1.1 Description and Status of Groundfish Stocks

There are over 90 stocks managed under the Pacific Coast Groundfish Fishery Management Plan (FMP). The actual number of FMP stocks is equivocal since all endemic species of the genus *Sebastes* are included and new species of this diverse genus are periodically described in the literature providing results of genetic/taxonomic research. These species include over 64 species of rockfish in the family *Scorpaenidae*, 7 roundfish species, 12 flatfish species, assorted shark, skate, and a few miscellaneous bottom-dwelling marine fish species. Table 1 depicts the latitudinal and depth distributions of groundfish species managed under the groundfish FMP, and Figure 1 depicts management area divisions.

The following sections contain information on the life histories of a subset of the groundfish managed under the groundfish FMP. While reading these sections, it is important to keep in mind how certain life history traits of the species have important implications on how the stocks are sustainably managed.

In contrast to the highly variable, and often volatile, population cycles of many coastal pelagic and invertebrate populations in the California Current, many of the resident groundfish in the California Current have evolved entirely different life history approaches to coping with environmental variability. Sablefish, Dover sole, spiny dogfish and a large number of rockfish (*Sebastes* and *Sebastolobus*) species have life spans that typically span decades, and in some extreme examples may reach ages of 100 or greater (Beamish, *et al.* 2006; Love, *et al.* 2002). Although large initial catches of many rockfish had given the impression that these stocks were also highly productive, a growing body of scientific evidence soon made it clear that many of these species were incapable of sustaining high intensity fishing pressure using modern fishing methods (Francis 1986; Gunderson 1977; Gunderson 1984; Leaman and Beamish 1984).

Among the concerns raised in some of the early research and analyses were that the large standing stocks of older individuals were simply maintaining themselves within the dynamic bounds of their ecosystem, and that the failure to consider the role of such longevity in Northeast Pacific groundfish could lead to management challenges. Factors such as extreme longevity, low natural mortality, increasing fecundity with age, and infrequent reproductive success (recruitment) were explicitly considered when initial harvest rate strategies were developed for the Council (Clark 1991). However, the paucity of data and magnitude of some of these factors as related to the low productivity of many species were not fully appreciated in many early studies, and are now known to be important considerations in developing harvest rate guidelines and management policies (Clark 2002; Dorn 2002a)Dorn, 2002 #490}. Consequently, harvest rates for many species have been reduced repeatedly in recent years to account for the improved knowledge regarding the overall productivity of these stocks. As new information continues to emerge regarding the significance of diverse age structures and other factors in sustaining groundfish resources (Berkeley 2004; Berkeley, *et al.* 2004; Bobko and Berkeley 2004), such information continues to be evaluated and incorporated into the stock assessment and assessment review processes that provide the scientific basis upon which management decisions are made.

Management of these groundfish species is based on principles outlined in the Magnuson-Stevens Fishery Management and Conservation Act (MSA), groundfish FMP, and National Standard Guidelines, which provide guidance on the 10 national standards in the MSA. Stock assessments are based on resource surveys, catch trends in west coast fisheries, and other data sources.

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Table 1. Latitudinal and depth distributions of groundfish species (adults) managed under the Pacific Coast Groundfish Fishery Management Plan. [a/]

Common name	Scientific name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Flatfish Species					
Arrowtooth flounder	*Atheresthes stomias*	N 34º N lat.	N 40º N lat.	10-400	27-270
Butter sole	*Isopsetta isolepis*	N 34º N lat.	N 34º N lat.	0-200	0-100
Curlfin sole	*Pleuronichthys decurrens*	Coastwide	Coastwide	4-291	4-50
Dover sole	*Microstomus pacificus*	Coastwide	Coastwide	10-500	110-270
English sole	*Parophrys vetulus*	Coastwide	Coastwide	0-300	40-200
Flathead sole	*Hippoglossoides elassodon*	N 38º N lat.	N 40º N lat.	3-300	100-200
Pacific sanddab	*Citharichthys sordidus*	Coastwide	Coastwide	0-300	0-82
Petrale sole	*Eopsetta jordani*	Coastwide	Coastwide	10-250	160-250
Rex sole	*Glyptocephalus zachirus*	Coastwide	Coastwide	10-350	27-250
Rock sole	*Lepidopsetta bilineata*	Coastwide	N 32º30' N lat.	0-200	summer 10-44 winter 70-150
Sand sole	*Psettichthys melanostictus*	Coastwide	N 33º50' N lat.	0-100	0-44
Starry flounder	*Platichthys stellatus*	Coastwide	N 34º20' N lat.	0-150	0-82
Rockfish Species [b/]					
Aurora rockfish	*Sebastes aurora*	Coastwide	Coastwide	100-420	82-270
Bank rockfish	*Sebastes rufus*	S. 39º30' N lat.	S. 39º30' N lat.	17-135	115-140
Black rockfish	*Sebastes melanops*	N 34º N lat.	N 34º N lat.	0-200	0-30
Black-and-yellow rockfish	*Sebastes chrysomelas*	S. 40º N lat.	S. 40º N lat.	0-20	0-10
Blackgill rockfish	*Sebastes melanostomus*	Coastwide	S. 40º N lat.	48-420	125-300
Blackspotted rockfish	*Sebastes melanostictus*	Coastwide	N 40º N lat.	27-400	27-250
Blue rockfish	*Sebastes mystinus*	Coastwide	Coastwide	0-300	13-21
Bocaccio [c/]	*Sebastes paucispinis*	Coastwide	S. 40º N lat., N 48º N lat.	15-180	54-82
Bronzespotted rockfish	*Sebastes gilli*	S. 37º N lat.	S. 37º N lat.	41-205	110-160
Brown rockfish	*Sebastes auriculatus*	Coastwide	S. 40º N lat.	0-70	0-50
Calico rockfish	*Sebastes dallii*	S. 38º N lat.	S. 33º N lat.	10-140	33-50
California scorpionfish	*Scorpaena gutatta*	S. 37º N lat.	S. 34º27' N lat.	0-100	0-100
Canary rockfish	*Sebastes pinniger*	Coastwide	Coastwide	27-460	50-100
Chameleon rockfish	*Sebastes phillipsi*	37º-33º N lat.	37º-33º N lat.	95-150	95-150
Chilipepper rockfish	*Sebastes goodei*	Coastwide	34º-40º N lat.	27-190	27-190
China rockfish	*Sebastes nebulosus*	N 34º N lat.	N 35º N lat.	0-70	2-50

Common name	Scientific name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Copper rockfish	*Sebastes caurinus*	Coastwide	S. 40º N lat.	0-100	0-100
Cowcod	*Sebastes levis*	S. 40º N lat.	S. 34º27' N lat	22-270	100-130
Darkblotched rockfish	*Sebastes crameri*	N 33º N lat.	N 38º N lat.	16-300	96-220
Dusky rockfish [d/]	*Sebastes ciliatus*	N 55º N lat.	N 55º N lat.	0-150	0-150
Dwarf-Red rockfish	*Sebastes rufinanus*	33º N lat.	33º N lat.	>100	>100
Flag rockfish	*Sebastes rubrivinctus*	S. 38º N lat.	S. 37º N lat.	17-100	shallow
Freckled rockfish	*Sebastes lentignosus*	S. 33º N lat.	S. 33º N lat.	22-92	22-92
Gopher rockfish	*Sebastes carnatus*	S. 40º N lat.	S. 40º N lat.	0-30	0-16
Grass rockfish	*Sebastes rastrelliger*	S. 44º40' N lat.	S. 40º N lat.	0-25	0-8
Greenblotched rockfish	*Sebastes rosenblatti*	S. 38º N lat.	S. 38º N lat.	33-217	115-130
Greenspotted rockfish	*Sebastes chlorostictus*	S. 47º N lat.	S. 40º N lat.	27-110	50-100
Greenstriped rockfish	*Sebastes elongatus*	Coastwide	Coastwide	33-220	27-136
Halfbanded rockfish	*Sebastes semicinctus*	S. 36º40' N lat.	S. 36º40' N lat.	32-220	32-220
Harlequin rockfish [e/]	*Sebastes variegatus*	N 40 º N lat.	N 51º N lat.	38-167	38-167
Honeycomb rockfish	*Sebastes umbrosus*	S. 36º40' N lat.	S. 34º27' N lat.	16-65	16-38
Kelp rockfish	*Sebastes atrovirens*	S. 39º N lat.	S. 37º N lat.	0-25	3-4
Longspine thornyhead	*Sebastolobus altivelis*	Coastwide	Coastwide	167->833	320-550
Mexican rockfish	*Sebastes macdonaldi*	S. 36º20' N lat.	S. 36º20' N lat.	50-140	50-140
Olive rockfish	*Sebastes serranoides*	S. 41º20' N lat.	S. 40º N lat.	0-80	0-16
Pacific ocean perch	*Sebastes alutus*	Coastwide	N 42º N lat.	30-350	110-220
Pink rockfish	*Sebastes eos*	S. 37º N lat.	S. 35º N lat.	40-200	40-200
Pinkrose rockfish	*Sebastes simulator*	S. 34º N lat.	S. 34º N lat.	54-160	108
Puget Sound rockfish	*Sebastes emphaeus*	N 40º N lat.	N 40º N lat.	6-200	6-200
Pygmy rockfish	*Sebastes wilsoni*	N 32º30' N lat.	N 32º30' N lat.	17-150	17-150
Quillback rockfish	*Sebastes maliger*	N 36º20' N lat.	N 40º N lat.	0-150	22-33
Redbanded rockfish	*Sebastes babcocki*	Coastwide	N 37º N lat.	50-260	82-245
Redstripe rockfish	*Sebastes proriger*	N 37º N lat.	N 37º N lat.	7-190	55-190
Rosethorn rockfish	*Sebastes helvomaculatus*	Coastwide	N 38º N lat.	65-300	55-190
Rosy rockfish	*Sebastes rosaceus*	S. 42º N lat.	S. 40º N lat.	8-70	30-58
Rougheye rockfish	*Sebastes aleutianus*	Coastwide	N 40º N lat.	27-400	27-250
Semaphore rockfish	*Sebastes melanosema*	S. 34º27' N lat.	S. 34º27' N lat.	75-100	75-100
Sharpchin rockfish	*Sebastes zacentrus*	Coastwide	Coastwide	50-175	50-175
Shortbelly rockfish	*Sebastes jordani*	Coastwide	S. 46º N lat.	50-175	50-155

Common name	Scientific name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Shortraker rockfish	*Sebastes borealis*	N 39º30' N lat.	N 44º N lat.	110-220	110-220
Shortspine thornyhead	*Sebastolobus alascanus*	Coastwide	Coastwide	14->833	55-550
Silvergray rockfish	*Sebastes brevispinis*	Coastwide	N 40º N lat.	17-200	55-160
Speckled rockfish	*Sebastes ovalis*	S. 38º N lat.	S. 37º N lat.	17-200	41-83
Splitnose rockfish	*Sebastes diploproa*	Coastwide	Coastwide	50-317	55-250
Squarespot rockfish	*Sebastes hopkinsi*	S. 38º N lat.	S. 36º N lat.	10-100	10-100
Starry rockfish	*Sebastes constellatus*	S. 38º N lat.	S. 37º N lat.	13-150	13-150
Stripetail rockfish	*Sebastes saxicola*	Coastwide	Coastwide	5-230	5-190
Swordspine rockfish	*Sebastes ensifer*	S. 38º N lat.	S. 38º N lat.	38-237	38-237
Tiger rockfish	*Sebastes nigrocinctus*	N 35º N lat.	N 35º N lat.	30-170	35-170
Treefish	*Sebastes serriceps*	S. 38º N lat.	S. 34º27' N lat.	0-25	3-16
Vermilion rockfish	*Sebastes miniatus*	Coastwide	Coastwide	0-150	4-130
Widow rockfish	*Sebastes entomelas*	Coastwide	N 37º N lat.	13-200	55-160
Yelloweye rockfish	*Sebastes ruberrimus*	Coastwide	N 36º N lat.	25-300	27-220
Yellowmouth rockfish	*Sebastes reedi*	N 40º N lat.	N 40º N lat.	77-200	150-200
Yellowtail rockfish	*Sebastes flavidus*	Coastwide	N 37º N lat.	27-300	27-160
Roundfish Species					
Cabezon	*Scorpaenichthys marmoratus*	Coastwide	Coastwide	0-42	0-27
Kelp greenling	*Hexagrammos decagrammus*	Coastwide	N 40º N lat.	0-25	0-10
Lingcod	*Ophiodon elongatus*	Coastwide	Coastwide	0-233	0-40
Pacific cod	*Gadus macrocephalus*	N 34º N lat.	N 40º N lat.	7-300	27-160
Pacific whiting	*Merluccius productus*	Coastwide	Coastwide	20-500	27-270
Sablefish	*Anoplopoma fimbria*	Coastwide	Coastwide	27->1,000	110-550
Shark and Skate Species					
Big skate	*Raja binoculata*	Coastwide	S. 46º N lat.	2-110	27-110
California skate	*Raja inornata*	Coastwide	S. 39º N lat.	0-367	0-10
Leopard shark	*Triakis semifasciata*	S. 46º N lat.	S. 46º N lat.	0-50	0-2
Longnose skate	*Raja rhina*	Coastwide	N 46º N lat.	30-410	30-340
Soupfin shark	*Galeorhinus zyopterus*	Coastwide	Coastwide	0-225	0-225
Spiny dogfish	*Squalus acanthias*	Coastwide	Coastwide	0->640	0-190

Common name	Scientific name	Latitudinal Distribution		Depth Distribution (fm)	
		Overall	Highest Density	Overall	Highest Density
Other Species					
Finescale codling	*Antimora microlepis*	Coastwide	N 38º N lat.	190-1,588	190-470
Pacific rattail	*Coryphaenoides acrolepis*	Coastwide	N 38º N lat.	85-1,350	500-1,350
Ratfish	Hydrolagus colliei	Coastwide	Coastwide	0-499	55-82

a/ Data from (Casillas, *et al.* 1998), (Eschmeyer, *et al.* 1983), (Hart 1988), (Miller and Lea 1972), (Love, *et al.* 2002), and NMFS survey data. Depth distributions refer to offshore distributions, not vertical distributions in the water column.
b/ 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.
c/ Only the southern stock of bocaccio south of 40º 10' N lat. is listed as overfished.
d/ Only two occurrences of harlequin rockfish south of 51º N lat. (off Newport, OR and La Push, WA; (Casillas, *et al.* 1998)).

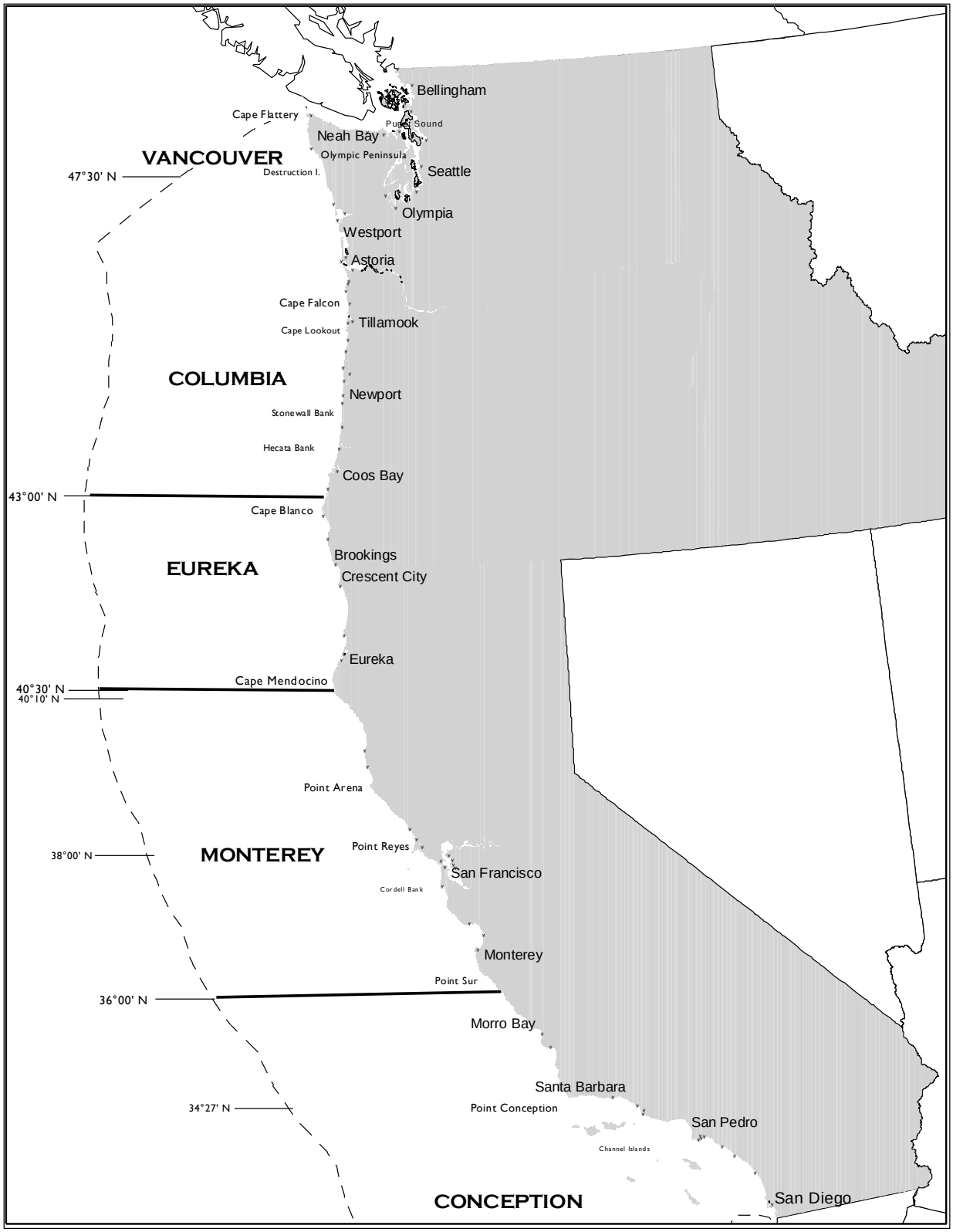

Figure 1. Fishery management lines on the U.S. west coast.

The passage of the Sustainable Fisheries Act in 1996 and the reauthorization of the MSA in 2006[1] incorporated the current conservation and rebuilding mandates into the MSA. These mandates—including abundance-based standard reference points for declaring the status of a stock (overfished; in a "precautionary" status; or at levels that can support maximum sustainable yield (MSY) (healthy or "rebuilt"))—were subsequently incorporated in the groundfish FMP with adoption of Amendments 11, 12, and 23. These reference points are determined relative to an estimate of "virgin" or unexploited spawning biomass of the stock, denoted as B_0, which is defined as the average equilibrium abundance of a stock's spawning biomass before it is affected by fishing-related mortality.[2] B_0 is then used to estimate MSY, as identified in the MSA and National Standard Guidelines. MSY represents a theoretical maximum surplus production from a population of constant size; National Standard Guidelines define it as "the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions." For a given population and set of ecological conditions, there is a biomass that produces MSY (denoted as B_{MSY}), which is less than the equilibrium size in the absence of fishing (B_0). (Generally, population sizes above B_{MSY} are assumed to be less productive because of competition for resources or other density dependent factors.) The harvest rate used to achieve or sustain B_{MSY} is referred to as the Maximum Fishing Mortality Threshold (MFMT, denoted as F_{MSY}). Three harvest specification reference points, defined in the groundfish FMP, provide guidance in setting the harvest rate: an overfishing limit (OFL), an acceptable biological catch (ABC), and an annual catch limit (ACL) (see section 1.2 for more information on harvest specifications). The Council identifies the ACL as the management target for each species or species complex. When the stock biomass is determined to be lower than B_{MSY}, the ACL is set to an adequately low level to rebuild the stock to a healthy level in a timely fashion.

The biomass level that produces MSY (i.e., B_{MSY}) is generally unknown and assumed to be variable over time due to long-term fluctuations in ocean conditions, so that no single value is appropriate. Furthermore, F_{MSY} is tightly linked to an assumed level of density dependence in recruitment, and there is insufficient information to determine that level for many west coast groundfish stocks. Therefore, the use of approximations or proxies is necessary; absent a more accurate determination of F_{MSY}, the Council applies default MSY proxies (see section 1.1.1 for more details). The Council adopts management actions aimed to maintain abundance of each stock at or above the specified B_{MSY} target. The threshold for declaring a stock overfished is when the stock's spawning biomass declines to less than the specified Minimum Stock Size Threshold or MSST (i.e., 12.5% of B_0 or $B_{12.5\%}$ for assessed flatfish stocks and $B_{25\%}$ for all other groundfish stocks). A rebuilding plan that specifies how total fishing-related mortality is constrained to achieve an MSY abundance level within the legally allowed time is required by the MSA and groundfish FMP when a stock is declared overfished.

Of the more than 90 species managed under the groundfish FMP, only a portion are individually managed. Thus, the remaining species are managed and accounted for in groupings or stock complexes (see section 1.1.5) because individually they comprise a small part of the landed catch and, in general, insufficient information exists to develop the stock assessments necessary to set harvest specifications based on yield estimates. The Council has also decided to continue to manage some assessed stocks in complexes to avoid management complications such as disruption to the trawl rationalization program. Catch-based methods described in section 1.1.1 are used to set OFLs for unassessed stocks. Additionally, there is a category of stocks that are incidentally caught in groundfish fisheries for which

[1] The Magnuson-Stevens Act is again up for reauthorization in 2014.

[2] The current abundance of a stock relative to its unfished level is commonly written as a percentage or a proportion; this value represents the stock's depletion level. In addition to using a comparison between current spawning biomass and unfished spawning biomass to determine this reference point, some stock assessment authors compare current and unfished levels of spawning output or of total stock biomass, depending on the information that is available.

no harvest limits are specified. This category of stocks, termed Ecosystem Component (EC) species, are not considered to be in the fishery and are neither targeted nor generally retained for sale or personal use. EC species are determined not to likely become subject to overfishing or to be overfished in the absence of conservation and management measures. There is a monitoring requirement for species designated as EC to the extent that any new pertinent scientific information becomes available (e.g., catch trends, vulnerability, etc.) to determine changes in their status or their vulnerability to the fishery. The Council is proposing an EC designation for some species currently managed in the FMP, as well as other non-FMP species (see section 1.1.6).

1.1.1 Productivity and Susceptibility Assessment of Stocks to Overfishing

The vulnerability to potential overfishing of a stock to the fishery for each groundfish stock in the FMP was defined as a first step in assisting with two specific tasks set forth in the FMP: 1) to define species as either "in the fishery" or as an "ecosystem component," and 2) identify stock complexes. In addition, the vulnerability scores were considered when prioritizing stock assessments and determining data collection needs.

