 cm and 28 cm, respectively, whereas, off British Columbia, 50% of both male and female redbanded rockfish mature at 19 years (42 cm) (Love, et al. 2002).

Growth and Development

Redbanded rockfish grow to 65.5 cm in length and 106 years (Hart 1973, Eschmeyer, et al. 1983, Love, et al. 1996, Love, et al. 2002).

Trophic Interactions

No information.

Redstripe Rockfish (Sebastes proriger)

Range

Redstripe rockfish occur from southern Baja California to the Bering Sea (Hart 1973 Allen and Smith 1988, Love, et al. 2002).

Fishery

Off California, redstripe rockfish are occasionally taken in sport fishers and are an important component of the commercial trawl fishery (Lea 1992, Love, et al. 2002).

Habitat

Redstripe rockfish inhabit the outer shelf and upper slope (Allen and Smith 1988). Redstripe rockfish have been reported between 12 and 425 m in depth, but are most common (95%) between 150 and 275 m (Love, et al. 2002). Adults are semi-demersal, while larvae and juveniles are pelagic to semi-demersal (Garrison and Miller 1982). Young redstripe rockfish can occur in estuaries (Kendall and Lenarz 1987). All life stages of this species are found in Puget Sound, but they are relatively uncommon (Garrison and Miller 1982).

Adult and juvenile redstripe rockfish are generally found slightly off the bottom (1 m or so) over both high- and low-relief rocky areas (Starr, et al. 1996, California Dept. of Fish and Game 2003), and adults are often found at the interface between sand and rock (Cailliet, et al. 2000). Jagielo, et al. (2003) compared densities of groundfish in “trawlable” and “untrawlable” areas off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. “Trawlable” bottoms were primarily mud, pebble, and mud-pebble (94%), whereas “untrawlable” bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). Redstripe rockfish were found only in the “untrawlable” habitat.

Migrations and Movements

Redstripe rockfish are very sedentary, exhibiting little or no movement from a home habitat or range (Matthews, et al. 1986). In one study off California (Matthews, et al. 1986), redstripe rockfish showed a fidelity to a specific habitat type as opposed to a specific area.

Reproduction

Off Oregon, larvae are released between April and July, but later off northern and central California, during July through September (Kendall and Lenarz 1987). Larvae are released during July in Puget Sound (Garrison and Miller 1982).

Growth and Development

Extruded larvae are between 3 and 7 mm in length (Kendall and Lenarz 1987). The length at 50% maturity of this species is 28–29 cm for both sexes in Puget Sound, (Garrison and Miller 1982). Redstripe rockfish may grow to reach 61 cm (Hart 1973), and reach the age of 55 years (Munk 2001).

Trophic Interactions

Larvae and juveniles of this species were found to feed primarily on copepods, their eggs, and copepod nauplii, as well as all stages of euphausiids (Kendall and Lenarz 1987). Food of adult redstripe rockfish also consists of small fish such as anchovies, herring, and early stages of other groundfish, as well as squid (Starr, et al. 1996).

Juvenile redstripe rockfish are consumed by Chinook salmon (Love, et al. 2002).

Rosethorn Rockfish (Sebastes helvomaculatus)

Range

Rosethorn rockfish range from Guadalupe Island, Baja California, to the Gulf of Alaska, (Hart 1973, Phillips 1957, Richardson and Laroche 1979, Washington 1977). Prior to 1971, rosethorn rockfish may have been confused with rosy rockfish because they are similar in appearance (Alverson 1967, Mason 1995, Washington 1977).

Fishery

They are of minor importance to commercial fisheries and are somewhat uncommon in sport catches (Love, et al. 2002).

Habitat

Rosethorn rockfish occur in water 25-549 m deep (Alverson 1967, Hart 1973, Phillips 1957, Richardson and Laroche 1979, Love, et al. 2002) and are generally categorized with other deep-water rockfishes (Alverson 1967, Richardson and Laroche 1979). Most (96%) occur from 100 to 350 m (Allen and Smith 1988). Rosethorn rockfish also occur in Puget Sound (Washington 1977). Love, et al. (2002) stated that adults are generally found in muddy areas adjacent to boulders, cobble, or rock; occasionally they are found in rocky areas without mud, and in association with sea lilies. In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult rosethorn rockfish were most commonly found in habitat consisting of boulders, cobble, demosponges, and brittlestars (*Ophiacantha*). They were rock habitat generalists that were generally abundant and evenly distributed. Jagielo, et al. (2003) compared densities of groundfish in “trawlable” and “untrawlable” areas off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. “Trawlable” bottoms were primarily mud, pebble, and mud-pebble (94%), whereas “untrawlable” bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). The density of rosethorn rockfish was 162 times higher in the “untrawlable” areas compared to those in the “trawlable” areas. Juveniles are found on both hard and soft substrata (California Dept.Fish and Game 2003).

Migrations and Movements

No information.

Reproduction

Parturition of rosethorn rockfish occurs during May and June in northern and central California (Kendall and Lenarz 1987), and primarily in June from Oregon to British Columbia (Richardson and Laroche 1979).

Growth and Development

Young rosethorn rockfish are pelagic until about 40–60 mm standard length (Richardson and Laroche 1979). The largest pelagic juvenile taken off Oregon by Richardson and Laroche (1979) was 41.6 mm and the smallest benthic juvenile was 136.4 mm. Small larvae (<10 mm) are taken only in July and August. Pelagic juveniles are captured in August, September, and November (Richardson and Laroche 1979). Off California, male rosethorn rockfish first mature at age 7 and all are mature by age

10. For females, the age of first maturity is 5 years; half are mature at age 8 and all are mature at age 10 (Wyllie Echeverria 1987). Rosethorn rockfish can grow to a maximum length of 33 cm (Hart 1973, Love, et al. 1990, Phillips 1957) and they can reach an age of 87 years (NMFS, et al. 1998).

Trophic Interactions

Off central California, principal prey items are euphausiids and other crustaceans (P. Reilly[33]).

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[33] P. Reilly, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814. Pers. Commun., July 2003.

Rosy Rockfish (Sebastes rosaceus)

Range

Rosy rockfish are reported from Strait of Juan de Fuca near Puget Sound to Bahia Toirtugas in southern Baja California (Miller and Lea 1972, Love, et al. 2002). This species has also been observed near the Cobb Seamount off the coast of Washington (Orr, et al. 1998, 2000).

Fishery

Rosy rockfish are commonly caught aboard sport fishing party and private vessels in southern and central California (to about Morro Bay). They are occasionally taken in the commercial hook-and-line fishery for rockfish (Love 1996).

Habitat

Rosy rockfish have been taken from 7 to 262 m (Love, et al. 2002), however adults are common between 30 and 46 mOrr, et al. 2000. Juveniles are found from 30–61 m (Love 1996), and recruit to rocky areas (Love, et al. 2002).

Adult rosy rockfish are solitary, bottom-dwelling rockfish, found over hard, high relief and low relief among rocks and sand (Love 1996, Love, et al. 2002). Both juveniles and adults are sometimes associated with oil platforms (Love, et al. 2002).

Migrations and Movements

No information.

Reproduction

Spawning occurs in southern California from January to September, peaking in May, and takes place farther north from April to July, peaking in June. Female rosy rockfish spawn from 13,000 eggs (15-cm female) to 95,000 eggs (23-cm female) (Love, et al. 1990). Rosy rockfish are multiple brooders (Love, et al. 1990).

Growth and Development

Off southern California, 50% of rosy rockfish are mature by 15 cm and all are mature by 20 cm. Off central and northern California, 50% of rosy rockfish are mature at 20 cm and all are mature by 25 cm. Rosy rockfish have been reported to reach 36 cm, but individuals over 25 cm are rare. They have been aged to 14 years and it is likely they live longer (Love 1996).

Estimated age of first maturity is 4 years, and age of 100% maturity is 8 years (Wyllie Echeverria 1987).

Trophic Interactions

Rosy rockfish primarily eat small, bottom-dwelling animals, such as shrimp and crabs (Love 1996).

Rougheye Rockfish (Sebastes aleutianus)

Range

Rougheye rockfish are reported from the Aleutian Islands to San Diego, California (Clemens and Wilby 1961, Eschmeyer, et al. 1983, Grinols 1965, Hart 1973). They are also found in Pacific waters off Japan to California (Tokranov 1998), and Japan to Navarin Canyon in the Bering Sea (Allen and Smith, 1988).

Fishery

Rougheye rockfish are commercially captured from central California northward through the Bering Sea. They are commonly caught with Pacific Ocean perch and shortraker rockfish at higher latitudes (Wilderbuer 1986).

Habitat

Rougheye rockfish are common in offshore waters and are rare in nearshore waters (Alverson 1967, Hart 1973). Rougheye rockfish occur from 25 to 875 m deep, but about 94% occur between 50 and 450 m (Allen and Smith 1988). Records of rougheye rockfish occurring at depths to 2820 m are probably misidentification of shortraker rockfish (Allen and Smith 1988). They have also been reported to commonly occur at 100–450 m (Orr, et al. 2000), and 201–400 m in the Gulf of Alaska (Sigler and Zenger 1989).

Rougheye rockfish are sometimes found in small schools. In a study conducted in the eastern Gulf of Alaska, two thirds of rougheye/shortraker rockfish appeared in groups of 2–6 fish while only two groups contained more than 12 fish (Krieger and Ito 1999). Rougheye rockfish are found on the bottom (Eschmeyer, et al. 1983, Grinols 1965). Off California, young rougheye rockfish recruit to soft substrata (Love, et al. 1991). When observed from a manned submersible, the greatest densities of rougheye rockfish were associated with soft substrata, frequent boulders, and slopes greater than 20°. It is hypothesized that their association with soft substrata may be prey-related (Krieger and Ito 1999). In a study in southeastern Alaska fjords, juveniles were found over muddy bottoms (Carlson and Haight, 1976). Adults are most commonly observed over steeply sloped bottom (Sigler and Zenger 1989).

Migrations and Movements

No information.

Reproduction

Rougheye rockfish larvae are released during May off Oregon (Wyllie Echeverria 1987), and from February to June off British Columbia (Love, et al. 2002). Also off British Columbia, the size at 50% maturity is 40 cm for males and 47 cm for females, and are about 20 years old (Westrheim, et al. 1968, Love, et al. 2002).

Growth and Development

Rougheye rockfish can grow to 97 cm in length (Eschmeyer, et al. 1983, Love, et al. 2002), and reach the age of approximately 200 years (Munk 2001).

Trophic Interactions

Rougheye rockfish are piscivorous, but also prey upon shrimps, crabs and other crustaceans (Love, et al. 2002).

Sharpchin Rockfish (Sebastes zacentrus)

Range

Sharpchin rockfish occur from San Diego, California, to Semisopochnoi Island in the Aleutian Islands, Alaska (Allen and Smith 1988). More specifically, Shaw (1999) reported their occurrence from San Clemente Island (32.8° N 117.4° W) to Resurrection Bay, Alaska (60.0° N 149.4° W) in the north, and Petrel Bank near the Aleutian Island chain (52.3° N 179.8° W) to the west. They are less common south of Monterey, California (36.5° N 122.0° W) (Shaw 1999).

Fishery

Sharpchin rockfish are taken in commercial fisheries along the West Coast.

Habitat

Sharpchin rockfish is an outer shelf-mesobenthal species. They occur from 25 to 475 m deep, but about 96% occur from 100 to 350 m (Allen and Smith 1988). A depth range of 91– 320 m has also been reported by Eschmeyer, et al. (1983), and a common depth of 150–300 m was reported by Orr, et al. (2000).

In a study conducted off Oregon (Laroche and Richardson 1981), larval sharpchin rockfish were collected during August 46–184 km offshore, over approximately 270–2,800 m deep water. In the same study, pelagic juveniles occurred 9–148 km offshore. Small sharpchin rockfish are found over rocky banks off Oregon associated with vase sponges and fields of crinoids (Love, et al. 2002). Sharpchin rockfish are sometimes found in small schools (Shaw 1999). Stein, et al. (1992) identified sharpchin as schooling species, although they also occurred singly.

Sharpchin rockfish can occur over soft bottoms (Eschmeyer, et al. 1983), but they apparently prefer mud and cobble, and mud and boulder substrata, and are associated with boulder and cobble fields (Stein, et al. 1992). In a study conducted in British Columbia (Matthews and Richards 1991), sharpchin rockfish dominated untrawlable habitat. CPUE's were found to be eight times higher over “untrawlable” grounds compared to trawlable areas (Shaw 1999). In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult sharpchin rockfish were most commonly found in habitat consisting of boulders, cobble, demosponges, and brittlestars (*Ophiacantha*). They occurred in dense patches on and within 2 m of the bottom, often mixed with pygmy rockfish.

Migrations and Movements

No information.

Reproduction

Parturition occurs from March through July off Oregon and from May through June off northern and central California (Wyllie Echeverria 1987).

Growth and Development

Sharpchin rockfish transform from larvae to pelagic juveniles when they are between 13.5 and 20 mm in length. Transition from pelagic to benthic habitat takes place at lengths somewhere between 35 and 65 mm (Laroche and Richardson 1981). Sharpchin rockfish can grow to 33 cm (Miller and Lea 1972).

Trophic Interactions

The diet of *S. zacentrus* includes euphausiids, shrimp, amphipods, copepods, and small fishes. Off Oregon, euphausiids made up 85% of stomach contents (by weight). In the Gulf of Alaska, this species utilized a variety of prey taxa; however, 84% of stomach contents were amphipods, euphausiids, and copepods. Stomachs were collected from fish from commercial trawl catches in both Oregon and Gulf of Alaska areas (Shaw 1999).

Shortbelly Rockfish (Sebastes jordani)

Range

Shortbelly rockfish are found from San Benito Islands, Baja California, Mexico to La Perouse Bank, British Columbia (Eschmeyer, et al. 1983, Lenarz 1980).

Fishery

Shortbelly rockfish are not commonly taken in commercial or recreational fisheries, largely because of their small size; however, some are collected as bycatch in the hake fishery (Love, et al. 2002, J. Orr[34]).

Habitat

Shortbelly rockfish are considered a middle shelf-mesobenthal species, inhabiting waters from 50–350 m (Allen and Smith 1988). From central California to Vancouver Island, they are most common at depths of 50–250 m (Orr, et al. 2000); however, off southern California, they are at depths greater than 200 m (Love, et al. 2002).

Shortbelly rockfish are a cold-temperate species occurring on the continental shelf (Chess, et al. 1988) and upper-slope (Stull and Tang 1996). Larvae are found up to 278 km offshore, but are generally taken much closer to shore (Lenarz 1980), mostly within 19 km of land (MacGregor 1986). In a study conducted in the California Bight, Moser, et al. (2000) reported that shortbelly rockfish larvae collected by plankton tows were almost exclusively in waters over the continental shelf at depths less than 200 m, with most of the larvae occurring near the coast at depths around 200 m. Sakuma and Ralston (1995) conducted similar studies off the coast of central California and found that larvae accumulated on the shoreward side of temperature fronts located 100 to 150 km off the continental shelf. Juveniles are pelagic for 3–5 months, and they recruit to kelp beds, outer margins of kelp beds, and to deep rock outcrops (Love, et al. 2002). Young-of-the-year shortbelly rockfish have been observed in the surf line off California (Lenarz 1992). Off California, young shortbelly rockfish recruit to soft substrata and low-relief (<1 m) reefs (Love, et al. 1991).

The habitat of adult shortbelly rockfish is wide ranging (Eschmeyer, et al. 1983). They occur in midwater and away from underwater objects such as reefs or kelp more often than most, if not all, California rockfishes (Lenarz 1980). Adults commonly form very large schools over smooth bottom near the shelf break and sharp dropoffs (Lenarz 1992). Shortbelly rockfish are also detected along the ledges of submarine canyons (Sullivan 1995, Ralston, et al. 2003).

Migrations and Movements

During intense upwelling (May to June) relatively small fish stay deep, presumably to avoid advection to shore (Lenarz, et al. 1991). During the day, shortbelly rockfish are found near the bottom in dense aggregations that often extend 15 m up in the water column. At night they are more dispersed, 20–70 m above the bottom but still more than 30 m below the surface of the water (Chess, et al. 1988).

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[34] J. W. Orr, NOAA Fisheries, AFSC, RACE Division, 7600 Sand Point Way N.E., Seattle, WA 98115. Person. Commun., July 2004.

During the summer, shortbelly rockfish tend to move into deeper waters and to the north as they grow, but they do not make long return migrations to the south in the winter to spawn (Lenarz 1980). Shortbelly rockfish sometimes are found forming large schools well offshore and off-bottom (Eschmeyer, et al. 1983).

Sakuma, et al. (1999) reported evidence suggesting that shortbelly rockfish larvae made diurnal vertical migrations, with highest catches occurring at night. The larvae tended to stay within or above the pycnocline at all times. These results, which were obtained off of central California, could have also been partially explained by avoidance of the sampling nets by larvae during daylight and twilight hours.

Reproduction

Shortbelly rockfish spawn off California during January through April (Lenarz 1992). A 50-g fish produces approximately 115 eggs (larvae) per gram of spawning female, whereas a 275-g fish should produce 139 eggs per gram of body weight (MacGregor 1986).

Growth and Development

At 10 mm, shortbelly rockfish larvae are the longest at birth of any eastern Pacific rockfish. Also, their larval period is long prior to transformation to the juvenile stage when compared with other eastern Pacific rockfish (Lenarz 1980). On average, developing shortbelly rockfish grow at a rate of 0.52–0.64 mm per day (Lenarz, et al. 1991). Larvae undergo flexion at 8–10 mm standard length (Laidig, et al. 1991). Larvae metamorphose to juveniles at 27 mm and appear to begin forming schools at the surface at that time (Laidig, et al. 1991, Lenarz 1980). Juveniles up to 62.8 mm have been taken by dip nets and benthic individuals have been taken as small as 70 mm (Lenarz 1980). The size of shortbelly rockfish tends to increase with depth and the size for a given depth stratum tends to increase in a northerly direction between lat. 34 and 39°N (Lenarz 1980).

A few shortbelly rockfish mature at 15.2 cm, weighing 31 g (age 2); 50% are mature at 16.5 cm, weighing 30 g (age 3). Nearly all are mature by age 4 (Lenarz 1992). Their maximum size is 30.6 cm or 275 g, and they can live to be about 10 years old (Lenarz 1980, MacGregor 1986). The maximum-recorded age is 22 years (Lenarz 1992).

Trophic Interactions

Shortbelly rockfish feed primarily on various life stages of euphausiids and calanoid copepods both during the day and night (Chess, et al. 1988, Lenarz, et al. 1991).

Shortbelly rockfish play a key role in the food chain, as they are preyed upon by Chinook and coho salmon, lingcod, black rockfish, hake, bocaccio, chilipepper, pigeon guillemots, western gull, marine mammals, and others (Chess, et al. 1988, Eschmeyer, et al. 1983, Hobson and Howard 1989, Lenarz 1980).

Shortraker Rockfish (Sebastes borealis)

Range

Shortraker rockfish are reported from Japan, to southeastern Kamchatka Peninsula in the Bering Sea (Allen and Smith 1988, Eschmeyer, et al. 1983, Krieger 1992, Kreiger and Ito 1999), throughout the Aleutian Islands, and south to Point Conception, California (Allen and Smith 1988).

Fishery

Shortraker rockfish are captured by commercial fisheries from central California northward through the Gulf of Alaska, the Aleutian Islands, and the Bering Sea (Wilderbuer 1986). They are commonly caught with Pacific ocean perch and rougheye rockfish (Wilderbuer 1986).

Habitat

Shortraker rockfish are an offshore, demersal species (Krieger 1992). They occur from 0 to 875 m deep, but primarily inhabit the middle shelf to the mesobenthal slope with 95% at depths of 50–650 m (Allen and Smith 1988). The most common depths for shortraker rockfish have also been reported as 100–600 m (Orr, et al. 2000). In the vicinity of the Kamchatka Peninsula, shortraker were found as deep as 1200 m (Mecklenburg, et al. 2002), and in the Gulf of Alaska, they are most abundant at 300–400 m (Krieger 1992).

Fishermen have reported schooling behavior above rugged, steep-slope habitat with most of the fish being relatively small (<5 kg). A study in the Gulf of Alaska observed large shortraker rockfish (>7 kg) to be solitary individuals on or near the bottom and among moderately sloped, smooth habitat (Krieger 1992). In a study conducted in the eastern the Gulf of Alaska, two thirds of rougheye/ shortraker rockfish appeared in groups of 2–6 fish while only two groups contained more than 12 fish (Krieger and Ito 1999).

Shortraker rockfish can be found on soft bottom (Eschmeyer, et al. 1983). In an observation study with a submersible in the eastern Gulf of Alaska, shortraker rockfish were mostly observed near boulders 0.5–4.0 m in diameter surrounded by soft bottom, or over fine- grained substrata of silt or pebbles (Krieger 1992). They also seemed to prefer sloping substrata of 3–12° and currents of 0.1–0.4 km/hr. Shortraker rockfish are common over hard, steeply sloped bottoms (Sigler and Zenger 1989, Krieger and Ito 1999).

Migrations and Movements

A study in the Pacific waters of Kamchatka and western part of the Bering Sea suggests shortraker rockfish may perform seasonal vertical migration; with the depth range expanding during the months of June through November and decreasing from spring to autumn (Tokranov and Davydov 1997). Migrations may also occur in response to food availability with larger individuals performing greater migrations than smaller ones (Orlov and Abramov 2001).

Reproduction

From Oregon to the Gulf of Alaska, 50 % of both male and female shortraker rockfish mature at 45 cm (Love, et al. 2002). Females have fully developed embryos from March through July, they generally release larvae from summer through fall at depths between 300 and 500 m (Love, et al. 2002).

Growth and Development

They can grow to lengths of 1.2 m and weigh as much as 23 kg (Love 2002). They are among the longest-lived rockfishes, having been aged to 157 years (Love, et al. 2002).

Trophic Interactions

In a study of the Gulf of Alaska, Yang and Nelson (2000) found shrimp to be the most important food of shortraker rockfish. In addition, cephalopods (mainly squid), as well as mysids, bathylagids, and myctophids, were also consumed by shortraker rockfish (Yang and Nelson 2000). A similar analysis off northern Kuril Islands and southeast Kamchatka revealed that crustaceans, mollusks, and fish are consumed in varying frequencies within the studied areas (Orlov and Abramov 2001).

Shortspine Thornyhead (Sebastolobus alascanus)

Range

Shortspine thornyheads are found from northern Baja California to the Bering Sea and occasionally to the Commander Islands north of Japan (Jacobson and Vetter 1996). They are common from at least southern California northward (Love 1996).

Fishery

Shortspine thornyheads are commercially important (Jacobson and Hunter 1993). Between central California and Washington, thornyheads are harvested by a deep-water bottom trawl fishery that also targets Dover sole and sablefish (Jacobson and Vetter 1996, Love 1996). Juvenile shortspine thornyheads are common in bottom trawls at 600–1200 m (Wakefield and Smith 1990). Shortspine thornyheads have also been caught in traps and on setlines (Eschmeyer, et al. 1983); they are not taken by sport fishers (Love 1996).

Habitat

Shortspine thornyheads inhabit areas over the continental shelf and slope (Erickson and Pikitch 1993, Wakefield and Smith 1990, Wilderbuer 1986). They constitute a deep-water assemblage along with Pacific Ocean perch, and darkblotched, splitnose, red-banded, and rougheye rockfishes (Weinberg 1994). Shortspines occur as shallow as 20 m (Love, et al. 2002), and as deep as 1524 m (Orr, et al. 2000). They commonly occur between 100 and 850 m (Orr, et al. 2000). Thornyhead larvae have been taken in research surveys up to 560 km off the California coast (Cross 1987, Moser, et al. 1993). Most were more than 32 km offshore. Juveniles reportedly settle on mud bottoms at about 100 m (Jacobson and Vetter 1996).

Juveniles usually occupy shallower waters than adults (Love 1996), usually at depths between 100 and 600 m (Jacobson, et al. 2001) over muddy bottoms near rocks (Love, et al. 2002). Recently settled individuals are more abundant at the deep end of their range than the shallow end; mid-sized individuals are more abundant at the shallow end; and adults are more abundant at deep locations. Cross (1987) suggested that juveniles recruit to the bottom regardless of depth, i.e., if they settle in water deeper than preferred for growth, they will move up the slope to preferred depths. As adults, they move back into deeper water.

In assessments of habitat types and associated fish assemblages using submersibles at Heceta Bank off the southern Oregon coast, adults were commonly found on muddy bottoms and bottoms with mixtures of mud and cobble and mud and boulders at depths between 160 and 230 m (Stein, et al. 1992, Pearcy, et al. 1989, Eschmeyer, et al. 1983, Love 1996). Tissot, et al. (In Review) also found that adult shortspine thornyheads were most commonly found in habitat consisting of mud and sea urchins. They were evenly and sparsely distributed over mud bottoms. Jacobson and Vetter (1996) also reported the highest abundance of adults between 200 and 400 m. In one study off southern California (Cross 1987), shortspine thornyheads dominated the trawl and longline catches on mud and banks; moreover, Jacobson and Vetter (1996) reported highest densities between 400 and 600 m.