The Productivity-Susceptibility Assessment (PSA) approach of Patrick et al. (2009) was used to characterize vulnerability and has two components: 1) productivity as defined by life histories traits, and 2) susceptibility to current fishing practices. Each vulnerability component is comprised of several attributes (10 productivity and 12 susceptibility attributes) and the weighted mean score of all attributes defines the overall productivity and susceptibility score. Table 2 includes the vulnerability scores for all species in the FMP relative to the current fishery. Table 2 shows the vulnerability scores for currently overfished rockfish species relative to the fishery circa 1998. Scores are presented in two-dimensions, with productivity on the x-axis and susceptibility on the y-axis (Figure 2). Cope et al. (2011) established vulnerability reference points of unassessed west coast groundfish stocks to determine vulnerability groups as follows:

- $V \geq 2.2$ indicate species of major concern.
- $2.0 \leq V < 2.2$ indicate species of high concern.
- $1.8 \leq V < 2.0$ indicate species of medium concern.
- $V < 1.8$ indicate species of low concern.

Rockfish and elasmobranches showed the highest vulnerabilities (>2.0), with the deepest-residing members of those groups often the most vulnerable, though there were several species of nearshore rockfish (China, quillback, and copper rockfish) with some of the highest scored vulnerabilities. Flatfishes in general showed the lowest vulnerabilities.

In addition to scoring each productivity and susceptibility attribute, the quality of the data used for each score was also recorded (Table 2, Table 3, and Figure 3). Data quality is scored for each productivity and susceptibility attribute, with the overall data quality score calculated as the weighted mean of all attributes. A scoring scale of 1-5 was used, with the best data score being 5.

Recording the data quality can highlight vulnerability scores that can be improved with additional data or that should be interpreted with caution because of questionable data contribution. Data quality scores can also be used to justify future data collection on particular attributes.

In general, susceptibility was harder to score (lower data quality) than productivity. Flatfishes as a group had the least informed species, but elasmobranches and several rockfish species also showed low-quality data informing vulnerability scores (Table 2).

PSA analyses are anticipated to be re-done every biennial specifications cycle. Productivity scores are not expected to vary much over time since they are based on life history traits. However, susceptibility scores may vary based on changes in fishing practices and/or management, and an updated understanding of the stock's interaction with the fishery. As susceptibility scores change, so do the vulnerability scores.

Table 2. Overall scores and results of the Productivity and Susceptibility Assessment (PSA) ranked from most to least vulnerable to overfishing relative to the current west coast fishery based on the GMT's scoring.

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
21	Copper rockfish	1.95	1.60	2.27
67	Rougheye rockfish	1.17	2.33	2.27
72	Shortraker rockfish	1.22	2.38	2.25
20	China rockfish	1.33	2.29	2.23
58	Quillback rockfish	1.31	2.43	2.22
61	Redstripe rockfish	1.31	2.33	2.16
22	Cowcod	1.25	2.00	2.13
77	Spiny dogfish	1.11	1.98	2.13
10	Bronzespotted rockfish	1.37	2.14	2.12
16	California skate	1.33	2.00	2.12
35	Greenblotched rockfish	1.28	2.24	2.12
2	Aurora rockfish	1.89	2.29	2.10
76	Speckled rockfish	1.33	2.29	2.10
65	Rosethorn rockfish	1.19	2.05	2.09
81	Starry rockfish	1.25	2.14	2.09
7	Blackgill rockfish	1.22	2.08	2.08
84	Tiger rockfish	1.25	2.10	2.06
70	Sharpchin rockfish	1.36	2.24	2.05
86	Vermilion rockfish	1.22	2.02	2.05
87	Widow rockfish	1.31	2.16	2.05
18	Chameleon rockfish	1.39	2.20	2.03
3	Bank rockfish	1.28	1.88	2.02
55	Pink rockfish	1.33	2.14	2.02
60	Redbanded rockfish	1.28	2.05	2.02
74	Silvergray rockfish	1.22	1.95	2.02
75	Soupfin shark	1.11	1.71	2.02
8	Blue rockfish	1.22	2.16	2.01
17	Canary rockfish	1.61	2.43	2.01
43	Leopard shark	1.26	2.00	2.00
88	Yelloweye rockfish	1.22	1.92	2.00
4	Big skate	2.45	2.05	1.99
11	Brown rockfish	1.72	2.08	1.99
26	Dusky rockfish	1.75	1.76	1.99
36	Greenspotted rockfish	1.39	2.14	1.98

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
30	Flag rockfish	1.83	1.80	1.97
40	Honeycomb rockfish	1.36	2.10	1.97
89	Yellowmouth rockfish	1.61	2.38	1.96
5	Black rockfish	1.21	2.14	1.94
39	Harlequin rockfish	1.31	1.95	1.94
54	Petrale sole	1.70	2.44	1.94
83	Swordspine rockfish	1.33	2.00	1.94
9	Bocaccio	1.28	2.04	1.93
24	Darkblotched rockfish	1.39	2.24	1.92
34	Grass rockfish	1.61	2.29	1.89
66	Rosy rockfish	1.61	2.29	1.89
37	Greenstriped rockfish	1.28	1.76	1.88
90	Yellowtail rockfish	1.33	1.88	1.88
48	Olive rockfish	1.69	2.33	1.87
79	Squarespot rockfish	1.61	2.24	1.86
51	Pacific grenadier	1.44	1.95	1.82
56	Pinkrose rockfish	1.31	1.67	1.82
78	Splitnose rockfish	1.28	1.60	1.82
47	Mexican rockfish	1.50	2.00	1.80
73	Shortspine thornyhead	1.33	1.68	1.80
82	Stripetail rockfish	1.39	1.81	1.80
63	Rock greenling	1.78	2.29	1.77
33	Gopher rockfish	1.56	2.00	1.76
85	Treefish	1.67	2.10	1.73
59	Ratfish	1.63	2.05	1.72
6	Black-and-yellow rockfish	1.83	1.68	1.70
50	Pacific ocean perch	1.44	1.67	1.69
53	Pacific whiting	2.00	2.36	1.69
13	Cabezon	1.33	2.48	1.68
45	Longnose skate	1.53	1.80	1.68
68	Sablefish	1.61	1.88	1.64
42	Kelp rockfish	1.83	2.12	1.62
41	Kelp greenling	1.83	2.04	1.56
44	Lingcod	1.75	1.92	1.55
25	Dover sole	1.36	2.57	1.54
27	Dwarf-red rockfish	1.06	1.88	1.54
46	Longspine thornyhead	1.47	1.16	1.54
29	Finescale codling	2.45	2.10	1.48
14	Calico rockfish	1.39	2.04	1.46
32	Freckled rockfish	1.80	1.96	1.44
57	Pygmy rockfish	1.78	1.71	1.42
64	Rock sole	1.95	1.95	1.42
15	California scorpionfish	1.28	0.00	1.41
19	Chilipepper	1.83	0.00	1.35

Stock ID	Stock Name	Productivity	Susceptibility	Vulnerability
49	Pacific cod	2.11	2.00	1.34
62	Rex sole	2.05	1.86	1.28
31	Flathead sole	2.25	1.92	1.26
38	Halfbanded rockfish	2.00	1.76	1.26
52	Pacific sanddab	2.40	2.10	1.25
23	Curlfin sole	1.72	1.75	1.23
69	Sand sole	2.35	2.05	1.23
1	Arrowtooth flounder	1.33	2.05	1.21
28	English sole	2.30	2.05	1.19
12	Butter sole	1.78	1.76	1.18
71	Shortbelly rockfish	1.94	1.40	1.13
80	Starry flounder	2.15	1.60	1.04

Table 3. Retrospective Productivity and Susceptibility Assessment (PSA) vulnerability scores of currently overfished rockfish species ranked from most to least vulnerable to overfishing relative to stock status and the fishery circa 1998, based on the GMT's scoring.

Stock Name	Stock ID	Susceptibility	Vulnerability
Bocaccio	25_H	2.72	2.43
Canary	23_H	2.84	2.52
Cowcod	10_H	2.68	2.57
Darkblotched	51_H	2.76	2.39
POP	92_H	2.32	2.08
Yelloweye	18_H	2.80	2.53

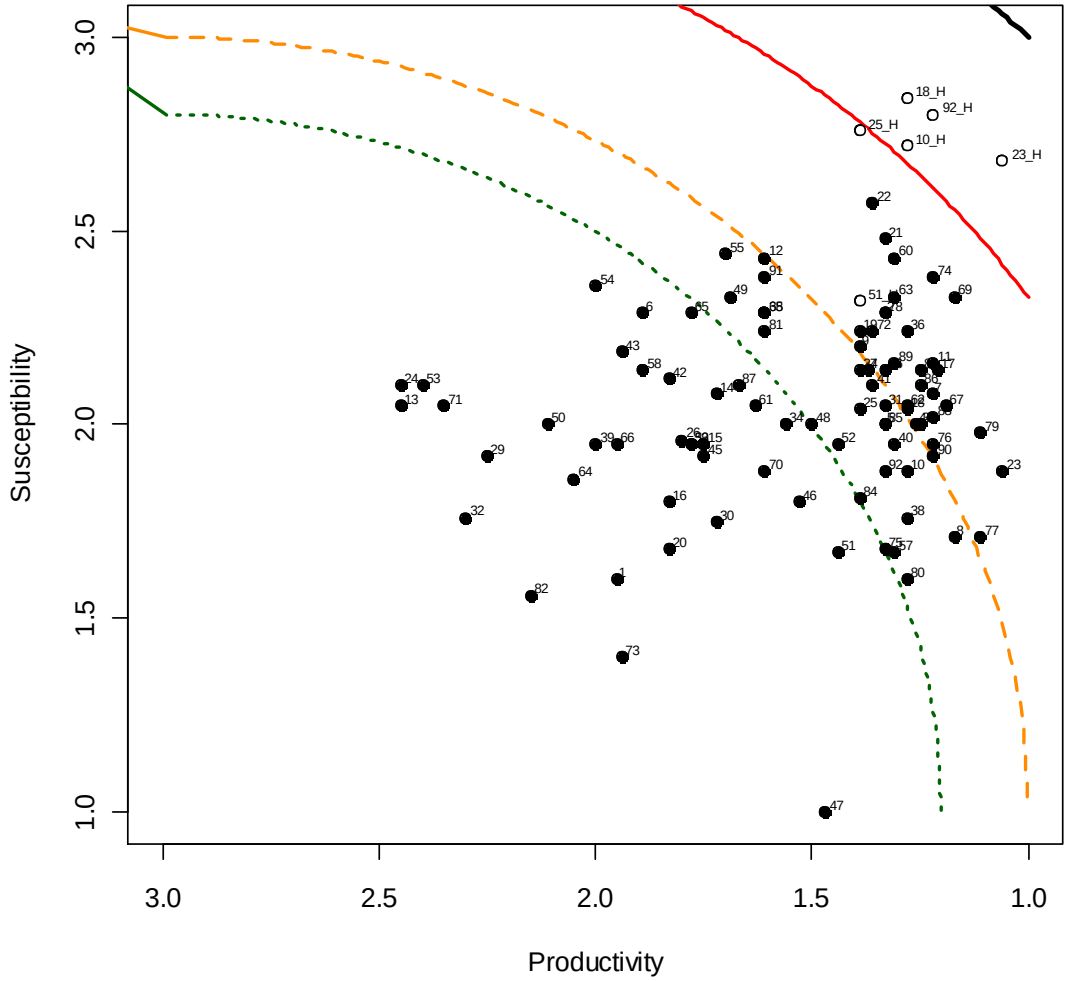

Figure 2. Productivity and Susceptibility Analysis (PSA) plot for species in the west coast groundfish FMP. Contours delineate areas of relative vulnerability (V, i.e. distance from the origin), with the highest vulnerability stocks above the solid red line (V = 2.2), high vulnerability above the orange broken line (V=2), medium vulnerability above the green dotted line (V=1.8) and the lowest vulnerability below the green dotted line. The maximum vulnerability (V=2.8) is indicated with the solid black line. Solid circles are based on current PSA scores. Open circles are based on PSA scores circa 1998. Numbers refer to the Stock ID in Table 2 and Table 3.

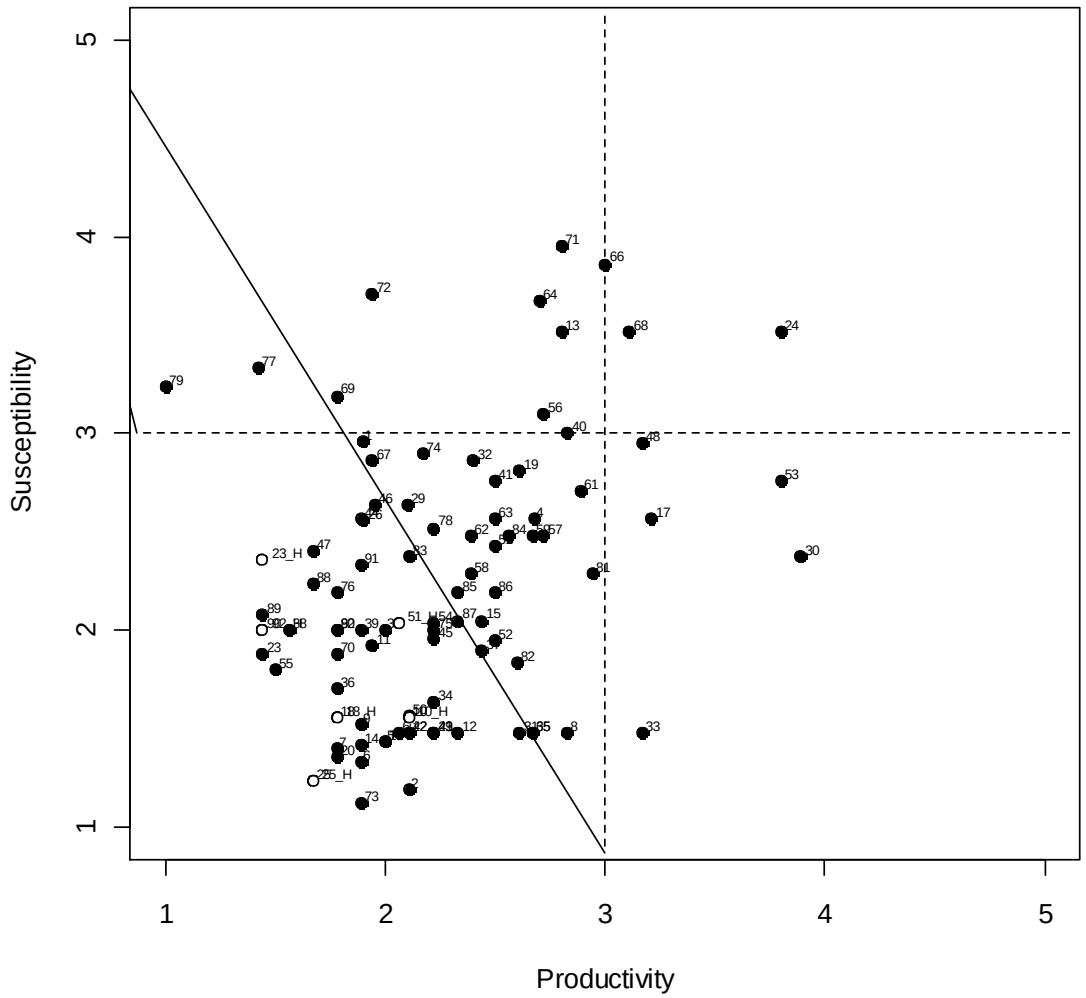

Figure 3. Data quality plots for the productivity and susceptibility scores in the PSA for each species (represented numerically in Table 2 and Table 3) in the west coast groundfish FMP. Higher scores indicate less data quality. Vertical and horizontal lines provide a general guide to relative data quality with values above 3 on either axis considered data-poor.

1.1.2 Stock Assessments and Rebuilding Analyses Used to Estimate Stock Status and Inform Management Decisions

Stock assessments are used for setting harvest specifications by providing estimates of MSY, OFL, the MFMT, the MSST, ABC, OY, and ACLs. Stock assessments are also used to determine the status of a fish population or subpopulation (stock) terms of estimating population size, reproductive status, fishing mortality, and sustainability. In the terms of the Groundfish FMP, stock assessments provide: 1) an estimate of the current biomass and reproductive potential, 2) an estimate of F_{MSY} (the harvest rate estimated to produce MSY) or proxy thereof translated into exploitation rate or spawning potential ratio (SPR; *cite section describing SPR*), 3) the estimated MSY biomass (B_{MSY}), or proxy thereof, 4) estimated unfished biomass (B_0), and 5) the estimated variance (e.g., confidence interval) for the current biomass estimate. With the exception of Pacific whiting, which is assessed annually as specified in the Agreement with Canada on Pacific Hake/Whiting, groundfish stock assessments are conducted on a two-year cycle. Given the large number of groundfish species and limited state and Federal resources, a subset of all groundfish stocks are assessed in each stock assessment cycle. Overfished species' stock assessments are typically conducted every two years, although a catch report can be substituted for an assessment to monitor compliance with adopted rebuilding plans. The process for setting groundfish specifications involves the adoption of new and updated stock assessments. During the biennial specification process, the SSC reviews stock assessments and rebuilding analyses for overfished species and makes recommendations to the Council relative to the standards of the best available science and the soundness of the scientific information relative to management decisions. The Council then approves all or a portion of the stock assessments, or recommends further analysis.

The perception of stock status and productivity for many stocks may change substantially between stock assessments. Such changes can result from technical changes in the model, including how a given assessment model is structured, the assumptions used to fix or estimate key parameters (i.e., whether parameters such as natural mortality and steepness are fixed, estimated freely, or estimated with an informative prior), and the evolution of methods for developing time series and estimates of uncertainty from different sources of raw data. The population dynamics of target species themselves are responsive to a mix of complex (and often poorly-understood) biological, oceanographic, and interspecies interactions. New data sources (e.g., new data, extensions of existing data sets, incorporation of environmental factors into assessments) can result in changes in parameter estimates and model outputs.

All stock assessments are subject to a peer review process, consistent with the MSA (§302(g)(1)(E)). The process considers components of the assessments starting with data collection and continuing through to scientific recommendations and information presented to the Council and its advisors. The terms of reference for the groundfish stock assessment process defines the expectations and responsibilities for various participants in the groundfish stock assessment review (STAR) process, and outlines the guidelines and procedures for a peer review process. The STAR process is a key element in an overall process designed to review the technical merits of stock assessments and other scientific information used by the SSC. This process allows the Council to make timely use of new fishery and survey data, to analyze and understand these data as completely as possible, to provide opportunity for public comment, and to assure that the results are as accurate and error-free as possible.

Harvest specifications, and the science used as the basis for management decision-making are derived from the most recent assessments and/or rebuilding analyses prepared for those stocks informed by an assessment. The newest assessments were those prepared and adopted in 2013 and the oldest assessments informing management decisions for fisheries in 2015 and beyond were prepared and adopted in 2005. Table 4 presents a summary of the management quantities estimated by base models of the most recent assessments informing management in 2015 and beyond. Table 5 lists life history

parameters from the stocks assessed since 2005, excluding those done using XDB-SRA; steepness of the spawner-recruitment curve (h), recruitment variability (sigma-r), the von Bertalanffy Equation growth constant (k), and natural mortality (M) are each important contributors to the understanding of the productivity and resiliency of these stocks. Table 6 lists life history parameters from the stocks assessed in 2013 using XDB-SRA; B_{MSY}, F_{MSY}, M, B_{MSY}/B_0, and F_{MSY}/M inform the relative productivity and resiliency of these stocks.

All stock assessments, STAR panel reports, and rebuilding analyses used to inform management decisions on west coast groundfish stocks and fisheries can be found on the Council's web site at http://www.pcouncil.org/groundfish/stock-assessments/.

1.1.2.1 Types of Assessments Used in Managing Groundfish Stocks

The Council uses various types of assessments that range from data-rich full assessments (also known as benchmark assessments) to data-poor catch-based models used to only estimate an OFL. The Council decides which groundfish stocks will be assessed and, based on SSC recommendations, what type of assessment will be used (i.e., full, update, data-moderate) each cycle. These stock assessment priorities are decided in even years and assessments are conducted, reviewed, and adopted in odd years. Results from these assessments are used to inform management decisions for the following biennial cycle, which begins in the next odd year. The SSC reviews all assessments and recommends to the Council if they represent the best available science for the stock and whether and how they can be used to inform Council decisions.

The SSC categorizes stocks based on the type of assessment and the quality of data informing that assessment. The FMP harvest specification framework calls for increasing uncertainty buffers translated into lower ABCs (and ACLs) for stocks informed by less certain assessments (see section 1.2.2). Stock categories range from category 1, characterized by stocks informed by full assessments with reasonably good estimates of year class strength, to unassessed category 3 stocks where there is only a data-poor estimate of the OFL. A more detailed description of the assessment models used in current groundfish management follows.

Data-Poor Assessments

Data-poor assessments employ catch-based statistics to estimate an OFL for a stock. Since there are no survey or other abundance indices used in a data-poor assessment, stock status cannot be determined using these types of assessment. The most rudimentary data-poor assessment is simply average historical catch to estimate an OFL. However, there is great uncertainty whether that is a "true" OFL since the historical catch used to compute the average could have been unsustainably high. Therefore, the SSC categorizes stocks informed by a data-poor OFL as category 3 stocks, thus mandating a higher buffer to determine the ABC. While this category of data-poor methods are being characterized as "assessments" here, stocks with OFLs informed with data-poor methods are considered unassessed since there is no estimate of relative depletion or status. Other approved data-poor methods (DCAC and DB-SRA) more sophisticated than average catch are described below.

Depletion-Corrected Average Catch

The Depletion-Corrected Average Catch (DCAC) method provides an estimate of sustainable yield (the OFL) for data-poor stocks of uncertain status (MacCall 2009). DCAC adjusts historical average catch to account for one-time "windfall" catches that are the result of stock depletion, producing an estimate of yield that was likely to be sustainable over the same time period. Advantages of the DCAC approach for determining sustainable yield for data-poor stocks include: 1) minimal data requirements, 2)

biologically-based adjustment to catch-based yield proxies with transparent assumptions about relative changes in abundance, and 3) simplicity in computing.

Depletion-Based Stock Reduction Analysis

The Depletion-Based Stock Reduction Analysis (DB-SRA) method extends the DCAC method by 1) restoring the temporal link between production and biomass, and 2) evaluating and integrating alternative hypotheses regarding changes in abundance during the historical catch period (Dick and MacCall 2011). This method combines DCAC's distributional assumptions regarding life history characteristics and stock status with the dynamic models and simulation approach of stochastic stock reduction analysis.

Data-Moderate Assessments

Data-moderate assessments are less complicated than full assessments and can therefore be reviewed more expeditiously. Unlike a full assessment, which is reviewed by a STAR panel and the SSC, only the SSC reviews a data-moderate assessment.

Data-moderate assessments combine catch-based methods with a time series of relative abundance estimates from one or more surveys or other types of abundance indices (e.g., CPUE time series). This type of assessment represents the minimal structure of an assessment used to determine stock status according to the NMFS National Stock Assessment Improvement plan (Mace, *et al.* 2001). These assessments exclude compositional age and length data, which are used to determine survey and/or fishery selectivities and to estimate other parameters in a full assessment model. The addition of compositional data complicates an assessment requiring more review time to understand what data are driving model results. Data-moderate assessments were therefore developed to increase the number of groundfish stocks assessed given the resources available to conduct and review assessments each cycle. There are two data-moderate assessment models in current use that have been reviewed and recommended by the SSC: Extended Simple Stock Synthesis (exSSS) and Extended Depletion-based Stock Reduction Analysis (XDB-SRA). These are described in more detail below.