However, in studies conducted in the Gulf of Alaska, Else, et al. (2002) reported adults were observed primarily over hard bottoms consisting of cobble and rock-boulders at depths ranging from 200 to 350 m. Tokranov and Nivikov (1997) reported that the highest densities of shortspine thornyhead in an area east of the Kamchatka Peninsula in the western Bering Sea were associated with “sites of the continental shelf with sharp drops in depths and great slopes.” In their studies, most of this species were caught at 400–600 m. Orlov and Nesin (2000) conducted trawl surveys in the same general area of the western Bering Sea, and reported collecting most of the juvenile shortspine thornyhead at depths of 357 and 615 m (60% were from depths of 450–550 m), whereas adults were collect over a much larger depth range (351–>800 m).

Genetic studies by Stepien, et al. (2000) demonstrated significant geographic isolation among shortspine thornyhead populations, primarily between Alaskan and southern California groups.

Migrations and Movements

Shortspine thornyheads undergo ontogenetic migration from shallow into deep water. Their gelatinous egg masses float to the surface; larvae and young juveniles are pelagic for 14– 15 months (Owen and Jacobson 1992). These early life history stages are likely widely transported, primarily via the Alaskan Gyre system and the California Current (Stepien, et al. 2000). Butler, et al. (1996) hypothesized that these stages are also transported northward by the California Counter current. During January to June, juveniles settle onto the continental shelf and then move into deeper water as they become adults (Jacobson and Hunter 1993). The ontogenetic migration transports particulate organic carbon from the bottom to the surface by eggs and particulate organic matter from the surface back down to the bottom as recruiting juveniles (Wakefield and Smith 1990). Small shortspine thornyheads (10 cm) were found in shallow water (200–600 m) but migrate to deeper water with growth (Jacobson and Vetter 1996, Vetter and Lynn 1997).

Reproduction

Shortspine thornyheads spawn pelagic bi-lobed, gelatinous hollow egg masses, 15–61 cm long (Erickson and Pikitch 1993, Wakefield and Smith 1990) between December and May off the West Coast (Wakefield and Smith 1990, Pearson and Gunderson 2003). Shortspine thornyheads are single spawners with determinate annual fecundity (3,000–106,000 eggs per year) (Wakefield and Smith 1990). The length at which 50% of this species is mature is 18.2 cm for West Coast populations, and is 21.5 cm for Alaskan populations (Pearson and Gunderson 2003). Off California, they begin to mature at 5 years; 50% are mature by 12–13 years; and all are mature by 28 years (Owen and Jacobson 1992). However, Love (1996) reported that they all are mature by age 16 and they can live more than 62 years.

Growth and Development

Spawning occurs at 600–1000 m in the OMZ. Eggs rise to the surface to develop and hatch. Larvae are pelagic for about 12–15 months. Juvenile shortspine thornyheads spend 14– 15 months in midwater (Cross 1987, Jacobson and Vetter 1996, Love 1996). Juveniles transforming to a benthic stage are larger than 50 mm total length (Cross 1987).

Shortspine thornyheads grow throughout their life (Eschmeyer, et al. 1983, Jacobson and Vetter 1996, Love, et al. 1996). Males and females are of similar size (Butler, et al. 1989). Although it is difficult to determine the age of older individuals, Owen and Jacobson (1992) report that off California, they may live to over 100 years of age, and their maximum size is 80 cm (Love, et al. 2002). The mean size of shortspine thornyheads increases with depth and is greatest at 1000–1400 m (Jacobson and

Vetter 1996). Shortspine thornyheads have a non- asymptotic growth pattern with relatively high growth rates after sexual maturity (Jacobson and Vetter 1996).

Trophic Interactions

Benthic individuals are sit-and-wait predators that rest on the bottom and remain motionless for extended periods of time (Jacobson and Vetter 1996). Off Alaska, shortspine thornyhead eat a variety of invertebrates such as shrimp, crabs, and amphipods, as well as fishes and worms (Owen and Jacobson 1992). In the western Bering Sea, their primary dietary components were decapod copepods and gammarid amphipods, representing 83% and 15.7% by weight, respectively (Orlov and Nesin 2000). Longspine thornyheads are commonly found in the stomachs of shortspine thornyhead. Cannibalism of newly settled juveniles is important in the life history of thornyheads (Jacobson and Vetter 1996) because it decreases the number of juveniles, but in turn provides more food for adults.

Silvergray Rockfish (Sebastes brevispinis)

Range

Silvergray rockfish are found from Santa Barbara Island, southern California, to the Bering Sea (Allen and Smith 1988, Hart 1973). They are most common between the central Gulf of Alaska and Oregon (Love, et al. 2002).

Fishery

Silvergray rockfish are commercially important and are included in the shelf rockfish assemblage (Hart 1973, Nagtegaal 1983). Silvergrays are taken in the commercial catch off Washington along with Pacific Ocean perch, yellowtail rockfish, and canary rockfish (Adams 1980).

Habitat

Silvergray rockfish are common in open coastal regions (Westrheim 1964) and inhabit the outer shelf-mesobenthal zone (Allen and Smith 1988). They occur in depths from 0 to 436 m with 95% of survey catches taken in depths of 100–300 m (Allen and Smith 1988, Love, et al. 2002). Subadults and adults are found on a variety of rocky-bottom habitats, and form loose aggregations over various rocky-bottom habitats (Love, et al. 2002, Johnson, et al. 2003). Jagielo, et al. (2003) compared densities of groundfish in "trawlable" and "untrawlable" off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. "Trawlable" bottoms were primarily mud, pebble, and mud-pebble (94%), whereas "untrawlable" bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder- cobble (89%). Although low densities (0.79 ave. no./hectare) of silvergray rockfish were found in the "untrawlable" areas, this species was not collected in the "trawlable" areas. Young silvergray rockfish were occasionally observed in shallow embayments and associated kelp beds (Rosenthal, et al. 1982, Love, et al. 2002).

Migrations and Movements

No information.

Reproduction

The length at which 50 % of silvergray rockfish in Alaskan and British Columbia waters are mature ranges between 34 and 45 cm for males and 37 and 46 cm for females (Love, et al. 2002). Off Oregon and southeast Alaska, young are released between April and August (Love, et al. 2002).

Growth and Development

They achieve a maximum size of 73 cm (Love, et al. 2002) and reach an age of 82 years (Munk 2001, Love, et al. 2002).

Trophic Interactions

No information.

Speckled Rockfish (Sebastes ovalis)

Range

Speckled rockfish are found from the northern coast of Washington to northern Baja California (Nichol, et al. 1989, Love, et al. 2002). They are common from central California southward (Love 1996).

Fishery

Speckled rockfish form a relatively important part of the party- and private-vessel sport fisheries in Southern California, and occasionally, they are taken by commercial fishers, primarily with hook-and-line and gill nets (Love, et al. 2002).

Habitat

Speckled rockfish can be found as shallow as 18 m (P. Reilly[35]) and as deep as 366 m (Miller and Lea 1972). Adults usually live between 76 and 152 m (Love 1996). Juveniles can often be found as deep as 142 m (Love, et al. 2002), but are most common from 30 to 89 m (Love, et al. 1990, Love 1996). They occur in midwater over rocks (Love, et al. 1990, Love 1996). They are also found near the bottom on reefs (Love 1996), among boulders, and to a lesser degree among cobble (Love, et al. 2002). They also occur along the Monterey Canyon ledge (Sullivan 1995). Off California, young fish recruit to hard substrata, boulders, and high-relief (>1 m) reefs, often in association with macrophytes and crinoids (Love, et al. 1991, 2002).

Migrations and Movements

Speckled rockfish are an aggregating species (Love, et al. 1990) and probably move from reef to reef (Love 1996).

Reproduction

Speckled rockfish spawn multiple broods (two or more per season) from September to May, peaking in January and February off southern California and in May off central and northern California (Love, et al. 1990). A 33-cm female spawned 61,000 larvae and a 39- cm female spawned 160,000 larvae (Love, et al. 1990). The length at first maturity for male and female speckled rockfish is 23 cm; 50% maturity occurs at 24 cm; and 100% maturity occurs at 32 cm (Love, et al. 2002). For northern California, the estimated age of first maturity is 4 years and all are mature by age 5 (Wyllie Echeverria 1987).

Growth and Development

Speckled rockfish larvae are 4.9–5.1 mm at extrusion (Moser and Butler 1987). Adults can grow to 56 cm (Love, et al. 1990) and can live for at least 37 years (Love 1996). Females grow larger and live longer than males. A 30-cm male is around 20 years old; a female of similar size is about 12 years old (Love 1996).

Trophic Interactions

They feed primarily on plankton, although they will occasionally eat small fish (Love 1996).

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[35] P. Reilly, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814. Pers. Commun., July 2003.

Splitnose Rockfish (Sebastes diploproa)

Range

Splitnose rockfish occur from the Alaska Peninsula and Prince William Sound, Alaska to San Martin and Cedros Islands, Baja California (Miller and Lea 1972, Allen and Smith 1988).

Fishery

Splitnose rockfish are part of the deep-water complex taken by commercial fisheries; however, they have minimal market value because of their small size (Love, et al. 2002). They are only occasionally taken in sport fisheries (Lea 1992).

Habitat

Splitnose rockfish occur from 80 to 800 m and inhabit the outer shelf-mesobenthal zone (Mecklenburg, et al. 2002). Nearly 98% of survey catches occur in depths of 150–450 m (Allen and Smith 1988, Orr, et al. 2000). The relative abundance of juveniles (<21 cm) is quite high in the 91–272 m depth zone and then decreases sharply in the 274–475 m depth zone (Boehlert 1980). Splitnose rockfish have a pelagic larval stage, a pelagic pre-juvenile stage, and a benthic juvenile stage (Boehlert 1977). In a study conducted in the California Bight, Moser, et al. (2000) reported that splitnose rockfish larvae collected by plankton tows were almost exclusively in waters over the continental shelf at depths less than 2000 m. Pelagic juveniles are reported to be associated with drifting algae in Puget Sound, southern California, and Queen Charlotte Sound (Love, et al. 2002). Adults and juveniles are found in non-rocky shelf, continental slope/basin habitat (NMFS, et al. 1998), and occasionally in submarine canyons (California Dept. of Fish and Game 2003). Weinberg (1994) analyzed the results of groundfish surveys conducted between 1977 and 1992 in the coastal waters of Oregon and Washington. Using recurrent group analysis, he found that splitnose rockfish occurred in the same group as darkblotched and redbanded rockfish, shortspine thornyhead, and Pacific Ocean perch. This group was most commonly collected at depths of 155–366 m.

Benthic splitnose rockfish associate with mud habitats (Boehlert 1980) near isolated rock, cobble, and boulder fields (Love, et al. 2002). Young occur in shallow water, often at the surface under drifting kelp (Eschmeyer, et al. 1983), algae, and seagrasses (LeClair and Buckley 2001).

Young splitnose rockfish from the San Juan Islands are found drifting under vegetative habitat, which is temporally and spatially complex and provides food, refuge, and possibly transport from offshore to nearshore habitats during summer and fall months. Juveniles are commonly associated with *Fucus* sp. (dominant), eelgrass, and bull kelp (Shaffer, et al. 1995). Juvenile splitnose rockfish off southern California are the dominant rockfish species found under drifting kelp (Boehlert 1977). They recruit to soft substrata and low-relief (<1 m) habitat (Love, et al. 1991).

Migrations and Movements

Emigration of juveniles from surface waters occurs primarily in May and June (Boehlert 1977). Small benthic juveniles appear in July and August; abundance peaks in November and December and tapers off thereafter (Boehlert 1977). The temporal discrepancy between disappearance from the surface and peak benthic appearance suggests that migrant juveniles may occupy an intermediate habitat between emigration and settlement (Boehlert 1977). Emigrating pelagic juveniles descend to a depth of 200–250 m and migrate horizontally until they reach the bottom at an age of approximately 1-year-old (Moser and Ahlstrom 1978). Adults form schools that are occasionally found as 100 m up into the water column (Love, et al. 2002).

Reproduction

Fecundity ranges from 14,000 young for a 19-cm female to 255,000 for a 37-cm female (Hart 1973). They may have two parturition seasons (July and October to December off British Columbia), or may possibly release larvae throughout the year (Boehlert 1977). In general, as one goes further north, the main parturition season is progressively shorter and later; off Oregon, the season is mid-May to June, June to July off Washington, and July off British Columbia (Boehlert 1977). Young are born at a length of 5.2 mm (Hart 1973).

Growth and Development

Splitnose rockfish growth rates vary with latitude, being generally faster in the north. Their mean sizes increase with depth in a given latitudinal area. Mean lengths of females are generally greater than males (Boehlert 1980). Young splitnose settle to benthic habitat at less than 50 mm (Boehlert 1977, 1980). In the San Juan Islands, average total length of juveniles in June is 21.3 mm, 27.4 mm in August, and 31.1 mm in October (Shaffer, et al. 1995). Off California, 50% maturity occurs at 21 cm, or 5 years of age, whereas off British Columbia 50% of males and females are mature at 27 cm (Hart 1973). Adults can achieve a maximum size of 46 cm (Boehlert 1980, Eschmeyer, et al. 1983, Hart 1973), and they reach an age of about 80 years (Wilson and Boehlert 1990, Munk 2001).

Trophic Interactions

Adult splitnose rockfish off southern California feed on midwater plankton, primarily euphausiids (Allen 1982). Juveniles feed mainly on planktonic organisms, including copepods, during June and August. In October, their diets shift to larger epiphytic prey and are dominated by a single amphipod species. Juvenile splitnose rockfish actively select prey (Shaffer, et al. 1995). Gomez-Buckley (2001) reported small calanoid copepods and gammarid amphipods to comprise the majority of the diet of juveniles. The shift from small calanoids to larger gammarids, as reported in the previous 1992 study (Shaffer, et al. 1995), was not verified in the recent study in the Central San Juan Archipelago, Washington conducted by Gomez-Buckley (2001). Instead an increase in gammarid consumption was observed in the diet with increasing size of fish collected in August. However, calanoids remained an important part of the diet (Gomez-Buckley 2001). Juveniles were found to feed both on planktonic organisms only present in plankton samples and on epibenthic organisms mostly present on drifting habitat samples, suggesting a dynamic feeding behavior and the use of drifting habitat as a transitional feeding area (Gomez-Buckley 2001). Gomez-Buckley (2001) determined that juveniles have a general tendency towards consuming prey of size less than 2 mm (maximum dimension). Juveniles are probably diurnally active, while adults are probably nocturnally active (Allen 1982).

Squarespot Rockfish (Sebastes hopkinsi)

Range
Squarespot rockfish are found from central Baja California and Guadalupe Island northward to the southern Oregon coast (Erickson, et al. 1991, Love 1996).

Fishery
Squarespot rockfish are important to the party- and private-vessel sport fishery in southern California (Love, et al. 1990, Love 1996). They are rare in the commercial catch (Love 1996).

Habitat
Squarespot rockfish occur in water 18–224 m deep, and are most common between 30 and 150 m (Miller and Lea 1972, Love, et al. 2002). Juveniles are pelagic for 3–4 months (Love, et al. 2002). In the southern California Bight, very small, young fish are found in the shallowest part of the species' depth range, often in water 27–46 m deep (Love, et al. 1990, Love 1996).

Young recruit in water 30 m or deeper there (Love, et al. 1990), and settle out over nearshore rocky areas in waters as shallow as 27 m (Love, et al. 2002). Squarespot rockfish are found over high rocky reefs and in areas with cobble (Love, et al. 1990, Love 1996, Love, et al. 2002). They are observed swimming near the bottom to perhaps at least 10 m above it (Love, et al. 2002, Love 1996). They also occur along the Monterey Canyon ledge (Sullivan 1995).

Migrations and Movements
Squarespot rockfish tend to form schools, often consisting of hundreds to thousands individuals (Love 1996).

Reproduction
For males, length at first and 50% maturity is 13 cm, and at 100% maturity is 16 cm. Females first begin to mature at 14 cm; 50% maturity occurs at 14 cm; and 100% maturity occurs at 15 cm (Love, et al. 1990). The estimated age of first maturity for males is 4 years and all are mature by age 5; for females, first maturity occurs at age 5 and all are mature by age 7 (Wyllie Echeverria 1987). Off central California they spawn in February and March; off southern California, spawning occurs from January to April, peaking in January and February (Love 1996). They spawn multiple broods and a 17-cm female can spawn 9,000 larvae whereas a 24-cm female may spawn 40,000 larvae (Love, et al. 1990)

Growth and Development
Squarespot rockfish are small, reaching only 29 cm, and they live to around 19 years. Females grow more quickly than males, grow to a much larger size, and live longer (Love 1996).

Trophic Interactions
These fish feed entirely on plankton, primarily copepods, krill, and crab larvae (Love 1996).

Starry Rockfish (Sebastes constellatus)

Range

Starry rockfish are found from San Francisco to southern Baja California (Miller and Lea 1972), commonly from central California southward (Love 1996).

Fishery

Starry rockfish are important to both sport and commercial fisheries (Love, et al. 1990). They are a minor part of the party- and private-vessel sport fishery in southern California and central California. They are primarily taken by hook and line, and gill nets in the commercial fishery (Love 1996).

Habitat

Starry rockfish have an overall depth range of 24–274 m (Orr, et al. 2000), and Love, et al. (2002) reported that they are most commonly found at depths of 60–150 m off of southern California. Juveniles are common from 30 to 120 m (Love, et al. 2002), and are associated with rocks and irregular features like oil platforms (Love, et al. 2002). Starry rockfish are generally solitary, and live right on the bottom, often in crevices. They rarely go more than 0.5 m or so above the reef. They are exclusively found over hard bottoms, usually around large rocks, boulders, and occasionally over cobble or wrecks. They have been observed inside vase sponges, and rarely over mud near rocks (Love, et al. 2002, Love, et al. 1990, Love 1996).

Migrations and Movements

Starry rockfish are usually solitary, but occasionally form small aggregations. It is unlikely that they move from reef to reef (Love 1996).

Reproduction

Starry rockfish spawn from February to July in southern California (peaking in May) and April to May off central California. A 24-cm female spawns 33,000 eggs and a 3-cm female spawns 228,000 eggs (Love, et al. 1990). Starry rockfish are multiple brooders (Love, et al. 1990).

Growth and Development

Starry rockfish grow to 46 cm and live at least 32 years (Love, et al. 2002). Males and females grow at about the same rates, but males mature at a slightly smaller size than females (Love 1996). Males first begin to mature at 18 cm, 50% are mature at 19 cm (6–7 years), and all are mature by 27 cm. Females begin to mature at 21 cm, 50% are mature at 22 cm, and all are mature by 29 cm (Love, et al. 1990).

Trophic Interactions

Their diet of consists of small fishes, crabs, shrimp, and other small invertebrates (Love, 1996).

Stripetail Rockfish (Sebastes saxicola)

Range

Stripetail rockfish are found from Sebastian Vizcaino Bay, central Baja California to southeast Alaska (Hart 1973, Miller and Lea 1972). They are most commonly found between British Columbia and southern California (Love, et al. 2002).

Fishery

Stripetail rockfish are not generally targeted by commercial or recreational fishers because of their relatively small size; however, they are an important bycatch species (Love, et al. 2002). Few are caught north of Northern California.

Habitat

Stripetail rockfish occur from 10 to 547 m, but 97% of survey catches occurred at depths between 100 and 350 m (Allen and Smith 1988, Orr, et al. 2000). They inhabit the outer shelf- upper slope (Stull and Tang 1996). Stripetail rockfish are a dominant soft-bottom fish off southern California, along with Dover sole, slender sole, Pacific sanddab, plainfin midshipman, yellowchin sculpin, and speckled sanddab (Stull and Tang 1996). Pelagic juveniles are found over a relatively narrow depth range, 50–60 m (Lenarz, et al. 1991). Juveniles recruit to soft bottom habitats and to habitats consisting of low-relief rocks and sedimentary outcrops bounded by mud and sand, commonly at depths of 60 to 100 m (Johnson, et al. 2001). Some juveniles are found in waters as deep as 224 m (Love, et al. 2002). Most adults are demersal, associated with mud bottoms and bottoms containing mud and scattered small rocks, although some adults are parademersal near these habitat types (Love, et al. 2002). Juveniles recruit to soft substrata (sandy bottoms) in association with macrophytes (Love, et al. 1991), to cobble, and in some cases to oil platforms (Love, et al. 2002).

Migrations and Movements

Juvenile stripetail rockfish are probably diurnally active and adults are probably nocturnally active (Allen 1982). Once recruited to shallower depths, they gradually move to depths commonly used by adults (Johnson, et al. 2001).

Reproduction

Off California, the estimated age of first maturity for males is 3 years and all are mature by age 4; females first mature at age 2 and all are mature by age 3 (Wyllie Echeverria 1987). Females produce about 15,000 young at 18 cm and 200,000 at 32 cm (Hart 1973). Young about 4.3 mm in length are released mainly in February in British Columbia and January and February off Oregon (Hart 1973). The release period is much longer in northern and central California, from November through March (Kendall and Lenarz 1987).

Growth and Development

Stripetail rockfish can grow to 41 cm, and live to at least 38 years (Love, et al. 2002). Larvae are extruded at 3.3–5.2 mm notochord length (Laidig, et al. 1996). Benthic juveniles grow 0.32 mm/d (Love, et al. 2002).

Trophic Interactions

Adult stripetail rockfish pursue pelagic prey such as euphausiids (Allen 1982, Stull and Tang 1996), and juveniles off southern California feed primarily on calanoid copepods (Allen 1982).

Tiger Rockfish (Sebastes nigrocinctus)

Range

Tiger rockfish are distributed from Tanner and Cortes Banks, southern California to Kodiak Island, Alaska (Love, et al. 2002). They are most common between Southeast Alaska and northern California (Love, et al. 2002)

Fishery

Tiger rockfish are a moderately important commercial species, especially in Alaskan waters, and are caught primarily by hook-and-line and longline, although some are captured in bottom trawls (Love, et al. 2002). They are also moderately important in the recreational fishery towards the northern portion of its distribution (Love, et al. 2002).

Habitat

Tiger rockfish occur from shallow water (Moulton 1977) to 274 m (Orr, et al. 2000). They are generally found in waters less than 30 m in Puget Sound (Moulton 1977). The species is usually found at depths of 55–274 m (Orr, et al. 2000). In the northeastern Strait of Georgia, tiger rockfish are generally captured in 21–140 m of water (Murie, et al.1994).

Juveniles of the species are pelagic, commonly found near the water surface often associated with drifting algae mats and plant debris (Love, et al. 2002), and they are observed around rocky reefs, as shallow as 9 m (Rosenthal, et al. 1982). Adults are semi-demersal to demersal (Garrison and Miller 1982). Tiger rockfish are commonly found in caves along undersea cliffs or on the sea floor, generally in high-relief areas with strong currents (Moulton 1977, Johnson, et al. 2003). Jagielo, et al. (2003) compared densities of groundfish in "trawlable" and "untrawlable" areas off the northern Washington coast at depths 90 and 148 m using visual observations made from a submersible. "Trawlable" bottoms were primarily mud, pebble, and mud-pebble (94%), whereas "untrawlable" bottoms consisted largely of pebble, pebble-boulder, boulder-pebble, and boulder-cobble (89%). The density of tiger rockfish was 18 times higher in the "untrawlable" areas compared to those in the "trawlable" areas. Tiger rockfish are solitary and territorial; they will defend a home crevice in the reef (Oregon Dept. of Fish and Wildlife 2002). Murie, et al. (1994) noted that tiger rockfish are often associated with "wall" habitat.

Young have been noted resting among gooseneck barnacles near Triangle Island, British Columbia (Hart 1973). Off southeast Alaska, habitat requirements for tiger rockfish are similar to those of yelloweye and China rockfishes; for example, Waldo Wakefield36 reports observing adults commonly associated with the voids between stacked boulders during submersible studies.

Migrations and Movements

Tiger rockfish are territorial (Hart 1973), although they are reported to make short storm- related movements (Love, et al. 2002).

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[36] W. Wakefield, NOAA Fisheries, NWFSC, NRS, 2032 SE OSU Drive, Newport, OR 97365. Person. commun., July 2003.

Reproduction

In Puget Sound, the spawning season peaks in May and June (Moulton 1977).

Growth and Development

Tiger rockfish reach lengths of 35 cm by 17 years of age (Moulton 1977); their maximum size is reportedly 61 cm (Miller and Lea 1972), and they live to be as old as 116 years (Love, et al. 2002).

Trophic Interactions

Tiger rockfish exit their caves in the evening to feed. They are known to prey upon caridean shrimp, crabs (particularly rock crabs), amphipods and small fishes like herring and juvenile rockfish in the Gulf of Alaska (Rosenthal, et al. 1988). This species is a generalized feeder that depends on currents bringing food items near its home territory (Moulton 1977). Larvae are planktonic and likely prey on smaller plankton such as copepods. Larvae are likely prey of planktonic predators such as siphonophores and chaetognaths (Oregon Dept. of Fish and Wildlife 2002).

Treefish (Sebastes serriceps)

Range

Treefish are found from San Francisco to Cedros Island, Baja California (Miller and Lea 1972); however, they are common from about Santa Barbara, California, southward (Love 1996).

Fishery

Treefish are occasionally taken by party- and private-vessel anglers and by divers, mainly from Santa Barbara southward (Love 1996). In recent years, they have become an important component of the live-fish fishery (Love, et al. 2002).

Habitat

Treefish are found to depths of 97 m, but are most common at depths less than 60 m (Love, et al. 2002). They shelter during the day in holes along rocky reefs at Catalina Island (Garrett 1980). Pelagic juveniles are often found in drifting kelp mats, which have broken free from beds and are traveling with the currents (Love 1996). They recruit to hard substrata with high relief (>1 m) (Mitchell and Hunter 1970, Kendall and Lenarz 1987, Love, et al. 1991, Moser and Boehlert 1991, Love 1996) at shallow, subtidal depths to 30 m (Love, et al. 2002). Juvenile habitat includes artificial reefs. Adults are found on shallow rocky reefs, frequently in caves and crevices (Hart 1973, Feder, et al. 1974, Ebeling and Bray 1976, Love 1996, Starr 1998, Bloeser 1999), and on artificial reefs (Cailliet 2000).

Migrations and Movements

Treefish are solitary (Love 1996) and highly territorial, defending their shelter against intruders (Garrett 1980, Haaker 1978, Love 1996). Translocated adults consistently return to the same shelter (Garrett 1980).

Reproduction

Treefish probably spawn in late winter (Love 1996).

Growth and Development

They can grow to 41 cm (Love 1996).

Trophic Interactions

Treefish feed on bottom invertebrates (such as shrimp, mollusks, and crabs) and small fishes (Love 1996). Treefish are nocturnally active (Garrett 1980). Juveniles are fed upon by rockfishes, lingcod, cabezon, salmon, birds, porpoise, and least terns (Miller and Geibel 1973, Morejohn, et al. 1978, Ainley, et al. 1981, Love, et al. 1991, Ainley, et al. 1993). Adults are preyed upon by sharks, dolphins, and seals (Morejohn, et al. 1978, Antonelis and Fiscus 1980). Treefish may compete with other treefish and nearshore rockfishes, such as gopher, grass, and black-and-yellow rockfishes, for food and shelter (Feder, et al. 1974, Larson 1980, Love 1980, Love 1996).

Vermilion Rockfish (Sebastes miniatus)

Range

Vermilion rockfish are found from Prince William Sound, Alaska south to central Baja California, Mexico (O'Connell, et al. 1992, Love 1996, Love, et al. 2002). They are most abundant from northern California to northern Baja California (Love, et al. 2002).

Fishery

Vermilion rockfish are popular in both sport and commercial fisheries (Love, et al. 1990, Love 1996). They are highly prized by party- and private-vessel anglers throughout California with the majority of catches occurring from Monterey Bay south. Divers on the central California coast occasionally take large solitary individuals. Juveniles are caught from piers from about Santa Barbara northward. Adults are taken primarily by gill net and hook and line, and make up a substantial part of the rockfish commercial catch off California (Eschmeyer, et al. 1983, Love 1996).

Habitat

Vermilion rockfish occur in shallow water when young and in deeper water as larger adults (Eschmeyer, et al. 1983, Mason 1995). Adults occur at depths up to 436 m, and commonly occur at depths of 50-150 m (Love, et al. 2002). They have been observed at 7 m in Diablo Canyon (Love, et al. 1990). Newly released larvae are pelagic and found near the surface for three to four months, and are frequently associated with algae (Ven Tresca 2001). They then settle to the bottom (Ven Tresca 1992) in waters between 5 and 30 m deep (Love, et al. 1990).

Vermilion rockfish are usually found over rocks, along drop-offs, and over hard bottom, often in aggregations. Adults inhabit rocky reefs at depths of 15–274 m. They are more common on shallower reefs, but have been taken from as deep as 467 m. Generally, they live in shallower waters in the more northerly portions of the species' range. Their preferred depth in the California Bight seems to be 70–270 m, with larger individuals at greater depths (Oregon Dept. of Fish and Wildlife 2002). Juveniles inhabit shallow waters. Young vermilion rockfish recruit to sand, to sand/low-rock substrata without algae or kelp (Carr 1991), and to other structures, such as worm tubes, eelgrass, and pilings, which are surrounded by sand (Love, et al. 2002). In general, young are recruited to the bottom on soft or hard substrata with low relief (<1 m) (Love, et al. 1991). Juveniles are secretive and often take refuge in dense algae (Ven Tresca 1992) and kelp beds (Cailliet, et al. 2000). Adults occur mostly on or near the bottom in areas with high-relief rocky reefs, rarely rising more than 3 m above the bottom, and they are occasionally associated with oil platforms and kelp beds (Cailliet, et al. 2000, Love 1996, Love, et al. 2002).

Migrations and Movements

Vermilion rockfish are usually found aggregating near or slightly above the bottom, often over high relief (Love, et al. 1990) or artificial structures such as wastewater discharge pipes and oil drilling platforms (MBC Applied Environmental Sciences 1987). They probably move from reef to reef, particularly in deep water, but it is unknown how far they move (Love 1996). Lea, et al. (1999) reported that the results of tagging studies conducted off of central California suggested that this species has strong site fidelity and moves very little from its primary habitat type. Movements of vermilion rockfish off reefs may be associated with following schools of prey, such as squid (Love 1981).

Reproduction

The length at first maturity for male vermilion rockfish is 32 cm, 50% are mature at 35 cm, and all are mature by 37 cm. Females begin to mature at 31 cm, 50% are mature at 37 cm, and all are mature at 47 cm (Love, et al. 1990). Half the population is mature at 8 years (Ven Tresca 1992).

Peak spawning months are September in northern California and November in southern California (Ven Tresca 1992). A 46-cm standard length female spawned 158,915 eggs while a 68-cm standard length female spawned 2,683,768 eggs (Love, et al. 1990). Vermilion rockfish are single brooders (Love, et al. 1990).

Growth and Development

Young-of-the-year appear in inshore water beginning in February (Love 1996). Vermilion rockfish can grow to 76 cm and 6.8 kg (Eschmeyer, et al. 1983). The oldest individual aged was 25 years old (Ven Tresca 1992).

Trophic Interactions

Vermilion rockfish prey on other fishes (anchovies, lanternfishes, small rockfishes), octopi, squids, and krill (Love 1996). Pelagic young feed primarily upon crustaceans (Ven Tresca 1992).

Widow Rockfish (Sebastes entomelas)

Range

Widow rockfish range from Albatross Bank off Kodiak Island to Todos Santos Bay, Baja California (Eschmeyer, et al. 1983, Laroche and Richardson 1981, Miller and Lea 1972, NOAA 1990).

Fishery

Widow rockfish make up an important component of the West Coast groundfish fishery (Pearson 1996). Widow rockfish are mostly taken with midwater trawls, at night at approximately 140 m or deeper (Hightower 1990, NOAA 1990). They occasionally are important in central and southern California gill net fisheries (NOAA 1990). Widow rockfish are moderately important in the recreational fisheries off California and are taken year round by sport anglers from southern British Columbia to southern California.

Habitat

Adults are sublittoral to bathyal over depths of 24–549 m, and are most common at 100– 350 m (Eschmeyer, et al. 1983, NOAA 1990, Orr, et al. 2000, Love, et al. 2002). Larvae and small juveniles are neritic and epipelagic, occurring from near surface to 20 m deep and nearshore to 300 km offshore (Laroche and Richardson 1981, NOAA 1990). Larger juveniles occur near- bottom, commonly over depths of 9–37 m (Eschmeyer, et al. 1983, NOAA 1990), but are found as deep as 140 m (Love, et al. 2002). Young-of-the year are often associated with nearshore areas containing kelp and other algae (Love, et al. 2002). All life stages are pelagic, but older juveniles and adults are often associated with the bottom (NOAA 1990). Adults are frequently found in large schools, but can also be solitary (Love, et al. 2002).

All life stages are fairly common from Washington to California (NOAA 1990). Off Oregon they are reported to be most common on the continental shelf (Laroche and Richardson 1981). Pelagic larvae and juveniles co-occur with yellowtail rockfish, chilipepper, shortbelly rockfish, and bocaccio larvae and juveniles off central California (Reilly, et al. 1992). In a study off central California (Ven Tresca, et al. 1996), post-pelagic newly settled widow rockfish were first observed at the seaward, sand-rock interface of nearshore reefs in depths of 6–20 m. They were associated with crevices, sand channels among the rocks, or depressions in the reef (Ven Tresca, et al. 1996), and with oil and gas production platforms (Schroeder 1999b). They also recruit to soft substrata and low relief (<1 m) in association with macrophytes (Love, et al. 1991). Juvenile widow rockfish have also been reported from 8 to 20 m in Diablo Canyon (Love, et al. 1990), and adult widow rockfish occur along the Monterey Canyon ledge (Sullivan 1995).

Widow rockfish occur over hard bottoms along the continental shelf (NOAA 1990). Substrata preferred by widow rockfish are rocky banks, seamounts, ridges near canyons, headlands, and muddy bottoms near rocks. Yoklavich, et al. (2000) used submersibles to quantify and characterize rockfish habitat in Soquel Submarine Canyon, Monterey Bay California, and reported finding widow rockfish primarily near rock outcrops surrounded by mud. At a site near Point Conception, California, Love, et al. (1994) compared the population characteristics of rockfish associated with a variety of habitat types, including high-relief (outcroppings more than 1 m high), deep (195–213 m), and shallow sites (113–160 m); and low- relief (sand, cobble, and lower outcroppings), deep and shallow sites. They reported that over 80% of the widow rockfish were found near deep sites with either high or low relief.

Other studies have shown that all life stages of widow rockfish occur in euhaline (31–34 ppt) waters (Eschmeyer, et al. 1983, NOAA 1990), and temperatures of 6.0–15.5° C and dissolved oxygen levels of 1.0 to 7.0 ppm (MBC Applied Environmental Sciences 1987).

Large widow rockfish concentrations occur off headlands such as Cape Blanco, Cape Mendocino, Pt. Reyes, and Pt. Sur, common characteristics of these areas include extended points of land, offshore canyons, and current circulation eddies inshore of main currents. These oceanographic characteristics appear to be associated in some manner with aggregations of widow rockfish during their reproductive cycle (Quirollo 1987). Furthermore, aggregations of widow rockfish have been reported around offshore seamounts, including Cobb Seamount (Pearson, et al. 1993) and Bowie Seamount (Love, et al. 2002).

Migrations and Movements

Adults form dense, irregular, mid-water and semi-demersal schools deeper than 100 m at night and disperse in mid-water during the day (Eschmeyer, et al. 1983, NOAA 1990, Wilkins 1986). Similarly, juveniles are reported to inhabit rocky areas containing macro algae during the night, and the water column during the day (Love, et al. 2002). However, Stanley, et al. (2000) conducted an acoustic survey of widow rockfish near the edge of the continental shelf off of British Columbia, and reported that they had a strong affinity for the high-relief bottom during the day.

Reproduction

Age and size at sexual maturity varies by region and gender, generally increasing northward and at older ages and larger sizes for females. Some mature in 3 years (25–26 cm), 50% are mature by 4–5 years (25–35 cm), and most are mature in 8 years (39–40 cm) (Barss and Wyllie Echeverria 1987, NOAA 1990). Mating occurs from late fall-early winter, occurring earliest off California, and latest off British Columbia. Off Oregon, mating occurs mostly in December, and in September off California. The mating process occurs in current circulation eddies inshore of main currents, often off extended points of land and in offshore canyons.

Parturition of larvae occurs from late winter to early spring with a regional timing sequence similar to mating. Larval release occurs from December to February off California, and from February to March off Oregon, and in April off British Columbia and Alaska.

Fecundity increases with size of the female, from 55,000 eggs at 32 cm, to 915,000 eggs at 51 cm (NOAA 1990).

Growth and Development

Larvae are 5 mm at parturition and the larval period lasts several weeks. Juveniles are 21–31 mm at metamorphosis, and they grow to 25–26 cm over 3 years. Although NOAA (1990) reported the maximum age of widow rockfish is 28 years, but rarely over 20 years for females and 15 years for males, Munk (2001) reported that widow rockfish off of British Columbia reached a maximum age of 60 years. Females grow at a faster rate than males, and males reach a maximum length prior to females (Love, et al. 2002). The largest size is 59 cm, about 2.1 kg, although fish off Oregon and Washington grow faster than those off California (NOAA 1990, Love, et al. 2002).

Trophic Interactions

Widow rockfish are carnivorous. Adults feed on small pelagic crustaceans, midwater fishes (such as age-1 or younger Pacific hake), salps, caridean shrimp, and small squids (Adams 1987, NOAA 1990). They pursue nektonic prey in the water column, probably hunting by sight, feeding in upper levels at night and in deeper water during the daytime. During spring, the most important prey item is salps; during the fall, fish are more important; and during the winter, widow rockfish primarily eat sergestid shrimp (Adams 1987). Feeding is most intense in the spring after spawning (NOAA 1990). Pelagic juveniles are opportunistic feeders and their prey consists of various life stages of calanoid copepods and sub-adult euphausiids (including eggs) (Reilly, et al. 1992).

Yelloweye Rockfish (Sebastes ruberrimus)

Range

Yelloweye rockfish range from the Aleutian Islands, Alaska to northern Baja California; they are common from central California northward to the Gulf of Alaska (Clemens and Wilby 1961, Eschmeyer, et al. 1983, Hart 1973, Love 1996, Miller and Lea 1972, O'Connell and Funk 1986).

Fishery

Yelloweye rockfish are important in commercial and recreational fisheries from the central California coast to the Gulf of Alaska (Love, et al. 2002). They are also an important bycatch species in the Pacific halibut fishery (Love, et al. 2002).

Habitat

Yelloweye rockfish occur in water 25–475 m deep (Orr, et al. 2000); they most commonly occur at depths from 91 to 180 m (Love, et al. 2002). It is a middle shelf-mesobenthal species (Allen and Smith 1988). Young-of-the-year have been observed in areas of high relief at depths greater than 15 m (Love, et al. 2002). Richards (1986) reported the results of submersible studies in British Columbia in which younger fish (<20 cm fork length) tended to be more abundant at depths less than 80 m, whereas fish longer than 20 cm were more commonly found at depths greater than 80 m. In the Gulf of Alaska, juveniles prefer shallow-zone broken-rock habitat (O'Connell and Carlile 1993). Richards (1986) reported that young fish were frequently associated with sponge beds in low-relief areas, whereas Love, et al. (2002) stated that they are often found near sponges on vertical walls.

Adult yelloweye rockfish are bottom dwelling, generally solitary, rocky reef fish, found either on or just over reefs and in submarine canyons (Eschmeyer, et al. 1983, Love 1996, O'Connell and Funk 1986, California Dept. of Fish and Game 2003). Off British Columbia, Murie, et al. (1994) observed yelloweye rockfish only over complex or wall habitats, and in the Gulf of Alaska, O'Connell and Carlile (1993) and O'Connell, et al. (1998) observed yelloweye rockfish in cobble, continuous rock, broken rock, caves, large cracks, overhangs, and boulder habitats. Boulder areas in deep water (>180 m) are the most densely populated habitat (O'Connell and Carlile 1993). They also reportedly occur around steep cliffs and offshore pinnacles (Rosenthal, et al. 1982), although rugged pinnacles are preferred over smooth ones (O'Connell and Carlile 1993). The presence of refuge spaces is an important factor affecting their occurrence (O'Connell and Carlile 1993). In studies conducted on Fairweather Grounds, Alaska, fewer yelloweye rockfish were observed on shallow water banks (<100 m) comprised of few complex structures compared to deep-water areas (to 160 m deep) composed of bedrock, pinnacles, boulders, and interfaces containing structural and erosional scarps adjacent to sand and gravel sea floor (W. Wakefield[37]). High densities were associated with "gravel covered fractured bedded rock," but low densities were found in areas "where sedimentary bedrock has been smoothed by glaciation, and in extensive areas of sand and gravel." Love, et al. (2002) also reported that few adults are found on mixtures of mud and boulders.

Migrations and Movements

Yelloweye rockfish probably do not make diel movements (O'Connell and Carlile 1993).

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[37] W. Wakefield, NOAA Fisheries, NWFSC, NRS, 2032 SE OSU Drive, Newport, OR 97365. Person. commun., July 2003.

Reproduction

Off Washington, young are born in June (Hart 1973). Love (1996) broadly classified yelloweye rockfish as being spring-summer spawners, releasing young from April to September with a June peak. Off central/northern California, 50% of all fish are mature at 41 cm and all reproduce by 46 cm (Love 1996). The age of first maturity is estimated at 6 years and all are estimated to be mature by 8 years (Wyllie Echeverria 1987).

Growth and Development

Yelloweye rockfish can grow to 91 cm (Eschmeyer, et al. 1983, Hart 1973) Females grow to a slightly larger size than males (Love, et al. 2002). The growth rate of yelloweye rockfish levels off at approximately 30 years of age (O'Connell and Funk 1986). Yelloweye rockfish are among the longest lived rockfish, living to be at least 118 years old (Love 1996, O'Connell and Funk 1986, Love, et al. 2002).

Trophic Interactions

Yelloweye rockfish are a large predatory reef fish that usually feeds close to the bottom (Rosenthal, et al. 1988). They are opportunistic feeders, consuming such prey as fish, crabs, shrimp, and snails. The fish prey they consume includes rockfish, cods, sand lances, and herring (Love 1996). Rockfish prey of yelloweye rockfish includes Puget Sound rockfish, quillback rockfish, rosethorn rockfish, redstripe rockfish, and juvenile yelloweye rockfish. Other prey includes juvenile gadids, sand lance, herring, and lumpsucker. Puget Sound rockfish are the most important prey item both by number and volume; as many as three adult Puget Sound rockfish have been found in a single yelloweye rockfish stomach (Rosenthal, et al. 1988). Caridean shrimp, lithodid crab, green sea urchin, gastropod snails, and lingcod eggs are also consumed by yelloweye rockfish (Rosenthal, et al. 1988). Off Oregon, the major food items of the yelloweye rockfish include cancroid crabs, cottids, righteye flounders, adult rockfishes, and pandalid shrimp (Steiner 1978). Quillback and yelloweye rockfish have similar diets (Rosenthal, et al. 1988).

Yellowmouth Rockfish (Sebastes reedi)

Range
Yellowmouth rockfish occur from Sitka, Alaska to Point Arena, California (Love, et al. 2002). They occur most commonly between southeast Alaska and Oregon (Love, et al. 2002).

Fishery
Yellowmouth rockfish are an important commercial species from British Columbia to Oregon, and are harvested by bottom and midwater trawling (Love, et al. 2002).

Habitat
Yellowmouth rockfish occupy a depth range from 100-431 m, usually 180-275 m over rough bottom (Kramer and O'Connell 1988, Love, et al. 2002). They are found on the rocky shelf on the continental slope/basin (Eschmeyer, et al. 1983, Coad, et al. 1995, NMFS, et al. 1998). Pelagic juveniles are collected off Oregon (Love, et al. 2002).

Migrations and Movements
No information.

Reproduction
Off Oregon, yellowmouth rockfish release their young from February through June (Kendall and Lenarz 1987).

Growth and Development
Yellowmouth females mature at 33 cm or larger (9 years old), and males mature at lengths greater than 31 cm (9 years old). They grow to 58 cm and can live to 99 years of age (Hart 1973, Love, et al. 2002).

Trophic Interactions
No information.

Yellowtail Rockfish (Sebastes flavidus)

Range

Yellowtail rockfish range from Kodiak Island, Alaska to La Jolla, California (Miller and Lea 1972, Fraidenburg 1980, Gotshall 1981, Lorz, et al. 1983, Love 1996, Norton and MacFarlane 1995, Love, et al. 2002). The center of yellowtail rockfish abundance is from southeast Alaska to central California (Fraidenburg 1980, Love, et al. 2002).

Fishery

Commercial fisheries harvest yellowtail rockfish with bottom and midwater trawls at 91– 182 m (Tagart 1991), especially at night (Lorz, et al. 1983), and to a lesser amount by gill net and hook and line (Love 1996). Yellowtail rockfish are caught incidentally in midwater trawl fisheries for widow rockfish and Pacific hake (Tagart 1991). Besides being of importance to the commercial fishery, yellowtail rockfish are also important to the recreational fishery (Carlson and Haight 1972, Fraidenburg 1980, Love 1996, Norton and MacFarlane 1995, Pearcy 1992).

Habitat

Yellowtail rockfish is a common species that is most abundant over the middle shelf (Carlson and Haight 1972, Fraidenburg 1980, Tagart 1991, Weinberg 1994). In the North Pacific, they are considered a middle shelf-mesobenthal species, and have been reported at depths of 0–549 m, although nearly all were taken between 50 and 250 m in survey catches (Allen and Smith 1988, Orr, et al. 2000). However, Love, et al. (2002) describe this species as being most abundant between 90 and 180 m. Off Heceta Bank, Oregon, they usually remain at midwater depths of 25–35 m, well above seafloor depths of approximately 75 m (Love 1996, Pearcy 1992). Yellowtail adults are considered semi-pelagic (Stanley, et al. 1994, Laroche and Richardson 1981) or pelagic, because they range over wider areas than benthic rockfish (Pearcy 1992). Yellowtail rockfish are most common near the bottom, but not on the bottom (Love 1996, Stanley, et al. 1994, Murie, et al. 1994). Pelagic juveniles occur 24–266 km offshore. Benthic juveniles occur nearshore, in 20–37 m deep water (Tagart 1991), usually in rocky areas with giant kelp or bull kelp (Love, et al. 2002). In some cases, young-of-the-year are plentiful around oil platforms at mid-water depths.

Yellowtail rockfish are part of the shelf rockfish assemblage that includes Pacific Ocean perch, bocaccio, chilipepper, canary, silvergray, black, and widow rockfishes (Adams 1980, Fraidenburg 1980, Hightower 1990, Love 1996, Laroche and Richardson 1981). Based on research trawl surveys, the area from Cape Flattery to Cape Blanco is characterized by a canary- yellowtail-silvergray assemblage in 91–181 m of water. The Cape Blanco to Cape Mendocino region is dominated by yellowtail and stripetail rockfishes in the 91–181 m zone. Yellowtail rockfish are not as common in survey catches from Cape Mendocino to Point Hueneme (Gunderson and Sample 1980), although yellowtail rockfish are relatively common in recreational catches off central California (Lea, et al. 1999). In Puget Sound, Washington, yellowtail rockfish are more abundant in northern, than in central areas (Tagart 1991). Pereyra, et al. (1969) reported significant catches in Astoria Canyon near the mouth of the Columbia River.

Adult yellowtail rockfish occur along steeply sloping shores with walls and cliffs, or above rocky reefs (Hart 1973, Murie, et al. 1994, Stanley, et al. 1998). They can be found above mud with cobble, boulder, and rock ridges, and sand habitats; they are not, however, found on mud or flat rock (Love

1996, Laroche and Richardson 1981). In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult yellowtail rockfish were most commonly found in habitat consisting of ridges and boulders, vase sponges (*Scypha* and *Iophon*), and basketstars (*Gorgonocephalus*) in areas near the top of the bank at depths less than 100 m. They were generally observed sitting on the bottom, or form schools, commonly within 2 m of the bottom, although sometimes the schools were several meters off of the bottom. Young-of-the-year commonly school together with olive rockfish during their association with nearshore kelp forests (Lea, et al. 1999).

Migrations and Movements

Yellowtail rockfish form large (sometimes greater than 1,000 fish) schools and can be found alone or in association with other rockfishes (Love 1996, Pearcy 1992, Rosenthal, et al. 1982, Laroche and Richardson 1981, Tagart 1991). These schools may persist at the same location for many years (Pearcy 1992). In one study, yellowtail rockfish made rapid descents to near bottom depths, but no obvious diel vertical or horizontal migrations were detected (Pearcy 1992). However, others (Lorz, et al. 1983, Tagart 1991, Stanley, et al. 1999) report that yellowtail rockfish exhibit diurnal vertical migrations in behavior associated with feeding on vertically migrating prey.

Yellowtail rockfish can make long distance movements (Stanley, et al. 1994). Lea, et al. (1999) reported movements of up to 158 km in tag-and-release studies. Young-of-the-year come into shallow water, often into kelp beds, and usually migrate to deeper water as they mature (Carlson 1986, Love 1996, Stanley, et al. 1994). Adult yellowtail rockfish show strong site fidelity and homing abilities (Carlson 1986, Carlson and Haight 1972, Gotshall 1981, Pearcy 1992, Carlson, et al. 1995).

Reproduction

Along the West Coast yellowtail rockfish mate from October to December, parturition peaks in February and March (ranges from November to June) off Oregon-British Columbia (Love 1996, Tagart 1991, Westrheim 1975) and from November to March off California (Westrheim 1975). Fecundity varies with length: 66,000 eggs at 30 cm to 1.15 million eggs at 53 cm in length (Phillips 1964, Tagart 1991).

Growth and Development

Larvae are approximately 4.5 mm in length when extruded (Tagart 1991). Larvae transform to pelagic juveniles at 23–27 mm in length. They transform to benthic juveniles at 40 – 50 mm in length. Young-of-the-year pelagic juveniles often appear in kelp beds beginning in April and live in and around kelp, in midwater during the day, descending to the bottom at night (Love 1996, Tagart 1991). Benthic juveniles begin to settle from June to November (Tagart 1991). Male yellowtail rockfish are 34–41 cm in length (5–9 years) at 50% maturity, females are 37–45 cm (6–10 years) (Tagart 1991).

Yellowtail rockfish are long-lived and slow-growing; the oldest recorded was 64 years old (Fraidenburg 1981, Tagart 1991). Even though they are slow growing, like other rockfish, they have a high growth rate when compared to other rockfish (Tagart 1991). They reach a maximum size of about 55 cm in approximately 15 years (Tagart 1991).