Since data-moderate assessments are less informative than full assessments, the SSC categorizes stocks informed with such assessment as category 2 stocks.

Extended Simple Stock Synthesis

Extended Simple Stock Synthesis (exSSS) is based on sampling parameters (steepness, natural mortality and depletion) from prior distributions and using Stock Synthesis to solve for virgin recruitment (R0) given inputs for selectivity, growth, and fecundity. ExSSS extends Simple Stock Synthesis, originally a data-poor method reviewed by the SSC, by allowing index data (and potentially length and age data) to be used for parameter estimation using the Stock Synthesis platform. Parameter estimation for exSSS is either based on maximum likelihood or Bayesian (Markov chain Monte Carlo (MCMC)) methods. ExSSS assumes that recruitment is related deterministically to the stock-recruitment relationship. The outputs from exSSS include biomass trajectories, as well as estimates of (and measures of uncertainty for) the OFL. The prior for depletion is based on the results of a regression of depletion on the PSA vulnerability score (see section 1.1.1).

Extended Depletion-Based Stock Reduction Analysis

Extended Depletion-Based Stock Reduction Analysis (XDB-SRA), an extension of DB-SRA, is another model approved by the SSC for use in data-moderate assessments. XDB-SRA can be implemented

within a Bayesian framework, with the priors for the parameters updated based on index data. The additional parameters in XDB-SRA compared with DB-SRA include the catchability coefficient (q), and the extent of observation variance additional to that inferred from sampling error (a). The priors for these parameters are a weakly informative log-normal and a uniform distribution, respectively.

Full Stock Assessments

Full, or benchmark, stock assessments are those where Stock Assessment Teams (STATs) can propose new models and explore new data to determine the status and dynamics of a fish stock. The Council has a rigorous process for first determining those stocks that will be assessed and, once determined, how they will be reviewed (the process is codified in the Stock Assessment and Review Terms of Reference, which is updated every other year; available at http://www.pcouncil.org/groundfish/stock-assessments/terms-of-reference/). Full assessments are more vigorously reviewed than other types of assessments since they are inherently more complicated. A week-long Stock Assessment Review (STAR) panel meeting occurs with STATs presenting assessment models to a panel of experts (typically comprised of one SSC Groundfish Subcommittee member who chairs the meeting, one west coast groundfish assessment expert, two independent reviewers from the Center of Independent Experts, one Groundfish Management Team advisor, one Groundfish Advisory Subpanel advisor, and a member of the Council staff). The STAR panel prepares a report recommending whether the assessment is robust enough to be used in management, along with other detailed recommendations on how to interpret assessment results and how to improve the assessment next time it is conducted. STAR panel reports also detail the model and data explorations that occurred during the review. The draft assessment and STAR panel report are then reviewed by the SSC. The assessment is only adopted for use in management decision-making if recommended by the SSC.

Stocks assessed with SSC-endorsed assessments are categorized either as category 1, category 2, or assigned a stock-specific category depending on the quality of data informing the assessment, relative uncertainty of model estimates, and/or whether individual year class strength (i.e., recruitment) is estimated.

Stock Synthesis

Most of the groundfish assessments on the U.S. west coast used to currently inform management decisions have been done in Stock Synthesis (SS). Stock Synthesis provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock sub-areas. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS features include ageing error, growth estimation, spawner-recruitment relationship, movement between areas. SS is most flexible in its ability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys. The ADMB C++ software in which SS is written searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian and MCMC methods. A management layer is also included in the model allowing uncertainty in estimated parameters to be propagated to the management quantities, thus facilitating a description of the risk of various possible management scenarios, including forecasts of possible annual catch limits. The structure of Stock Synthesis allows for building of simple to complex models depending upon the data available. The latest version of SS used in most of the assessments done in 2013 is version 3.24f (download available at http://nft.nefsc.noaa.gov/SS3.html).

Extended Depletion-Based Stock Reduction Analysis

XDB-SRA, described above, was used in the 2013 full assessment of cowcod in the Southern California Bight (see section 1.1.3.3). While XDB-SRA is an approved data-moderate assessment model, it can also be parameterized to incorporate compositional data[3].

Updated Assessments

An update assessment uses the model structure of the stock's last full, SSC-endorsed assessment, but is generally restricted to the addition of new data that have become available since the last full assessment. It must carry forward the fundamental structure of the last full assessment reviewed and endorsed by a STAR panel, the SSC, and the Council. Assessment structure here refers to the population dynamics model, data sources used as inputs to the model, the statistical platform used to fit model to the data, and how the management quantities used to set harvest specifications are calculated. Particularly, when an update assessment is developed, no substantial changes should be made to 1) the particular sources of data used, 2) the software used in programming the assessment, 3) the assumptions and structure of the population dynamics model underlying the stock assessment, 4) the statistical framework for fitting the model to the data and determining goodness of fit, and 5) the analytical treatment of model outputs in determining management reference points.

Major changes to the assessment should be postponed until the next full assessment. Minor alterations to the input data and the assessment can be considered as long as the update assessment clearly documents and justifies the need for such changes. A step-by-step transition (via sensitivity analysis) from the last full assessment to an update assessment under review should be provided. Minor alterations can be considered under only two circumstances: first, when the addition of new data reveals an unanticipated sensitivity of the model, and second, when there are clear and straightforward improvements in the input data and how it is processed and analyzed for use in the model. Examples of minor alterations include: 1) changes in how compositional data are pooled across sampling strata, 2) the weighting of the various data components (including the use of methods for tuning the variances of the data components), 3) changes in the time periods for the selectivity blocks, 4) correcting data entry errors, and 5) bug fixes in software programming. This list is not meant to be exhaustive, and other alterations can be considered if warranted. Ideally, improved data or methods used to process and analyze data would be reviewed by the SSC prior to being used in assessments.

The SSC reviews all updated assessments; a STAR panel review is not needed since the assessment only updates the last full, STAR panel-reviewed assessment.

1.1.2.2 Rebuilding Analyses

Rebuilding analyses use the results of stock assessments and project stock rebuilding periods under alternative harvest control rules in a stochastic fashion. In other words, a rebuilding analysis involves projecting the status of the overfished resource into the future under a variety of alternative harvest strategies to determine the probability of recovery to B_{MSY} (or its proxy) within a pre-specified time-frame. Rebuilding analyses are used to develop new rebuilding plans or in consideration for modifying existing rebuilding plans; rebuilding plans dictate the target year to rebuild a stock, the harvest control rules for rebuilding the stock, and any other special management measures designed to foster rebuilding. Rebuilding analyses also are used to determine the OFLs and ACLs for overfished stocks.

[3] Note that the 2013 cowcod assessment excluded compositional data within the model. However, the model was subject of the two-step (i.e., STAR panel and SSC) review process defined for full assessments.

The steps when conducting a rebuilding analysis are 1) estimation of B_0 (and hence B_{MSY} or its proxy), 2) selection of a method to generate future recruitment, 3) specification of the mean generation time (defined as the predicted time it would take for a mature female in the population to replace herself), 4) calculation of the minimum and maximum times to recovery, and 5) identification and analysis of alternative harvest strategies and rebuilding times. Most rebuilding analyses are done using software developed by Dr. André Punt from the University of Washington (informally termed the Puntalyzer; available at http://fish.washington.edu/people/punt/software.html).

The Puntalyzer uses "Monte Carlo simulation" to derive a probability estimate for a given rebuilding strategy. This method projects population growth many times in separate simulations. It accounts for possible variability by randomly choosing the value of a key variable, in this case total recruitment or recruits per spawner from a range of values. These values can be specified empirically, by listing some set of historical values, or by a relationship based on a model. The SSC recommends that the rebuilding analyses use historical values. Because of this variability in a key input value, each simulation will show a different pattern of population growth. As a result, a modeled population may reach the target biomass that defines a rebuilt stock (B_{MSY}) in a different year in each of the simulations.

This technique is first used to calculate minimal time to rebuild a stock given its level of depletion and productivity from the time of implementing the first rebuilding plan (T_{MIN}) in probabilistic terms, which is defined as the time needed to reach the target biomass in the absence of fishing with a 50 percent probability. In other words, in half the simulations the target biomass was reached in some year up to and including the computed T_{MIN}. Given T_{MIN}, the maximum legal time to rebuild (T_{MAX}) is computed as 10 years or by adding the value of one mean generation time to T_{MIN}, if T_{MIN} is greater than or equal to 10 years. In cases, where there is consideration for modifying an existing rebuilding plan, the shortest time to rebuild is calculated as the biological limit for the stock to rebuild in the absence of fishing beginning in the year the modified rebuilding plan is implemented; this limit is denoted, "$T_{F=0}$".

A target rebuilding year, T_{TARGET}, is set as a year at T_{MIN} (or $T_{F=0}$) or greater, which does not exceed T_{MAX} ,and which is as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, and the interaction of the stock of fish within the marine ecosystem. Prior to Amendment 16-4, the Council set T_{TARGET} in part by considering the probability of rebuilding the stock by T_{MAX}. The Council may continue to review the probability of rebuilding the stock by T_{MAX} given differing harvest control rules, a reference parameter known as "P_{MAX}." The Magnuson-Stevens Act, however, simply requires that rebuilding periods be as short as possible, taking into account:

- the status and biology of any overfished stocks of fish;
- the needs of fishing communities;
- recommendations by international organizations in which the United States participates; and
- the interaction of the overfished stock of fish within the marine ecosystem (§304(e)(4)(A)(i)).

It is important to recognize that some of the terms introduced and described above represent policy decisions at the national level and the Council **does not have a choice** in setting their values. The dates for T_{MIN} and T_{MAX} are determined based on guidelines established at the national level. Mean generation time is a biological characteristic that cannot be chosen by policymakers. Thus, the Council cannot choose these values and then use them as a basis for management. Defined in national guidelines, T_{MIN} is a consequence of the productivity of the fish stock and is calculated by fishery biologists based on information they get from a particular stock. Similarly, T_{MAX}, which is calculated from T_{MIN}, does not represent a Council choice.

Policy flexibility comes into play in determining T_{TARGET}, or the time by which the stock is projected to rebuild. As explained earlier, the time to rebuild must be as short as possible, taking into account the

status and biology of the stock, the needs of fishing communities, and the interaction of the stock of fish within the marine ecosystem. When developing a management strategy the Council can choose a fishing mortality rate and corresponding annual level of fishing. However, when rebuilding overfished species, the choice of the harvest control rule is based on the value of T_{TARGET}, keeping in mind that these values cannot be chosen independently of one another. In other words, the Council may choose one value and derive the other from it, but they cannot choose these values independently of the other.

The current groundfish rebuilding plan parameters are depicted in Table 7.

Table 4. Management quantities estimated from the most recent stock assessments informing management in 2015 and beyond.

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Arrowtooth flounder	2007	0.79	80,313 mt	63,302 mt	85,175 mt	22,524 mt	0.162	5,833 mt	$F_{30\%}$
Aurora rockfish	2013	0.64	2,626 mt	1,673 mt	4,366 mt	1,213 mt	0.025	67 mt	$F_{50\%}$
Black rockfish (S of Cape Falcon)	2007	0.71	4,578.5 M larvae	3,227 M larvae	23,232 M larvae	1,831.4 M larvae	0.072	1,035.4 mt	$F_{50\%}$
Black rockfish (N of Cape Falcon)	2007	0.53	2,321 mt	1,239 mt	7,558 mt	928 mt	0.110	408 mt	$F_{50\%}$
Blackgill rockfish	2011	0.30	1,188 M larvae	359 M larvae	6,585 mt	543.0 M larvae	0.022	177 mt	$F_{50\%}$
Blue rockfish	2007	0.30	2,077 M larvae	622 M larvae	5,447 mt	831 mt	0.040	275 mt	$F_{50\%}$
Bocaccio	2013	0.31	8,117,510 M eggs	2,551,060 M eggs	19,077 mt	3,307,000 M eggs	0.067	1,341 mt	$F_{50\%}$
Brown rockfish	2013	0.42	1,794 mt	727 mt	1454 mt	582	0.102	149	$B_{40\%}$
Cabezon (CA)	2009	0.48	1,298 mt	627 mt	1,342 mt	515 mt	0.118	149 mt	$F_{45\%}$
Cabezon (OR)	2009	0.52	409 mt	214 mt	455 mt	157 mt	0.120	49 mt	$F_{45\%}$
California scorpionfish	2005	0.80	1,024 mt	816 mt	1,866 mt	259 mt	0.161	127 mt	est.
Canary rockfish	2011	0.23	27,846 mt	6,458 mt	16,124 mt	9,545 mt	0.033	799 mt	$F_{50\%}$
Chilipepper rockfish	2007	0.71	33,390 mt	23,827 mt	32,401 mt	15,482 mt	0.088	2,099 mt	$F_{50\%}$
China rockfish (N of 40º10’ N. lat.)	2013	0.37	243 mt	84 mt	168 mt	97 mt	0.045	9 mt	$B_{40\%}$
China rockfish (S of 40º10’ N. lat.)	2013	0.66	405 mt	264 mt	527 mt	162 mt	0.100	32 mt	$B_{40\%}$
Copper rockfish (N of Pt. Con.)	2013	0.48	1,704 mt	795 mt	1,590 mt	681 mt	0.083	114 mt	$B_{40\%}$
Copper rockfish (S of Pt. Con.)	2013	0.76	942 mt	699 mt	1,397 mt	377 mt	0.109	84 mt	$B_{40\%}$
Cowcod	2013	0.34	1,549 mt	524 mt	1,049 mt	620 mt	0.050	62 mt	$B_{40\%}$
Darkblotched rockfish	2013	0.36	3,358 M eggs	1,214 M eggs	16,613 mt	1,343 M eggs	0.040	675 mt	$B_{40\%}$
Dover sole	2011	0.84	469,866 mt	393,507 mt	684,685 mt	119,033 mt	0.128	34,743 mt	$F_{30\%}$
English sole	2013	0.89	29,349 mt	26,152 mt	46,968 mt	4,898 mt	0.618	4,136 mt	$F_{30\%}$
Gopher rockfish	2005	0.97	1,995 mt	1,931 mt	2,440 mt	798 mt	0.103	101 mt	$F_{50\%}$

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Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Greenspotted rockfish	2011	0.35	1,357.8 B eggs	449.9 B eggs	3,110 mt	621 B eggs	.034 N; .024 S	95.6 mt	$F_{50\%}$
Greenstriped rockfish	2009	0.81	7,090 M eggs	5,736 M eggs	29,391 mt	3,101 M eggs	0.044	738 mt	$F_{50\%}$
Kelp greenling (OR)	2005	0.49	b/	b/	b/	b/	b/	b/	b/
Lingcod (WA & OR)	2009	0.62	33,075 mt	20,484 mt	32,222 mt	13,671 mt	0.082	1,710 mt	$F_{45\%}$
Lingcod (CA)	2009	0.74	25,311 mt	18,656 mt	31,266 mt	10,462 mt	0.084	1,492 mt	$F_{45\%}$
Longnose skate	2007	0.66	7,034 mt	4,634 mt	71,971 mt	844 mt	0.043	787 mt	$F_{45\%}$
Longspine thornyhead	2013	0.75	39,134 mt	29,436 mt	68,131 mt	15,654 mt	0.060	2,487 mt	$F_{50\%}$
Pacific ocean perch	2011	0.19	6,556 B eggs	1,079.4 B eggs	106,847 mt	1,311.2 B eggs	0.032	863 mt	$F_{50\%}$
Pacific sanddabs	2013	0.96	b/	b/	b/	b/	b/	b/	b/
Pacific whiting	2013	0.72	2.081 M mt	1.504 M mt	NA	.556 M mt	0.184	.243 M mt	$F_{40\%}$
Petrale sole	2013	0.22	32,426 mt	7,233 mt	15,015 mt	8,107 mt	0.170	2,750 mt	$B_{25\%}$
Rex sole	2013	0.79	8,162 mt	6,474 mt	18,497 mt	560 mt	0.560	1,956 mt	$F_{30\%}$
Rougheye/blackspotted rockfish	2013	0.47	5,394 mt	2,552 mt	8,176 mt	2,491 mt	0.027	194 mt	$F_{50\%}$
Sablefish	2011	0.33	182,136 mt	60,957 mt	205,662 mt	61,926 mt	0.050	10,021 mt	$F_{45\%}$
Sharpchin rockfish	2013	0.89	16,208 mt	14,426 mt	12,767 mt	1,944 mt	0.101	1,004 mt	$F_{50\%}$
Shortbelly rockfish	2007	0.73	c/	35,000 mt	NA	NA	NA	NA	NA
Shortspine thornyhead	2013	0.74	189,765 mt	140,753 mt	244,400 mt	75,906 mt	0.015	2,034 mt	$F_{50\%}$
Spiny dogfish	2011	0.63	70,724 K fish	44,660 K fish	215,988 K fish	28,290 K fish	0.006	831 mt	$B_{40\%}$
Splitnose rockfish	2009	0.66	12,853 M eggs	8,426 M eggs	74,772 mt	5,006 M eggs	0.033	1,244 mt	$F_{50\%}$
Starry flounder	2005	0.50	7,158 mt	3,566 mt	7,638 mt	1,830 mt	0.229	1,848 mt	$F_{30\%}$
Stripetail rockfish	2013	>0.775	b/	b/	b/	b/	b/	b/	b/
Widow rockfish	2011	0.51	71,126 mt	36,342 mt	68,238 mt	32,315 mt	0.067	4,758 mt	$F_{50\%}$

Stock	Year of Most Recent Assessment	Est. Depletion a/	Initial Spawning Biomass (B_0)	Current Spawning Biomass a/	Current Total Biomass a/	Spawning Biomass at MSY	Harvest Rate at MSY	MSY	MSY Basis
Yelloweye rockfish	2011	0.21	1,028 M eggs	219 M eggs	2,188 mt	411 M eggs	0.022	58 mt	$F_{50\%}$
Yellowtail rockfish	2013	0.69	68,887 mt	38,168 mt	143,384 mt	19,020 mt	0.163	11,172 mt	$F_{50\%}$

a/ Estimates pertain to the most recent assessment year.

b/ The assessment results were only used for informing status since the scale of the population could not be adequately determined.

c/ A dynamic B_0 was modeled with an initial biomass estimate of 187,000 mt in 1950 and a mean unfished biomass of 48,000 mt.

Table 5. Parameters estimated and/or assumed in base models in the most recent west coast groundfish stock assessments, excluding those done using XDB-SRA.

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (K)		Natural Mortality (M)		
		value	est.?		females	males	females	males	est.?
Arrowtooth flounder	10.26	0.90	N	0.8	0.17	0.39	0.166	0.274	N
Aurora rockfish	6.64	0.78	N	0.5	0.09	0.09	0.035	0.037	a/
Black rockfish (S of Cape Falcon)	8.97	0.60	N	0.5	0.17	0.26	0.160 < 10 yrs 0.240 > 15 yrs	0.160	N
Black rockfish (N of Cape Falcon)	8.04	0.60	N	0.35	0.164	0.194	0.200	0.160	Y
Blackgill rockfish	7.73	0.65	N	0.5	0.028	0.047	0.063	0.065	N
Blue rockfish	8.08	0.58	N	0.5	0.147	0.295	0.100	0.120	N
Bocaccio	8.55	0.61	Y	1.0	0.22	0.27	0.150	0.150	N
Cabezon (CA N of Pt. Con.)	6.78	0.70	N	0.5	0.149	0.269	0.250	0.300	N
Cabezon (CA S of Pt. Con.)	5.33	0.70	N	0.7	0.130	0.230	0.250	0.300	N
Cabezon (OR)	5.27	0.70	N	0.5	0.190	0.178	0.250	0.300	N
California scorpionfish	7.63	0.70	N	1.0	0.13	0.12	0.250	0.250	N
Canary rockfish	8.12	0.51	N	0.5	0.125	0.162	0.060 < 6 yrs 0.092 ≥ 6 yrs	0.060	Y
Chilipepper rockfish	19.45	0.57	N	1.0	0.2 - 0.32 b/	0.2 - 0.32 b/	0.160	0.200	N
Darkblotched rockfish	7.84	0.78	N	0.75	0.2	0.26	0.050	0.067	a/

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (K)		Natural Mortality (M)		
		value	est.?		females	males	females	males	est.?
Dover sole	12.85	0.80	N	0.35	0.150	0.171	0.117	0.142	Y
English sole	11.62	0.80	N	0.8	0.393	0.480	0.260	0.260	N
Gopher rockfish	7.92	0.65	N	0.5	0.186	0.186	0.200	0.200	N
Greenspotted rockfish (CA N of Pt. Con.)	6.15	0.76	N	0.7	0.057	0.057	0.065	0.065	N
Greenspotted rockfish (CA S of Pt. Con.)	6.65	0.76	N	0.7	0.042	0.042	0.065	0.065	N
Greenstriped rockfish	9.62	0.69	N	0.84	0.11	0.15	0.080	0.080	N
Kelp greenling (OR)	7.02	0.70	N	1.0	0.3	0.4	0.260	0.260	N
Lingcod (WA & OR)	8.06	0.80	N	0.5	0.13	0.22	0.180	0.320	N
Lingcod (CA)	8.17	0.80	N	0.5	0.11	0.23	0.180	0.320	N
Longnose skate	9.65	0.40	N	c/	0.064	0.064	0.200	0.200	N
Longspine thornyhead	11.82	0.60	N	0.6	0.109	0.109	0.111	0.111	N
Pacific ocean perch	9.14	0.40	N	0.7	0.159	0.195	0.050	0.051	N
Pacific whiting	21.71	0.82	Y	1.4	d/	d/	0.224	0.224	Y
Petrale sole	9.72	0.86	Y	0.4	0.13	0.21	0.150	0.169	Y
Rex sole	9.97	0.80	N	0.8	0.388	0.388	0.200	0.190	Y
Rougheye/blackspotted rockfish	6.19	0.78	N	0.4	0.081	0.081	0.042	0.042	Y
Sablefish	10.01	0.60	N	0.6	0.335	0.419	0.080	0.065	Y
Sharpchin rockfish	9.16	0.95	Y	0.8	0.17	0.20	0.080	0.080	N
Shortbelly rockfish	12.64	0.65	N	1.0	0.198	0.200	0.260	0.260	N
Shortspine thornyhead	10.32	0.60	N	0.5	0.018	0.018	0.051	0.051	N
Spiny dogfish	10.07	0.28	e/	0.2	0.026	0.052	0.064	0.064	N
Splitnose rockfish	9.54	0.58	N	1.0	0.156	0.165	0.048	0.048	N
Starry flounder (OR & WA)	7.96	0.80	N	1.0	0.251	0.426	0.510	0.760	N
Starry flounder (CA)	7.23	0.80	N	1.0	0.251	0.426	0.510	0.760	N
Widow rockfish	10.06	0.76	N	0.65	0.209	0.233	0.120	0.129	Y
Yelloweye rockfish	5.43	0.44	Y	b/	0.047	0.047	0.046	0.045	Y
Yellowtail rockfish	10.28	0.95	Y	0.8	0.170	0.190	0.110	0.110	Y

a/ Female M was fixed and male M was estimated as an offset to female M.

b/The base case model allowed growth for each sex to differ between blocks of time, based on freely estimating the K parameter.

c/ Recruitment variability (sigma-r) not estimated.

Stock	ln(R0)	Steepness (h)		Sigma-r	von-Bertalanffy Growth Coefficient (K)		Natural Mortality (M)		
		value	est.?		females	males	females	males	est.?

d/ The 2013 Pacific whiting assessment uses weight-at-age, thus there is no estimate of growth. Weight-at-age varies between years; therefore, growth is time-varying.

e/ Steepness was a derived quantity from the 2011 assessment, not an estimated parameter from an alternative stock-recruitment relationship modeled in the assessment.

Table 6. Parameters estimated and/or assumed in base models in 2013 west coast groundfish stock assessments using XDB-SRA.

Stock	ln(R0)	Productivity Parameters				von-Bertalanffy Growth Coefficient (K)		Natural Mortality (M)		
		B_{MSY}	F_{MSY}	B_{MSY}/B_0	F_{MSY}/M	females	males	females	males	est.?
Brown rockfish		1,387.4	0.129	0.400	0.954	0.16	0.16	0.134	0.137	Y
China rockfish (N of 40º10’ N lat.)		186.1	0.053	0.395	0.918	0.192	0.194	0.057	0.055	Y
China rockfish (S of 40º10’ N lat.)		417.2	0.088	0.464	1.304	0.192	0.194	0.065	0.055	Y
Copper rockfish (N of Pt. Con.)		1,103.9	0.099	0.404	1.092	0.127	0.224	0.089	0.090	Y
Copper rockfish (S of Pt. Con.)		1,058.4	0.094	0.481	1.040	0.127	0.224	0.089	0.090	Y
Cowcod		1,239.5	0.050	0.422	1.051	NA	NA	0.054	NA	Y

1.1.3 Overfished Groundfish Stocks

There are six overfished west coast rockfish stocks (i.e., bocaccio south of 40º10' N lat., canary rockfish, cowcod south of 40º10' N lat., darkblotched rockfish, Pacific ocean perch, and yelloweye rockfish) and one overfished flatfish stock (i.e., petrale sole) at the start of 2013. All seven of these stocks are rebuilding and three (i.e., bocaccio south of 40º10' N lat., darkblotched rockfish, and petrale sole) are predicted to rebuild by the start of 2015. Descriptions of these overfished groundfish stocks follows.

Stock rebuilding parameters estimated from the most recent rebuilding analyses and current rebuilding parameters specified at the start of 2013 are provided in Table 7.

Table 7. Rebuilding parameters estimated in the most recent rebuilding analyses and specified in rebuilding plans for overfished groundfish stocks at the start of the 2013-2014 management cycle.

Stock	T_{MIN}	$T_{F=0}$	T_{MAX}	T_{TARGET}	Harvest Control Rule Specification
Bocaccio	2018	2018	2031	2022	SPR 77.7%
Canary	2027	2028	2050	2030	SPR 88.7%
Cowcod	2059	2060	2097	2068	SPR 82.7%
Darkblotched	2012	2016	2037	2025	SPR 64.9%
POP	2040	2043	2071	2051	SPR 86.4%
Petrale sole	2014	2014	2021	2016	25-5 Rule
Yelloweye	2044	2047	2089	2074	SPR 76%

1.1.3.1 Bocaccio

Distribution and Life History

Bocaccio (*Sebastes paucispinis*) is a rockfish species that ranges from Stepovak Bay on the Alaskan Peninsula (as well as Kodiak Island, Alaska) to Punta Blanca, Baja California, Mexico (Hart 1988; Miller and Lea 1972). Love, et al. (2002) and Thomas and MacCall (2001) describe bocaccio distribution and life history. Bocaccio are historically most abundant in waters off central and southern California. The southern bocaccio stock is most prevalent in the 54-82 fm depth zone (Casillas, *et al.* 1998).

Bocaccio are found in a wide variety of habitats, often on or near bottom features, but sometimes over muddy bottoms. They are found both nearshore and offshore (Sakuma and Ralston 1995). Larvae and small juveniles are pelagic (Garrison and Miller 1982) and are commonly found in the upper 100 m of the water column, often far from shore (MBC 1987). Large juveniles and adults are semi-demersal and are most often found in shallow coastal waters over rocky bottoms associated with algae (Sakuma and Ralston 1995). Adults are commonly found in eelgrass beds, or congregated around floating kelp beds love (Love, *et al.* 1990; Sakuma and Ralston 1995). Young and adult bocaccio also occur around artificial structures, such as piers and oil platforms (MBC 1987). Although juveniles and adults are usually found around vertical relief, adult aggregations also occur over firm sand-mud bottoms (MBC 1987). Bocaccio move into shallow waters during their first year of life hart (Hart 1988), then move into deeper water with increased size and age (Garrison and Miller 1982).

Bocaccio are ovoviviparous (live young are produced from eggs that hatch within the female's body) (Garrison and Miller 1982; Hart 1988). Love et al. (1990) reported the spawning season to last nearly an

entire year (>10 months). Parturition occurs during January to April off Washington, November to March off Northern and Central California, and October to March off Southern California (MBC 1987). Fecundity ranges from 20,000 to 2,300,000 eggs. In California, two or more broods may be born per year (Love, *et al.* 1990). The spawning season is not well known in northern waters. Males mature at three to seven years, with about half maturing in four to five years. Females mature at three to eight years, with about half maturing in four to six years (MBC 1987).

Maximum age of bocaccio was radiometrically determined to be at least 40 years, and perhaps more than 50 years. Bocaccio are difficult to age, and stock assessments used length measurement data and growth curves to estimate the age composition of the stock (Ralston and Ianelli 1998). Although recent assessments have described the true natural mortality rate as a key unknown for estimating stock status, recent assessments have used a value of 0.15 (which is associated with an 86 percent adult annual survival rate in the absence of fishing mortality).

Larval bocaccio 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). Both Phillips (1964) and Love et al. (2002) described bocaccio rockfish as almost exclusively piscivorous, and include other rockfish, Pacific whiting, sablefish, anchovy, mesopelagic fishes and squid as the key prey for large juvenile and adult bocaccio. Bocaccio are eaten by sharks, salmon, other rockfishes, lingcod, albacore, sea lions, porpoises, and whales (MBC 1987). Adult bocaccio are often caught with chilipepper rockfish and have been observed schooling with speckled, vermilion, widow, and yellowtail rockfish (Love, *et al.* 2002). As pelagic juveniles, they may compete with chilipepper, widow, yellowtail, shortbelly, and other pelagic juvenile rockfishes for both food and habitat (Reilly, *et al.* 1992).

Stock Status and Management History

Bocaccio are managed as two separate west coast populations. The southern stock exists south of Cape Mendocino and the northern stock north of Cape Mendocino (the northern stock density is limited south of 48° N lat. with increasing abundance off Cape Flattery, Washington and points north). It is unclear whether this stock separation implies stock structure. The distribution of the two populations and evidence of lack of genetic intermixing suggests stock structure, although MacCall (2002) reported some evidence for limited genetic mixing of the two populations. Nonetheless, assessment scientists and managers have treated the two populations as independent stocks north and south of Cape Mendocino.

Bocaccio have long been an important component of California rockfish fisheries. Catches increased to high levels in the 1970s and early 1980s as relatively strong year-classes recruited to the stock. The Council began to recommend increasingly restrictive regulations after an assessment of the southern stock in 1990 (Bence and Hightower 1990) indicated that fishing rates were too high. The southern stock suffered poor recruitment during the warm water conditions that prevailed off Southern California beginning in the late 1980s. The 1996 assessment (Ralston, *et al.* 1996) indicated the stock was in severe decline. NMFS formally declared the stock overfished in March 1999 after the groundfish FMP was amended to incorporate the tenets of the Sustainable Fisheries Act. MacCall et al. (1999) confirmed the overfished status of bocaccio and estimated spawning output of the southern stock to be 2.1 percent of its unfished biomass.

In the 2002 assessment (MacCall 2002) relative abundance increased slightly from the previous assessment (4.8 percent of unfished biomass), potential productivity (as evidenced from the steepness of the spawner/recruit relationship, which reflects the level of compensatory production at low stock sizes) appeared lower than previously thought, making for a more pessimistic outlook. Furthermore, the 2002 assessment revealed that although the 1999 year class was the strongest in several years, it was weak

relative to the range of possibilities considered in the 1999 assessment. The 2002 rebuilding analysis (MacCall and He 2002) predicted the stock would not rebuild within maximum time legally possible (T_{MAX}) even with no fishing-related mortality. Total mortality in 2003 fisheries was restricted to less than 20 mt as a means of conserving the stock while minimizing adverse socioeconomic impacts to communities.

The 2003 bocaccio assessment (MacCall 2003b) estimated a higher stock biomass (7.4% depletion) relative to the 2002 assessment. The instantaneous rate of natural mortality was changed from 0.2 to 0.15. Additional CalCOFI data indicated an increasing abundance trend due to recruitment of the 1999 year class. This was corroborated by a dramatic increase in recreational CPUE, which was at a record high level in central California north of Pt. Conception. The 2003 rebuilding analysis suggested the stock could rebuild to B_{MSY} within 25 years while sustaining an OY of approximately 300 mt in 2004 (MacCall 2003a).

The 2003 assessment was updated in 2005 and 2007 (MacCall 2006b; MacCall 2008b) using the original 2003 base model (i.e., STATc) in SS1. These assessments were used to establish annual specifications and management measures consistent with a strategy of a higher OY than the impacts anticipated under the suite of management measures adopted. This strategy was designed to buffer the effects of a large recruitment event like that observed for the 1999 year class. Such effects include disruption to fisheries as experienced in previous years when fisheries closed early to avoid young bocaccio. This buffer strategy, which addressed the large, episodic recruitment pattern inherent in the stock's dynamics, became a tenet of the bocaccio rebuilding plan.

A bocaccio rebuilding plan was adopted by the Council in 2004 under Amendment 16-3 (PFMC 2004). The rebuilding plan established a target rebuilding year of 2023 and a harvest control rule of F = 0.0498 (with a rebuilding probability (P_{MAX}) of 70 percent). (It was later clarified in the 2005 rebuilding analysis (MacCall 2006a) that the target rebuilding year had been incorrectly stated in the rebuilding plan to be 2023 since the 2003 rebuilding analysis indicated that a 50 percent probability rebuilding would require 23 years, and that this assumed a beginning date of 2004 (the first simulated year). Therefore, the Council amended the rebuilding plan's target year to 2026.

A new rebuilding analysis was conducted in 2007 (MacCall 2008a) based on the results of the 2007 stock assessment (MacCall 2008b). The 2007 bocaccio rebuilding analysis showed a similar rebuilding trajectory to that adopted in Amendment 16-4 and the rebuilding plan was maintained for the 2009-2010 management cycle.

A new bocaccio assessment (Field, *et al.* 2009) and rebuilding analysis (Field and He 2009) were prepared in 2009. Field et al. (2009) extended the assessment north of Cape Mendocino to Cape Blanco, Oregon; the U.S. west coast stock north of this point has not been assessed. Indications of strong 2009 and 2010 year classes were projected to result in increased abundance. Depletion in 2011 was estimated at 26 percent (18.7 -33.1 percent), with the stock projected to be rebuilt by 2019. Based on these analyses, the Council changed the target year for rebuilding bocaccio from 2026 to 2022; the amended rebuilding plan was implemented in 2011.

A bocaccio stock assessment update (Field 2011b) and rebuilding analysis (Field 2011a) were prepared in 2011. The 2011 bocaccio assessment was originally scheduled to be an update of the 2009 full assessment; however, the STAT some limited changes in the 2009 model structure since a strict update estimated that the 2010 year class was extraordinarily and unrealistically strong, based on length frequency data collected in the 2010 NMFS trawl survey. The modified update was ultimately reviewed, endorsed by the SSC, and adopted for use in management decision-making. The 2011 bocaccio rebuilding analysis indicated rebuilding progress was well ahead of schedule with a predicted median year

to rebuild of 2021 or one year earlier than the target rebuilding year (Field 2011a). The Council elected to maintain the revised rebuilding plan implemented in 2011.

An update of the 2011 bocaccio assessment model was prepared in 2013, which confirmed the 2009 and 2010 year classes were indeed strong (Field 2013). The assessment estimated a depletion of 31.4 percent at the start of 2013 (Figure 4) and predicted the stock would rebuild by 2015. The SSC recommended maintaining the current rebuilding plan for the 2015-2016 management cycle and a full assessment be done in 2015 to confirm this prediction. The SSC further recommended against preparing a rebuilding analysis in 2013.

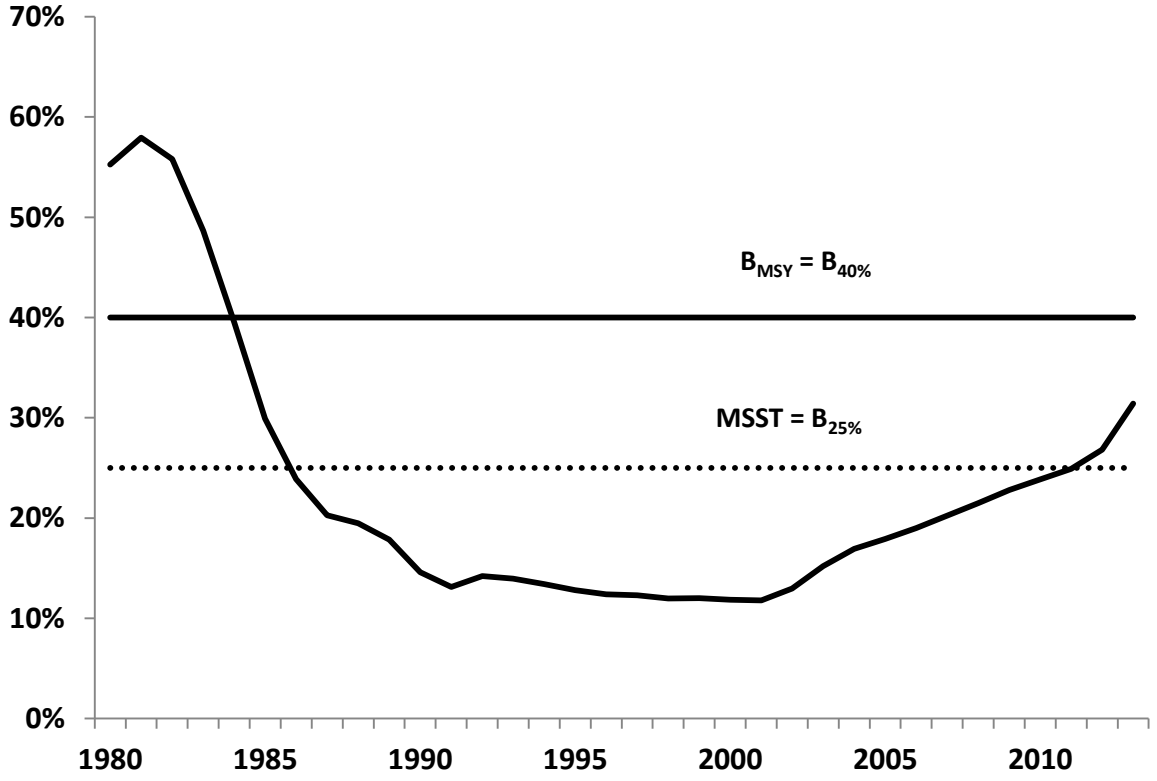

Figure 4. Relative depletion of bocaccio south of 40º10' N lat. from 1980 to 2013 based on the 2013 stock assessment update.

Stock Productivity Relative to Rebuilding Success

The 2013 bocaccio assessment produced a (very slightly) more optimistic estimation of steepness (from 0.595 to 0.614) relative to the 2011 model (the 2009 model had a point estimate of 0.573). Despite these modest changes, the overall trajectory of spawning output, relative spawning output, total biomass and recruitment are barely distinguishable as changed from the 2011 model, with the most important change being the relative strength of the 2010 year class. The strength of the 2010 year class is estimated with less uncertainty in the 2013 assessment.

Recruitment for bocaccio is highly variable, with a small number of year classes tending to dominate the catch in any given fishery or region. Adult abundance is highly variable even in the absence of fishing

(MacCall 2002). Recruitment appears to have been at very low levels throughout most of the 1990s, but the 1999 year class was the highest since 1988, and led to a substantive increase in abundance during the early 2000s. Several year classes of moderate strength (2003, 2005) occurred in the mid-2000s, and two recent very strong year classes (2009 and 2010) are now estimated to be comparable to (2009) and roughly double (2010) the size of the 1999 year class (Figure 5). These year classes were strongly evident in recreational length frequency data, in the NWFSC hook and line survey data (and length comps), and in the power plant impingement dataset modeled by Field (2013), as well as in an index (not included in the 2013 assessment update) of recreational CPUE. These strong year classes are already estimated to have resulted in an increase in abundance and spawning output, and should propel the stock spawning output to target levels by approximately 2015 as the 2010 year class continues to grow and mature. Preliminary estimates from the juvenile rockfish survey also indicate very strong abundance of young-of-the-year rockfish of many species (including bocaccio) in 2013, suggesting anecdotally that 2013 will also be a strong recruitment year for bocaccio, as well as for other species. However, these data are not incorporated in the 2013 update, which only includes data through 2012. Although poorly understood, the stock assessment suggests that recovery may be taking place more rapidly in the south, and recovery in the central/northern California region may be dependent on an influx of fish from the southern area.

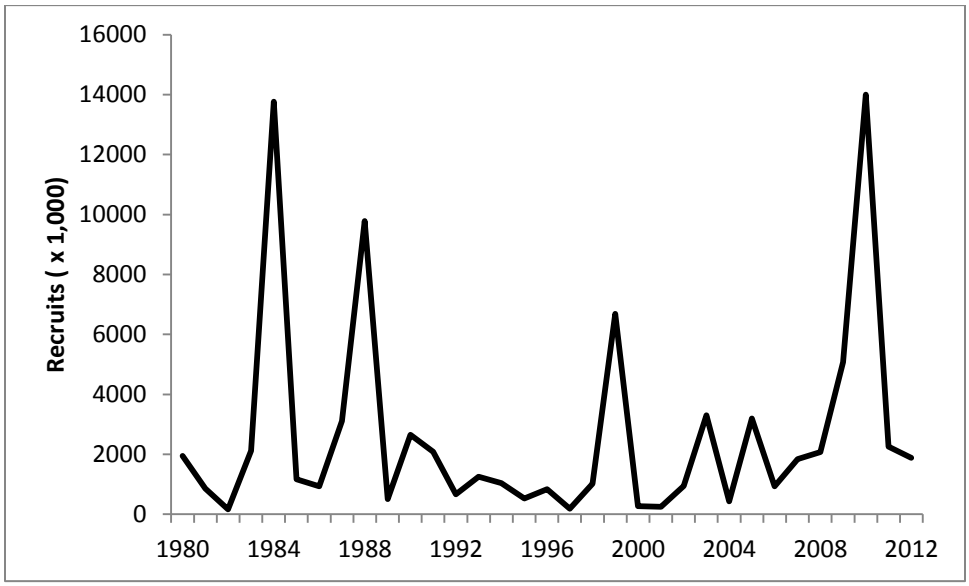

Figure 5. Estimated bocaccio recruitments, 1980-2012 (from Field 2013).

Fishing Mortality

The presence of a banner 2010 year class in the bocaccio stock is not entirely unexpected. Bocaccio stock production is characterized by high episodic recruitment and relatively rapid juvenile growth rates Field, et al. 2009. Juvenile bocaccio also recruit to shallow waters and are consequently caught in nearshore recreational fisheries as evidenced by dramatic spikes in both catch rates and the percentage of the total southern California rockfish catch that is bocaccio following strong recruitment events. Unlike most rockfish species where recruitment to fisheries usually takes several years due to low growth rates, juvenile bocaccio can recruit to nearshore fisheries in California within a year or two of parturition. Recruitment of the strong 1999 year class complicated management of California fisheries in 2001-2003, as this unpredictable event could not be reacted to in time given the lag in reconciling recreational catch estimates. Most species' rebuilding analyses are able to project recruitment into affected fisheries in time to decide and implement responsive management measures that will not compromise rebuilding plans.

However, the fast growth and unpredictable recruitment of bocaccio poses the unique problem of having to react to a large recruitment event in real time. This experience has led the Council to a strategy of adopting higher bocaccio OYs/ACLs and more conservative management measures that are predicted to result in catches much lower than these harvest limits. The rebuilding strategy has been formalized by deciding OYs/ACLs to determine rebuilding objectives and more stringent HGs for California. The buffer between the ACL (formerly the OY) and the HG accommodates the management uncertainty of an unforeseen recruitment event disrupting fisheries. Unlike an ACL, fisheries do not need to close upon attainment of an HG. The difference between the projected catch and the HG or ACL provides managers time to react to a strong recruitment to minimize mortality on bocaccio while minimizing disruptions to ongoing fisheries. This strategy has worked well to enhance bocaccio rebuilding while minimizing harm to California fishing communities.

Catch monitoring uncertainty is relatively high given the fact that a substantial amount of the total fishing mortality of bocaccio now occurs in the California recreational fishery, the sector with the largest bocaccio take in recent years. Recent recreational catch is estimated using the new California Recreational Fishing Survey (CRFS) program, which has been in existence since 2004. Prior to 2004, all recreational catch was estimated using the Marine Recreational Fisheries Statistical Survey (MRFSS) program, a survey methodology designed to understand long-term national trends in marine recreational catch and participation. The higher uncertainty in monitoring California recreational catches also translates into higher uncertainty in projecting recreational total mortalities. The fact that a substantial portion of the current take of bocaccio is in the California recreational fishery is another consideration for a relatively larger buffer between the predicted mortalities of bocaccio and the preferred ACLs.

Insert text and figure showing annual SPRs rel. to SPR of 77.7%

Rebuilding Duration and Probabilities

There is a high probability of successful bocaccio rebuilding by 2015 given the strength of recent year classes currently recruiting into the spawning population. The SSC has recommended a full assessment in 2015 to confirm this prediction.

1.1.3.2 Canary Rockfish

Distribution and Life History

Canary rockfish (*Sebastes pinniger*) are distributed in the northeastern Pacific Ocean from the western Gulf of Alaska to northern Baja California; however, the species is most abundant from British Columbia to central California (Hart 1988; Love, *et al.* 2002; Miller and Lea 1972). Adults are primarily found along the continental shelf shallower than 300 m, although they are occasionally observed in deeper waters. Juvenile canary rockfish are found in shallow and intertidal areas (Love, *et al.* 2002).