Trophic Interactions

Yellowtails feed mainly on pelagic animals, but are opportunistic, occasionally eating benthic animals as well (Lorz, et al. 1983). Large juveniles and adults eat fish (small hake, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms (euphausiids, salps, and pyrosomes) (Love 1996, Phillips 1964, Rosenthal, et al. 1982, Tagart 1991), as well as mysids (Pereyra, et al. 1969). Yellowtail rockfish caught in bottom trawls off Washington fed almost exclusively on euphausiids, while those caught in midwater trawls off Queen Charlotte Sound fed on euphausiids as well as pelagic and benthic fishes (Lorz, et al. 1983). Feeding primarily occurs during night or early morning hours, although some feeding probably occurs during the daytime as well (Lorz, et al. 1983).

Rockfishes Group Summary Information (Updated September 2012)

From 2004–2011, 90 publications that contain information on spatial associations and/or trophic interactions were located for the Rockfishes group. Most publications reported information for multiple species and species were occasionally combined for convenience or because identification was uncertain (e.g., Lauth, et al. 2004; Wilson, et al. 2008; Marilave and Challenger 2009). Shortspine thornyhead (34 publications) and Pacific Ocean perch (30 publications) were the most studied Rockfishes, whereas blackgill (6 publication) and chilipepper (8 publications) were the least studied. Data summaries from fishery–independent surveys provided a great deal of general information on distribution and abundance patterns along the U.S. West Coast (e.g., Keller, et al. 2005, 2007, 2008) and throughout Canadian (e.g., Choromanski, et al. 2004, 2005; Workman, et al. 2008; Yamanaka, et al. 2008) and Alaskan waters (e.g. Hoff and Britt 2005; Rooper 2008; von Szalay, et al. 2010). However, the great majority of this information was derived from trawl surveys, which are limited in their capability to sample rocky substrates and therefore under–represent the distribution and abundance patterns of most rockfishes (PFMC 2008). Results of these surveys should therefore be interpreted cautiously for the Rockfishes group. In addition, many directed studies focused on specific aspects of resource utilization (i.e., spatial associations, trophic relationships) and provided detailed information that was relevant for the description of EFH. Only 15 of the 89 contemporary publications contained trophic information, and there is a dearth of recent diet composition information for Rockfishes throughout the eastern North Pacific.

Spatial Associations (updated September 2012)

A substantial amount of new information is available concerning spatial associations of species in the Rockfishes group. Several studies used manned submersibles or, to a lesser extent, ROVs to determine habitat associations of Rockfishes (and Other Rockfishes) along the U.S. West Coast, including southern California (e.g., Love and York 2005; Love, et al. 2009), central California (e.g., Anderson and Yoklavich 2007; Laidig, et al. 2009), and Oregon (Tissot, et al. 2007; Hart, et al. 2010). Habitat associations were typically determined for individual species and often combined to investigate co–occurrence or to create habitat guilds. In southern California, several publications determined that oil platforms serve an important function as artificial reefs for a variety of rockfishes, including bocaccio and cowcod (e.g., Love and York, 2006; Love, et al. 2006). A submersible study on Coquille Bank, Oregon compared species assemblages on trawled and untrawled seafloor and found similar densities of splitnose rockfish in each habitat (Hixon and Tissot 2007). A species–specific study determined the following information for juvenile cowcod in southern California: 1) the observed depth range was 32–330 m; 2) small juveniles (5– 20" TL) were associated with cobbles and cobbles/small boulders, with larger juveniles occupying higher relief rocky habitats, and 3) small juveniles were found with pygmy and swordspine rockfishes, whereas larger juveniles were associated with juvenile bocaccio and widow rockfish (Love and Yoklavich 2008). Several studies provided information on spatial associations during larval stages, especially in the California Current region (e.g., Field and Ralston 2005; Sakuma, et al. 2006; Phillips, et al. 2009). Field and Ralston (2005) found that 51–72% of year–to–year variability in recruitment was shared coastwide among chilipepper, widow, and yellowtail rockfishes, with a lesser fraction associated with fine scale geographic features. Off Oregon and Washington, Miller and Shanks (2004) determined that black rockfish exhibited limited larval dispersal (< 120 km). A study of black rockfish populations along the U.S. West Coast, however, found only weak genetic differentiation among regions (Sivasundar and Palumbi 2010). By contrast, yellowtail rockfish exhibited a strong genetic break between Monterey and Oregon (Sivasundar and Palumbi 2010). Young-of-the year

(YOY) Black rockfish were observed in the rocky intertidal of central California from May to August with peak abundance in May or June and interannual variability in number of recruits (Studebaker and Mulligan 2008). Telemetry studies were conducted for black (Parker, et al. 2007; Green and Starr 2011; Hannah and Rankin 2011), bocaccio (Lowe, et al. 2009), canary (Hannah and Rankin 2011), widow (Lowe, et al. 2009), and yelloweye (Hannah and Rankin 2011) rockfish with all of these studies conducted along the U.S. West Coast. Black rockfish exhibited medium to high site fidelity, but large vertical movements were observed (Hannah and Rankin 2011) and some individuals traveled more than 50 km from the capture site (Green and Starr 2011). Yelloweye (Hannah and Rankin 2011) and widow (Lowe, et al. 2009) rockfish exhibited high site fidelity, whereas canary rockfish (Hannah and Rankin 2011) and bocaccio (Lowe, et al. 2009) exhibited low site fidelity.

Trophic Interactions (updated September 2012)

New information on trophic interactions was available for most members of the Rockfishes group and, although limited, covered a wide range of topics. In the Aleutian Islands, diet composition of juvenile Pacific Ocean perch consisted mainly of a mixture of large copepods and euphausiids, but size–based, temporal, and spatial differences were observed (Boldt and Rooper 2009). Euphausiids were the primary prey items of larger juvenile Pacific ocean perch in the Aleutian Islands (Boldt and Rooper 2009), as well as large juveniles and adults in the Gulf of Alaska (Yang, et al. 2006) and Hecate Strait, British Columbia (Pearsall and Fargo 2007). Canary and widow rockfish off Oregon exhibited high temporal dietary variability coinciding with environmental changes due to El Niño Southern Oscillation (ENSO) conditions (Lee and Sampson 2009). By contrast, canary rockfish in this region had a very consistent diet composed almost exclusively of euphausiids (Lee and Sampson 2009). Diet composition of juvenile canary (euphausiids, copepods), darkblotched (gelatinous zooplankton, crustaceans), widow (gelatinous zooplankton), and yellowtail (copepods) rockfish was investigated throughout the U.S. West Coast (Miller and Brodeur 2007). In Carmel Bay, Johnson (2006) determined that juvenile bocaccio can alter patterns of density dependence in kelp, gopher, black and yellow rockfish. Several predators of species in the Rockfishes group were identified. Shortbelly rockfish were of minor importance in the diet of jumbo (or Humboldt) squid in the California Current (Field, et al. 2007), and juvenile canary, darkblotched, and widow rockfish were minor prey items of Pacific hake in the same region (Harvey, et al. 2008). However, at higher consumption rates, Pacific hake could considerably prolong rebuilding times of canary rockfish (Harvey, et al. 2008). Shortbelly and splitnose rockfish were minor components of longnose skate diet off central California (Robinson, et al. 2007), and thornyheads (combined) were eaten in trivial quantities by Stellar sea lions off Kodiak Island, Alaska (McKenzie and Wynne 2008).

Other Rockfishes Group Summary Information
(Updated September 2012)

New literature on spatial associations and trophic interactions of the Other Rockfishes group consists of 85 publications, with several publications providing information for multiple species. Species were sometimes combined for convenience or because identification was uncertain (e.g., Beaudreau and Essington 2007; Wilson, et al. 2008; Frid and Marliave 2010). The most studied Other Rockfishes were rougheye (26 publications), copper (25 publications), greenstriped (25 publications), and redbanded (25 publications). Many species received sparse scientific attention, and no information was available for bronzespotted, California scorpionfish, chameleon, and semaphore rockfishes. Data summaries from fishery–independent surveys provided a great deal of general information on distribution and abundance patterns along the U.S. West Coast (e.g., Keller, et al. 2005, 2007, 2008) and throughout Canadian (e.g., Choromanski, et al. 2004, 2005; Workman, et al. 2008; Yamanaka, et al. 2008) and Alaskan waters (e.g. Hoff and Britt 2005; Rooper 2008; von Szalay, et al. 2010). In addition, many directed studies were published and provided information on a wide variety of topics related to EFH (e.g., habitat associations, genetics/distribution, and movement patterns). Although a substantial amount of new spatial information was available, trophic information was comparatively sparse, a situation that reflects the relative amount of scientific attention as well as the substantial contribution of newly published fishery–independent survey data. Nine new species were added to the Other Rockfishes group since the last EFH review was conducted (chameleon, dwarf–red, freckled, halfbanded, pinkrose, Puget Sound, pygmy, and semaphore, and swordspine rockfishes). Literature reviews for these species were performed from 2002–2011 and references published during 2002–2003 (Bernardi, et al. 2009; Johnson, et al. 2009) are listed below. For historic information on these species, refer to Love, et al. (2002). In addition, the species name of the dusky rockfish is listed incorrectly as *Sebastes ciliatus* in the current list of FMP groundfish species. *Sebastes ciliatus* refers to the more northernly distributed dark rockfish, whereas the dusky rockfish (*S. variabilis*) ranges throughout most of the U.S. West Coast (Orr and Blackburn 2004). The information and literature referenced here therefore refers to the dusky (*S. variabilis*), not dark (*S. ciliatus*), rockfish.

Spatial Associations (updated September 2012)

Contemporary spatial information is available to a highly variable degree for the many species contained in the Other Rockfishes group. Much of the information is derived from trawl surveys (e.g., Choromanski 2004; Hoff and Britt 2007; Keller, et al. 2008), which are biased in their ability to accurately represent rockfish distribution and abundance patterns (PFMC, 2008) and typically do not report many additional findings that are useful for EFH determination. Depth distributions, however, are regularly reported in data summaries from surveys and present important baseline information about general occurrence patterns. These data have been used in detailed, assemblage-level analyses of groundfishes, including Other Rockfishes, throughout the U.S. West Coast (Tolimieri and Levin 2006; Tolimieri 2007). Considerable, detailed habitat association information is available for some species, as many Other Rockfishes have been incorporated into assemblage-level studies along the West Coast (e.g., Tissot, et al. 2007; Marliave and Challenger 2009; Du Preez and Tunnicliffe 2011) and especially off California (e.g., Anderson and Yoklavich 2007; Love and Schroeder 2007; Laidig, et al. 2009). Anderson and Yoklavich (2007) reported habitat associations at three different scales for a groundfish assemblage that included several Other Rockfishes (e.g., greenstriped, rosy, squarespot) on the outer continental slope and upper continental shelf of central California. Laidig, et al. (2009) determined that several Other Rockfishes (pygmy, rosy, squarepot, starry, vermillion) were strongly associated with boulder habitat off central California. Both of these studies grouped co-occurring species into habitat guilds. Love and York investigated the importance of oil pipelines (2005) and platforms (2006) off southern California and determined that some species (e.g., copper, greenbltoched, halfbanded, stripetail, vermillion) were found in higher locally densities in association with these structures. Off the coast of British Columbia, Marliave, et al. (2009) determined that subadult and adult greenstriped and redstriped rockfishes were associated with bioherms, whereas juvenile quillback rockfish were associated with sponge gardens. On Coquille Bank, Oregon, greenstriped and sharpchin rockfish were only found on untrawled seafloor, whereas halfbanded rockfish were only found on trawled grounds (Hixon and Tissot 2007). Based on a laboratory study, Lee and Berejikian (2009) determined that juvenile china rockfish exhibited site fidelity and territoriality with size-based dominance centered on competition for structurally complex habitats. Watson, et al. (2010) found a strong correspondence between realized and potential distribution patterns of larval kelp rockfish, suggesting that circulation patterns dictate spatial distribution of this species. In population genetic studies conducted primarily along the U.S. West Coast, Buonaccorsi, et al. determined that grass (2004) and brown (2005) rockfish only moved about 10 km per generation, suggesting limited larval dispersal. Movement patterns of several Other Rockfishes were studied, primarily along the U.S. West Coast (e.g., Jorgensen, et al. 2006; Lowe, et al. 2009; Tolimieri, et al. 2009). Off Oregon, Hannah and Rankin (2011) found high site fidelity and limited vertical movements (2-3 m) for china, quillback, tiger and vermillion rockfishes. Lowe, et al. (2009) determined that some rockfishes exhibited high site fidelity to oil platforms (e.g., flag, treefish) whereas others did not (e.g, blue, Mexican, vermillion).

Trophic Interactions (updated September 2012)

Contemporary information on trophic interactions was extremely limited and only available for a small proportion of the species in the Other Rockfishes group. Yang, et al. (2006) provided diet composition results for 5 Other Rockfishes in the Gulf of Alaska, but sample sizes were quite low for most species (< 6 for dusky, redbanded, sharpchin, and shortraker). Based on a larger sample size (n = 25), rougheye rockfish in the Gulf of Alaska had a very diverse diet, with pandalid shrimps and euphausiids contributing most by weight (Yang, et al. 2006). Diets of greenstriped (euphausiids), redbanded (shrimp, crabs, bivalves, anomurans) and silvergray rockfish (fish, euphausiids) were estimated in Hecate Strait, British Columbia (Pearsall and Fargo 2007). Diet compositions of these species exhibited little spatial variation, but silvergray exhibited temporal differences in diet and variation with size (greater proportion of fishes in larger specimens). Studebaker and Mulligan (2008) found a high degree of interannual dietary variation in juvenile blue rockfish sampled in the rocky intertidal off northern California, especially with regard to the relative proportion of gammarid amphipods, their dominant prey type. In eelgrass beds of the same region, Studebaker and Mulligan (2009) determined that the diet of YOY copper rockfish consisted largely of harpactacoid copepods, gammarid amphipods, and caprellid amphipods. The effects of predation on Other Rockfishes was the subject of some contemporary studies. One such study determined that juvenile bocaccio can alter patterns of density dependence in kelp, gopher, black and yellow rockfish in Carmel Bay, California (Johnson 2006). Frid and Marliave (2010) reported that lingcod had an indirect positive effect on pandalid shrimps by eating pygmy, copper, and quillback rockfish (which probably mediate competition between pandalid shrimps). Beaudreau and Essington (2007) determined that pygmy, copper, and quillback rockfish (mainly 4-24 cm, standard length) collectively totaled 11% of lingcod diet by weight in the San Juan Archipelago, Washington. However, consumption was 5-10 times greater in marine reserves, which apparently served as predator sinks (Beaudreau and Essington 2009). In Monterey Bay, California, stripetail rockfish were a minor prey item (1.3% of diet by weight) longnose skate diet (Robinson, et al. 2007). In addition, trophic linkages, ranging from 3 in harlequin rockfish to 42 in rougheye rockfish, were determined and incorporated into a food web model for the Gulf of Alaska (Gaichas and Francis 2008).

7. ROUNDFISH

The members of the roundfish group have varying degrees of similarity, although they all tend to have elongate body forms (Eschmeyer, et al. 1983). All of these species are oviparous with external fertilization (NOAA 1990). This group contains six species from two different orders – Gadiformes and Scorpaeniformes. The two gadiform species are Pacific cod (Gadus microcephalus) and Pacific hake (Merluccius productus), while the four scorpaeniform species are lingcod (Ophiodon elongatus) and kelp greenling (Hexagrammos decagrammos) from the family Hexagrammidae, cabezon (Scorpaenichthys marmoratus) from the family Cottidae, and sablefish (Anoplopoma fimbria) from the family Anoplopomatidae. The roundfish group formerly included Pacific flatnose (Antimora microlepis) [formerly known as finescale codling (Nelson, et al. 2004)] and Pacific grenadier (Coryphaenoides acrolepis) [formerly known as Pacific rattail (Eschmeyer, et al. 1983). However, they were designated as "ecosystem component species in Amendment 28 to the FMP and no longer have designated EFH.

Gadiform Roundfishes

Pacific Cod (Gadus macrocephalus)

Range

Pacific cod are found in the waters of the northeast Pacific from the Sea of Japan, east to the Bering Sea in Alaska, south along the West Coast to Santa Monica, California (Allen and Smith 1988, Hart 1973, Love 1996, Stepanenko 1995).

Pacific cod in Puget Sound are generally categorized into three components — the North Sound component (located in U.S. waters north of Deception Pass, including the San Juan Islands, Strait of Georgia, and Bellingham Bay), the West Sound component (located west of Admiralty Inlet and Whidbey Island, and in the U.S. section of the Strait of Juan De Fuca, including Port Townsend), and the South Sound component (located south of Admiralty Inlet) (Stout, et al. 2001). The primary densities of numerous populations have historically been in the North Pacific, including the Bering Sea and the waters near northern Japan, suggesting that cod populations in Puget Sound are relatively isolated and distant (Westrheim 1996, Bakkala, et al. 1984).

Fishery

Primary fishing methods are bottom trawling, and longlining. Pacific cod are also fished recreationally from boats and piers.

Habitat

Adult Pacific cod are a member of the inner shelf-mesobenthal community (NOAA 1990). Adults occur as deep as 875 m (Allen and Smith 1988), but the vast majority occurs between 50 and 300 m (Allen and Smith 1988, Hart 1973, Love 1996, NOAA 1990). Spawning occurs from 40–265 m (NOAA 1990, Palsson 1990).

Eggs are demersal and found sublittorally (Palsson 1990). Larvae and small juveniles are pelagic; large juveniles and adults are parademersal (Dunn and Matarese 1987, NOAA 1990). Larvae are found in the upper 45 m of the water column; highest abundances are between 15 and 30 m (Garrison and Miller 1982, Matarese, et al. 1981, NOAA 1990, Palsson 1990). Eggs and larvae are found over the continental shelf between Washington and central California from winter through summer (Dunn and Matarese 1987, Palsson 1990). Small juveniles usually settle between 60 and 150 m, gradually moving into deeper water with increased age (NOAA 1990).

Pacific cod are historically an important groundfish of shallow, soft-bottom habitats in marine and estuarine environments along the West Coast (Garrison and Miller 1982). Garrison and Miller (Garrison and Miller 1982) reported that all life stages of Pacific cod occur in various bays in Puget Sound and in the Strait of Juan de Fuca near Vancouver Island. Adults and large juveniles prefer mud, sand, and clay, although Palsson (1990) and Garrison and Miller (1982) found adults associated with coarse sand and gravel substrata. Busby, et al. (In Press) observed Pacific cod in the Bering Sea with a remotely operated vehicle and found them generally associated with silty sediments, although occasionally they were observed in mixtures of silt, mud, sand, gravel, and cobble.

Eggs are demersal, adhesive, and found in polyhaline to euhaline waters between 1° C and 10° C (Alderdice and Forrester 1971b, Dunn and Matarese 1987, Forrester 1969, Hart 1973, Palsson 1990). Optimal hatching was found to be in the range of 3–6° C, salinities of 12.7–24.6 ppt, and dissolved oxygen levels from 3ppm to saturation (Alderdice and Forrester 1971b, Forrester 1969). Adults are found in marine waters, whereas juveniles are found in polyhaline to euhaline waters. Alderdice and Forrester (1971b) found that no spawning occurs below 0° C or above 10–13° C, speculating that eggs may experience high mortality or decreased development.

Migrations and Movements

Although they are not considered to be a migratory species, adult Pacific cod have been found to move more than 1,000 km (NOAA 1990, Shimada and Kimura 1994). Genetic analysis indicates two spawning stocks in North America (NOAA 1990). There exists a seasonal bathymetric movement from deep spawning areas of the outer shelf and upper slope in fall and winter to shallow middle-upper shelf feeding grounds in the spring (Dunn and Matarese 1987, Hart 1973, NOAA 1990, Shimada and Kimura 1994, Stepanenko 1995).

Larvae may be transported by tidal current to nursery areas (Garrison and Miller 1982). There is some evidence to suggest that the fish move in to deeper water with growth (Hart 1973, NOAA 1990), but they are not found exclusively in deeper water (Brodeur, et al. 1995, Palsson 1990).

Reproduction

Spawning occurs from late fall to early spring in Puget Sound (Garrison and Miller 1982); stocks further north in the Gulf of Alaska and the Bering Sea spawn in winter through spring (Klovach, et al. 1995).

A 60-cm female (3–4 years) may produce 1.2 million eggs. A 78-cm female (5–7 years) may have up to 3.3 million eggs. Fecundity has been estimated between 225,000 and 5 million eggs per spawning female (Alderdice and Forrester 1968, Forrester 1969, Hart 1973, NOAA 1990, Palsson 1990). Eggs are demersal, adhesive, and found in polyhaline to euhaline waters between 1° C and 10° C (Alderdice and Forrester 1971, Dunn and Matarese 1987, Forrester 1969, Hart 1973, Palsson 1990). Fertilized eggs are spherical, 0.98–1.08 mm in diameter (Forrester 1969, Hart 1973, Palsson 1990). Cod eggs have been found associated with coarse sand and cobble bottoms (Phillips and Mason 1986), and because most winter concentration areas have bottom sediments consisting of coarse sand and cobble, it is inferred that cod preferentially spawn near these bottom types (Palsson 1990).

Growth and Development

Embryonic development is indirect and external. Eggs hatch in 8–9 days at 11° C, 20 days at 5° C, and 28 days at 2° C (Alderdice and Forrester 1968, Forrester 1969, Hart 1973, NOAA 1990). Larvae hatch at about 3–4 mm (Dunn and Matarese 1987, Palsson 1990) with a yolk sac that is absorbed in about 10 days. Larvae metamorphose at 20–25 mm (Alderdice and Forrester 1971, Dunn and Matarese 1987, Palsson 1990) and settle into the benthic community by 35 mm (Palsson 1990).

Half of females are mature by 3 years and 55 cm, and half of males are mature by 2 years and 45 cm (Dunn and Matarese 1987, Hart 1973). In Puget Sound, both sexes mature by 2 years and 45 cm (NOAA 1990).

Trophic Interactions

Larval feeding is poorly understood. It is known that at about 20 mm, larvae eat copepods (Hart 1973), but it is not known what they eat between yolk absorption and this size. Juveniles and adults are carnivorous, and feed at night (Allen and Smith 1988, Palsson 1990). Young juveniles in the Bering Sea eat copepods, small shrimp, and amphipods, and switch to more crabs with increased size (Tokranov and Vinnikov 1991).

Adult Pacific cod have been described as euryphages because the main part of their diet is whatever prey species is most abundant (Kihara and Shimada 1988, Klovach, et al. 1995). Klovach, et al. (1995) found that 20–40 cm cod in the Bering Sea eat shrimp, mysids, and amphipods; 40–50 cm cod eat crabs and amphipods; 50–70 cm cod prefer mainly sandlance; and 70+ cm cod consume almost exclusively walleye pollock when in season.

Larval Pacific cod are eaten by pelagic fishes and sea birds. Juveniles are eaten by larger demersal fishes, including Pacific cod. Adults are preyed upon by toothed whales, Pacific halibut, salmon shark, and larger Pacific cod (Hart 1973, Love 1996, NOAA 1990, Palsson 1990, Stepanenko 1995).

The closest competitor of the Pacific cod for resources is the sablefish (Allen 1982).

Pacific Hake (Pacific Whiting) (Merluccius productus)

Range

Pacific hake of the coastal stock range from Attu Island in the western Gulf of Alaska to Magdalena Bay, southern Baja California (Mechlenburg, et al. 2002). They are most abundant in the California Current System (Bailey 1982, Hart 1973, Love 1996, NOAA 1990). There are three much smaller stocks with much smaller ranges: a Puget Sound stock, a Strait of Georgia stock, and a dwarf stock limited to waters off Baja California (Bailey, et al. 1982, Stauffer 1985).

Fishery

Pacific hake support one of the most important commercial fisheries off the West Coast. Coastal stocks are fished with midwater trawls off northern California starting in April, and moving northward to British Columbia by late July. Fishing ceases in October (NOAA 1990). The interior stocks of Pacific hake in Puget Sound and the Strait of Georgia are fished from January through May (NOAA 1990). Pacific hake is not a recreationally sought-after species; almost all catch is made incidentally to salmon fishing.

Habitat

The coastal stock of Pacific hake is migratory and inhabits the continental slope and shelf within the California current system from Baja California to Southeast Alaska (Quirollo 1992, Mechlenburg, et al. 2002). All life stages are found in euhaline waters at 9–15° C (NOAA 1990). Adults are epi-mesopelagic (Bailey, et al. 1982, NOAA 1990, Sumida and Moser 1980). In survey data, they most frequently occur between 100 and 150 m, with nearly all taken at depths of 50–400 m (Allen and Smith 1988).