Canary rockfish spawn in the winter, producing pelagic larvae and juveniles that remain in the upper water column for 3-4 months (Love, *et al.* 2002). These juveniles settle in shallow water around nearshore rocky reefs, where they may congregate for up to three years (Boehlert 1980; Sampson 1996) before moving into deeper water. The mean size of individuals captured in the trawl survey shows a characteristic ontogenetic shift to deeper water with increasing body size. The degree to which this ontogenetic shift may be accompanied by a component of latitudinal dispersal from shallow rocky reefs is unknown. Canary rockfish are a medium to large-bodied rockfish; achieving a maximum size of around 70 cm. Female canary rockfish reach slightly larger sizes than males.

Adult canary rockfish primarily inhabit areas in and around rocky habitat. They form very dense schools, leading to an extremely patchy population distribution that is reflected in both fishery and survey encounter rates.

Canary rockfish are relatively long-lived, with a maximum observed age of 95 years, however only males are commonly observed above the age of 50, while females tend to be rare above age 30. The degree to which this pattern reflects behavioral differences translating to reduced availability to fishery and survey fishing gear, or an increase in relative mortality for older females has been the focus of much discussion and remains unclear. A similar pattern has been observed for yellowtail rockfish (*Sebastes flavidus*), a closely related, but more pelagic species with a similar distribution (Wallace and Lai 2006).

Canary rockfish off the west coast exhibit a protracted spawning period from September through March, probably peaking in December and January off Washington and Oregon (Hart 1988; Johnson, *et al.* 1982). Female canary rockfish reach sexual maturity at roughly eight years of age. Like many members of Sebastes, canary rockfish are ovoviviparous, whereby eggs are internally fertilized within females, and hatched eggs are released as live young bond 1979 (Bond 1979; Golden and Demory 1984; Kendall and Lenarz 1986). Canary rockfish are a relatively fecund species, with egg production being correlated with size (e.g., a 49-cm female can produce roughly 0.8 million eggs, and a female that has realized maximum length (approximately 60 cm) produces approximately 1.5 million eggs (Gunderson 1971).

Very little is known about the early life history strategies of canary rockfish. The limited research that has been conducted indicates that larvae are strictly pelagic (near the ocean surface) for a short period of time and begin to migrate to demersal waters during the summer of their first year of life. Larvae develop into juveniles around nearshore rocky reefs, where they may congregate for up to three years (Boehlert 1980; Sampson 1996) . Evaluations of length distributions by depth demonstrate an increasing trend in mean size of fish with depth (Methot and Stewart 2006). Since 1990, stock assessments have assumed a base natural mortality rate of 0.06 (94 percent adult annual survival when there is no fishing mortality). Due to the rarity of old females in both survey and catch data, female canary rockfish have long been assumed to have increasing natural mortality rates with age (Golden and Wood 1990).

Little is known about ecological relationships between canary rockfish and other organisms. Adult canary rockfish are often caught with bocaccio, sharpchin, yelloweye, and yellowtail rockfishes, and lingcod. Researchers have also observed canary rockfish associated with silvergray and widow rockfish. Young-of-the-year feed on copepods, amphipods, and young stages of euphausiids. Adult canary rockfish feed primarily on euphausiids, as well as pelagic shrimp, cephalopods, mesopelagic fishes and other prey (Brodeur and Percy 1984; Lee 2002; Phillips 1964). Small canary rockfish are consumed by seabirds, Chinook salmon, lingcod, and marine mammals.

Stock Status and Management History

Canary rockfish have long been an important component of rockfish fisheries. The Council began to recommend increasingly restrictive regulations after an assessment in 1994 (Sampson and Stewart 1994) indicated that fishing rates were too high. Wallace and Cope (2011) estimated that the abundance of the canary rockfish stock dropped below B_{MSY} ($B_{40\%}$) in 1983 and below the MSST in 1990, at which time the annual catch was more than double the current estimate of the MSY level. Harvest rates in excess of the current fishing mortality target for rockfish (SPR = 50%) is estimated to have begun in the late 1970s and persisted through 1999. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since 1999, and recent SPR values are in excess of 90 percent.

A 1999 stock assessment showed the stock had declined to 6.6 percent of unfished biomass in the northern area (Columbia and U.S. Vancouver management areas) (Crone, *et al.* 1999) and in the southern

area (Conception, Monterey, and Eureka areas) (Williams, *et al.* 1999). The stock was declared overfished in January 2000. The first rebuilding analysis (Methot 2000) used results from the northern area assessment to project rates of potential stock recovery. The stock was found to have extremely low productivity, defined as production of recruits in excess of the level necessary to maintain the stock at its current, low level. Rates of recovery were highly dependent upon the level of recent recruitment, which could not be estimated with high certainty. The initial rebuilding OY for 2001 and 2002 was set at 93 mt based upon a 50 percent probability of rebuilding by the year 2057, a medium level for these recent recruitments, and maintaining a constant annual catch of 93 mt through 2002.

A coastwide 2002 canary rockfish assessment estimated stock depletion to be 7.9 percent at the start of 2002 (Methot and Piner 2002b). A canary rockfish rebuilding plan was adopted in 2003 under Amendment 16-2 based on the results of the 2002 rebuilding analysis (Methot and Piner 2002a). The rebuilding plan established a target rebuilding year of 2074 and the harvest control rule of F = 0.022 (with a P_{MAX} of 60 percent).

A full canary rockfish assessment was done in 2005 indicating a stock depletion of 9.0 percent at the start of 2005 (Methot and Stewart 2006). The assessment was based on two equally plausible models; one with differential male and female gear selectivities and one without gender-specific selectivities. A critical uncertainty in canary rockfish assessments was the lack of older, mature females in surveys and other assessment indices. There were two competing explanations for this observation. Older females could have a higher natural mortality rate, resulting in their disproportionate disappearance from the population. Alternatively, survey and fishing gears may be less effective at catching them, perhaps because older females are associated with habitat inaccessible to most trawl gear. If this is the case, then these fish (which, because of their higher spawning output, may make an important contribution to future recruitment) are part of the population, but remain poorly sampled. Methot and Stewart (2006) assumed a linear increase in female natural mortality from 0.06 at age 6 to approximately 0.09 at age 14. In the base model (differential male-female selectivity) B_0 was estimated to be 34,798 mt, resulting in a depletion level of 5.7 percent. In the alternate model (no difference in selectivity) B_0 was estimated to be 33,872 mt, with a depletion level of 11.3 percent. The steepness of the spawner-recruitment relationship, which largely determines the rate of increase in recruitment as the stock rebuilds, was estimated to be 0.33 in the base model, and 0.45 in the alternate model. The approved canary rockfish rebuilding analysis (Methot 2006) blended the two models by alternately re-sampling between the two input parameter sets.

The 2005 canary rebuilding analysis (Methot 2006) was used to inform the revised canary rebuilding plan adopted under Amendment 16-4, which specified a target rebuilding year of 2063 and a constant harvest strategy (SPR = 88.7%). Amendment 16-4 rebuilding plans were implemented in 2007.

The 2007 canary assessment estimated relative depletion level was 32.4 percent at the start of 2007 (Stewart 2008b). This was a significant departure from the previous assessment and largely driven by a higher assumed steepness (h = 0.51) relative to past assessments. The 2007 canary rebuilding analysis (Stewart 2008a) predicted the SPR harvest rate in the rebuilding plan (88.7%) would rebuild 42 years earlier (2021) than the originally estimated rebuilding schedule (2063). A modification of the Amendment 16-4 canary rockfish rebuilding plan specifying a target rebuilding year of 2021 while maintaining the SPR harvest rate of 88.7% was implemented in 2009.

The 2009 canary assessment (Stewart 2009c), an update of the 2007 assessment, estimated stock depletion at 23.7% at the start of 2009. This change in stock status was due to a lower estimate of initial, unfished biomass (B_0) largely attributable to the inclusion of revised historical California catches from a formal reconstruction of 1916-1980 California catch data (Ralston, *et al.* 2010). The 2009 canary rebuilding analysis (Stewart 2009a) predicted the stock would not rebuild to the target year of 2021 with at least a 50% probability even in the absence of fishing-related mortality starting in 2011 ($T_{F=0}$). The

rebuilding plan was revised by changing the target to rebuild the stock to 2027 while maintaining the 88.7% SPR harvest rate; the revised rebuilding plan was implemented in 2011.

Another update assessment was prepared in 2011 (Wallace and Cope 2011), which estimated stock depletion was 23.2 percent at the start of 2011 (Figure 6). This change in stock status was due to a lower estimate of initial, unfished biomass (B_0) largely attributable to the inclusion of revised historical Oregon catches from a formal reconstruction of Oregon catch data. For the period 2000-2011, the spawning biomass was estimated to have increased from 11.2 percent to 23.2 percent of the unfished biomass level.

The 2011 canary rebuilding analysis (Wallace 2011) predicted the stock would not rebuild to the target year of 2027 with at least a 50% probability. The rebuilding plan was revised slightly by changing the target to rebuild the stock to 2030 while maintaining the 88.7% SPR harvest rate; the revised rebuilding plan was implemented in 2013.

A canary catch report was provided in 2013 (Agenda Item F.5.a, Attachment 9, June 2013), which indicated 2010-2012 total catches were below specified ACLs/OYs.

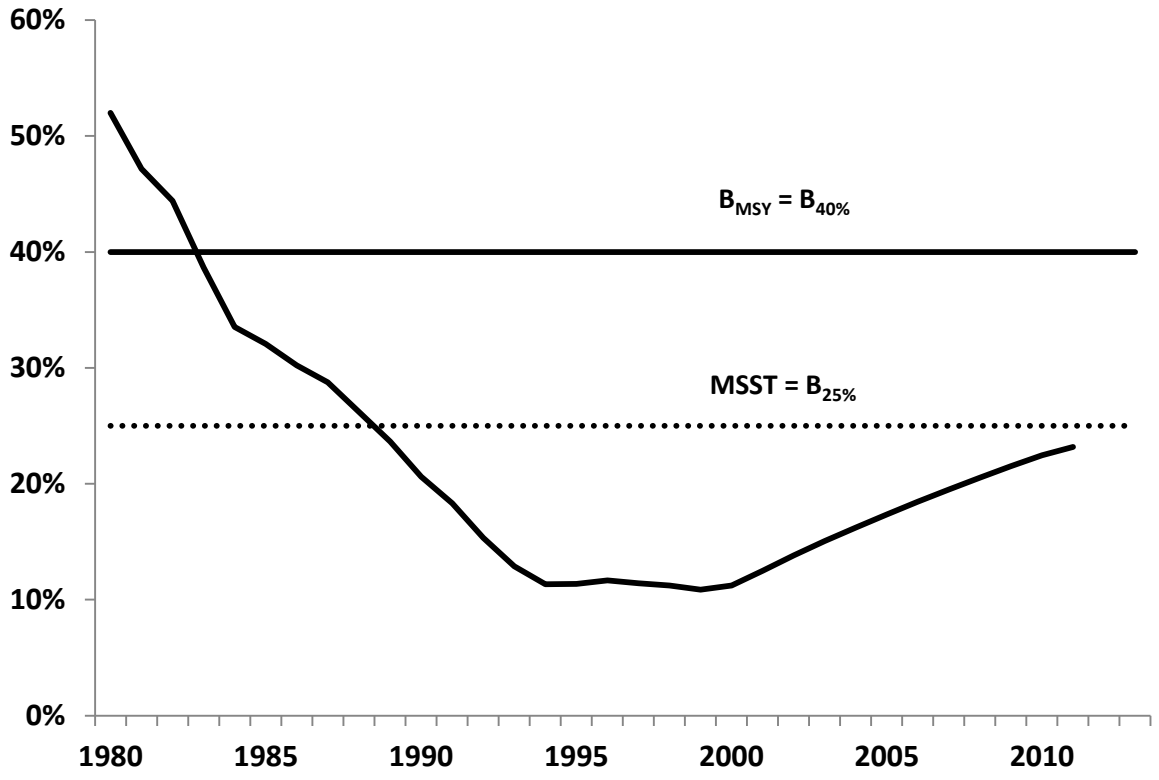

Figure 6. Relative depletion of canary rockfish from 1980 to 2011 based on the 2011 stock assessment update.

Stock Productivity Relative to Rebuilding Success

Steepness is assumed to be 0.511 in the latest full assessment (Stewart 2008b) and the subsequent updates to that assessment (Stewart 2009c; Wallace and Cope 2011). This is a moderate to relatively low value of steepness for rockfish, as compares to the prior mean steepness (0.779) derived from meta-analysis of west coast rockfish stocks used in 2013 assessments (e.g., darkblotched rockfish, see section 1.1.3.4).

Lower steepness implies a greater dependence on the size of the spawning population. The projected increase in the canary rockfish biomass from the 2011 assessment is very sensitive to the value for steepness and was projected to slow as below average recruitments begin to contribute to the spawning biomass.

Steepness is a difficult parameter to estimate and canary rockfish assessments are especially uninformative of steepness. The assumed canary steepness of 0.511 used in the last three assessments was based on the Dorn (2002a; Dorn 2002b) meta-analysis of west coast rockfish stocks The value used in many 2013 assessments was based on an update of the Dorn (2002a) analysis (J. Thorson, pers. comm.).

Wallace and Cope (2011) estimated canary rockfish recruitment deviations based on the data. After a period of above average recruitments, recent year-class strengths (1997-2010) have generally been low, with only 2 of the 10 years (2001 and 2007) producing large estimated recruitments (Figure 7). The strength of the 2007 year class is subject to greater uncertainty than other strong recruitment events in the last 30 years because of the limited number of years in which it has been observed. As the larger recruitments from the late 1980s and early 1990s move through the population in future projections, the effects of recent poor recruitment may tend to slow the rate of recovery.

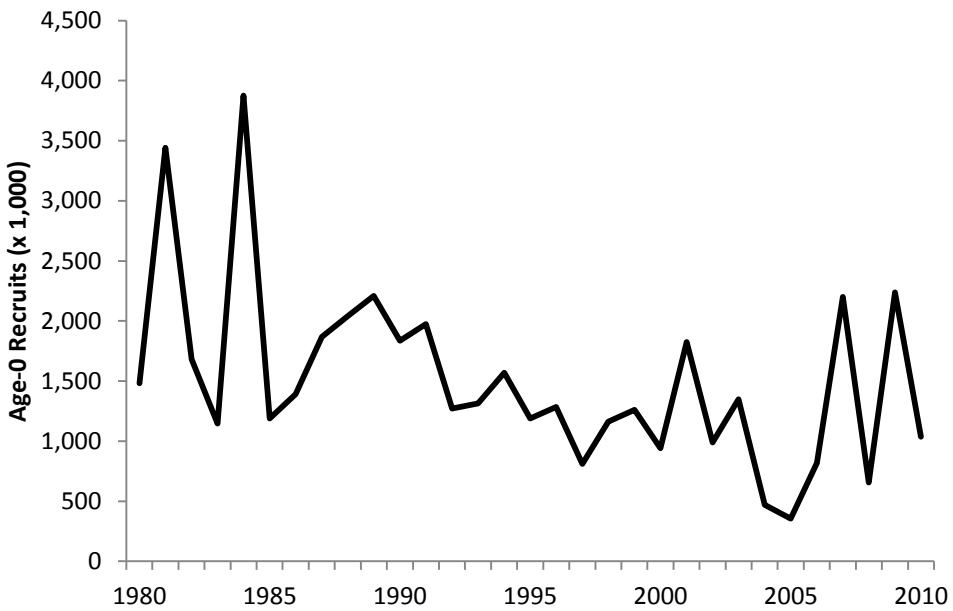

Figure 7. Estimated canary rockfish recruitments, 1980-2010 (from Wallace and Cope 2011).

Fishing Mortality

Fishing mortality rates for canary rockfish in excess of the current proxy F_{MSY} harvest rates for rockfish (SPR = 50%) are estimated to have begun in the late 1970s and persisted through 1999. Figure 8 depicts estimated annual harvest rates relative to the overfishing limit (F_{MSY}) and the current SPR harvest rate limit specified in the rebuilding plan. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since before 1999 and maintained harvest rates below the current rebuilding SPR since 2005. Relative exploitation rates (catch/biomass of age-5 and older fish) are estimated to have been less than 1% since 2001.

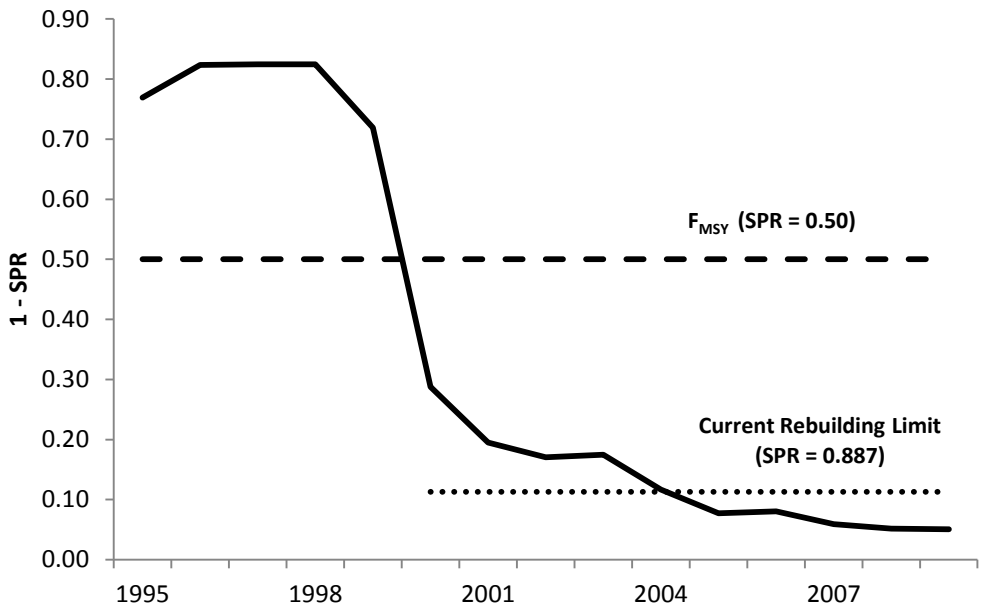

Figure 8. Estimated spawning potential ratio (SPR) of canary rockfish relative to the current F_{MSY} and rebuilding harvest rates, 1995-2010. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

Rebuilding Duration and Probabilities

Wallace 2013 estimated the canary rebuilding probability (P_{MAX}) under the current SPR harvest rate of 88.7% is 75 percent. There is a 50 percent probability of recovering by the current target year of 2030.

1.1.3.3 Cowcod

Distribution and Life History

Cowcod (*Sebastes levis*) is a species of large rockfish with a distribution from Newport, Oregon, to central Baja California, Mexico (Love et al., 2002). They are most common from Cape Mendocino (California) to northern Baja California, in depths from 50-300 m. Hess et al. (submitted) recently used genetic and otolith microchemistry tools to study cowcod population structure from California to Oregon. Specifically, they tested the hypothesis that a phylogeographic boundary exists at Point Conception. Their results supported a hypothesis of two primary lineages with a geographic boundary falling south of, rather than at Point Conception. Both lineages co-occur in the Southern California Bight (SCB), with no clear pattern of depth stratification or spatial structure within the Bight. Within lineages, there is evidence for considerable gene flow across the Point Conception boundary. Cowcod found north of Point Conception consist primarily of a single lineage, also found in northern areas of the SCB.

Cowcod are easily identified at all life stages, including larvae. Adults are piscivorous, with a diet consisting mainly of fishes, squids, and octopi. Cowcod are considered to be parademersal (transitional between a midwater pelagic and benthic species). Larvae develop into a pelagic juvenile stage, settling to benthic habitats after about 3 months. Juvenile cowcod were once thought to associate primarily with soft sediments, but Love and Yoklavich (Love and Yoklavich 2008), using visual surveys, found juveniles mainly associate with low-relief, hard substrate. Young-of-the-year were observed over a wide depth range (52-277 m), with juveniles slightly deeper, and adults mainly deeper than 150 m. Larger juveniles

increasingly associate with high-relief, complex rocky substrate, the primary habitat for adult cowcod. Adult cowcod are generally solitary, but occasionally aggregate (Love, *et al.* 1990). Although cowcod are generally not migratory, they may move, to some extent, to follow food (Love 1996).

Cowcod are a long-lived, slow-growing species that require a decade or more to reach sexual maturity. Fertilization is internal, with females giving birth to planktonic larvae mainly during winter months. Spawning peaks in January in the Southern California Bight (MacGregor 1986) and large females may produce up to three broods per season (Love, *et al.* 1990). Larvae emerge at about 5.0 mm (MacGregor 1986).

Cowcod are a highly fecund species, with large females producing 2 million eggs (fecundity is dependent on size and ranges from 181,000 to 1,925,000 eggs) (Love, *et al.* 2002). Dick et al. (2009) found no evidence of increasing weight-specific fecundity (i.e., spawning output is roughly proportional to spawning biomass).

Maximum observed age for cowcod is 55 years (Love, *et al.* 2002). Dick et al. (2007) estimated the natural mortality rate (M) using three methods, reporting a range of values from 0.027 to 0.064 based on Beverton's (1992) method, a range of total mortality (Z) estimates from 0.038 to 0.072 based on catch curve analysis, and Hoenig's geometric mean regression. Females reach 90 percent of their maximum expected size by 42 years.

Little is known about ecological relationships between cowcod and other organisms. Small cowcod feed on planktonic organisms such as copepods. Juveniles eat shrimp and crabs, and adults eat fish, octopus, and squid (Allen 1982). Adults consume a wide range of prey items, but are primarily piscivorous (Love, *et al.* 2002).

Stock Status and Management History

While cowcod are not a major component of the groundfish fishery, they are highly desired by both recreational and commercial fishers because of their bright color and large size. The cowcod stock in the Conception area was first assessed in 1998 (Butler, *et al.* 1999b). Abundance indices decreased approximately tenfold between the 1960s and the 1990s, based on commercial passenger fishing vessel (CPFV) logs (Butler, *et al.* 1999b). Recreational and commercial catch also declined substantially from peaks in the 1970s and 1980s, respectively.

NMFS declared cowcod in the Conception and Monterey management areas overfished in January 2000, after Butler et al. (1999b) estimated the 1998 spawning biomass to be at 7 percent of B_0, well below the 25 percent overfishing threshold. Because cowcod is a fairly sedentary species, closed areas were established in 2002 to reduce cowcod mortality. Two Cowcod Conservation Areas (CCAs), in the Southern California Bight, were selected due to their high density of cowcod. The larger of the two areas (CCA West) is a 4200 square mile area west of Santa Catalina and San Clemente Islands. A smaller area (CCA East) is about 40 miles offshore of San Diego, and covers about 100 square miles. Bottom fishing is prohibited deeper than 20 fm within the CCAs.

A cowcod rebuilding analysis was completed in 2003 which validated the assumption that non-retention regulations and area closures had been effective in constraining cowcod fishing mortality (Butler, *et al.* 2003). These encouraging results were based on cowcod fishery-related landings in recreational and commercial fisheries, although the assessment included discard information only with respect to CPFV observations (which indicated negligible discards in that sector). This rebuilding review pointed out a common problem among the analyses of overfished species: reliance on landings (fishery-dependent) data for providing relative abundance values becomes increasingly difficult as the allowable catch is decreased

and fishery observer data remains low. Monitoring stock status and recovery thus becomes increasingly difficult in the absence of fishery-independent surveys.

As in the 1999 assessment, the 2005 cowcod assessment (Piner, *et al.* 2006) considered only the cowcod population in Southern California Bight (from the US-Mexico border north to Point Conception) population, as this is the area in which cowcod are most abundant, adult habitat is most common, and catches are highest.. The 2005 assessment used only two data sources, the CPFV time series and the visual survey estimate data (Yoklavich, *et al.* 2007). The model was developed in Stock Synthesis 2, and although the base model estimated only three parameters (two of which were "nuisance parameters," the other was equilibrium recruitment), the STAR Panel determined that this simplicity was appropriate given the paucity of data. The assessment provided a set of results corresponding to three different values for assumed steepness (h), the key parameter in the stock-recruitment relationship (h=0.4, 0.5, and 0.6) and one the key uncertainties in the assessment. The assessment estimated that the 2005 spawning biomass was 18 percent of unfished levels and within a range of 14 to 21 percent depending on the value assumed for steepness, a considerably more optimistic result than the 1999 assessment. The corresponding 2005 cowcod rebuilding analysis (Piner 2006) was used to develop the cowcod rebuilding plan adopted in the groundfish FMP under Amendment 16-4. The rebuilding plan established a target rebuilding year of 2039 and an SPR of 90%.

A full cowcod assessment was conducted in 2007, which estimated spawning biomass to be 3.8 percent of its unfished level at the start of 2007 (Dick, *et al.* 2007). The 2007 cowcod assessment was an age-structured production model assuming a Beverton-Holt stock-recruitment function with deterministic recruitment, fit to the aggregated CPFV logbook index and the 2002 visual survey biomass estimate (Yoklavich, *et al.* 2007). Productivity parameters were fixed (steepness = 0.6, natural mortality = 0.055), leaving only virgin recruitment (R_0) to be estimated. Spawning biomass in 2007 was estimated to be between 3.4 percent and 16.3 percent of the unfished level. The poor precision of this estimate was due to 1) a lack of data to inform estimates of stock productivity, and 2) conflicting information from fishery-dependent and fishery–independent data. However, even the most optimistic model, which assumed a high-productivity stock and ignored declines in CPFV catch rates, suggested that spawning biomass was below 25 percent since 1980. Since retention of cowcod was prohibited and bycatch was thought to be minimal, it was considered unlikely that overfishing was an issue. It is likely that the 2007 base model underestimated the uncertainty about stock status given steepness and the natural mortality rate were treated as fixed and known in the model.

The 2007 assessment was originally prepared as an "update" stock assessment; however, while preparing the update, an error was discovered in the previous assessment's specification of the selectivity curve. Several revisions were proposed, including new estimates of historical landings, a corrected growth curve, and a two-fishery model. The 2007 assessment used Stock Synthesis 2, revised estimates of historical commercial catch, contained corrections to gear selectivity curves, utilized a revised growth curve, and separated the catch into commercial (all gears) and recreational fisheries rather than a single fishery. Recreational catches in the 2007 assessment were identical to those in the previous assessment, but estimates of commercial catches had been updated to reflect three additional data sources: 1) recovered port samples from Southern California (1983-1985), 2) regional summaries of total rockfish landings (1928-1968) provided by the NMFS SWFSC Environmental Research Division, and 3) California rockfish landings by region (1916-1927), published in CDF&G Fish Bulletin No. 105 (1958).

The 2007 rebuilding analysis (Dick and Ralston 2007) estimated a new T_{MAX} of 2098, 24 years later than the date estimated by Piner (2006), due in part to the corrections described above, but only 1 year earlier than the 2099 date estimated previously (Butler, *et al.* 2003). It was noted in the rebuilding analysis that rebuilding scenarios were extremely uncertain for this data-poor species, particularly with respect to steepness. Moreover, there was widespread concern about the ability to monitor the stock, and

consequently to evaluate progress towards rebuilding in the future. The 2007 rebuilding analysis projections indicated that it would not be possible to rebuild the cowcod stock by 2039, even if all the catches are eliminated, and the estimated time to rebuild under the current harvest rate (SPR = 90%) was 26 years greater than the target year of 2039 adopted under Amendment 16-4. Therefore, a modification of the Amendment 16-4 cowcod rebuilding plan was implemented in 2007 which prescribed a target year of 2072 and an SPR harvest rate of 82.1%.

The 2007 cowcod assessment was updated in 2009, with stock depletion estimated to be 4.5 percent of its unfished level at the start of 2009 (Dick, *et al.* 2009). Estimates of female spawning stock biomass in 2009 were highly uncertain. Spawning biomass had declined from an unfished biomass of 2,101-2,461 mt to 93-441 mt in 2009. The 2009 cowcod rebuilding analysis (Dick, *et al.* 2009) was used to reconsider the cowcod rebuilding plan adopted under Amendment 16-4 as mandated in a legal challenge (*NRDC v. Locke*). The revised rebuilding plan, implemented in 2011, prescribed a target year of 2068 and an SPR harvest rate 82.7%.

A new cowcod assessment of the stock in the Southern California Bight was conducted in 2013 (Dick and MacCall 2013b), which estimated stock depletion to be 33.9 percent of unfished spawning biomass at the start of 2013 (Figure 9). The 2013 assessment suggested that cowcod in the Southern California Bight constitute a smaller, but more productive stock than was estimated from previous assessments. Median unfished and 2013 spawning biomasses were estimated to be 1,549 mt and 524 mt, respectively (Table 4).

The 2013 assessment used the XDB-SRA modeling platform to estimate stock status, scale, and productivity. Dick et al. (2013b) fit five fishery-independent data sources: four time series of relative abundance (CalCOFI larval abundance survey, Sanitation District trawl surveys, NWFSC trawl survey, and NWFSC hook-and-line survey), and the 2002 Yoklavich et al. (2007) visual survey estimate of absolute abundance.

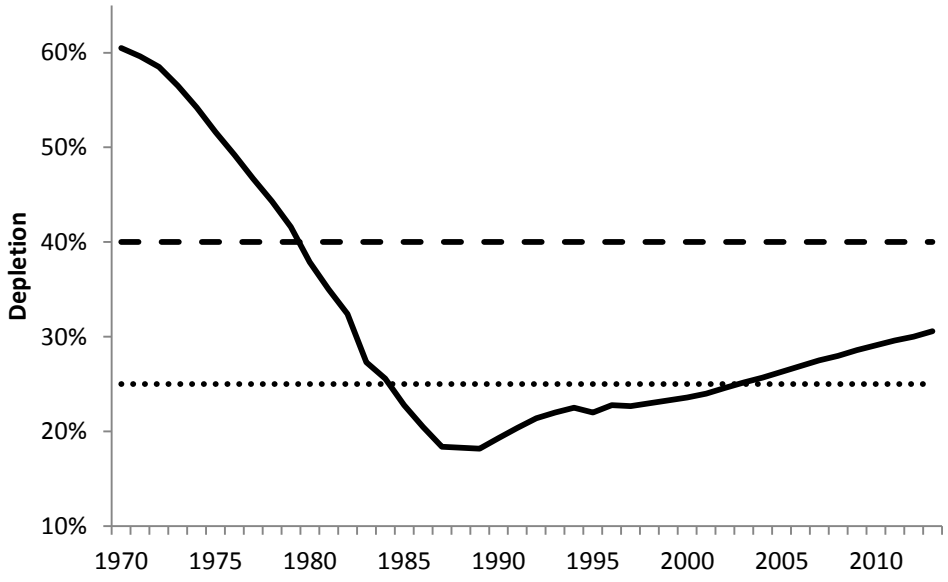

Figure 9. Relative depletion of cowcod south of 40º10' N lat. from 1970 to 2013 based on the 2013 stock assessment. *Data from Table 38 – NOTE: different trajectory than Figure 94*

Stock Productivity Relative to Rebuilding Success

As in the previous assessment, production in the 2013 assessment is assumed to be a deterministic function of spawning biomass. Recruitment pulses may be evident in the abundance indices, but insufficient information is available to reliably estimate the relative strength of individual year classes.

Insert figure of B_{MSY}/B_0 & F_{MSY}/M?

Fishing Mortality

Estimated harvest rates for cowcod were highest during the mid-1980s (Figure 10). Retention of cowcod was prohibited from January 2001 to present. Dick and MacCall 2013 estimated that removals of cowcod have been less than 0.2% of vulnerable biomass since 2003. The estimated harvest rate that produces long term MSY (5.5%) is nearly twice the proxy (SPR = 50%) harvest rate from the last assessment (2.7%). Unlike previous assessments, the recent increasing trends in fishery-independent surveys allow the model to estimate the rate of increase in stock size. However, the 95% posterior interval for the MSY harvest rate (2.2% - 12.6%) reflects uncertainty in the data regarding overall productivity of the stock.

Median harvest rates around 1930 were near the MSY rate, then declined due to shifts in fishing effort and WWII (Figure 10). Following the war, catch rates slowly increased until about 1970, then rose quickly to a maximum of approximately 54% of vulnerable biomass in the mid-1980s. The MSY harvest rate estimated in the 2013 assessment is 5.5%, similar to the proxy ($B_{40\%}$) harvest rate of 5%, but higher than the SPR harvest rate in the 2009 assessment (2.7%). Median harvest rates were roughly 8-10 times the median MSY harvest rate in the mid-1980s, then declined to near zero after 2000, followed by steady increases in stock biomass.

Under the current SPR harvest rate specified in the rebuilding plan (82.7%), the median time to rebuild is 2020 (Dick and MacCall 2013a). This SPR harvest rate is equivalent to an exploitation rate (catch over age 11+ biomass) of 0.007 based on the 2009 assessment.

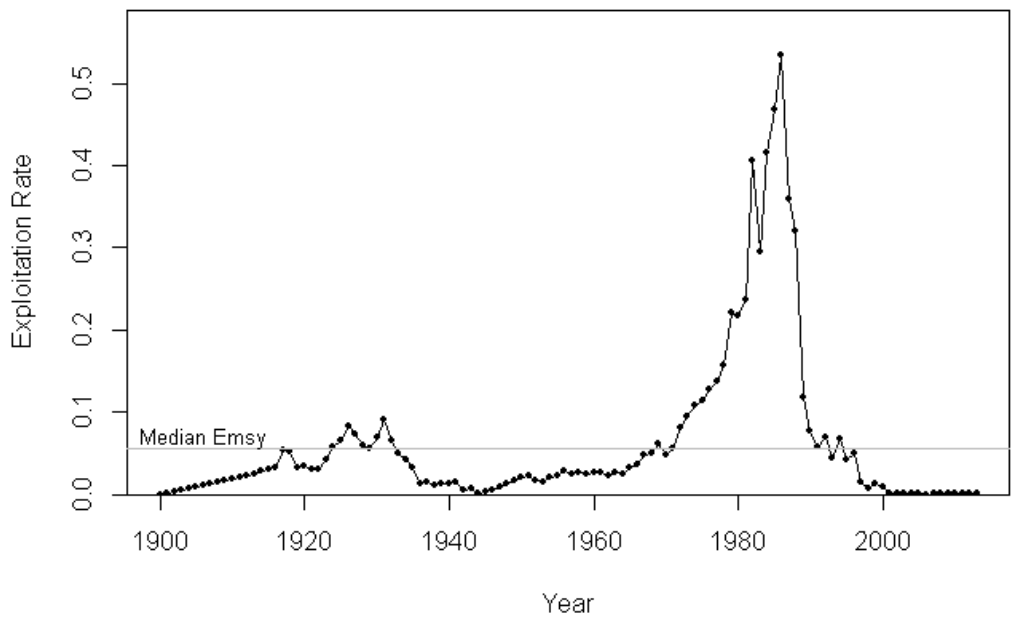

Figure 10. Time series of median harvest rates (total catch divided by age-11 and older biomass) from the base model in the 2013 cowcod assessment. The gray line is the estimated median harvest rate producing MSY.

Rebuilding Duration and Probabilities

The 2013 rebuilding analysis (Dick and MacCall 2013a) was unique in that the Punt rebuilding program (Punt 2005) was not used given its incompatibility with XDB-SRA. In each rebuilding model run, 15,000 simulated trajectories were generated using draws from the joint posterior distribution. Since the XDB-SRA platform is not compatible with spawning potential ratios, harvest control rules were translated into exploitation rates (E) calculated as catch/estimated age 11+ biomass. Similar to the previous cowcod rebuilding analysis, variability in future recruitment was expressed as a weighted set of different states of nature (parameter values), rather than random deviations from an average stock-recruitment relationship. While the previous rebuilding analysis accounted only for uncertainty in the Beverton-Holt steepness parameter, the current analysis accounts for uncertainty in all estimated model parameters. Estimates of total cowcod mortality have not exceeded the ACL (or OY) in any year since 2003. The estimate of median time to rebuild under the current harvest rate (2020) is 48 years earlier than the current target year of 2068.

1.1.3.4 Darkblotched Rockfish

Distribution and Life History

Darkblotched rockfish (*Sebastes crameri*) are found from Santa Catalina Island off Southern California to the Bering Sea (Miller and Lea 1972; Richardson and Laroche 1979). They are most abundant from Oregon to British Columbia. Darkblotched primarily occur on the outer shelf and upper slope off Oregon, Washington, and British Columbia (Richardson and Laroche 1979). Based upon genetic information and

the absence of large scale gaps in catches, there are no clear stock delineations for darkblotched rockfish in U.S. waters. This does not mean there are not more fine scale groupings to be found, and in fact, darkblotched catches are characterized by infrequent large tows of larger fish. Distinct population groups have been found off the Oregon coast between 44°30' N lat. and 45°20' N lat. (Richardson and Laroche 1979). This species co-occurs with an assemblage of slope rockfish, including Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*).

Darkblotched rockfish mate from August to December, eggs are fertilized from October through March, and larvae are released from November through April love (Love, *et al.* 2002). Older larvae and pelagic juvenile darkblotched rockfish are found closer to the surface than many other rockfish species. Pelagic juvenile settle at 4 to 6 cm in length in about 55 to 200 m (Love, *et al.* 2002). As many other Sebastes, this species exhibits ontogenetic movement, with fish migrating to deeper waters as they mature and increase in size and age (Lenarz 1993; Nichol 1990).

Darkblotched rockfish are among the longer living rockfish; the data used in the most recent assessment (Gertseva and Thorson 2013) includes individuals that have been aged to be 98 years old. The maximum reported age of darkblotched rockfish is 105 years (Love, *et al.* 2002). As with many other *Sebastes* species, darkblotched rockfish exhibit sexually dimorphic growth; females reach larger sizes than males, while males attain maximum length earlier than females (Love, *et al.* 2002; Nichol 1990; Rogers, *et al.* 2000).

Darkblotched rockfish are ovoviviparous (Nichol and Pikitch 1994). Insemination of female darkblotched rockfish occurs from August to December, and fertilization and parturition occur from December to March off Oregon and California, and primarily in February off Oregon and Washington (Hart 1988; Nichol and Pikitch 1994; Richardson and Laroche 1979). Fecundity is dependent on size and ranges from 20,000 to 610,000 eggs.

Little is known about ecological relationships between darkblotched rockfish and other organisms. Pelagic juveniles feed on planktonic organisms such as copepods. Adults are often caught with other fish such as Pacific ocean perch and splitnose rockfish. Midwater animals such as euphausiids and amphipods dominate the diet of adult fish. Albacore and Chinook salmon consume pelagic juveniles (Hart 1988). Little is known about predation of adults.

Stock Status and Management History

Darkblotched rockfish are primarily with commercial trawl gear, as part of a complex of slope rockfish, which includes Pacific ocean perch (*Sebastes alutus*), splitnose rockfish (*Sebastes diploproa*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*). Catches of darkblotched rockfish first became significant in the mid-to-late 1940s due to increased demand for fish protein during World War II. During the mid-1960s to mid-1970s darkblotched rockfish were caught by both domestic and foreign fleets (Rogers 2003b). Domestic landings rose from late 1970s until the late 1980s, although limits on rockfish catch were first instituted in 1983, when darkblotched was rockfish managed as part of a group of around 50 species (designated as the Sebastes complex) (Rogers, *et al.* 2000). During the 2000s, progressive steps have been taken to reduce the catch of darkblotched rockfish, following the declaration of its overfished status in 2001.

The first full assessment of the darkblotched rockfish stock was conducted in 2000, which estimated stock depletion at 14–31 percent of its unfished level, depending on assumptions regarding the historic catch of darkblotched rockfish in the foreign fishery from 1965-1978 (Rogers, *et al.* 2000). The base model assumed 10 percent of foreign catch was comprised of darkblotched, leading to the conclusion that the

spawning stock biomass was at 22 percent of its unfished level. NMFS declared darkblotched rockfish to be overfished in 2001 based on these results.

The 2001 rebuilding analysis for the stock (Methot and Rogers 2001) incorporated results of the 2000 Alaska Fishery Science Center triennial slope trawl survey and modeled a more recent time series of recruitments. Incorporating these data resulted in a downward revision of the estimated recruitment and abundance throughout the time series compared to what had been used in the Rogers et al. (2000) assessment. This led to a revised estimate of spawning stock biomass at the beginning of 2002 of 14 percent of its unfished level and a longer projected rebuilding period.

A 2003 assessment and rebuilding update for darkblotched rockfish (Rogers 2003a) estimated a lower depletion ($B_{11\%}$), but provided evidence of strong recent recruitment not yet recruited to the spawning population. This analysis was used to inform the darkblotched rockfish rebuilding plan adopted under Amendment 16-2, which established a target rebuilding year of 2030 and a fishing mortality rate of F = 0.027. A revised darkblotched rebuilding plan was implemented in 2004 that specified a higher harvest rate (F = 0.032) to avoid negative socioeconomic impacts.

The 2005 full darkblotched assessment estimated a spawning stock depletion of 16 percent of unfished biomass at the start of 2005 (Rogers 2005a). The assessment estimated strong recruitment of the 1999 and 2000 year classes. The 2005 rebuilding analysis (Rogers 2005b) was used to inform a revised rebuilding plan adopted under Amendment 16-4 and implemented in 2007. The revised rebuilding plan specified a target year of 2011 and a constant harvest rate strategy (SPR = 60.7%).

The 2007 darkblotched rockfish assessment estimated a stock depletion of 22.7 percent at the start of 2007 (Hamel 2008c). The 2007 darkblotched rebuilding analysis (Hamel 2008a) predicted the median time to rebuild would be 19 years later than the target year of 2011 under the SPR harvest rate adopted under Amendment 16-4. The Council revised the Amendment 16-4 rebuilding plan by specifying a target year to rebuild the stock of 2028 and decreasing the harvest rate (SPR = 62.1%).

The 2007 darkblotched assessment was updated in 2009 and 2011. The 2009 stock assessment update estimated a stock depletion of 27.5 percent at the start of 2009 (Wallace and Hamel 2009). The 2009 darkblotched rebuilding analysis (Wallace 2009) was used to inform a revised rebuilding plan, which was implemented in 2011 The revised rebuilding plan specified a target year to rebuild the stock of 2025 and decreased the harvest rate to SPR = 64.9%. The 2011 stock assessment update estimated a stock depletion of 30.2 percent at the start of 2009 (Stephens, *et al.* 2011). No revisions to the rebuilding plan were made based on the 2011 assessment update and accompanying rebuilding plan (Stephens 2011).

A full darkblotched stock assessment in 2013 (Gertseva and Thorson 2013) estimated a stock depletion of 36 percent at the start of 2013 (Figure 11). The assessment also predicts the stock will be rebuilt by the start of 2015. The improved stock status and rebuilding outlook were largely attributed to 1) reduced fishing mortality under the rebuilding program; 2) inferences that follow from more favorable perceptions of steepness, fecundity, and age at maturity of the stock; and 3) length and age data indicating relatively large recruitments in 1999, 2000, and 2008. The SSC recommended maintaining the current rebuilding plan for the 2015-2016 management cycle and a full assessment be done in 2015 to confirm this prediction. The SSC further recommended against preparing a rebuilding analysis in 2013.

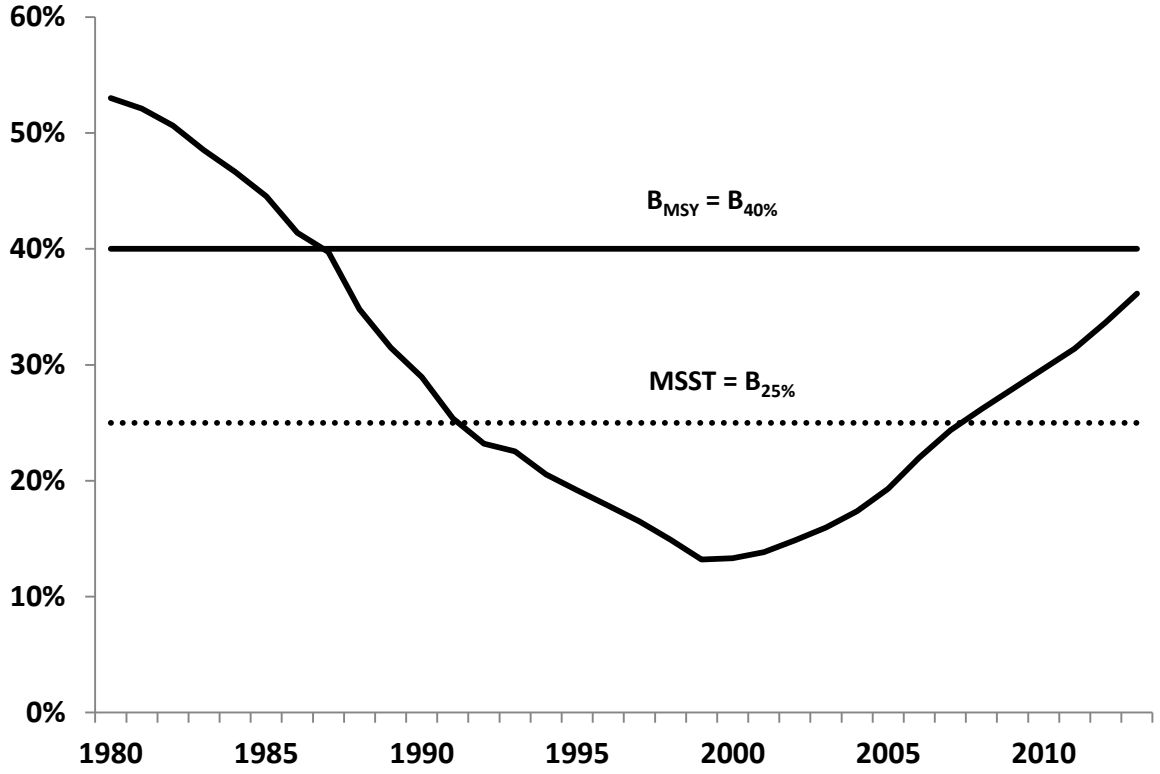

Figure 11. Relative depletion of darkblotched rockfish from 1980 to 2013 based on the 2013 stock assessment.