Eggs and larvae of the coastal stock are pelagic in 40–140 m of water (Smith 1995); adults are epi-mesopelagic (Bailey, et al. 1982, NOAA 1990, Sumida and Moser 1980). Moser, et al. (1997) investigated the abundance and distribution of Pacific hake eggs at sites off central and southern California, and reported that most of the eggs were at depths of 50–150 m. They also reported that the early-stage eggs were deeper (75–150 m) in the water column compared to the depth (50–100 m) of later-stage eggs. Larvae tend to aggregate near the base of the thermocline or mixed layer (Stauffer 1985). This association with the thermocline or mixed layer may partially explain why Pacific hake in the Strait of Georgia and Puget Sound spawn near major sources of freshwater, which would cause a stratified layer of low-salinity water on top of the well-mixed marine waters common during the winter. Horne and Smith (1997) analyzed CalCOFI data on the abundance and distribution of Pacific hake larvae from sites off central and southern California for 1955–1984, and reported that the biomass of Pacific hake larvae is strongly influenced by mortality and drift with prevailing currents. They reported that the location of spawning largely determined the survival of the larvae, with higher survival occurring in warm years (when spawning adults moved northward) compared to cold years (when spawning adults moved southward). Sakuma and Ralston (1995) conducted similar studies off the coast of central California and found that larvae accumulated in warmer nearshore waters (approximately 100 m).

Juveniles reside in shallow coastal waters, bays, and inland seas (Bailey 1981, Bailey, et al. 1982, Dark 1975, Dark and Wilkins 1994, Dorn 1995, NOAA 1990, Iakuma and Ralston 1995, Smith 1995), and move to deeper water as they get older (NOAA 1990). Sakuma and Ralston (1997) reported that juveniles are less abundant in upwelled nearshore coastal waters compared to non-upwelled water. The importance to juveniles of submarine canyons in southern California with high levels of organic enrichment by macrophyte detritus was evaluated by Vetter and Dayton (1999). They compared these canyons to flat areas, and reported that the canyons had much higher megafauna abundance and species richness, and the relative abundance of juvenile Pacific hake was hundreds of times higher in the canyons at depths of 150–200 m. Overall, highest densities of Pacific hake are usually between 50 and 500 m, but adults occur as deep as 920 m and as far offshore as 400 km (Bailey 1982, Bailey, et al. 1982, Dark and Wilkins 1994, Dorn 1995, Hart 1973, NOAA 1990, Stauffer 1985). Spawning is greatest at depths between 130 and 500 m (Bailey, et al. 1982, NOAA 1990, Smith 1995).

The Puget Sound and Strait of Georgia stocks live their whole lives in these inland seas (McFarlane and Beamish 1986, Shaw, et al. 1990).

Smith (1995) recognizes three habitats utilized by the coastal stock of Pacific hake: 1) a narrow 30,000 km^2 feeding habitat near the shelf break of British Columbia, Washington, Oregon, and California populated 6–8 months per year; 2) a broad 300,000 km^2 open-sea area of California and Baja California populated by spawning adults in the winter and embryos and larvae for 4–6 months; and 3) a continental shelf area of unknown size off California and Baja California where juveniles brood.

Eggs of the Pacific hake are neritic and float to neutral buoyancy (Bailey 1981, Bailey, et al. 1982, NOAA 1990). All life stages are found in euhaline waters and at 9–15° C (NOAA 1990).

Migrations and Movements

The Pacific hake is unorthodox amongst the groundfish, because it is highly migratory, moving into many areas of the West Coast, including nearshore shelf, shelf break, and slope. Coastal stocks spawn off Baja California in the winter at depths exceeding 1000 m (Saunders and McFarlane 1997) then the mature adults begin moving northward and inshore, following food supply and Davidson currents (NOAA 1990). Post-spawned females tend to make this migration prior to post-spawned males (Saunders and McFarlane 1997). Pacific hake reach as far north as south eastern Alaska by late summer or fall (G. Fleisher[38]). They then begin the southern migration to spawning grounds and further offshore (Bailey, et al. 1982, Dorn 1995, Smith 1995, Stauffer 1985). Juveniles move to deeper water as they get older (NOAA 1990). During the summer, Pacific hake form extensive midwater aggregations near the continental shelf break, with highest densities located over bottom depths of 200–300 m (Dorn, et al. 1994).

Stocks in the Strait of Georgia and Puget Sound undergo similar migration patterns, but on a greatly reduced scale (McFarlane and Beamish 1986, Shaw, et al. 1990). In both areas, spawning occurs in locations proximate to major sources of freshwater inflow: near the Frazer River in the Strait of Georgia, and near the Skagit and Snohomish Rivers in Port Susan (McFarlane and Beamish 1985, Pederson 1985). These stocks are considered distinct from the offshore stocks of Pacific hake on the basis of genetic, morphological, physiological, and behavioral differences (Gustafson, et al. 2000).

Pacific hake school at depth during the day, then move to the surface and disband at night for feeding (McFarlane and Beamish 1986, Sumida and Moser 1984, Tanasich, et al. 1991).

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[38] G. Fleisher, Northwest Fisheries Science Center, NOAA Fisheries, 2725 Montlake Blvd. East, Seattle, WA, 98112, Pers. Commun., July, 2004

Reproduction

The coastal stock of Pacific hake spawns from December through March, peaking in late January (Smith 1995). In the Strait of Georgia, spawning occurs from March through May and peaks in late April (Beamish and McFarlane 1986, Shaw, et al. 1990). In Puget Sound, spawning occurs primarily during February through April, peaking in March (W. Palsson[39]). Spawning aggregations begin to form up to a month before actual spawning.

Pacific hake may spawn more than once per season, so absolute fecundity is difficult to ascertain. Coastal stocks have 180–232 eggs/gram body weight, but Puget Sound and Strait of Georgia stocks have only 50–165 eggs/gram body weight (Mason 1986). Bailey (1982) estimated that a 28-cm female had 39,000 eggs, while a 60-cm female had 496,000 eggs.

Growth and Development

Eggs are spherical and 1.14–1.26 mm in diameter with a single oil droplet (Bailey, et al. 1982). Embryonic development is indirect and external (NOAA 1990). Hatching occurs in 5–6 days at 9–10C and 4–5 days at 11–13EC (Bailey 1982, Hollowed 1992). Larvae hatch at 2–3 mm total length (Stauffer 1985, Sumida and Moser 1980) with a yolk sac that is gone in 5–7 days (Bailey 1982). Larvae metamorphose into juveniles at 35 mm, typically in 3–4 months (Hollowed 1992). Juveniles range from 35 mm to 40 cm depending on gender (Bailey, et al. 1982, Beamish and McFarlane 1986, Hollowed 1992).

In Puget Sound and the Strait of Georgia, female Pacific hake mature at 37 cm and 4–5 years (McFarlane and Beamish 1986). Females of the coastal stock mature at 3–4 years and 34– 40 cm, and nearly all males are mature by 3 years and as small as 28 cm. Females grow more rapidly than males after four years; growth ceases for both sexes at 10–13 years (Bailey, et al. 1982).

Trophic Interactions

All life stages feed near the surface late at night and early in the morning (Sumida and Moser 1984). Larvae eat calanoid copepods, as well as their eggs and nauplii (McFarlane and Beamish 1986b, Sumida and Moser 1984). Juveniles and small adults feed chiefly on euphausiids (NOAA 1990). Large adults also eat amphipods, squid, herring, smelt, crabs, sometimes juvenile Pacific hake, and pelagic schooling fish (e.g., eulachon and herring) (Bailey 1982, Dark and Wilkins 1994, McFarlane and Beamish 1986b, NOAA 1990, Livingston and Bailey 1985). Buckley and Livingston (1997) reported the results of stomach content analyses of Pacific hake collected from 1989 to 1992 along the west coast of the U.S., from southern California to Vancouver Island. They found that diet varied with latitude and season. In general, in all areas the diet was dominated by fishes, but euphausiids were also consistently found in the diets of Pacific hake from all areas. Clupeidae (primarily Pacific herring) were dominant prey in fish from sites off of Vancouver Island, Washington, and Oregon, whereas northern anchovy and rockfish dominated the diets in central and southern California, respectively. In areas where a broad range of sizes of Pacific hake were found, considerable cannibalism was observed among fish larger than 40 cm fork length, with a frequency of occurrence of 39%. Some of the major seasonal differences in diet for Pacific hake from sites off of Oregon and Washington included dominance by euphausiids in fish 30–49 cm fork length in the summer compared to dominance by fish and shrimp in the autumn; and in fish from sites off of California, a dominance of fish in the spring

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[39] W. A. Palsson, Washington Dept. of Fish and Wildlife, Olympia, WA. Pers. commun., September 1999.

compared with a dominance of cannibalized Pacific hake in the autumn (Buckley and Livingston 1997).

Eggs and larvae of Pacific hake are eaten by pollock, herring, invertebrates, and sometimes Pacific hake. Juveniles are eaten by lingcod, Pacific cod, and rockfish species. Adults are preyed on by sablefish, albacore, pollock, Pacific cod, soupfin sharks, and spiny dogfish (Fiscus 1979, McFarlane and Beamish 1986b, NOAA 1990). Another important group of predators of adult Pacific hake are marine mammals, including the northern elephant seal (*Mirounga angustirostris*), northern fur seal (*Callorhinus usrsinus*), California sea lion (*Zalophus californianus*), and several species of dolphins and whales (Methot and Dorn 1995).

Gadiform Roundfishes Group Summary Information (updated September 2012)

New literature on spatial associations and trophic interactions for the gadiform roundfishes consisted of 64 individual references, with 42 references for Pacific cod and 34 for Pacific hake.

Spatial Associations

Several studies concerned distribution and abundance patterns of Pacific cod and showed that new recruits occur in shallow waters (< 20 m) and move to deeper water with ontogeny (Abookire, et al. 2007; Laurel, et al. 2009). New recruits and early juveniles appear to prefer structured habitats (e.g., kelp, seagrass beds, sea cucumber mounds) (Abookire, et al. 2007; Laurel, et al. 2007; Hamilton and Konar 2007), whereas larger juveniles and adults are highly mobile and found in more open habitats (Laurel, et al. 2007; Conners and Munro 2008). Agostini, et al. (2006) determined that Pacific hake are associated with subsurface poleward, which defines adult habitat and migration patterns, rather than temperature. Age 0 Pacific hake are one of the most common micronekton along the West Coast (Phillips, et al. 2009). Nursery areas are principally along the coastal shelf and slope of California, but shift northward during ENSO events (Phillips, et al. 2007; Agostino, et al. 2008; Funes–Rodriguez, et al. 2009). In addition, spawning and recruitment sites of Pacific hake have expanded northward, probably in relation to increased winter/spring temperatures in the northern California Current (Phillips, et al. 2007). The Pacific grenadier is among the most abundant groundfish species in continental slope waters of the West Coast (Keller, et al. 2005; Tolimieri 2007), but specific patterns of distribution and abundance are not addressed in the contemporary literature. However, this species and the Pacific flatnose are commonly found at California seamounts (Lundsten, et al. 2009).

Trophic Interactions

Contemporary trophic information on the gadiform subgroups is also largely focused on Pacific cod and Pacific hake. Several recent diet studies were conducted on Pacific cod in British Columbia and the Gulf of Alaska. Pacific cod were found to be major predators of herring (Schweigert, et al. 2010) and capelin (Yang, et al. 2005). Young Pacific cod eat copepods and other small crustaceans (Abookire, et al. 2007), with older, larger fishes eating larger crustaceans (e.g., shrimps, tanner crab) and other fishes (e.g., sand lance, pollock) (Yang, et al. 2006). Dietary variability was noted with size and depth (Abookire, et al. 2007) and, since this species feeds opportunistically, likely also includes temporal and spatial differences. Observed, long–term dietary changes in Pacific cod have been attributed to changing environmental conditions and shifting bottom–up and top–down control (Yang, et al. 2004; Litzow and Ciannelli 2007). Contemporary diet studies of Pacific hake were mainly focused on commercially important prey items. Pacific hake predation was not determined to have a major effect on Columbia River salmon populations (Emmett and Krutzikowsky 2008) but could impact canary rockfish recovery in California (Harvey, et al. 2008). Pacific hake were also one of the main predators of Pacific herring off British Columbia (Schweigert, et al. 2010). Scavenging is an important component of diet of Pacific grenadiers and Pacific flatnose, probably as a result of low standing prey biomass in the deep ocean (Yeh and Drazen 2011). Because of their high relative abundance, Pacific cod and Pacific hake are important prey items for a wide variety of species. Pacific cod are eaten in high proportions by Stellar sea lions between Oregon and the Aleutian Islands (e.g., Bredeson, et al. 2006; Csepp, et al. 2011) and are also present in the diet of Aleutian skates (Yang 2007), arrowtooth flounder (Yang, et al. 2006), Pacific halibut (Yang, et al. 2006), and sablefish (Yang, et al. 2006). Pacific hake are commonly eaten by Stellar sea lions (Bredeson, et al. 2006, Csepp, et al. 2011), harbor seals (Orr, et al. 2004), California sea lions (Orr, et al. 2011), Humboldt squid (Field, et al. 2007), albacore (Glaser 2010), and thresher sharks (Preti, et al. 2004).

Scorpaeniform Roundfishes

Cabezon (Scorpaenichthys marmoratus)

Range

Cabezon are found in southeast Alaska to as far south as Punta Abreojos in central Baja California (Hart 1973, Miller and Lea 1972, O'Connell 1953).

Fishery

In central California, a commercial fishery centered around Morro Bay targets cabezon to supply a live-fish market (P. Reilly[401]). There is also a small commercial market, especially in southern California that is mainly supported by the incidental catch of cabezon while fishing for other species (Love 1996). Catch is mainly by trap, gill net, and hook and line. Cabezon are taken throughout their range by fishers on boats, piers, and rocky banks, and by spear-fishing divers (Hart 1973, Love 1996).

Habitat

Cabezon are found on hard bottoms in shallow water from intertidal pools to depths of 76 m (Love 1996). Cabezon are abundant all year in estuarine and subtidal areas, as well as to mid- depths along the continental shelf.

Eggs, large juveniles, and adults are demersal; larvae and small juveniles are pelagic and planktivorous (O'Connell 1953). Larvae have been found offshore as far as 322 km (O'Connell 1953). Juveniles and adults reside primarily in shallow water bays and estuarine areas (Hart 1973, Matthews 1987). Pelagic juveniles are silvery when small, spending their first three to four months in the open ocean feeding on tiny crustaceans and other zooplankton. In California, juveniles first appear in kelp canopies, tide pools, and other shallow rocky habitats such as breakwaters from April to June (Quast 1968a; O'Connell 1953). Some juveniles are also associated with oil and gas production platforms (Schroeder 1999b). Off Washington, adults are found as deep as 80 m, but are most common intertidally to 25 m (Matthews 1987). Off Washington and Oregon, cabezon occur only infrequently at depths over 50 m. However, off California, cabezon are found in moderate to great abundance in the waters along the inner shelf (California Dept. Fish and Game 2003).

Cabezon are most abundant in estuaries of the West Coast, where all life stages can be found. Eggs and larvae are found there from winter through spring (Shenker 1988).

Eggs, juveniles and adults are not reported to occur far offshore. However, neustonic planktivorous larvae have been reported as far from shore as 200 miles (O'Connell 1953, Shenker 1988).

Cabezon are found intertidally or in shallow, subtidal areas on a variety of habitats, often in the vicinity of kelp beds, jetties, oil platforms, isolated rocky reefs or pinnacles, and in shallow tide pools (Wilson-Vandenberg 1992). Rocky bottoms and cobble substrata are utilized most frequently. Eelgrass beds and occasionally sandy bottoms are used (Lauth 1987, Mathews and LaRiviere 1987, O'Connell 1953). Adults tend to move to somewhat deeper waters with increased size (O'Connell 1953).

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[40] P. Reilly, California Department of Fish and Game, 1416 Ninth Street, Sacramento, California 95814. Pers. Commun., July 2003.

Females in Puget Sound are rarely found deeper than 9 m (Lauth 1987). Wilson-Vandenberg (1992) reported that cabezon spawn their eggs on subtidal, algae-free rocky surfaces, which can be horizontal or vertical in orientation.

Migrations and Movements

Adult cabezon are not known to make any significant migrations. A tag-recapture study in Monterey Bay showed the cabezon to be residential (Miller and Geibel 1973). Adults are known to move inshore with a flood tide, and retreat offshore on an ebb tide (Miller and Geibel 1973, O'Connell 1953). Planktivorous larvae can be carried great distances by offshore oceanic currents.

Wilson-Vandenberg (1992) reported that cabezon spend most of their time sitting in holes on reefs, in pools, or on kelp blades beneath the canopy, but not actively swimming. In shallow water they move in and out with the tide to feed. Their habit of sitting makes them an easy target for recreational divers.

Reproduction

The spawning season for cabezon runs from late October to March and peaks in January in southern California (O'Connell 1953), and is from November to early May in Puget Sound, peaking in March (Lauth 1987).

Cabezon spawn more than once per year, so absolute fecundity is not known. Cabezon males build and guard nests, and more than one female may deposit egg masses in the same male's nest. Batch fecundity of a 433-mm female is approximately 48,700 eggs. Based on estimated weight-to-batch fecundity relationships, a 2.5-kg female had an estimated 62,000 viable oocytes, whereas a 6.5-kg female contained an estimated 154,000 viable oocytes (Lauth 1987, Matthews 1987).

Growth and Development

Fertilized eggs are adherent to rocks and macroalgae, and are 1.4–1.7 mm in diameter (Lauth 1989, California Dept. Fish and Game 2003). Eggs hatch in 12–16 days (O'Connell 1953). Larvae are 5–6 mm long with a yolk sac, which is absorbed by 10 mm (O'Connell 1953). These small juveniles are planktonic and settle out to the bottom at about 65 mm (Lauth 1989).

Male cabezon mature at 2–3 years and 25–30 cm. Females grow faster, become larger, and live longer than do males. Females mature at 3–5 years and 30–40 cm (Love 1996). Cabezon may reach an age of more than 20 years (Wilson-Vanderberg 1992).

Trophic Interactions

Larvae are planktivorous. Larvae eat copepods, barnacle larvae, fish larvae, and fish eggs (Hart 1973, Lauth 1989, Matthews 1987, O'Connell 1953). Cannibalism of eggs and newly hatched larvae may be very high among the larvae. Newly metamorphosed juveniles eat amphipods and small shrimp. Juveniles and adults are carnivorous, feeding opportunistically (Hart 1973). Small juveniles depend mainly on amphipods, shrimp, crabs, and other small crustaceans (Quast 1968b). Adult fish eat crabs, small lobsters, mollusks (abalone, squid, octopus), small fish (including rockfishes), and fish eggs (Quast 1968b, Love 1996). At 14 cm, cabezon begin to prey on crabs, which become the dominant crustacean in the cabezon diet thereafter (O'Connell 1953).

Cabezon eggs, though toxic to humans, are eaten by scalyhead sculpin, striped surfperch, and pile perch (Lauth 1989, Matthews 1987). Juveniles and adults are preyed upon by other rocky reef fishes, including lingcod. Juveniles are taken by rockfishes and larger cabezon, as well as by lingcod and other sculpins. Large cabezon may be taken by harbor seals or sea lions. In British Columbia, sea otters, pigeon guillemots, least terns, and Brandts cormorants have been identified as predators of adult cabezon (Love 1996).

Kelp Greenling (Hexagrammos decagrammus)

Range

Kelp greenling are relatively common all along the west coast of North America from the Aleutian Islands to southern California off La Jolla. They are not commonly found south of Point Conception, California (Garrison and Miller 1982, Hart 1973, Kendall and Vinter 1984, Love 1996).

Fishery

The kelp greenling has not been a commercially important species (Hart 1973, Love 1996), although it is becoming important in the live-fish fishery. Kelp greenling supports a popular sport fishery, mainly north of central California (Love 1996). They are captured from rocky banks, piers, and private and charter vessels, and are targeted by spear-fishing divers.

Habitat

Adults, spawning adults, and large juveniles are abundant in coastal waters and in inland seas, such as Puget Sound. (Garrison and Miller 1982, Gorbunova 1962, Hart 1973, Moulton 1977).

Eggs are demersal and found subtidally (Garrison and Miller 1982). Larvae and small juveniles are pelagic (Gorbunova 1962, Hart 1973, Matthews 1987). Large juveniles are demersal (Matthews 1987). Adults are demersal and not commonly found below 20 m (Love 1996), although they may range down to 52 m (Howard 1992). In Puget Sound, adults are most abundant between 7 and 12 m and male kelp greenling are found an average of 3 m deeper than females (Garrison and Miller 1982).

Adults inhabit rocky reefs of shallow nearshore areas. Kelp greenling show a very high affinity to rocky banks near dense algae or kelp beds, or in kelp beds (Garrison and Miller 1982, Gorbunova 1962, Hart 1973, Kendall and Vinter 1984, Love 1996, Matthews 1987, Moulton 1977). Larvae and small juveniles are found in the upper 45 m of the water column in spring and summer (Kendall and Vinter 1984, Matthews 1987), and may be found up to 965 km offshore (Garrison and Miller 1982, Gorbunova 1962). Juveniles are commonly associated with rocky reefs and macroalgae (California Dept. Fish and Game 2003) and are occasionally found in tide pools (Love 1996).

For Puget Sound, Patten (1980) found that kelp greenling adults, spawning adults, eggs, and large juveniles prefer water temperatures between 9 and 13° C, and favorable salinities were 27.5–29.9 ppt. Larvae and small juveniles experience accelerated growth in the warmer surface waters of the open ocean. Eggs will not hatch and many die when held at 22° C for 10 minutes. Larvae were torpid after 10 minutes at 20° C (Patten 1980). Allen, et al. (1970) observed that the distribution of kelp greenling was influenced more by habitat type than by temperature; that is, rocky reefs, kelp beds and algae in water below 9° C or above 13° C are favored over sandy, muddy, or silty substrata in waters between 9° C and 13° C.

Migrations and Movements

Adult kelp greenling are not a migratory species. Matthews (1987) reported that most adults are in 13 m of water or less all year round, which inhibits migration. Moulton (1977), in a series of dives in northern Puget Sound, found no changes in kelp greenling density, indicating that no individuals were leaving or entering the study area. However, newly hatched larvae move out of estuaries or shallow nearshore areas and into open waters (Garrison and Miller 1982, Gorbunova 1962); this migration may take up to a year (Garrison and Miller 1982).

Reproduction

Spawning occurs in the fall in Puget Sound, peaking in October and November (Garrison and Miller 1982, Moulton 1977). In the Gulf of Alaska, spawning is earlier in the fall, and Love (1996) found that kelp greenling in California waters spawn in late fall to early winter.

Male and female kelp greenling mature at 3–5 years (Love 1996, Matthews 1987). The maximum age is 16 years (Howard 1992).

Growth and Development

Fertilized eggs are laid on or between rocks, or in algae beds and guarded by males. The substrata with which the egg clutches are associated may depend on geographical location. Crow, et al. (1997) reported that for egg clutches observed at sites located in Canadian coastal waters, 50% were on rocks, 30% were associated with a complex of rock and biogenetic substrata (e.g., barnacle test, scallop shell, worm tubes, and algae), and 20% were solely on biogenic substrata. However, at California coastal sites, only 20% of the clutches were on rock, 68% were on rock and biogenic complexes of substrata, and 12% were solely on biogenic substrata. Incubation time is estimated at about 20 days, because Garrison and Miller (1982) reported newly hatched larvae were found in the water column in early December. Larvae are 7–8 mm at hatching (Gorbunova 1962, Hart 1973, Moulton 1977). Larvae immediately move to open seas for about one year, and return as demersal juveniles. Female kelp greenling grow faster and larger than do males (Love 1996).

Kelp greenling are approximately 4–5 cm after one year (Gorbunova 1962). Age at maturity for both sexes is 3–5 years. Love (1996) observed that a typical 25-cm specimen is 6–9 years old. Kelp greenling may reach 53 cm and 12 years of age (Hart 1973, Love 1996).

Trophic Interactions

Pelagic kelp greenling larvae and juveniles feed on copepods and copepod nauplii, amphipods, brachyuran larvae, euphausiids, and larval fish (Gorbunova 1962, Hart 1973). Adult kelp greenling feed on just about anything present, with preferences for shrimp, crabs, worms, octopi, brittle stars, snails, and small fishes (Love 1996, Hobson, et al. 2000). Feeding occurs during the day. They are inactive at night.

Eggs are preyed on heavily by other kelp greenling, other closely related species, and by the male guarding the egg mass. Larval kelp greenling are eaten by pelagic fishes like salmon and steelhead, and marine birds (Hart 1973). Adults are eaten by spiny dogfish, lingcod and other hexagrammids (Hart 1973). Kelp greenling compete very closely for preferred habitat and food with other fishes of the rocky reef assemblage (Garrison and Miller 1982, Moulton 1977).

Lingcod (Ophiodon elongatus)

Range

Lingcod occur from Punta San Carlos, Baja California to off Shumagin Island in the Gulf of Alaska. Highest densities are found from Point Conception, California to Cape Spencer, Alaska (Phillips and Barraclough 1977, Mecklenburg, et al. 2002).

Fishery

Lingcod support an important commercial and recreational fishery throughout their range. Lingcod are caught commercially through five main gear types: bottom trolling, handline jigging, otter trawls, set nets, and set lines (Shaw and Hassler 1989). Catches are generally highest in 70–150 m of water and catches on the West Coast have been highest from Vancouver Island to the Columbia River estuary (Pikitch 1989). Lingcod are taken by recreational fishermen from boats, docks, and shore, as well as by spear-fishing divers.