Stock Productivity Relative to Rebuilding Success

Gertseva and Thorson (2013) fixed steepness at its prior mean of 0.779. This prior was estimated using a likelihood profile approximation to a maximum marginal likelihood mixed-effect model for steepness from ten category 1 rockfish species off the U.S. west coast (Pacific ocean perch, bocaccio, canary, chilipepper, black, darkblotched, gopher, splitnose, widow, and yellowtail rockfish). Both northern and southern assessments of black rockfish were used, although the log-likelihood for each was given a 0.5 weighting, to ensure that the together these two assessments had an equal weighting to the other species. This likelihood profile model is intended to synthesize observation-level data from assessed species, while avoiding the use of model output and thus improving upon previous meta-analyses (Dorn 2002a; Forrest, *et al.* 2010). This methodology has been simulation tested, and has been recommended by the SSC for use in stock assessments.

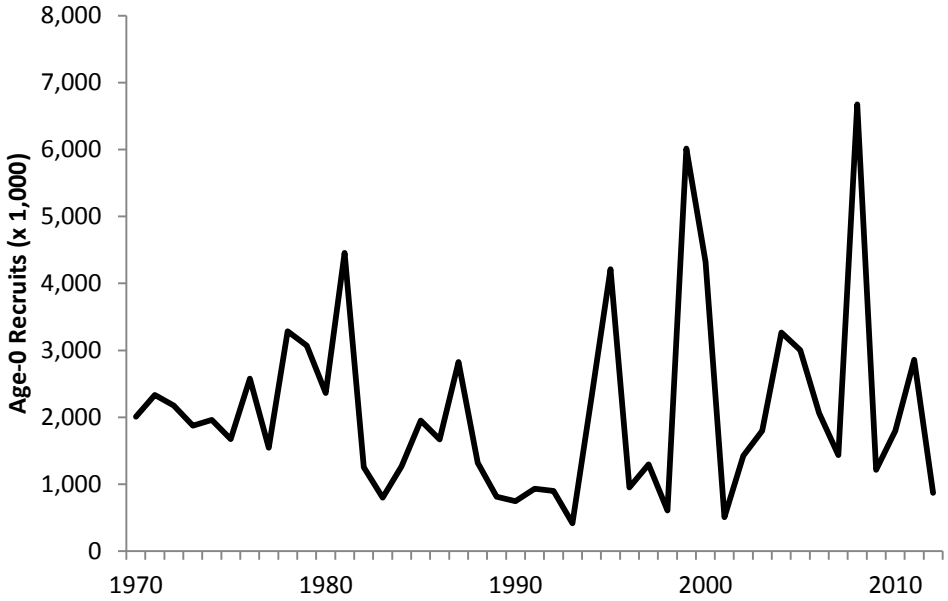

Figure 12. Estimated recruitments of darkblotched rockfish, 1970-2012.

Fishing Mortality

Historically, the spawning output of darkblotched rockfish dropped below the B_{MSY} target for the first time in 1987, as a result of intense fishing by foreign and domestic fleets. It continued to decline and reached the level of 13 percent of its unfished output in 1999. Since 2000, when the stock was declared overfished, the spawning output slowly increased primarily due to management regulations implemented for the stock.

Overfishing for darkblotched has not occurred in the last 10 years (Gertseva and Thorson 2013). Historically, the darkblotched rockfish has experienced overfishing in the 1980s and 1990s, during the peak years of the Pacific ocean perch fishery, as well as in the mid-1960s when foreign trawl fleets were targeting groundfish off the west coast. Exploitation rates were effectively decreased after the stock was declared overfished in 2000 and rebuilding measures were implemented.

Rebuilding Duration and Probabilities

The 2013 darkblotched assessment predicts the stock will be rebuilt by 2015. Therefore, rebuilding probabilities (both P_{MAX} and P_{TARGET}) are high for darkblotched under the harvest control rule in the rebuilding plan. The SSC is recommending a new assessment be done in 2015 to confirm that prediction.

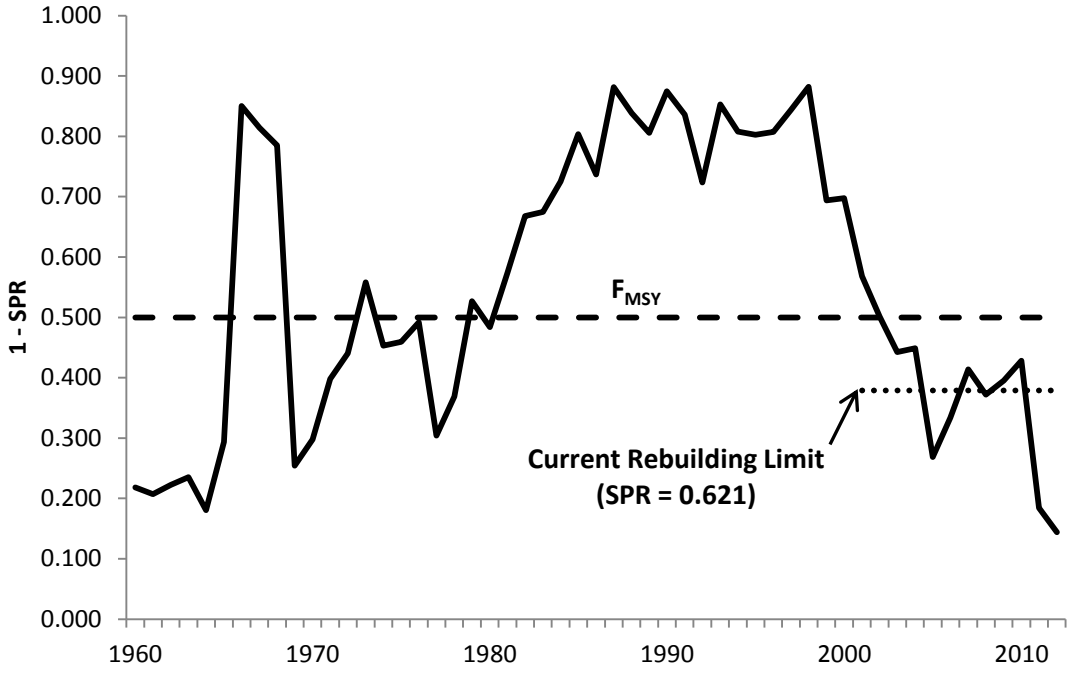

Figure 13. Time series of estimated SPR harvest rates of darkblotched rockfish, 1960-2012. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis.

1.1.3.5 Pacific Ocean Perch

Distribution and Life History

Pacific ocean perch (POP, *Sebastes alutus*) are most abundant in the Gulf of Alaska, and have been observed off of Japan, in the Bering Sea, and south to Baja California, although they are sparse south of Oregon and rare in southern California. (Eschmeyer, *et al.* 1983; Gunderson 1971; Miller and Lea 1972). They 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 as deep as 825 m, but usually are at 100 m to 450 m and along submarine canyons and depressions (NOAA 1990). Throughout their range, POP are generally associated with gravel, rocky, or boulder type substrate (Ito, *et al.* 1986). Larvae and juveniles are pelagic; subadults and adults are benthopelagic (living and feeding on the bottom and in the water column). 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 POP form ball-shaped schools near the surface or hide in rocks (NOAA 1990).

Pacific ocean perch winter and spawn in deeper water (>275 m). In the summer (June through August) they move to feeding grounds in shallower water (180 m to 220 m) to allow gonads to ripen (Archibald, *et al.* 1983; Gunderson 1971; NOAA 1990). They are slow-growing and long-lived; the maximum age has been estimated at about 98 years (Heifetz, *et al.* 2000). The can grow up to about 54 cm and 2 kg (Archibald, *et al.* 1983; Beamish 1979; Gunderson 1971; Ito, *et al.* 1986; Mulligan and Leaman 1992; NOAA 1990). POP are carnivorous. Larvae eat small zooplankton. Small juveniles eat copepods, and larger juveniles feed on euphausiids (krill). Adults eat euphausiids, shrimps, squids, and small fish. Immature fish feed throughout the year, but adults feed only seasonally, mostly April through August (NOAA 1990). POP predators include sablefish and Pacific halibut.

Stock Status and Management History

POP were harvested exclusively by U.S. and Canadian vessels in the Columbia and Vancouver INPFC areas prior to 1966. Large Soviet and Japanese factory trawlers began fishing for POP in 1965 in the Vancouver area and in the Columbia area a year later. Intense fishing pressure by these foreign fleets occurred from 1966 to 1975. The mandates of the MSA, passed by Congress in 1976, eventually ended foreign fishing within 200 miles of the United States coast.

The POP resource off the west coast was overfished before implementation of the groundfish FMP in 1982, and Council actions to conserve the resource likewise predate the FMP. Large removals of POP in the foreign trawl fishery, followed by significant declines in catch and abundance, led the Council to limit harvest beginning in 1979. A 20–year rebuilding plan for POP was adopted in 1981. Rebuilding under this original plan was largely influenced by a cohort analysis of 1966-1976 catch and age composition data (Gunderson 1979), updated with 1977-1980 data (Gunderson 1981), and an evaluation of trip limits as a management tool (Tagart, *et al.* 1980). This was the first time trip limits were used by the Council to discourage targeting and overharvest of an overfished stock, and it remains a management strategy in use today in the west coast groundfish fishery. In addition to trip limits, the Council significantly lowered the OY for POP. After twenty years of rebuilding under the original plan, the stock stabilized at a lower equilibrium than estimated in the pre-fishing condition. While continuing stock decline was abated, rebuilding was not achieved as the stock failed to increase in abundance to B_{MSY}.

Ianelli and Zimmerman (1998) estimated POP female spawning biomass in 1997 to be at 13 percent of its unfished level, thereby confirming that the stock was overfished. NMFS formally declared POP overfished in March 1999 after the groundfish FMP was amended to incorporate the tenets of the Sustainable Fisheries Act. The Council adopted and NMFS enacted more conservative management measures in 1999 as part of a redoubled rebuilding effort.

A 2000 POP assessment suggested the stock was more productive than originally thought (Ianelli, *et al.* 2000). A revised POP rebuilding analysis was completed and adopted by the Council in 2001 (Punt and Ianelli 2001). This analysis estimated a T_{MIN} of 12 years and a T_{MAX} of 42 years. It was noted in the rebuilding analysis that the ongoing retrospective analysis of historic foreign fleet catches was likely to change projections of POP rebuilding.

The 2003 POP assessment (Hamel, *et al.* 2003) incorporating updated survey and fishery data including the retrospective of foreign fleet catches (Rogers 2003b). The assessment covered areas from southern Oregon to the U.S. border with Canada, the southern extent of POP distribution. The overall conclusion was that the stock was relatively stable at approximately 28 percent of its unfished biomass ($B_{28\%}$). Of all the changes and additions to the data, the historical catch estimates had the greatest effect, resulting in lower estimates of both equilibrium unfished biomass (B_0) and MSY.

A POP rebuilding plan was adopted in 2003 under Amendment 16-2. The rebuilding plan was informed by a revised rebuilding analysis based on the 2000 assessment and conducted in 2001 (Punt and Ianelli 2001). The rebuilding plan established a target rebuilding year of 2027 and a harvest control rule of F = 0.0082 (with a P_{MAX} of 70 percent).

The 2003 assessment estimated a stock depletion of 28 percent at the start of 2003 (Hamel, *et al.* 2003). The 2003 rebuilding analysis (Punt, *et al.* 2003) was used to amend the harvest control rule and set annual POP OYs for the 2004-2006 period. The amended harvest control rule was F = 0.0257.

The 2003 POP assessment was updated in 2005, 2007, and 2009. The 2005 update assessment estimated a stock depletion of 23.4 percent of its unfished level at the start of 2005 (Hamel 2006b). The 2005 POP

rebuilding analysis (Hamel 2006a) was used to inform revisions to the POP rebuilding plan. The revised rebuilding plan, which was adopted under Amendment 16-4, specified a target rebuilding year of 2017 and a constant harvest rate strategy (SPR = 86.4%).

The 2007 POP assessment update estimated a stock depletion of 27.5 percent at the start of 2007 (Hamel 2008d). The 2007 rebuilding analysis indicated rebuilding was progressing ahead of schedule (Hamel 2008b). No modifications to the rebuilding plan were made.

The 2009 POP assessment estimated a stock depletion of 28.6 percent at the start of 2009 (Hamel 2009b). The 2009 POP rebuilding analysis (Hamel 2009a) predicted rebuilding would not occur by the target year of 2017 with at least a 50% probability even in the absence of fishing-related mortality beginning in 2011 (i.e., $T_{F=0}$). Therefore the rebuilding plan was revised by changing the target rebuilding year to 2020 while maintaining the constant SPR harvest rate of 86.4%.

A full assessment in 2011 estimated a stock depletion of 19.1 percent at the start of 2011 (Hamel and Ono 2011). The significant decrease in the estimated depletion of the stock was largely due to a much higher estimate of initial, unfished biomass (B_0). Previous assessments assumed a large recruitment in the late 1950s provided the higher biomass to support the estimated removals by the foreign fleets without any data to support that assumption. The assumption in the 2011 assessment is that the large foreign fleet catch fished the biomass down to critical levels, thus resulting in a substantially larger B_0 estimate. The 2011 assessment also estimated a longer sequence of higher recruitment based on fitting to the data available for early years of the assessment period. The 2011 rebuilding analysis (Hamel 2011) predicted rebuilding would not occur by the target year of 2020 with at least a 50% probability even in the absence of fishing-related mortality beginning in 2013 (i.e., $T_{F=0}$). Therefore the rebuilding plan was revised by changing the target rebuilding year to 2051 while maintaining the constant SPR harvest rate of 86.4%.

A POP catch report was provided in 2013 (Agenda Item F.5.a, Attachment 10, June 2013), which indicated 2010-2012 total catches were below specified ACLs/OYs.

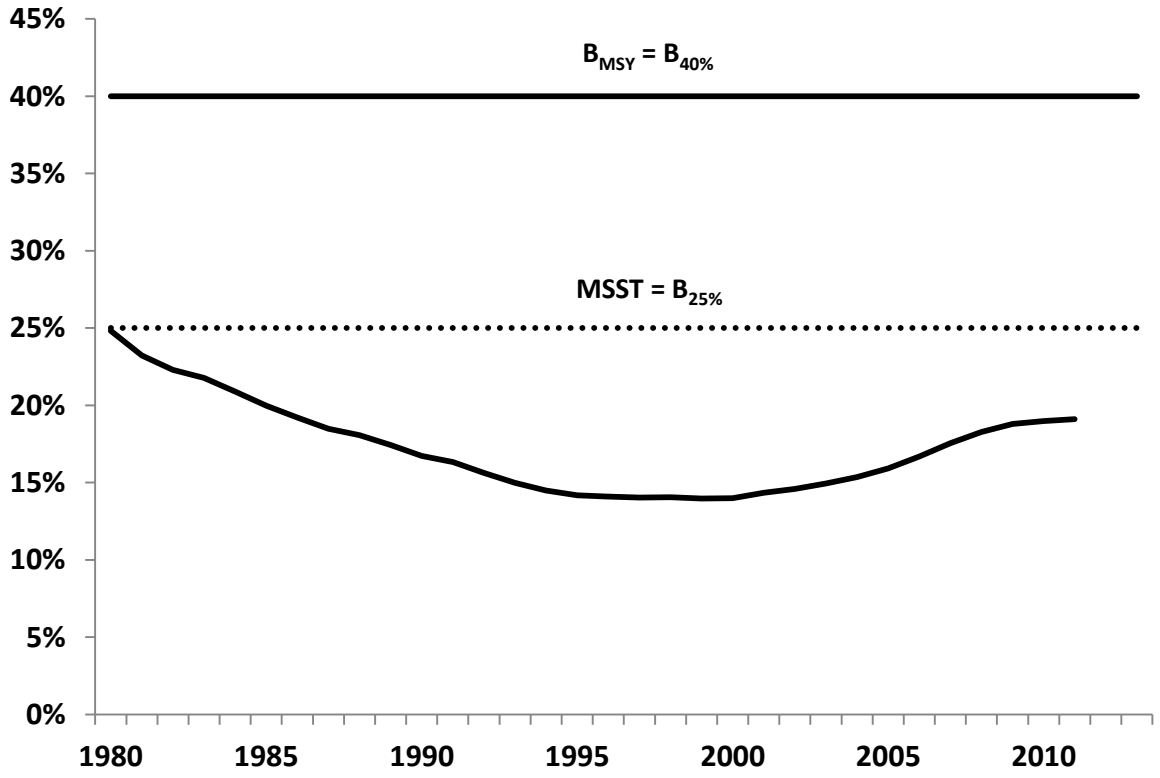

Figure 14. Relative depletion of Pacific ocean perch from 1980 to 2011 based on the 2011 stock assessment.

Stock Productivity Relative to Rebuilding Success

Stock-recruitment steepness was estimated external to the 2011 POP stock assessment base model at 0.4 (and then fixed in the model), which is low compared to steepness estimates from POP assessments conducted off Canada and Alaska. The 2011 assessment assumes no connectivity with the other assessed POP stocks in Canada and Alaska. POP off the U.S. west coast (mostly Washington and Oregon) are at the southern end of the range where there are enough POP to be commercially important, and the numbers seen are likely related to movement across the Canadian border, as well as reproductive success (recruitment) and fishing mortality north of the border. Given there is no evidence of stock structure in the meta-population of POP in the northeast Pacific and larval distribution of slope rockfish tends to be geographically widespread, this assumption of no connectivity with northern stocks is questionable. It is plausible that steepness is higher than determined in the 2011 assessment, which would tend to estimate a less depleted and more productive stock. The major axis of uncertainty in the assessment is steepness, with states of nature ranging from a low steepness of 0.35 to a higher value of 0.55. If steepness was as high as 0.55, the POP stock would be on the verge of being rebuilt at the start of 2011 (depletion = 39.9 percent) and projected to be rebuilt at the start of 2012. Under the base case model with a steepness of 0.4 and continuing to manage POP using the 86.4 percent SPR harvest rate in the current rebuilding plan, the stock is projected to be rebuilt by 2051.

Recruitment trends estimated in the 2011 POP assessment indicate that, like most assessed rockfish, recruitment has been relatively lower in the last few decades compared to the 1950s and 1960s. However,

the 1999 and 2000 year classes are estimated to be above average and the 2008 year class recruitment, while uncertain, appears to be the largest in at least the past 50 years (Figure 15).

Fishing practices are unlikely to have any effect on stock productivity, given the low fishing mortality implemented under the rebuilding plan limits. There is no indication that fishing operations are likely to substantially interfere with or disturb reproductive behavior or juvenile survival.

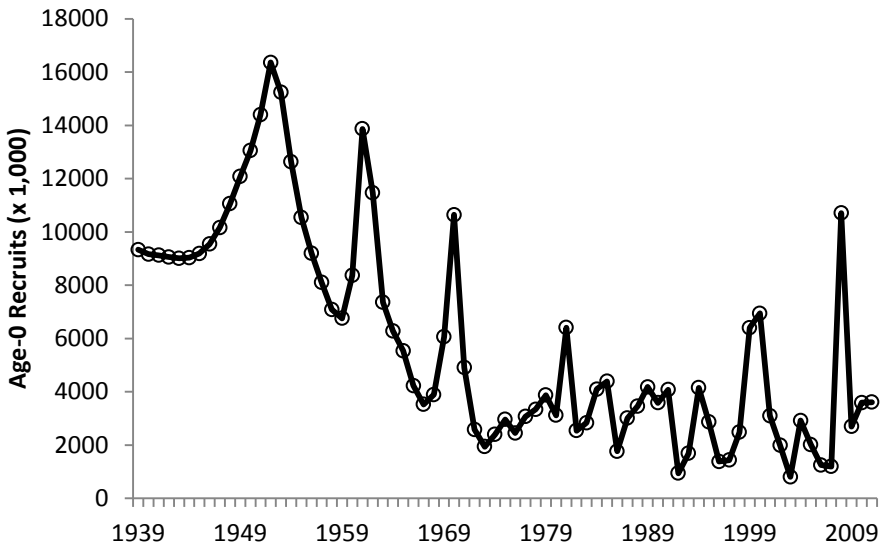

Figure 15. Time series of estimated (age-0) POP recruitments.

Fishing Mortality

POP are caught almost exclusively by groundfish trawl gear and predominantly bottom trawls operating on the outer continental shelf and slope north of 43º N lat. POP are distributed from 30-350 fm, with the core distribution between 110-220 fm.

According to the base model in the 2011 assessment, the fishing level has been below the proxy $F_{50\%}$ F_{MSY} harvest rate for the past 12 years (Figure 16), during which period the stock has begun to rebuild (Figure 14). The point estimates of summary (age 3+) biomass also show an upward trend over the past decade, increasing approximately 50 percent in that time.

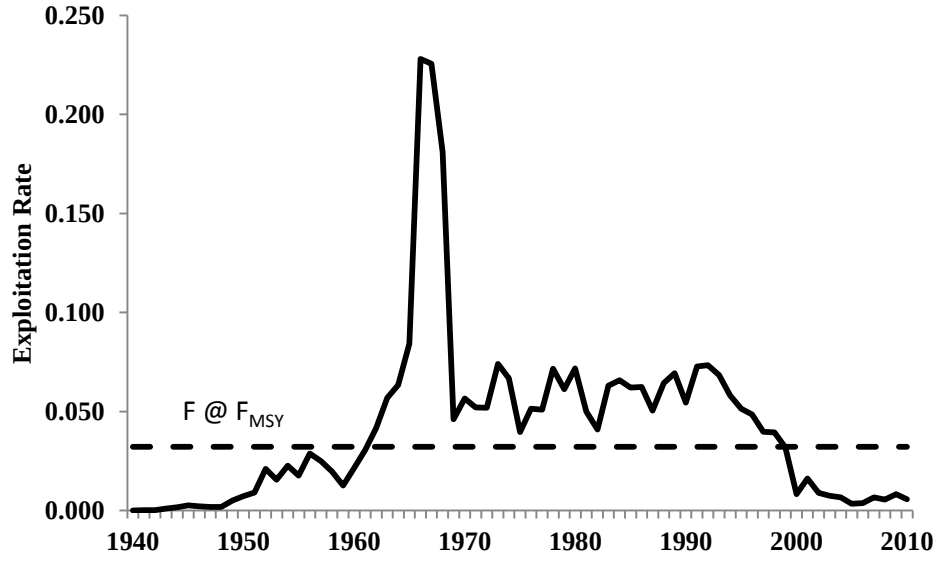

Figure 16. Time series of POP exploitation rates (catch/summary biomass), 1940-2010.

Rebuilding Duration and Probabilities

Hamel (2011) estimated a probability of rebuilding in the maximum time allowable (P_{MAX}) under the SPR harvest rate specified in the rebuilding plan of 72.3%. There is a 50% probability of rebuilding by the target year of 2051.

1.1.3.6 Petrale Sole

Distribution and Life History

Petrale sole (*Eopsetta jordani*) is a right-eyed flounder in the family Pleuronectidae ranging from the western Gulf of Alaska to the Coronado Islands, northern Baja California, (Hart 1988; Kramer and O'Connell 1995; Love, *et al.* 2002) with a preference for soft substrates at depths ranging from 0-550 m (Love, *et al.* 2002). In northern and central California petrale sole are dominant on the middle and outer continental shelf (Allen, *et al.* 2006).