Habitat

In the North Pacific, lingcod occupy the estuarine-mesobenthal zone, occurring from intertidal areas to 475 m (Allen and Smith 1988). In survey data, they most frequently occur between 100 and 150 m, with nearly all taken at depths of 50–400 m (Allen and Smith 1988). Older larvae and very young juveniles are epipelagic, primarily found in the upper three meters of the water column (Phillips and Barraclough 1977) in waters less than150 m. Off California, pelagic juveniles occur in the upper 35 m of surface waters (Adams and Hardwick 1992). Eggs, young larvae, older juveniles, and adults are demersal (Allen and Smith 1988, NOAA 1990, Shaw and Hassler 1989). Spawning generally occurs in waters 3–10 m below mean lower low water over rocky reefs in areas of swift current (Adams 1986, Adams and Hardwick 1992, Giorgi 1981, Giorgi and Congleton 1984, LaRiviere, et al. 1980).

Adults, spawning adults, and eggs are common in Puget Sound, Hood Canal, and Skagit Bay in Washington and Humboldt Bay in California. Juveniles are common in most large estuaries between Puget Sound and San Pedro Bay, California. Larvae are common in most Washington estuaries, as well as Coos Bay, Oregon and throughout San Francisco Bay, California (Emmett, et al. 1991).

Eggs and larvae occur in nearshore areas from winter through late spring. Small juveniles settle in estuaries and shallow waters all along the coast, but are more common in northerly extents of the range. Juveniles move to deeper waters as they grow, but are still most common in waters less than 150 m.

Eggs masses are found in association with rocky reefs (Giorgi 1981, Giorgi and Congleton 1984). Egg masses are usually found wedged in rock crevices or under overhanging boulders in areas with currents 3.5 km/h or greater to maintain interstitial oxygen levels in the center of the mass (Forrester 1969, Giorgi 1981, Hart 1973, Miller and Geibel 1973). Egg masses are also often located on rocky ledges with an opening directly behind the eggs to allow water to pass over the nest (Adams and Hardwick 1992).

Juveniles prefer sandy and rocky substrata in subtidal zones and estuaries (California Dept. Fish and Game 2003, Emmett, et al. 1991, Fitch and Schultz 1978, Hart 1973, NOAA 1990, Shaw and Hassler 1989). All life history stages occur in polyhaline to euhaline waters (18–30+ ppt) that are between 5 and 15EC, although juveniles may also be found in mesohaline waters (5–18 ppt) (Emmett, et al. 1991, NOAA 1990, Shaw and Hassler 1989).

Adults and large juveniles prefer two main habitat types: slopes of submerged banks 10– 70 m below the surface with seaweed, kelp, and eelgrass beds that form feeding grounds for small prey fish; in some cases they are found on soft bottoms and channels with swift currents that flow around rocky reefs, concentrating plankton and plankton-feeding fish (Emmett, et al. 1991, Giorgi and Congleton 1984, Love 1996, NOAA 1990, Shaw and Hassler 1989). In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult lingcod were most commonly found in habitat consisting of ridges and boulders, vase sponges (*Scypha and Iophon*), and basketstars (*Gorgonocephalus*) in areas near the top of the bank at depths less than 100 m. Lingcod were generally observed sitting on the bottom.

Migrations and Movements

Adult lingcod are considered a relatively sedentary species, but migrations greater than 100 km have been reported (Jagielo 1990, Mathews and LaRiviere 1987, Mathews 1992, Smith, et al. 1990). Long migrations were typically undertaken by sexually immature fish. Smith, et al. (1990) found that tagged male lingcod can move up to 500 m/day and tagged females can move more than 1,000 m/day. Jagielo (1990) and Matthews (1992) noted that fish in the San Juan Islands migrated from estuaries in a general southwesterly direction to nearshore areas in spring, but this was mostly by immature fish. Mature females live in deeper water than males and move from deep water to shallow water in the winter to spawn (Forrester 1969, Hart 1973, Jagielo 1990, LaRiviere, et al. 1980, Mathews and LaRiviere 1987, Mathews 1992, Smith, et al. 1990). Matthews (1992) found that tagged lingcod move only at night.

Mature males may live their whole lives associated with a single rock reef, possibly out of fidelity to a prime spawning or feeding area (Allen and Smith 1988, Pikitch 1989, Shaw and Hassler 1989). Larvae are carried by tidal currents into to rearing areas within estuaries. Larvae metamorphose in early summer, and juveniles rear until winter before moving to deeper waters (Mathews and LaRiviere 1987, Miller and Geibel 1973).

Reproduction

Lingcod are iteroparous and gonochoristic (Emmett, et al. 1991, Garrison and Miller 1982, Shaw and Hassler 1989). Spawning takes place December through April. For the Humboldt Bay stock, peak spawning is January through February; Yaquina Bay stocks peak from late January to early March; in Washington (Puget Sound, Hood Canal, Skagit Bay), spawning peaks from February to March (Adams 1986, Garrison and Miller 1982, Phillips and Barraclough 1977, Pikitch 1989). Fecundity of female fish ranges from about 40,000 (76-cm fish) to about 500,000 (97-cm fish). Embryonic development is indirect and external.

Growth and Development

Eggs are about 2.8 mm in diameter when laid; they increase to 3.5 mm diameter after being water-hardened (Forrester 1969, Giorgi 1981). Egg masses are adherent and usually laid in rock crevices or on rocky reefs (Giorgi 1981, Giorgi and Congleton 1984, Hart 1973, LaRiviere, et al. 1980, NOAA 1990). Males guard the nest until hatching, usually about six weeks (Giorgi 1981, LaRiviere, et al. 1980, Shaw and Hassler 1989). Larvae hatch at 7–10 mm with a yolk sac and stay on the bottom until it is absorbed, about 10 days. They then ascend into the water column. At 60–80 mm, they metamorphose into juveniles and settle out of the water column (Emmett, et al. 1991, Forrester 1969, NOAA 1990, Shaw and Hassler 1989). Juveniles are 6–76 cm total length, depending on gender (Emmett, et al. 1991, Hart 1973, Miller and Geibel 1973, Phillips and Barraclough 1977, Shaw and Hassler 1989).

In Humboldt Bay and San Francisco Bay, newly hatched larvae occur in January and February. From March until June, lingcod larvae grow and transform into pelagic juveniles, which are taken in pelagic trawls in the upper 35 m of the surface waters from April to June. After June, these juveniles disappear from surface waters and migrate to bottom habitats, frequently around kelp and eelgrass beds (Adams and Hardwick 1992).

Lingcod are about 27 cm at one year and 47 cm at two years. At this point, females begin to grow faster than males. Males begin maturing at about 2 years and 50 cm, whereas females mature at 3+ years and 76 cm. In northern extents of their range, fish mature at an older age and larger size (Emmett, et al. 1991, Hart 1973, Mathews and LaRiviere 1987, Miller and Geibel 1973, Shaw and Hassler 1989). Maximum age is about 20 years (Adams and Hardwick 1992).

Trophic Interactions

Larvae are zooplanktivores, feeding on all life stages of copepods, as well as small amounts of amphipods, euphausiids, and decapod larvae (NOAA 1990). Small demersal juveniles prey upon copepods, shrimp, and other small crustaceans. Larger juveniles shift to clupeids and other small fishes (Emmett, et al. 1991, NOAA 1990). Adults feed primarily on demersal fishes (including smaller lingcod), squids, octopi and crabs (Hart 1973, Miller and Geibel 1973, Shaw and Hassler 1989). Lingcod are a visual predator, feeding primarily by day.

Eggs are eaten by gastropods, crabs, echinoderms, spiny dogfish, and cabezon. Juveniles and adults are eaten by marine mammals, sharks, and larger lingcod (Miller and Geibel 1973, NOAA 1990).

Sablefish (Anoplopoma fimbria)

Range

Sablefish are very abundant in the north Pacific, from Honshu Island, Japan, north to the Bering Sea, and southeast to Cedros Island, Baja California. Large adults are uncommon south of Point Conception (Hart 1973, Love 1996, McFarlane and Beamish 1983a and b, NOAA 1990).

Fishery

Sablefish supports an important commercial fishery off the West Coast. Bottom trawling, traps, and longlines have been the primary methods of capture. Sablefish are not commonly fished recreationally, mostly because they live at depths too great for most kinds of recreational fishing gear.

Habitat

In the North Pacific, sablefish is considered an inner shelf-bathybenthal species. Adults are found as deep as 3,000 m, but are most abundant between 200 and 1,000 m (Beamish and McFarlane 1988, Kendall and Matarese 1987, Mason, et al. 1983, Love 1996). In survey data for the North Pacific, nearly all sablefish were taken at depths less than 700 m (Allen and Smith 1988). However, off southern California, sablefish were abundant to depths of 1500 m (MBC Applied Environmental Sciences 1987). Spawning takes place at depths greater than 300 m (Boehlert and Yoklavich 1985, Grover and Olla 1990, Hart 1973, Mason, et al. 1983). Jacobson, et al. (2001) analyzed data from eight bottom trawl surveys conducted on the upper continental shelf of the Pacific coast, and reported that sablefish (280–380 m, total length) were collected at depths between 200 and 400 m, whereas larger sablefish were collected throughout the depth range of 200–1200 m.

Sablefish eggs, larvae (after yolk sac is absorbed), and age-0 juveniles are pelagic whereas older juveniles and adults are benthopelagic on soft bottoms. Eggs are usually found deeper than 300 m (Hart 1973, Kendall and Matarese 1987, Mason, et al. 1983). Eggs and newly hatched larvae are found in these deep waters from January through March (Grover and Olla 1990, Kendall and Matarese 1987, Mason, et al. 1983, NOAA 1990). Newly hatched larvae are demersal until the yolk sac is absorbed (Mason, et al. 1983). At this time, larvae become pelagic and rise to the neuston layer at the surface. Larvae and young juveniles are found up to 370 km offshore, often near drifting kelp (NOAA 1990). Small (age-0) juveniles inhabit the upper 100 m of the water column (MBC Applied Environmental Sciences 1987). Larvae and small juveniles move inshore after spawning and may rear there for up to four years (Boehlert and Yoklavich 1985, Mason, et al. 1983). McFarlane, et al. (1997) reported that larval sablefish collected off the west coast of Vancouver Island tended to be most abundant in waters where mean currents were weakest. They suggest that the distribution of the larvae in the water column at the time of the spring transition (i.e., the onset of upwelling conditions) strongly influences the abundance and distribution of sablefish larvae. Older juveniles and adults inhabit progressively deeper waters, although juveniles are rarely found at depths greater than 200 m (Love 1996). These deeper waters tend to be in the oxygen minimum zone, and generally the peak spawning biomass of sablefish is found in this zone (Jacobson and Vetter 1996).

Sablefish are an important groundfish over soft substrata in deep marine waters (Love 1996). Adults and large juveniles form schools that commonly occur over sand and mud (McFarlane and Beamish 1983a, NOAA 1990). They were also reported on hard-packed mud and clay bottoms in the vicinity of submarine canyons (MBC Applied Environmental Sciences 1987), and they are associated with seamounts in the Gulf of Alaska (Alton 1986). In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult sablefish were most commonly found in habitat consisting of mud and sea urchins (*Allocentrotus*). They were evenly and sparsely distributed over mud bottoms, and swam within a few meters of the bottom.

The preferred salinity range of spawning adults is between 33.7 g/l and 34.5 g/l (Mason, et al. 1983, NOAA 1990), although eggs and larvae were occasionally found in less saline waters (NOAA 1990).

The optimal temperature range for egg incubation was 3.8–6.5° C (Mason, et al. 1983). The temperature range for larvae and epipelagic juvenile growth was found to range between 5.6–16.5° C and 11.7–16.5° C, respectively (Kendall and Matarese 1987, Mason, et al. 1983, NOAA 1990).

Migrations and Movements

Sablefish are not considered to be a migratory species, although some individuals have been recorded as moving up to 2,735 km (Love 1996). Kimura, et al. (1998) conducted tagging studies with Alaskan and West Coast sablefish, and reported that most West Coast fish were recaptured in the area in which they were released; fewer than 10% of these fish moved more than 927 km. Some of these longer migrations were to mid-ocean seamounts. Alaskan fish tended to migrate more than the West Coast fish; however, most of the southern migrants from Alaskan waters tended to concentrate in the northern area of the West Coast. Sexually mature adults do not undergo any spawning migration (Beamish and McFarlane 1988, Hart 1973, Mason, et al. 1983, McFarlane and Beamish 1983a). Small juvenile sablefish descend to the bottom during the fall and remain in relatively shallow water for about a year before moving into deeper water (MBC Applied Environmental Sciences 1987). Saunders, et al. (1997) reported that sablefish older than 10 years were most common at sites off the west coast of Canada deeper than 800 m. They also reported that "length at age declined with depth and increased with latitude." Kimura, et al. (1998) also reported that West Coast sablefish seem to have a deeper, lower limit to their distribution off the West Coast, compared with their distribution off Alaska.

Heifetz and Fujioka (1991) reported that small fish move much more than do large fish. Hart (1973) recognized localized movement from shallow summer waters to deeper waters in the winter.

Reproduction

Spawning occurs annually in the late fall through winter in waters greater than 300 m (Hart 1973, NOAA 1990). Spawning occurs increasingly later in the winter in southern waters (Cailliet, et al. 1988, NOAA 1990).

A 53-cm female (5–7 years) may produce 100,000 eggs. A 98-cm female (10+ years) may produce as many as 1.3 million eggs (Kendall and Matarese 1987, Mason, et al. 1983, NOAA 1990).

Growth and Development

Fertilized eggs are spherical and about 1.8–2.2 mm in diameter (Kendall and Matarese 1987, Love 1996, Mason, et al. 1983, McFarlane and Beamish 1983b, NOAA 1990). Embryonic development is indirect and external; eggs hatch in about 15 days at 6° C (Mason, et al. 1983, NOAA 1990). Larvae hatch at about 5 mm and metamorphose at about 38 mm (Hart 1973, Mason, et al. 1983, NOAA 1990). Juveniles join the benthic community after 1–2 years in a pelagic stage. Females grow faster and larger and live longer than males.

Age and size at maturity are difficult to know because sablefish exhibit such a discontinuous growth rate. It was estimated that 50% of females are mature at 5–6 years and 61 cm, and 50% of males are mature at 5 years and 51 cm. However, McFarlane and Beamish (1990) found that tagged sablefish experienced significantly depressed growth, so length-age relationships may not be accurate. The growth rate after reaching maturity slows to 0.17–0.26 cm/year for males, and 0.55–0.66 cm/year for females (McFarlane and Beamish 1983b).

Trophic Interactions

Sablefish larvae prey on copepods and copepod nauplii. Copepod eggs provide accelerated growth rates (Grover and Olla 1990, Kendall and Matarese 1987, NOAA 1990). Pelagic juveniles feed on small fishes, copepods, and cephalopods (mainly squids) (Allen 1982, Hart 1973, Mason, et al. 1983). In the Gulf of Alaska, the primary prey of pelagic juveniles was euphausiids (73% by weight), followed by pelagic tunicates (9% by weight) (Sigler, et al. 2001). Demersal juveniles eat small demersal fishes, amphipods, and krill (NOAA 1990). Adult sablefish feed on fishes like rockfishes and octopus (Hart 1973, McFarlane and Beamish 1983a). Fish (e.g., rockfish and anchovy) have been reported as the primary prey for sablefish 250–750 mm captured off of the coasts of Oregon and California (Laidig, et al.1997, Allen 1982). However, the predominant prey organisms in sablefish (average length of 500 ± 2.6 mm and 590 ± 2.5 mm for shelf- and slope-caught fish, respectively) collected off of the southwest coast of Vancouver Island were euphausiids (Tanasichuk 1997). Among the fish prey, this author reported that Pacific herring (*Clupea pallasi*) were the most important.

Larvae and pelagic juvenile sablefish are heavily preyed upon by sea birds and pelagic fishes. Juveniles are eaten by Pacific cod, Pacific halibut, lingcod, spiny dogfish, and marine mammals, such as Orca whales (Cailliet, et al. 1988, Hart 1973, Love 1996, Mason, et al. 1983, NOAA 1990).

Sablefish compete with many other co-occurring species for food, mainly Pacific cod and spiny dogfish (Allen 1982).

Scorpaeniform Roundfishes Group Summary Information (updated September 2012)

New literature on spatial associations and trophic interactions for the scorpaeniform roundfishes consisted of a total of 63 individual references: 42 for lingcod, 10 for kelp greenling, 2 for cabezon, and 10 for sablefish.

Spatial Associations

Some contemporary spatial information is available for all of the members of the scorpaeniform subgroup, although most attention has been focused on lingcod and sablefish. Cabezon tagged at an oil platform in Southern California were rather sedentary with a strong 24–hour activity cycle, but vertical movements along the platform may have obscured residency results (Lowe, et al. 2009). No significant difference in occurrence was found for kelp greenling among mud, oyster, and eel grass habitats in a Washington estuary (Hosack, et al. 2006); however, this species was also reported in association with boulders (Hart, et al. 2010), cobble and bedrock (Thedinga, et al. 2008). Canopy and understory kelp supported year–round populations of (primarily kelp) greenlings in Cook Inlet, Alaska (Hamilton and Konar 2007). No difference in abundance of lingcod was noted between day and night surveys at Hecate Bank (Hart, et al. 2010), or among mud, oyster or eelgrass habitats in a Washington estuary (Hosack, et al. 2010). This species can be considered a habitat generalist but it prefers some structure to open (mud or sand) seafloors (Love and York 2005, 2006; Anderson and Yoklavich 2007), especially during the juvenile stage (Petrie and Ryer 2006). Juvenile lingcod have high site fidelity (Petrie and Ryer 2006; Reynolds, et al. 2010) and variable home ranges. In the San Juan Islands, sizes corresponding to adult lingcod (70–80 cm TL) exhibited much larger home ranges (21,272 + 13,630 m2, Beaudreau and Essington 2011) than a mixture of presumably juvenile and adult lingcod (45–68 cm TL) in Puget Sound (~500–2200 m2). Starr, et al. (2004, 2005) determined that larger, adult lingcod (> 80 cm TL) frequently left the boundaries of a reserve off Sitka, Alaska, but only for short periods of time and generally showed high site fidelity. In the Gulf of Alaska, twenty years of tag returns showed that sablefish move to deeper water with age, and exhibit a general, counterclockwise migration pattern (Maloney and Sigler 2008). Sablefish are highly mobile and may migrate to (and spawn in) the western Bering Sea (Orlov 2004).

Trophic Interactions

Trophic information is available for lingcod, sablefish, and kelp greenling. Juvenile lingcod in the northern California Current ate primarily large copepods with small fishes also contributing substantially to diet composition (Miller and Brodeur 2007), whereas a wide size range of juvenile and adult lingcod (15–110 cm TL) were predominantly piscivorous in the San Juan Islands regardless of length. Lingcod were major predators of Pacific herring (Schweigert, et al. 2010) and rockfish (Beaudreau and Essington 2007) in British Columbia and northern Washington, respectively. Rockfish consumption was estimated to be 5–10 times greater in marine reserves than non–reserves in the San Juan Island region (Beaudreau and Essington 2009). Predation on rockfish by lingcod may indirectly increase abundance of pandalid shrimps, a major prey item of rockfish, in southern British Columbia (Frid and Marliave 2010). Juvenile sablefish ate mainly euphausiids in the northern California Current, with crabs and fishes also contributing substantially to diet composition (Miller and Brodeur 2007). In the Gulf of Alaska, a mixture of juvenile and adult sablefish ate primarily pollock, with cephalopods and gammarid amphipods also important prey taxa (Yang, et al. 2006). Sablefish are one of the main predators of Pacific herring off British Columbia (Schweigert, et al. 2010) and predation of salmon juveniles could negatively impact returns of adults in Southeast Alaska (Sturdevant, et al. 2009).

Scavenging behavior was reported for sablefish (Yang, et al. 2006; Yeh and Drazen 2011) and kelp greenling (Davies, et al. 2006). Kelp greenling has been reported in the diets of Alaska skates (Yang 2007), Stellar sea lions (Vollenweider, et al. 2006; McKenzie and Wynne 2008), California sea lions (Orr, et al. 2011), and pigeon guillemots (Robinette, et al. 2007). Lingcod has recently been reported in the diet of harbor seals (Orr, et al. 2004) and pigeon guillemots (Robinette, et al. 2007). Sablefish has been reported as common prey of Stellar sea lions off Southeast Alaska (Csepp, et al. 2011) and salmon sharks in Prince William Sound (Hurlburt, et al. 2005). Sperm whale depredation of sablefish from longline gear is common, especially in the central and eastern Gulf of Alaska (Sigler, et al. 2008).

8. ELASMOBRANCHS: SHARKS AND SKATES

Sharks and skates are members of the subclass Elasmobranchi and are cartilaginous fishes (class Chondrichthys (Ebert 2003). The leopard shark (*Triakis semifasciata*) is a ground shark (Order Carcharhiniformes) in the family Triakidae, and is considered to be small to medium sized among sharks. It is iteroparous viviparous, with fertilization occurring internally and embryogenesis occurring within the female, without the involvement of a yolk sac placenta (Ebert 2003). The Spiny dogfish (*Squalus suckleyi*) is also viviparous and is a member of the family Squalidae.

The two species of skates, big skate (*Beringiraja* (*Raja) binoculata*) and longnose skate (*R. rhina*), are in the family Rajidae, known as hardnose skates. They are both oviparous; eggs are fertilized internally and deposited on the bottom to develop and hatch. When the eggs are laid, they are covered with a thick leathery membrane, the egg capsule or shell (Cox 1963, Ebert 2003). When the eggs hatch, the young are fully developed although they do have a yolk sac that is gradually absorbed (Talley 1983).

Leopard Shark (Triakis semifasciata)

Range

Leopard sharks are found from southern Oregon to Baja California, Mexico including the Gulf of California (Eschmeyer, et al. 1983, Ebert 2003).

Fishery

Most leopard sharks are caught as part of the recreational fishery (Ebert 2003). They are also targeted by small-scale commercial line fisheries, especially in San Francisco Bay (Compagno 1984, Emmett, et al. 1991).

Habitat

A coastal species, the leopard shark is most abundant in northern California bays and estuaries and along southern California beaches (Ebert 2003). Although they are common in enclosed, muddy bays, other habitats of the leopard shark are flat, sandy areas, mud flats, sandy and muddy bottoms strewn with rocks near rocky reefs, and kelp beds (Compagno 1984, Emmett, et al. 1991, Eschmeyer, et al. 1983, Ferguson and Cailliet 1990, Love 1996, Smith 2001). It is common in littoral waters (Castro 1983, Compagno 1984, Ebert 1976, Emmett, et al. 1991, Eschmeyer, et al. 1983, Love 1996, Russo 1975) and around jetties and piers (Emmett, et al. 1991). It is also known to congregate around warm-water outfalls of power plants (Smith 2001). The leopard shark occurs in polyhaline-euhaline waters.

Leopard sharks are most common on or near the bottom in waters less than 20 m deep, but have been caught as deep as 91 m (Emmett, et al. 1991, Smith and Abramson 1990).

Estuaries (Emmett, et al. 1991) and shallow coastal waters (Smith 2001) appear to be used as pupping and feeding/rearing grounds. Neonate pups occur in and just beyond the surf zone in areas of southern California, such as Santa Monica Bay (Smith 2001), and they are also found near eel grass beds in other bays, such as San Francisco Bay and Humboldt Bay (Ebert 2003).

Migrations and Movements

Leopard sharks often enter shallow bays and onto intertidal flats during high tides and retreat on ebb tides. Leopard sharks are active during the day, unlike other nocturnal sharks (Emmett, et al. 1991, Eschmeyer, et al. 1983). They may form large nomadic schools that may be mixed with gray or brown smoothhounds, sevengill shark, bat rays, or spiny dogfish (Castro 1983, Compagno 1984, Emmett, et al. 1991, Love 1996, Ebert 2003). These schools are often composed single sexes or size cohorts (Ebert 2003).

In Elkhorn Slough, most adult leopard sharks arrive in April and leave by November, whereas juveniles are most abundant there during the summer (G. Cailliet[411]). Tagging studies in San Francisco Bay show most leopard sharks reside in the bay during March through September, but they also occur both inside and outside the bay from October to February (Emmett, et al. 1991, Smith and Abramson 1990).

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Reproduction

Leopard sharks have a gestation period of 10–12 months (Castro 1983, Emmett, et al. 1991, Kusher, et al. 1992, Smith and Abramson 1990). Mating occurs soon after the females give birth, probably in April and May. Females give birth to 7–36 pups (Smith 2001) from March to August (Compagno 1984, Emmett, et al. 1991).

Growth and Development

Young develop inside the mother but do not receive nourishment from her yolk. Leopard sharks are born as juveniles ranging in size from 18–20 cm at parturition (Castro 1983, Compagno 1984, Emmett, et al. 1991). The maximum recorded length of a leopard shark is 180 cm, but with an average growth rate estimated at 1.4 cm per year, most do not exceed 160 cm in length (Bannister 1989, Castro 1983, Compagno 1984, de Wit 1975, Ebert 1986, Emmett, et al. 1991, Eschmeyer, et al. 1983, Kusher, et al. 1992). Females may take 10–15 years to reach maturity, while males may only take 7–13 years (Smith In Press). Maximum age is reported to be 30 years (Smith 2001).

Trophic Interactions

The leopard shark utilizes several major food sources without depending upon one (Talent 1976), and feeding habits are dependent upon the size of the shark. Juveniles and adults are carnivorous, opportunistic, benthic and littoral feeders. Small sharks (<90 cm) in Elkhorn Slough are known to feed almost entirely on crabs (Talent 1976) and in San Francisco Bay, on crabs and shrimp, particularly of the genus *Crangon* (P. Reilly[42]). Leopard sharks 90–120 cm in length feed mostly on echiuroid worms (*Urechis caupo*). Sharks 120–130 cm feed on crabs, clam siphons, fishes, fish eggs, and *Urechis caupo* (Ebert 2003). Fishes make up the greatest portion of food eaten by 130–140 cm long sharks (Talent 1976). Leopard sharks also prey upon polychaete worms and octopi and feed rapidly on the eggs of herring, topsmelt, jacksmelt, and midshipmen when available (Compagno 1984, Love 1996).

Presence of mud-burrowing prey in their diet signifies that the leopard shark is feeding very close to or in the mud (Compagno 1984). The leopard shark must display a sucking or digging behavior to remove clam siphons and *Urecis caupo* from the mud (Russo 1975, Talent 1976).

In Elkhorn Slough, adult leopard sharks seasonally shift their diet preference. During the fall, when fish eggs are not abundant, they feed more on clams and crabs. During the winter and spring, the yellow shore crab decreases in importance whereas cancrid crabs, fish eggs, and *Urechis caupo* increase as prey items (Talent 1976). Leopard sharks do not compete for food sources with neighboring shark species because their diets differ (de Wit 1975).

The leopard shark probably has no major predators except man (Emmett, et al. 1991) and possibly other shark species (Smith 2001).

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Spiny Dogfish (Squalus suckleyi)

Range

Spiny dogfish are found in temperate and subarctic latitudes in both the northern and southern hemispheres. In the northern and central Pacific Ocean, they occur from the Bering Sea to Baja California (Allen and Smith 1988, Castro 1983, Eschmeyer, et al. 1983).

Fishery

They are the most abundant and economically important shark off North American coasts (Castro 1983). In recent years, large numbers of dogfish have been taken in commercial trawl, set net, and longline fisheries, especially in Puget Sound, to supply foreign markets.

Spiny dogfish can be readily caught by rod and reel, longline, trawl or set net (Allen and Smith 1988, Ebert 1986, Jones and Geen 1977a, Ketchen 1972). They are fished for biology class dissections and research (Lineaweaver and Backus 1984). Dogfish are often regarded as a menace to fisheries because they cause damage to nets and lines, and they rob hooks (Castro 1983, Lineaweaver and Backus 1984, NOAA 1990).

Habitat

For the North Pacific and Bering Sea, Allen and Smith (1988) report that the Spiny dogfish is an inner shelf-mesobenthal species with a depth range of 0–1236 m. From survey data, they determined that most dogfish inhabit waters less than 350 m deep (Bannister 1989, Castro 1983, Lineaweaver and Backus 1984, NOAA 1990). They occur from the surface and intertidal areas to greater depths (Allen and Smith 1988, Bannister 1989, Castro 1983, Lineaweaver and Backus 1984, NOAA 1990), and are common in inland seas, such as San Francisco Bay (Ebert 1986) and Puget Sound (Allen and Smith 1988), and in shallow bays from Alaska to central California (Eschmeyer, et al. 1983).

Adult females move inshore to shallow waters during the spring to release their young (Jones and Geen 1977a, NOAA 1990). Small juveniles (<10 years old) are pelagic, while subadults and adults are mostly sublittoral-bathyal (NOAA 1990, Ebert 2003). Subadults are found on muddy bottoms when not found in the water column (NOAA 1990).

Known physical and chemical requirements are euhaline waters of 3.7–15.6° C, with a preferred range of 7 - 15° C (NOAA 1990, Ebert 2003).

In southern California, Spiny dogfish are often found in close association with white croaker (Castro 1983, Ferguson and Cailliet 1990, NOAA 1990).

Migrations and Movements

Dogfish often migrate in large schools, which feed avidly on their journeys (Bannister 1989). Seasonal migrations are taken so as to stay in the preferred temperature range (Castro 1983). Schooling behavior occurs with inshore populations and with migratory offshore populations (Eschmeyer, et al. 1983). The schools, numbering in the hundreds, exhibit north-south coastal movements and onshore-offshore movements that are not completely understood (Castro 1983, Ferguson and Cailliet 1990, Lineaweaver and Backus 1984). The schools tend to divide up according to size and gender although the young, both male and female, tend to stay together (Ferguson and Cailliet 1990, NOAA 1990).

Spiny dogfish can travel long distances. In one instance a tagged dogfish from Queen Charlotte Sound in 1980 was recovered off the northeast coast of Japan in 1982 (Ferguson and Cailliet 1990, McFarlane and Beamish 1986a). They also make diel migrations from near bottom during the day to near surface at night (NOAA 1990).

Reproduction

Mating with internal fertilization occurs on the ocean bottom between September and January (Jones and Geen 1977a, Ketchen 1972, NOAA 1990). Fecundity is 2 – 12 eggs per female, per season (Castro 1983, Eschmeyer, et al. 1983, Jones and Geen 1977a, NOAA 1990, Ebert 2003). Males and females mate annually (Jones and Geen 1977a, NOAA 1990). Their gestation period lasts 18–24 months, depending upon area, the longest of any vertebrate (Bannister 1989, Jones and Geen 1977a, Nammack, et al. 1985, NOAA 1990, 301). Females release their young in the midwater zone over depths of 165 – 350 m during the spring in shallow waters (Ebert 2003). Small litters (4–7 pups) are common, but litter size may range from 2 to 20 pups. Newborn pups range in length from 22 to 33 cm (Castro 1983, Jones and Geen 1977a, Ketchen 1972, Lineaweaver and Backus 1984, Ebert 2003).

Growth and Development

Small litters (4–7 pups) are common, but litter size may range from 2 to 20 pups. Newborn pups range in length from 22 to 33 cm (Castro 1983, Jones and Geen 1977a, Ketchen 1972, Lineaweaver and Backus 1984, Ebert)._Females reach sexual maturity at 16–35 years, with an average age of 24 (Smith, et al. 1998, Ebert 2003), and males reach maturity at 11–19 years, average age of 14 (Ebert 2003). The maximum age of females is about 70 years (Smith, et al. 1998). Females live longer than males, which only live to a maximum of 36 years (Bannister 1989, Castro 1983, Eschmeyer, et al. 1983, Ferguson and Cailliet 1990, Jones and Geen 1977a, Ketchen 1972, Lineaweaver and Backus 1984, McFarlane and Beamish 1986a, NOAA 1990).

Spiny dogfish seem to be larger at the northern end of their range. Adults usually range in size from 75 to 103 cm, although they may reach a maximum size of 130 cm (10 kg) (Allen and Smith 1988, Bannister 1989, NOAA 1990) and maximum age of 66 years (Munk 2001). Their growth rate is 1.5–3.5 cm per year (Castro 1983, Ebert 1986).

Trophic Interactions

They are carnivorous scavengers (NOAA 1990). They are an opportunistic feeder, taking whatever is available. They are important predators on many commercial fishes and invertebrates (NOAA 1990). Their diet consists primarily of fish, especially sandlance, herring, smelts, cods, capelin, hake, and ratfish; and of invertebrates, particularly shrimp, crabs, worms, krill, squid, octopus, jellyfish, and sea cucumbers (Bannister 1989, Ebert 2003). Fish become a more important dietary source as the dogfish grow larger (Castro 1983, Ferguson and Cailliet 1990, Jones and Geen 1977b, NOAA 1990). Most of the diet of juveniles consists of pelagic prey, generally small invertebrates, whereas the adults prey largely on benthic organisms (Ebert 2003).

Based on occurrences, 55% of the diet of dogfish off British Columbia was teleosts, 35% crustaceans, and 5% mollusks. The principal food items consisted of herring and euphausiids (Jones and Geen 1977b). Pelagic prey consisted of 80% of their diet and they consumed twice as much food in the summer as in the winter (Jones and Geen 1977b, NOAA 1990).

Spiny dogfish may compete with sablefish, Pacific cod, soupfin shark, and sea lions (NOAA 1990). They are preyed upon by a variety of shark species, including sixgill, sevengill, leopard, and great white; by a variety of larger fishes, such as lancetfishes, and some rockfish; and by some marine mammals (Ebert 2003). For defense, it possesses a strong spine in front of its two dorsal fins that is partially sheathed by toxic tissue (Castro 1983, Jones and Geen 1977a, NOAA 1990).

Big Skate (Beringraja (Raja) binoculata)

Range

Big skates are found from the eastern Bering Sea to Cabo Falsa, southern Baja California, Mexico, but are uncommon south of Point Conception (Martin and Zorzi 1993, Ebert 2003).

Fishery

Coastal trawl fleets account for the majority of the catch off the West Coast, although they are generally taken as bycatch in other fisheries (Ebert 2003). Only the pectoral fins, or "wings," are bought commercially. Big skates are also occasionally taken by recreational fishers, particularly in Monterey Bay and San Francisco Bay (Roedel and Ripley 1950, Ebert 2003).

Habitat

Big skates are relatively abundant in northern and central California, but are not common south of Point Conception (Roedel and Ripley 1950). The big skate occupies inner and outer shelf areas (Allen and Smith 1988), particularly on soft bottom.

Records show big skates inhabiting water as shallow as 3 m (Martin and Zorzi 1993), but in survey catches in the North Pacific they are found most frequently on the outer shelf in waters 50–200 m deep (Allen and Smith 1988). Over their range, big skates have been taken from waters up to 800 m deep (Allen and Smith 1988, Martin and Zorzi 1993); however, few occur deeper than 350 m (Allen and Smith 1988). Juveniles are associated with soft bottom sediments (California Dept. of Fish and Game 2003). In an assessment of habitat types and associated fish assemblages using a submersible at Heceta Bank off the southern Oregon coast, Tissot, et al. (In Review) found that adult skate were most commonly found in habitat consisting of mud and sea urchins (*Allocentrotus*). They were evenly and sparsely distributed over mud bottoms, and usually lay on the bottom. In a limited study of big skate in the Bering Sea involving observations of only three skate, Busby, et al. (In Press) reported that they were either associated with silty sediment, or with sediment consisting of a mixture of mud, sand, gravel, and cobble.

Egg cases of big skates are deposited on the bottom. Off Oregon, egg cases were taken at depths up to 120 m, but were by far most abundant at 64 m (Hitz 1964).

Migrations and Movements

Little is known about the movements of big skates (Martin and Zorzi 1993).

Reproduction

Big skates have a low rate of fecundity (Talley 1983). The shape of the big skate egg capsule is characterized by two prominent dorsal ridges and the rectangular outline with short, flattened horns (Hitz 1964, Cox 1963). The egg case is unique among skates because it can measure up to 30 cm in length (Eschmeyer, et al. 1983) and can contain up to 7 eggs per case (Cox 1963) with an average of 3–4 (Eschmeyer, et al. 1983).

Clemens and Wilby (1961) believe egg cases are laid year round, whereas DeLacy and Chapman (1935) indicate a possible seasonal laying. The egg cases in early development are green-brown in color, and those in later stages of development are brownish black. DeLacy and Chapman (1935) also speculate that big skates remain in their egg cases for almost a year.

Growth and Development

The big skate is a long-lived species that grows and matures slowly. They probably live to be 20–30 years of age (Talley 1983). Off central California, some males may mature by age 6, but most are mature by age 10–11(at about 1.0 m) (Ebert 2003). Most females were mature by age 12 (at about 1.3 m) (Zeiner and Wolf 1990, Ebert 2003). Big skate can reach 2.4 m in length, but skate longer than 1.8 m are uncommon (Ebert 2003).

Trophic Interactions

Big skate adults feed on crustaceans, small benthic fishes, polychaete worms, and molluscs (Eschmeyer, et al. 1983, Hart 1973, Ebert 2003). Juveniles consume primarily polychaete worms and mollusks. Big skate are preyed upon by sevengill shark and northern elephant seals (Ebert 2003).

Longnose Skate (Raja rhina)

Range

Longnose skates are found from Navarin Canyon in the Bering Sea and Unalaska Island in the Aleutian Islands to Cedros Island, Baja California, Mexico, and the Gulf of California (Allen and Smith 1988, Martin and Zorzi 1993, Ebert 2003).

Fishery

Longnose skate have little commercial value, although the coastal trawl fleets account for the majority of catch off the West Coast in the form of bycatch (Ebert 2003). In California, the leading areas for skate landings are San Francisco and Monterey (Martin and Zorzi 1993).

Habitat

The longnose skate is one of the more common skates (Roedel and Ripley 1950) and occurs on the bottom in inner and outer shelf areas from 0 to 1,069 m (Lauth 1999, Ebert 2003). Based on survey data for the North Pacific, they are most frequently taken at depths of 100– 150 m, with nearly all taken at depths of less than 350 m (Allen and Smith 1988). Eggs are deposited on the bottom (Cox 1963). Juveniles and adults are associated with soft bottom sediments and with combinations of mud and cobble near high relief structures (California Dept. of Fish and Game 2003, Ebert 2003).

Migrations and Movements

Little is known about their movements (Martin and Zorzi 1993).

Reproduction

When longnose skate eggs are laid, they are enclosed in a rough, leathery shell with a loose covering of fibers and short horns (Cox 1963). Their egg cases generally hold one egg each and are 9.4 – 13.0 cm in length (DeLacy and Chapman 1935, Roedel and Ripley 1950).

Growth and Development

Skates are long-lived creatures that grow and mature slowly (Talley 1983). Their lifespan is estimated at 20–30 years (Talley 1983). Male longnose skates are smaller than females (Ebert 2003). Males are mature by age 10-11 years, and females are mature by 10–12 years (Zeiner and Wolf 1990, Ebert 2003).

Trophic Interactions

Longnose skate less than 60 cm generally prey on crustaceans, and those over 60 cm usually consume bony fishes; prey organisms are frequently found on or near reefs with a certain amount of vertical relief (Ebert 2003). They are preyed upon by sharks and sperm whales (Ebert 2003).

Elasmobranch Group Summary Information
(Updated September 2012)

Spatial Associations

Spatial information concerning eastern North Pacific elasmobranch fishes has increased substantially since the last EFH review. The longnose skate and spotted spiny dogfish occur in considerable abundance throughout the West Coast and are among the most common groundfish encountered in this region (Tolimieri and Levin 2006; Tolimieri 2007). These species are typically found on the outer continental shelf and upper continental slope, with spotted spiny dogfish occurring patchily throughout the water column in large schools (Taylor, et al. 2009). Studies of the movement patterns of three elasmobranch species were recently conducted. Female leopard sharks showed strong site fidelity within Elkhorn Slough and exhibited tidal movements that were probably related to foraging activity, and especially access to intertidal mudflats (Carlisle and Starr 2009, 2010). Leopard sharks also occupied relatively warm regions of southern California embayments during daylight hours, possibly to improve digestion and reproductive development (Hight and Lowe 2007). A large–scale tagging effort was conducted in British Columbia on big skate (King and McFarlane 2010) and spiny dogfish (McFarlane and King 2009). Although 75% of recaptures occurred within 21 km of the initial capture site, a small proportion of big skates (mainly females) traveled considerable distances (to 2340 km) (King and McFarlane 2010). Spiny dogfish tagged in the Strait of Georgia were largely recaptured within the same region, but a complex movement pattern and considerable exchange with North Puget Sound were evident (McFarlane and King 2009). The big skate and spotted spiny dogfish exhibited significant decreases in abundance with decreasing dissolved oxygen levels (Keller, et al. 2010). Love, et al. (2008) discovered a nursery area for the longnose skate between 125–151 m and 9.1–10.1° C on a high–relief rocky ridge off southern California.

Tropic Interactions

Trophic studies were additionally conducted for a number of elasmobranch species. A directed diet study in the Monterey Bay region showed that big skate ate crabs, fishes, and shrimps, but that comparably sized longnose skates ate mainly shrimps and fishes, with cephalopods also taken supplementally (Bizzarro, et al. 2007). By contrast, diets of large (> 60 cm TL) big and longnose skates differed substantially from those of small skates of all species, and contained a much greater proportion of fishes and marked reduction in the proportion of shrimps (Bizzarro, et al. 2007). A detailed, directed study of longnose skate diet was also conducted off central California and indicated dietary variability with increasing depth (more cephalopods and euphausiids) and size (decreasing amounts of crustaceans, increasing amounts of fishes and cephalopods) (Robinson, et al. 2007). Leopard sharks in Humboldt Bay ate primarily jack silverside eggs in early May, switching to cancer crabs in late May (Ebert and Ebert 2005). Several recent trophic studies suggested that spotted spiny dogfish have a diverse diet with considerable spatial and size–based variability (Miller and Brodeur 2007; Andrews and Foy 2009, Beamish and Sweeting 2009; Brodeur, et al. 2009). Predators of spiny dogfish were identified, including sixgill sharks (Gallucci and Langseth 2009), salmon sharks (Hurlburt, et al. 2005), Stellar sea lions (Vollenweider, et al. 2006), and California sea lions (Orr, et al. 2011).

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10. ABBREVIATIONS

CalCOFI = California Cooperative Fisheries Investigations unit

CDFW = California Department of Fish and Wildlife

CPUE = Catch per unit effort

EEZ = U.S. Exclusive Economic Zone (200 miles offshore)

EFH = Essential Fish Habitat

FL = Fork length

FMP = Fishery Management Plan

IUCN = International Union for the Conservation of Nature and Natural Resources, Brussels, Belgium

NMFS = National Marine Fisheries Service

NOAA = National Oceanic and Atmospheric Administration

NOS = National Ocean Service

ODFW = Oregon Department of Fish and Wildlife

PacFIN = Pacific Fisheries Information Network

PFMC = Pacific Fishery Management Council

ppm = parts per million

ppt = parts per thousand

WDFW = Washington Department of Fish and Wildlife

E = East longitude

W = West longitude

N = North latitude

S = South latitude

SL = Standard fish length

TL = Total fish length

OMZ = Oxygen minimum zone

NL = Notochord length

11. GLOSSARY

Abyssal zone. Ocean bottom at depths between 4,000 and 7,000 m.

Abyssopelagic. Living in the water column at depths between 4,000 and 7,000 m; the abyssopelagic zone.

Algae. A collective, or general name, applied to a number of primarily aquatic, photosynthetic groups (taxa) of plants and plant-like protists. They range in size from single cells to large, multicellular forms like the giant kelps. They are the food base for almost all marine animals. Important taxa are the dinoflagellates (division Pyrrophyta), diatoms (div. Chrysophyta), green algae (div. Chlorophyta), brown algae (div. Phaeophyta), and red algae (div. Rhodophyta). Cyanobacteria are often called blue-green algae, although blue-green bacteria is a preferable term.

Amphipoda. An order of laterally compressed (shrimp-like) crustaceans with thoracic gills, no carapace, and similar body segments. Although most are <1 cm long, they are an important component of zooplankton and benthic invertebrate communities. A few species are parasitic.

Anthropogenic. Refers to the effects of human activities. **Appendicularians.** A small tunicate found among surface marine plankton. **Areal.** Refers to a measure of area.
Ascidian. A tunicate (class Ascidiaceae) that has a generalized sac-like, cellulose body and is usually attached to the substratum.

Batch spawner. A species that spawns repeatedly, releasing batches of eggs and sperm.

Bathyal. The zone of ocean bottom at depths of 200 to 4,000 m, primarily on the continental slope and rise.

Bathybenthal. The intermediate and lower continental slope, usually at bottom depths of 500–2500 m in the Northeast Pacific Ocean.

Bathymetric. A depth measurement. Also refers to a migration from waters of one depth to another.

Bathypelagic. Ocean depths from 2,000 to 6,000 m.

Benthic. Pertaining to the bottom of an ocean, lake, or river. Also refers to sessile and crawling animals which reside in or on the bottom.

Benthopelagic. Occurring near or just above the bottom. *See also* **Demersal**. **Bight.** An inward bend or bow in the coastline.
Biomass. The total mass of living tissues (wet or dried) of an organism or collection of organisms of a species or trophic level, from a defined area or volume.

Bivalvia. Bilaterally symmetrical mollusks (also referred to as Pelecypoda) that have two lateral calcareous shells (valves) connected by a hinge ligament. They are mostly sedentary filter feeders. This class includes clams, oysters, scallops, and mussels.

Boreal region. The oceans of the northern hemisphere between the 0 and 13° C winter isotherms. In neritic waters of western North America, it extends from Point Conception, California, to the southern Bering Sea, Alaska.

Broadcast spawner. A species that releases eggs and sperm over a wide area of the ocean.

Bryozoa. Minute, moss-like colonial animals of the phylum Bryozoa. **Bycatch.** Marine species caught along with targeted species in a fishery. **Calcareous.** Composed of calcium or calcium carbonate.

Carangids. Burrowing shrimp.

Carnivore. An animal that feeds on the flesh of other animals. *See also* **Parasitism** *and* **Predation**. **Caudal fin.** The tail fin of a fish.

Cestode. A parasitic, ribbon-like worm having no intestinal canal; class Cestoda (e.g., tapeworms).

Chaetognaths. Known as arrowworms, these chordata are found in marine plankton; they are torpedo- shaped and 2–120 mm in length.

Chemotaxis. A response movement by an animal either toward or away from a specific chemical stimulus.

Chordata. A phylum of animals which includes the subphyla Vertebrata, Cephalochordata, and Urochordata. At some stage of their life cycles, these organisms have pharyngeal gill slits, a notochord, and a dorsal, hollow nerve cord (e.g., a spinal chord).

Cline. A series of differing physical characteristics within a species or population, reflecting gradients or changes in the environment (e.g., body size or color).

Colony. A group of organisms living in close proximity. An invertebrate colony is a close association of individuals of a species which are often mutually dependent and in physical contact with each other. A vertebrate colony is usually a group of individuals brought together for breeding and rearing young.

Commensalism. A relationship between two species, where one species benefits without adversely affecting the other.

Community. A group of plants and animals living in a specific region under relatively similar conditions. Further restrictions are often used, such as the algal community, the invertebrate community, the benthic gastropod community, etc.

Competition. Two types exist: interspecific and intraspecific. Interspecific completion exists when two or more species use one or more limited resources such as food, attachment sites, protective cover, or dissolved ions. Intraspecific competition exist when individuals of a single species compete for limited resource needed for survival and reproduction. This form of competition includes the same resources involved in interspecific competition as well as mates and territories. It is generally more intense than interspecific competition because resource needs are essentially identical within a species. *See also* **Niche**.

Congener. Referring to members of the same genus.

Continental rise. The gradually sloping seabed that connects the abyssal zone to the continental slope.

Continental shelf. The submerged continental land mass, not usually deeper than 200 m. The shelf may extend from a few miles off the coastline to several hundred miles.

Continental slope. The steeply sloping seabed that connects the continental shelf and continental rise.

Copepoda. A subclass of crustaceans with about 4,500 species, including several specialized parasitic orders. The free-living species are small (one to several mm) and have cylindrical bodies, one median eye, and two long antennae. One order is planktonic (Calanoida), one is benthic (Harpacticoida), and one has both planktonic and benthic species (Cyclopoida). In most species, the head appendages form a complex apparatus used to sweep in and possibly filter prey (especially algae). Thoracic appendages are used for swimming or crawling on the bottom. One of the most abundant group of animals on earth, they are a major link in aquatic food webs.

Crepuscular. Relates to animals whose peak activity is during the twilight hours of dawn and dusk.

Crustacea. A large class of over 26,000 species of mostly aquatic arthropods having five pairs of head appendages, including laterally opposed jaw-like mandibles and two pairs of antennae.

Ctenophora. A phylum of mostly marine animals that have oval, jellylike bodies bearing eight rows of comb-like plates that aid swimming (e.g., ctenophores and comb jellies).

Cumaceans. Sediment-dwelling invertebrate, is usually less than 2 cm in length. They have a carapace that encloses the anterior thoracic segments, which form a gill chamber.

Cypriot. Larval stage of a barnacle.

Decapod. Includes the order Decapoda, which includes shrimp, crabs, and other crustaceans.

Demersal. Refers to swimming animals that live near the bottom of an ocean, river, or lake. Also refers to eggs that are denser than water and sink to the bottom after being laid. *See also* **Parademersal**, **Semi-demersal**, *and* **Benthic**.

Deposit feeder. An animal that ingests small organisms, organic particles, and detritus from soft sediments, or filters organisms and detritus from such substrata.

Desiccate. To dry completely.

Detritivore. An organism that eats small fragments of partially decomposed organic material (detritus) and its associated micro-flora.

Diatoms. Single-celled protistan algae of the class Bacillariophyceae that have intricate siliceous shells composed of two halves. They range in size from about 10 to 200 microns. Diatoms sometimes remain attached after cellular divisions, forming chains or colonies. These are the most numerous and important group of phytoplankters in the oceans, and form the primary food base for marine ecosystems.

Diel. Refers to a 24-hour activity cycle based on daily periods of light and dark. *See also* **Diurnal**.

Dimorphism. A condition where a population has two distinct physical forms (morphs). In sexual dimorphism, secondary sexual characteristics are markedly different (e.g., size, color, and behavior).

Dinoflagellate. A planktonic photosynthetic, unicellular algae that typically has two flagella, one being in a groove around the cell and the other extending from the center of the cell.

Direct development. *See* Embryonic development.

Dispersal. The spreading of individuals throughout suitable habitat within or outside the population range. In a more restricted sense, the movement of young animals away from their point of origin to locations where they will live at maturity.

Distribution. (1) A species distribution is the spatial pattern of its population or populations over its geographic range. *See* **Range**. (2) A population age distribution is the proportions of individuals in various age classes. (4) Within a population, individuals may be distributed evenly, randomly, or in groups throughout suitable habitat.
Diurnal. Refers to daylight activities, or organisms most active during daylight. *See also* **Diel**.
Echinodermata. A phylum of radial-symmetrical marine animals, possessing a water vascular system, and a hard, spiny skeleton (e.g., sea stars, sea urchins, and sand dollars).

Echiurid proboscis. Some echiurans, or spoonworms, are sediment dwellers and extend their prostomium (or proboscis) onto the sediment surface.

Eelgrass. Vascular flowering plants of the genus Zostera that are adapted to living under water while rooted in shallow sediments of bays and estuaries.

Eelpout. Elongate, tapering marine fish commonly found in the North Pacific.

Electroreception. The ability to detect magnetic fields radiated by marine animals.

El Niño current. An intermittent warm water current from the tropics that overrides the opposing cold current along the Pacific coasts of north and South America (*see* **Gyre**). This raises near-surface temperatures, depresses the thermocline, and often suppresses upwelling, resulting in drastic drops in primary productivity and reduced recruitment of marine animals. This is most pronounced on the coast of Peru. Effects are not as severe in North America, but northward shifts in distributions of “southern” species are common in El Nino years.

Embryonic development. The increase in cell number, body size, and complexity of organ systems as an individual develops from a fertilized egg until hatching or birth. In direct development, individuals at birth or hatching are essentially miniatures of the adults. In indirect development, newly hatched individuals differ greatly from the adult, and go through periodic, major morphological changes (larval stages and metamorphosis) before becoming a juvenile.

Emigration. A movement out of an area by members of a population. *See also* **Immigration**.
Endemic. Refers to a species or taxonomic group that is native to a particular geographical region.

Epibenthic. Located on the surface of the bottom sediments, as opposed to within the bottom sediments.

Epidermal. Refers to an animal's surface or outer layer of skin.

Epifauna. Animals living on the surface of the bottom sediments.

Epi-mesopelagic. Zone of marine waters between epipelagic and mesopelagic.

Epipelagic. The upper sunlit zone of oceanic water where phytoplankton live and organic production takes place (approximately the top 200 m). *See also* **Euphotic**.

Escarpment. A steep slope in topography, as in a cliff or along the continental slope.

Estuary. A semi-enclosed body of water with an open connection to the sea. Typically there is a mixing of sea and fresh water, and the influx of nutrients form both sources results in high productivity.

Euhaline. Water with salt concentrations of 30–40 ppt. *See also* **Euryhaline, Hypersaline**, **Mesohaline**, **Polyhaline**, *and* **Fresh water**.

Euphausiid. Also known as krill, these shrimp-like crustaceans are about 3 cm in length and are pelagic.

Euphotic. Refers to the upper surface zone of a water body where light penetrates and phytoplankton (algae) carry out photosynthesis. *See also* **Epipelagic**.

Euryhaline. Refers to an organism that is tolerant of a wide range of salinities. *See also* **Euhaline, Hypersaline**, **Mesohaline**, **Polyhaline**, *and* **Fresh water**.

Eurythermal. Refers to an organism that is tolerant of a wide range of temperatures.

Extant. Existing or living at the present time; not extinct.

Fauna. All of the animal species in a specified region.

Fecundity. The potential of an organism to produce offspring (measured as a number of gametes). *See also* **Reproductive potential**.

Filter feeder. Any organism that filters small animals, plants, and detritus from water or fine sediments for food. Organs used for filtering include gills in clams and oysters, baleen in whales, and specialized appendages in crustaceans and marine worms.

Flagellate. Refers to cells that have motility organelles or microorganisms that possess one or more flagellum used for locomotion.

Flexion. A fish larval stage coincident with the urostyle bending dorsally and the principal fin rays developing into the caudal fin.

Flora. All of the plant species in a specified region.

Food web (chain). The feeding relationships of several to many species within a community in a given area during a particular time period. Two broad types are recognized: (1) grazing webs involving producers (e.g., algae), herbivores (e.g., copepods), and various combinations of carnivores and omnivores; and, (2) detritus webs involving scavengers, detritivores, and decomposers that feed on the dead remains or organisms from the grazing webs, as well as on their own dead. A food chain refers to organisms on different trophic levels, while a food web refers to a network of interconnected food chains. *See also* **Trophic level**.

Fork length – The length of a fish measured from the tip of the snout to the base of the fork in the tail.

Fouling. Occurs when large numbers of plants or animals attach and grow on various structures (floats, pipes, and pilings), often interfering with their use. Fouling organisms include barnacles, mussels, bryozoans, and sponges.

Fresh water. Water that has a salt concentration of 0.0–0.5 ppt. *See also* **Euryhaline, Hypersaline**, **Mesohaline**, **Polyhaline**, *and* **Euhaline**.

Gadids. Members of the family Gadidae, which includes Pacific cod and hake.

Gamete. A reproductive cell. When two gametes unite, they form an embryonic cell (zygote).

Gammarid. Amphipods commonly associated with sediments.

Gastropoda. The largest class of the Phylum Mollusca. This group includes terrestrial snails and slugs as well as aquatic species such as whelks, turbans, limpets, conchs, abalone, and nudibranch. Most have external shells that are often spiraled (but this has been lost or is reduced in some), and move on a flat, undulated foot. They are mostly herbivorous and scrape food with a radula, an organ analogous to a tongue.

Gonochoristic. Refers to a species that has separate sexes (i.e., male and female individuals).

Groundfish. Marine fish species that live on or near the bottom, often called bottomfish.

Gyre. An ocean current that follows a circular or spiral path around an ocean basin, clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

Habitat. The particular type of place where an organism lives within a more extensive area or range. The habitat is characterized by its biological components and/or physical features (e.g., sandy bottom of the littoral zone, or on kept blades within 10 m of the water surface).

Haracticoid. Members of the Order Harpacticoida, of the Class Copapoda. They are mostly free-living, bottom-dwelling copepods, although some are planktonic.

Herbivore. An animal that feeds on plants (phytoplankton, large algae, or higher plants).

Hydrozoa. A class of phylum Cnidaria. The primary life stage is nonmotile and has a sac-like body composed of two layers of cells and a mouth that opens directly into the body cavity. A second life stage, the free-living medusa, often resembles the common jellyfish.

Hyper saline. Water with a salt concentration over 40 ppt.

Immigration. A movement of an individual into a new population or region. *See also* **Emigration**, **Migration**, and **Recruitment**.

Incidental catch. Catch of a species that was not the focus of a fishery, but taken along with the species being sought. *See also* **Bycatch**.

Indirect development. *See* Embryonic development. Infauna. Animals living in bottom substrata. **Inner shelf**. The continental shelf extending from the mean low tide line to a depth of 20 m.

Instar. The intermolt stage of a young arthropod.

Insular. Of or pertaining to an island or its characteristics (i.e., isolated). **Intertidal**. The ocean of estuarine shore zone exposed between high and low tides. **Isobath**. A contour mapping line that indicates a specified constant depth.

Isopoda. An order of about 4,000 species of dorsoventrally compressed crustaceans that have abdominal gills and similar abdominal and thoracic segments. Terrestrial pillbugs and thousands of benthic marine species are included. Most species are scavengers and/or omnivores; a few are parasitic.

Isopondylous fish. Herring-like fishes with simplified anterior vertebrae.

Isotherm. A contour line connecting points of equal mean temperature for a given sampling period.

Iteroparous. Refers to an organism that reproduces several times during its lifespan (i.e., does not die after spawning).

Kelp holdfast. A branched, modified stem that attaches kelp to rocks or other hard substrata.

Kelp sporophyll. A leaf structure that bears sporangea (a spore-bearing structure).

Kinesis. A randomly directed movement by an animal in response to a sensory stimulus such as light, heat, or touch. When the response is directed, it is called a taxis. *See also* **Chemotaxis**.

Krill. *See* Euphausiid.

Lagoon. A shallow pond or channel linked to the ocean, but often separated by a reef or sandbar.

Larvae. An early developmental stage of an organism that is morphologically different from the juvenile or adult form. *See also* **Embryonic development**.

Lateral line. A pressure sensory system located in a line of pores under the skin on both sides of most fishes. The system is connected indirectly with the inner ear and senses water pressure changes due to water movement (including sound waves).

Lethal limit. The temperature or concentration of a substance that can cause mortality in an organism.

Littoral. The shore area between the mean low and high tide levels. Water zones in this area include the littoral pelagic zone and the littoral benthic zone.

Mean lower low water (MLLW). The arithmetic mean of the lower low water heights of a mixed tide over a specific 19-year Metonic cycle (the National Tidal Datum Epoch). Only the lower low water of each tidal day is included in the mean.

Megalopae. The larval stage of a crab characterized by an adult-like abdomen, thoracic appendages, and a developed carapace.

Meiofauna. Very small animals, usually <0.5 mm in diameter.

Meristic. Refers to countable measurements of segments or features such as vertebrae, fin rays, and scale rows. Counts of these are used in population comparisons and classifications.

Mesobenthic. Upper continental slope, usually at depths of 200–2,000 m in the Northeast Pacific Ocean.

Mesohaline. Water with a salt concentration of 5–18 ppt. *See also* **Euryhaline, Hypersaline**, **Euhaline**, **Polyhaline**, *and* **Fresh water**.

Mesopelagic. Ocean zone of intermediate depths from about 200–2,000 m below the surface, where light penetration drops rapidly and ceases.

Metamorphosis. Process of transforming from one body form to another form during development (e.g., tadpole changing to a frog). See **Embryonic development**.

Metric ton (mt). A unit of mass or weight equal to 2,204.6 lb.

Migration. Movement by a population or subpopulation from one location to another (often periodic or seasonal, and over long distances). Vertical migrations in the water column may be daily or seasonal within the same area. Migrations between deep and shallow areas are usually seasonal and related to breeding. Many marine birds and mammals have seasonal latitudinal migrations associated with breeding. *See also* **Emigration**, **Immigration**, **Range**, *and* **Recruitment**.

Milt. The seminal fluid and sperm of male fish.

Morphology. The appearance, form, and structure of an organism.

Mortality. Death rate expressed as a proportion of a population or community of organisms. Mortality is caused by a variety of sources, including predation, disease, environmental conditions, etc.

Motile. Capable of or exhibiting movement or locomotion.

Multiple brooders. Species which release multiple batches of larvae over the course of a spawning season.

Mutualism. An interaction between two species where both benefit. Some authorities consider true mutualism to be obligatory for both species, while mutually beneficial relationships that are not essential for either species are classified as protocooperative (e.g., the blacksmith cleaning fish eating external parasites from sea basses).

Mysids. Small shrimp-like crustaceans, 2–30 mm in length.

Nanoplankton. Microscopic, planktonic organisms smaller than 20 microns in diameter.

Naplii. Earliest stage of crustacean larvae.

Natal. Pertaining to birth or hatching.

Nearshore. Area between surf zone and continental shelf.

Nektonic. Refers to pelagic animals that are strong swimmers, live above the substrate in the water column and can move independently of currents.

Nemertea. A phylum of unsegmented, elongate marine worms having a protrusible proboscis and no body cavity, and live mostly in coastal mud or sand; nemertean.

Neritic. An oceanic zone extending from the mean low tide level to the edge of the continental shelf. *See also* **Inner shelf**, **Littoral**, *and* **Oceanic zones**.

Neuston. Organisms that live on or just under the water surface, often dependent on surface tension of support.

Niche. The fundamental niche is the full range of abiotic and biotic factors under which a species can live and reproduce. The realized niche is the set of actual conditions under which a species or a population of a species exists, and is largely determined by interactions with other species.

Nocturnal. Refers to night, or animals that are active during night.

Notochord – Longitudinal cartilaginous rod that supports of the axis of the body.

Notochord length – The distance from the tip of the snout to the posterior tip of the notochord.

Nudibranch. Known as sea slugs, they are slug-like molluscs without shells.

Oceanic. Living in or produced by the ocean.

Oceanic zone. Pelagic waters of the open ocean beyond the continental shelf. *See also* **Bathypelagic**, **Epipelagic**, **Abyssopelagic**, **Mesopelagic**, *and* **Neritic**.

Oligohaline. Water with a salt concentration of 0.5–5.0 ppt. *See also* **Fresh water**. **Omnivore**. An animal that eats both plants and animals.

Ontogenetic – Refers to the development of an organism and its behavior progressively changing with maturity.

Oocyte. The cells in ovaries that will mature into eggs.

Ophiouroids. Echinoderms known as basket stars or brittle stars.

Opisthobranchs. Gastropods with a well-developed shell and a single gill.

Oregon province. A zoogeographical designation for faunal distributions that extends from Cape Flattery, Washington, to Point Conception, California.

Otoliths. Small calcareous nodules located in the inner ear of fish used for sound reception and equilibration. They are often used by biologists to assess daily or seasonal growth increments.

Out-migration. Movement of animals out of or away from an area (e.g., juvenile salmonids moving from rivers to the ocean).

Ovigerous. The condition of being ready to release mature eggs; egg-bearing.

Oviparous. Refers to animals that produce eggs that are laid and hatched externally. *See also* Ovoviviparous *and* Viviparous.

Oviposition. The process of placing eggs on or in specific places, as opposed to randomly dropping or broadcasting them.

Ovoviviparous. Refers to animals whose eggs are fertilized, developed, and hatched inside the female, but receive no nourishment from her. *See also* **Oviparous** *and* **Viviparous**.

Parademersal. Refers to a species or animals that occupy a vertical zone somewhat intermediate between those that are clearly associated with the bottom and those usually observed well up in the water column. *See also* **Demersal.**

Parasitism. An obligatory association where one species (parasite) feeds on, or uses the metabolic mechanisms of the second (host). Unlike predators, parasites usually do not kill their hosts, although hosts may later die from secondary causes that are related to a weakened condition produced by the parasite. Parasitism may also be fatal when high parasite densities develop on or in the host.

Parturition. The act of giving birth. *See also* **Spawn**.

Pathogen. A microorganism or virus that produces disease and can cause death. **Pelagic**. Pertaining to the water column, or to organisms that live in the water column. **Pelagivore**. A carnivore that feeds in the water column.

Phylogeny. Refers to evolutionary relationships and lines of descent.

Phytoplankton. Microscopic plants and plant-like protists (algae) of the epipelagic and neritic zones that are the base of offshore food webs. They drift with currents, but usually have some ability to control their level in the water column. *See also* **Algae** *and* **Diatoms**.

Piscivorous. Refers to a carnivorous animal that eats fish.

Planktivorous. Refers to an animal that eats phytoplankton and/or zooplankton.

Plankton. *See* Phytoplankton *and* Zooplankton.

Polychaeta. A class of segmented, mostly marine, annelid worms that bear bristles and fleshy appendages on most segments.

Polyhaline. Water with a salt concentration between 18 and 30 ppt. *See also* **Euryhaline, Hypersaline**, **Mesohaline**, **Euhaline**, *and* **Fresh water**.

Population. All individuals of the same species occupying a defined area during a given time. Environmental barriers may divide the population into local breeding units with restricted immigration and interbreeding between the localized units. *See also* **Species**, **Subspecies**, *and* **Subpopulation**.

Post-flexion. A fish larvae stage after the development of fin rays. *See also* **Flexion**.

Predation. An interspecific interaction where one animal species (predator) feeds on another animal or plant species (prey) while the prey is alive or after killing it. The relationship tends to be positive (increasing) for the predator population and negative (decreasing) for the prey population. S*ee also* **Parasitism**, **Symbiotic**, **Carnivore**, *and* **Trophic level**.

Production. Gross primary production is the amount of light energy converted to chemical energy in the form of organic compounds by autotrophs like algae. The amount left after respiration is net primary production and is usually expressed as biomass or calories/unit area/unit time. Net production for herbivores and carnivores is based on the same concept, except that chemical energy from food, not light, is used and partially stored for life processes. Efficiency of energy transfers between trophic levels ranges from 10–65% (depending on the organism and trophic level). Organisms at high trophic levels have only a fraction of the energy available to them that was stored in plant biomass. After respiration loss, net production goes into growth and reproduction, and some is passed to the next trophic level. *See also* **Food web** *and* **Trophic level**.

Protistan. Pertaining to the eukaryotic unicellular organisms of the kingdom Protista, including such groups as algae, fungi, and protozoans.

Protozoa. A varied group of either free-living or parasitic unicellular flagellate and amoeboid organisms.

Pycnocline. A zone of marked water density gradient that is usually associated with depth.

Race. An intraspecific group or subpopulation characterized by a distinctive combination of physiological, biological, geographical, or ecological traits. In salmonids, a race is determined by when it returns to its natal stream.

Range. (1) The geographic range is the entire area where a species is known to occur or to have occurred (historical range). The range of a species may be continuous, or it may have unoccupied gaps between populations (discontinuous distribution). (2) Some populations, or the entire species, may have different seasonal ranges These may be overlapping, or they may be widely separated with intervening areas that are at most briefly occupied during passage on relatively narrow migration routes. (3) Home range refers to the local area that an individual or group uses for a long period of life. *See also* **Distribution** *and* **Territory**.

Recruitment. The addition of new members to a population or stock through successful reproduction and immigration.

Red tide. A reddish coloration of sea waters caused by a large bloom of red flagellates. The accumulation of metabolic by-products form these organisms is toxic to fish and many other marine species. The accumulation of these metabolites in shellfish makes shellfish toxic to humans.

Reproductive potential. The total number of offspring possible for a female of a given species to produce if she lives to the maximum reproductive age. This is found by multiplying the number of possible reproductive periods by the average number of eggs or offspring produced by females of each age class. This potential is seldom realized, but this and the age of first reproduction, or generation time, determine the maximum rate of population increase under ideal conditions.

Rheotaxis. A response movement by an animal toward or away from stimulation by a water current.

Roe. The egg-laden ovary of fish, or the egg mass of certain crustaceans.

Salp. A tunicate that forms asexual polymorphic colonies that are found in the upper levels of most oceans. Individuals are barrel-shaped without an exoskeleton.

Salt wedge. A wedge-shaped layer of salt water that intrudes upstream beneath a low-density freshwater lens that has "thinned" while flowing seaward.

San Diego province. A zoogeographical designation for faunal distributions that, based on minimum temperature requirements, extends from Point Conception, California, to Magdalena Bay, Baja California Sur.

Scavenger. Any animal that feeds on dead animals and remains of animals killed by predators. *See also*
Decomposer *and* Detritivore.

Seamount. An undersea mountain rising more than 3,000 feet (914 m) from the sea floor, but having a summit at least 1,000 feet (305 m) below sea level (in contrast to an island.)

Sedentary. Refers to animals that are attached to a substrate or confined to a very restricted area (or those that do not move or move very little). *See also* **Sessile**.

Semelparous. Animals that have a single reproductive period during their lifespan.

Semi-demersal. Refers to species found in the water column a few meters above the bottom.

Sessile. Refers to an organism that is permanently attached to the substrate. *See also* **Sedentary**.

Settlement. The act of or state of making a permanent residency. Often refers to the period when fish and invertebrate larvae change from a planktonic to a benthic existence.

Shoal. (1) A sand bar in a body of water that is exposed at low tide. (2) An area of shallow water. (3) A group of fish (school). (4) As a verb, to collect in a crowd or school.

Siphons. The "necks" or tubes of clams and other bivalves that carry water containing food and oxygen into the gills, and then expels water containing waste products (exhalent siphon).

Slough. A shallow inlet or backwater whose bottom may be exposed at low tide. Sloughs often border estuaries and typically have a stream passing through them.

Spat. Juvenile bivalve molluscs which have settled from the water column to the substrate to begin a benthic existence.

Spawn. The release of eggs and sperm during mating. Also, the bearing of offspring by species with internal fertilization. *See also* **Parturition**.

Species. (1) A fundamental taxonomic group ranking after a genus. (2) A group of organisms recognized as distinct from other groups, whose members can interbreed and produce fertile offspring. *See also* **Population**, **Subpopulation**, *and* **Subspecies**.

Spermatophore. A capsule or gelatinous packet (extruded by a male) containing sperm and used to transfer sperm to females. Spermatophores are produced by certain invertebrates and some primitive vertebrates.

Spit. A long narrow sand par or peninsula extending into a body of water which is at least partly connected to the shore. *See also* **Shoal**.

Standard length. The length of a fish measured from the tip of the snout to the start of the tail.

Stenohaline. Pertaining to organisms that are restricted to a narrow range of salinities, in contrast to Euryhaline.

Stipe. A thickened, stalk-like structure in kelps that bears other structures, such as blades. Also, the basal portion of the thallus or plant body of an alga.

Stock. A related group or subpopulation. *See also* **Population** *and* **Subpopulation**. **Subadults**. Maturing individuals that are not yet sexually mature.

Sublittoral. The benthic zone along a coast, or lake that extends from mean low tide to depths of about 200 m.

Subpopulation. A breeding unit of a larger population. These units may differ little genetically and taxonomically. *See* **Subspecies**. A subpopulation may intergrade with some interbreeding, or they may occupy a common seasonal range prior to the mating season. The units may have different reproduction times and be separated spatially or temporally. *See also* **Race**, **Stock**, *and* **Population**.

Subspecies. A taxonomic class assigned to populations and/or subpopulation when interbreeding (gene flow) between populations is limited, and there are significant differences in some combination of characteristics between subspecies (e.g., appearance, analogy, ecology, physiology, and behavior). While successful interbreeding can occur when the groups are in contact, under natural conditions reproductive isolation is complete and the groups are considered distinct. *See also* **Species**, **Population**, *and* **Subpopulation**.

Subtidal. *See* Sublittoral.

Supralittoral. The splash zone of land (adjacent to the sea) that is above the mean high tide level.

Suspension feeder. An animal that feeds directly or by filtration on minute organisms and organic debris that is suspended in the water column.

Symbiosis. The relationship between two interacting organisms that is positive, negative, or neutral in its effects on each species. *See also* **Competition, Mutualism, Parasitism,** *and* **Predation**.

Taxa. A taxonomic unit, such as a genus or a species.

Taxonomy. A system of describing, naming, and classifying animals and plants into related groups based on common features (e.g., structure, embryology, and biochemistry).

Temperate region. Oceanic waters between the 13 and 20° C winter isotherms. The temperate region of the neritic zone on the Pacific coast of North America extends form Point Conception, California, to Magdalena Bay, Baja California Sur.

Temporal. Pertaining to time. Used to describe organism activities, developing stages, and distributions as they relate to daily, seasonal, or geologic time periods.

Territory. An area occupied and used by an individual, pair, or larger social group, and form which other individuals or groups of the species are excluded, often with the aid of auditory, olfactory, and visual signals, threat displays, and outright combat.

Thermocline. A relatively narrow boundary layer of water there temperature decreases rapidly with depth. Little water or solute exchange occurs across the thermocline, which is maintained by solar heating of the upper water layers.

Tintinnids. A ciliated protozoan with tentacle-like organelles.

Total length. The length of a fish measured from the tip of the snout to the end of the tail.

Trematoda. A class of parasitic flatworms of the phylum Platyhelminthes. Trematodes have one or more muscular, external suckers and are also known as flukes.

Trochopore. A molluscan larval stage (except in Cephalopoda) following gastrulation (embryonic stage characterized by the development of a simple gut). It is commonly ciliated, biconically shaped, and free-swimming; it establishes an evolutionary link between annelids and molluscs, since both groups display a similar life stage.

Trophic level. The feeding level in an ecosystem food chain characterized by organisms that occupy a similar functional position. At the first level are autotrophs or producers (e.g., kelps and diatoms); at the second level are herbivores (e.g., copepods and snails); at the third level and above are carnivores (e.g., salmon and seals). Omnivores feed at the second and third levels. Decomposers and detritivores may feed at all trophic levels. *See also* **Food web** *and* **Production**.

Tunicate. A urochordate, most of which are sessile with a body covered with a complex exoskeleton tunic.

Turbellaria. A class of mostly aquatic, non-parasitic flatworms that are leaf-shaped and covered with cilia.

Turbot. A type of flatfish.

Upwelling. The process whereby prevailing seasonal winds create surface currents that allow nutrient rich cold water form the ocean depths to move into the euphotic or epipelagic zone. This process breaks down the thermocline and increases primary productivity, and ultimately fish abundance.

Urochordate. A subphyllum of Chordata distinguished by having a notochord, a dorsal hollow nerve cord, gill slits, and a post-anal tail.

Urostyle. Bony structure at the posterior terminus of the vertebral column of a fish larvae formed from the fusion of several vertebrae.

Veliger. A ciliated larval stage common in molluscs. This stage forms after the trochophore larva and has some adult features, such as a shell and foot.

Viviparous. Refers to animals that produce live offspring; eggs are retained and fertilized in the female (as compared to **Oviparous**).

Water column. The water mass between the surface and the bottom.

Year class-Refers to animals of a species population hatched or born in the same year at about the same time; also known as a cohort. Strong year classes result when there is a high larval and juvenile survival; the reverse is true for weak year-classes. The effects of strong and week year-classes on population size and structure persist for years in species with long lives. Variation in year-class strength often affects fisheries. *See also* **Distribution** *and* **Stock**.

Young-of-the-year. A cohort of animals in their first year of life.

Zoea. An early larval stage of various marine crabs and shrimp.

Zooplankton. Animal members of the plankton. Most range in size from microscopic to about 2.54 cm in length. They reside primarily in the epipelagic zone and feed on phytoplankton and each other. Although they have only a limited ability to swim against currents, many undertake diel migrations.