There is little information regarding the stock structure of petrale sole off the U.S. Pacific coast. Tagging studies show adult petrale sole can move up to 350 - 390 miles, having the ability to be highly migratory with the possibility for homing ability (Alverson and Chatwin 1957; MBC 1987). Juveniles show little coastwide or bathymetric movement while studies suggest that adults generally move inshore and northward onto the continental shelf during the spring and summer to feeding grounds and offshore and southward during the fall and winter to deep water spawning grounds (Hart 1988; Love 1996; MBC 1987). Adult petrale sole can tolerate a wide range of bottom temperatures (Perry, *et al.* 1994).

Mixing of fish from multiple deep water spawning grounds likely occurs during the spring and summer when petrale sole are feeding on the continental shelf. Fish that were captured, tagged, and released off the northwest coast of Washington during May and September were subsequently recaptured during winter from spawning grounds off Vancouver Island (British Columbia, 1 fish), Heceta Bank (central Oregon, 2 fish), Eureka (northern California, 2 fish), and Halfmoon Bay (central California, 2 fish) (Pederson 1975). Fish tagged south of Fort Bragg (central California) during July 1964 were later recaptured off Oregon (11 fish), Washington (6 fish), and Swiftsure Bank (southwestern tip of Vancouver

Island, 1 fish) (D. Thomas, California Department of Fish and Game, Menlo Park, CA, cited by Samson and Lee (1999)).

The highest densities of spawning adults off of British Columbia, as well as of eggs, larvae and juveniles, are found in the waters around Vancouver Island. Adults may utilize nearshore areas as summer feeding grounds and non-migrating adults may stay there during winter (Starr and Fargo 2004).

Petrale sole spawn during the winter at several discrete deepwater sites (270-460 m) off the U.S. west coast, from November to April, with peak spawning taking place from December to February (Best 1960; Casillas, *et al.* 1998; Castillo 1995; Castillo, *et al.* 1993; Garrison and Miller 1982; Gregory and Jow 1976; Harry 1959; Love 1996; Moser 1996; Reilly, *et al.* 1994). Females spawn once each year and fecundity varies with fish size, with one large female laying as many as 1.5 million eggs (Porter 1964). Petrale sole eggs are planktonic, ranging in size from 1.2 to 1.3 mm, and are found in deep water habitats at water temperatures of 4–10 degrees C and salinities of 25–30 ppt (Alderdice and Forrester 1971; Best 1960; Gregory and Jow 1976; Ketchen and Forrester 1966). The duration of the egg stage can range from approximately 6 to 14 days (Alderdice and Forrester 1971; Casillas, *et al.* 1998; Hart 1988; Love 1996).

Petrale sole larvae are planktonic, ranging in size from approximately 3 to 20 mm, and are found up to 150 km offshore foraging upon copepod eggs and nauplii (Casillas, *et al.* 1998; Hart 1988; MBC 1987; Moser 1996). The larval duration, including the egg stage, spans approximately 6 months with larvae settling at about 2.2 cm in length on the inner continental shelf (Pearcy, *et al.* 1977). Juveniles are benthic and found on sandy or sand-mud bottoms (Eschmeyer, *et al.* 1983; MBC 1987) and range in size from approximately 2.2 cm to the size at maturity, 50% of the population is mature at approximately 38 cm and 41 cm for males and females, respectively (Casillas, *et al.* 1998). No specific areas have been identified as nursery grounds for juvenile petrale sole. In the waters off British Columbia, Canada larvae are usually found in the upper 50 m far offshore, juveniles at 19–82 m and large juveniles at 25–125 m (Starr and Fargo 2004).

Adult petrale sole achieve a maximum size of around 50 cm and 63 cm for males and females, respectively (Best 1963; Pedersen 1975). The maximum length reported for petrale sole is 70 cm (Eschmeyer, *et al.* 1983; Hart 1988; Love, *et al.* 2002) while the maximum observed break and burn age is 31 years (Haltuch, *et al.* 2013).

Petrale sole juveniles are carnivorous, foraging on annelid worms, clams, brittle star, mysids, sculpin, amphipods, and other juvenile flatfish (Casillas, *et al.* 1998; Ford 1965; Pearsall and Fargo 2007). Predators on juvenile petrale sole include adult petrale sole as well as other larger fish (Casillas, *et al.* 1998; Ford 1965) while adults are preyed upon by marine mammals, sharks, and larger fishes (Casillas, *et al.* 1998; Love 1996; Trumble 1995).

One of the ambushing flatfishes, adult petrale sole have diverse diets that become more piscivorous at larger sizes (Allen, *et al.* 2006). Adult petrale sole are found on sandy and sand-mud bottoms (Eschmeyer, *et al.* 1983) foraging for a variety of invertebrates including, crab, octopi, squid, euphausiids, and shrimp, as well as anchovies. hake, herring, sand lance, and other smaller rockfish and flatfish (Birtwell, *et al.* 1984; Casillas, *et al.* 1998; Ford 1965; Kravitz, *et al.* 1977; Love 1996; Pearsall and Fargo 2007; Reilly, *et al.* 1994). On the continental shelf petrale sole generally co-occur with English sole, rex sole, Pacific sanddab, and rock sole (Kravitz, *et al.* 1977).

Castillo (1992) and Castillo et al. (1995) suggest that density-independent survival of early life stages is low and show that offshore Ekman transportation of eggs and larvae may be an important source of variation in year class strength in the Columbia INPFC area. The effects of the Pacific Decadal Oscillation (PDO) on California current temperature and productivity (Mantua, *et al.* 1997) may also

contribute to non-stationary recruitment dynamics for petrale sole. The prevalence of a strong late 1990s year class for many west coast groundfish species suggests that environmentally driven recruitment variation may be correlated among species with relatively diverse life history strategies.

Stock Status and Management History

Petrale sole were lightly exploited during the early 1900s. By the 1950s the petrale sole fishery was well-developed and showing clear signs of depletion and declines in catches and biomass. Haltuch et al. (2013) estimated petrale sole biomass on the U.S. west coast dropped below the $B_{25\%}$ management target during the 1960s and generally stayed there through 2013. The stock declined below the $B_{12.5\%}$ overfished threshold from the early1980s until the early 2000s (Figure 7). Since 2000 the stock has increased, reaching a peak of 14.2% of unfished biomass in 2005, followed by a decreasing trend through 2010. The petrale sole biomass currently shows an increasing trend with recent above-average year classes recruiting into the spawning biomass. The estimated relative depletion level in 2013 is 22.3 percent.

Early stock assessments only assessed petrale sole in the combined U.S.-Vancouver and Columbia INPFC areas (i.e., petrale in these areas were treated as a unit stock, using time series of data that began during the 1970s) (Demory 1984; Turnock, *et al.* 1993). The first assessment used stock reduction analysis and the second assessment used the length-based Stock Synthesis model. The third petrale sole assessment utilized the hybrid length-and-age-based Stock Synthesis 1 model, using data from 1977–1998 (Sampson and Lee 1999). Sampson and Lee (1999) estimated petrale sole stock depletion at 42 percent of unfished biomass at the start of 1999.

The 2005 petrale sole assessment (Lai, *et al.* 2006) was conducted assuming two separate stocks: the northern stock encompassing the U.S. Vancouver and Columbia INPFC areas and the southern stock including the Eureka, Monterey and Conception INPFC areas. Petrale sole in the north was estimated to be at 34 percent of unfished spawning stock biomass in 2005. In the south, the stock was estimated to be at 29 percent of unfished spawning stock biomass. Biomass trends were qualitatively similar in both areas, and also showed consistency with petrale sole trends in Canadian waters. Both stocks were estimated to have been below the Council's MSST of $B_{25\%}$[4] from the mid-1970s until very recently. Estimated harvest rates were in excess of the target fishing mortality rate of $F_{40\%}$[5] during this period as well. Petrale sole in both areas showed large recent increases in stock size, which was consistent with the strong upward trend in the shelf survey biomass index. In 2005, the STAR panel noted that the petrale sole stock trends were similar in both northern and southern areas in spite of the different modeling choices made for each area, and that a single coastwide assessment should be considered (Dorn, *et al.* 2006).

The 2009 petrale assessment estimated a stock depletion of 11.6 percent of its unfished biomass at the start of 2009 (Haltuch and Hicks 2009b). That result compelled NMFS to declare the stock overfished in 2010. The 2009 assessment treated petrale sole as a single coastwide stock, with the fleets and landings structured by state (WA, OR, CA) area of catch. Historical catches were extended back to 1876, the first year of estimated exploitation for the stock.

New proxy management reference points used to manage FMP flatfish stocks, such as petrale sole, were implemented in 2011 under FMP Amendment 16-5 (also referred to as Secretarial Amendment 1) in 2011 (PFMC and NMFS 2011). The proxy F_{MSY} harvest rate or MFMT of $F_{40\%}$, which is applied to the

[4] $B_{25\%}$ was the MSST or overfished threshold for all groundfish stocks from the implementation of Amendment 12 in 1998 through 2010.

[5] $F_{40\%}$ was the F_{MSY} proxy harvest rate for all flatfish stocks prior to 2011.

estimated exploitable biomass to determine the OFL, was changed to $F_{30\%}$; the B_{MSY} target of $B_{40\%}$ was changed to $B_{25\%}$; and the MSST of $B_{25\%}$, was changed to $B_{12.5\%}$. The SSC recommended these new proxy reference points to manage flatfish stocks based on a meta-analysis of the relative productivity of assessed west coast flatfish species and other assessed Pleuronectid species internationally. The precautionary ACL harvest control rule, referred to as the 25-5 rule and analogous to the 40-10 rule for other groundfish stocks (see Figure 36 and section 1.2.3 for more detail on these ACL harvest control rules), was also adopted for flatfish stocks under Amendment 16-5.

The 2009 rebuilding analysis (Haltuch and Hicks 2009a) was used to consider a petrale sole rebuilding plan for petrale sole, which was implemented under FMP Amendment 16-5. The rebuilding plan specified a target year of 2016 and the strategy of using the 25-5 harvest control rule after 2011 to set harvest levels (the 2011 ACL was set equal to the ABC to avoid unnecessary negative socioeconomic impacts). An emergency rule was implemented to reduce the 2010 petrale OY to 1,200 mt.

The 2011 petrale assessment estimated a stock depletion of 18 percent of its unfished biomass at the start of 2011 (Haltuch, *et al.* 2011). The assessment indicated an increasing spawning biomass trend with above average year classes recruiting into the spawning biomass. The 2011 rebuilding analysis (Haltuch 2011) indicated rebuilding was ahead of schedule and predicted spawning biomass would likely attain the B_{MSY} target of $B_{25\%}$ by the start of 2013. No modifications were made to the rebuilding plan based on this result.

The 2013 petrale assessment (Haltuch, *et al.* 2013) estimated a stock depletion of 22.3 percent of its unfished biomass at the start of 2013 and short of the prediction from the 2011 rebuilding analysis; spawning biomass is predicted to reach the B_{MSY} target by the start of 2014. The 2013 stock assessment continued with the coastwide stock assessment, but was restructured to summarize petrale sole landings by the port of landing and combined Washington and Oregon into a single fleet. The down-weighting of the trawl CPUE index used in the 2011 assessment was largely responsible for the more pessimistic result and the one year lag in rebuilding relative to the previous assessment. However, the estimation of recent recruitments indicated two very strong year classes (2007 and 2008; Figure 18) recruiting into the spawning population, which increases the likelihood of imminent success in rebuilding this stock.

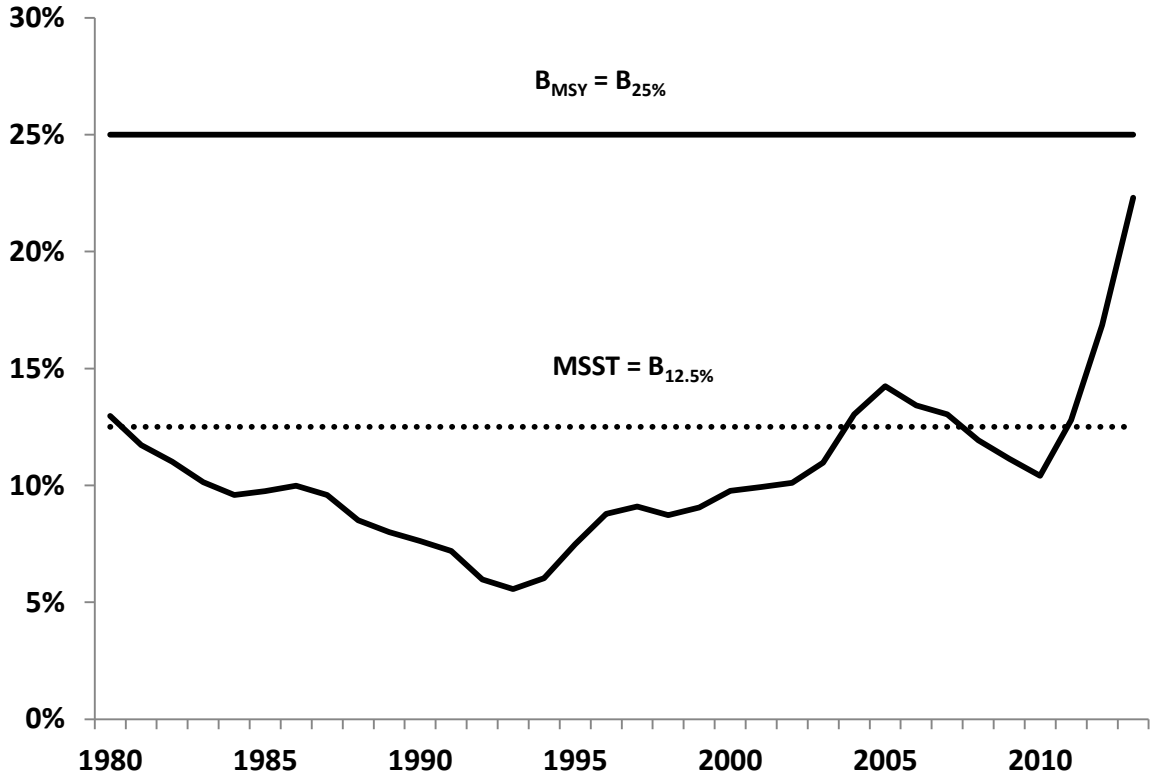

Figure 17. Relative depletion trend from 1980 to 2013 for petrale sole based on the 2013 stock assessment.

Stock Productivity Relative to Rebuilding Success

Petrale have high stock productivity with an estimated stock-recruitment steepness of 0.86 (Haltuch, *et al.* 2013); the prior for this estimate was based on a meta-analysis of flatfish species in the family *Pleuronectidae (Myers, et al. 1999)*. The time series of estimated recruitments shows a relationship with the decline in spawning biomass, punctuated by larger recruitments. The five weakest recruitments since 1934 are estimated to be from 1986, 1987, 1992, 1995, and 2001, while the five strongest recruitments since 1934 are estimated to be from 1939, 1966, 1998, 2007, and 2008. The 2007 and 2008 recruitments were the third and second largest estimated, respectively, behind only the record 1966 recruitment event (Figure 18). Until 2007, the most recent large recruitment event is estimated to be in 2006, which was smaller than the 1998 recruitment event.

The high stock productivity and the large recent recruitments contribute to a predicted quick recovery of the petrale sole stock. The 2013 petrale assessment predicts the stock will be successfully rebuilt by the start of 2014, with an estimated depletion of 26 percent.

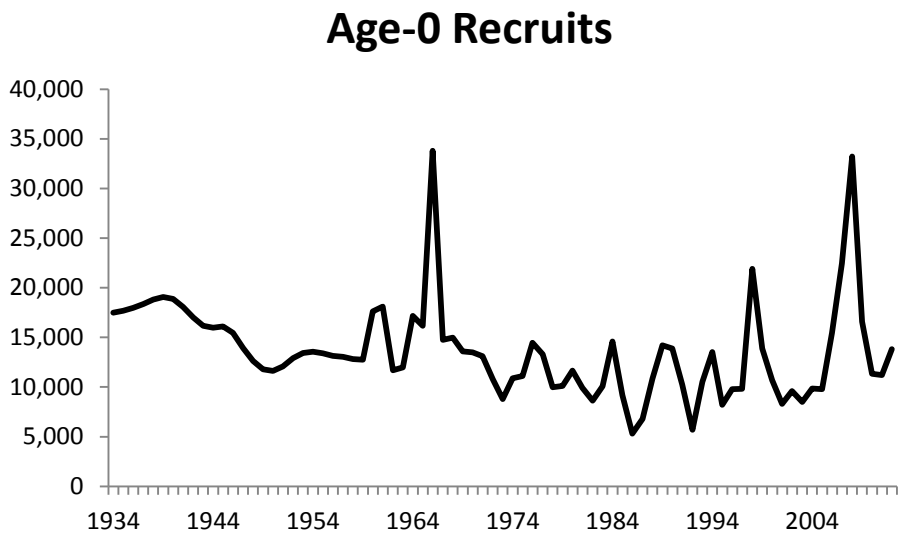

Figure 18. Time series of estimated (age 0) petrale sole recruitments, 1934-2012 (from Haltuch, *et al.* 2013).

Fishing Mortality

Most of the petrale sole catch is made by deep-water demersal trawls at depths of 164-252 fm. Recent petrale sole catch statistics exhibit marked seasonal variation, with substantial portions of the annual harvest taken from the spawning grounds in December and January. From the inception of the fishery in 1876 through the mid-1940s, the vast majority of catches occurred between March and October (the summer fishery), when the stock is dispersed over the continental shelf. The post-World War II period witnessed a steady decline in the amount and proportion of annual catches occurring during the summer months (March-October). Conversely, petrale catch during the winter season (November–February), when the fishery targets spawning aggregations, has exhibited a steadily increasing trend since the 1940s. Since the mid-1980s, catches during the winter months have been roughly equivalent to or exceeded catches throughout the remainder of the year. In 2009, catches of petrale sole began to be restricted due to declining stock size.

Petrale sole exhibit distinct seasonal depth migrations with higher abundance on the shelf during summer months and higher abundance in distinct spawning areas during winter months. Hence, RCA structures for this species could vary seasonally if RCA management is needed to control fishing mortality. The general pattern for petrale sole is a shallower depth distribution during the summer months (periods 3 and 4) and a deeper depth distribution during the winter months (periods 1 and 6). Petrale sole are typically in transition as they migrate between shallow and deeper depths during periods 2 and 5.

Petrale sole is a trawl-dominant species. Therefore, the uncertainty in catch monitoring and accounting is low, given the mandatory 100 percent observer coverage and near real-time reporting of total catches in the rationalized trawl fisheries.

Prior to 2010, when interim rebuilding measures were implemented, harvest rates were in excess of what is now considered the F_{MSY} limit of $F_{30\%}$ (i.e., SPR = 30%). Management measures implemented since 2010 have resulted in harvest rates below the F_{MSY} limit.

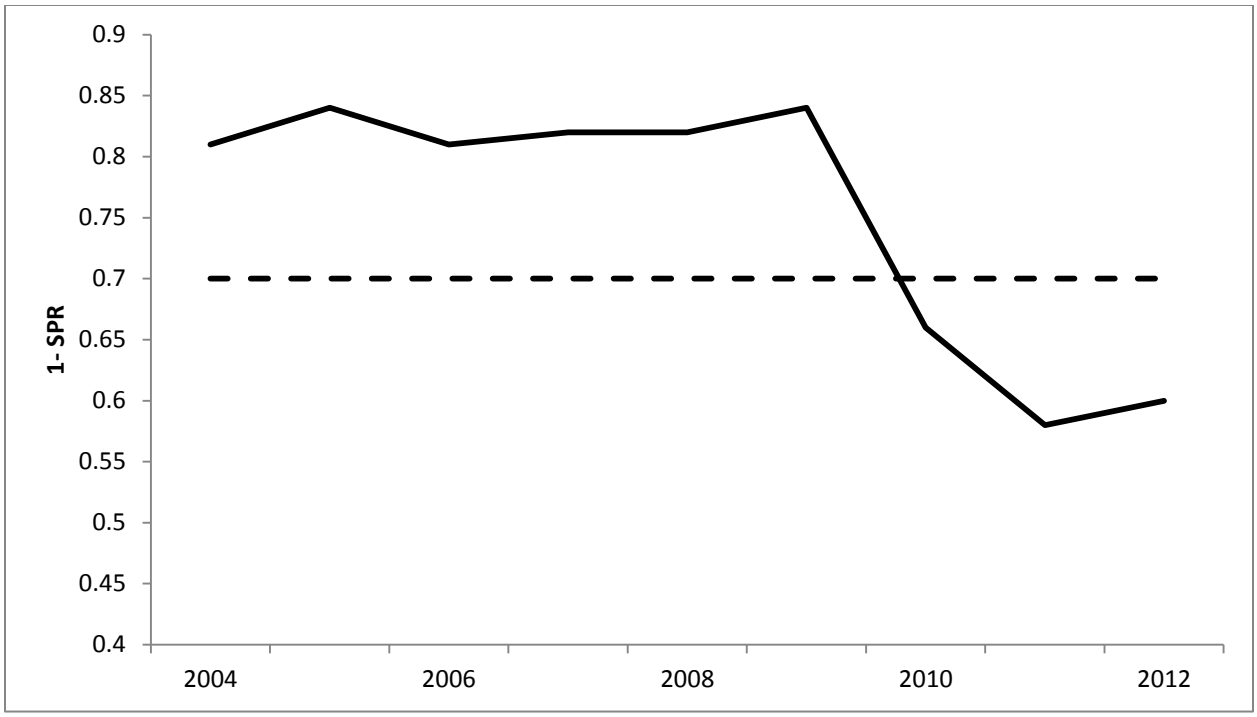

Figure 19. Estimated spawning potential ratio (SPR) of petrale sole, 2004-2012. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a dashed horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the F_{MSY} harvest rate (SPR = 30%).

Rebuilding Duration and Probabilities

The 2013 petrale assessment predicts the stock will be rebuilt by 2014. Therefore, rebuilding probabilities (both P_{MAX} and P_{TARGET}) are high for petrale sole under the harvest control rule in the rebuilding plan. The SSC is recommending a new assessment be done in 2015 to confirm that prediction.

1.1.3.7 Yelloweye Rockfish

Distribution and Life History

Yelloweye rockfish (*Sebastes ruberrimus*) range from the Aleutian Islands, Alaska, to northern Baja California, Mexico, and are common from Central California northward to the Gulf of Alaska (Eschmeyer, *et al.* 1983; Hart 1988; Love, *et al.* 2002; Miller and Lea 1972; O'Connell and Funk 1986). Yelloweye rockfish occur in water 25 m to 550 m deep with 95 percent of survey catches occurring from 50 m to 400 m (Allen and Smith 1988). Yelloweye rockfish are bottom dwelling, generally solitary, rocky reef fish, found either on or just over reefs (Eschmeyer, *et al.* 1983; Hart 1988; Love, *et al.* 2002; Miller and Lea 1972; O'Connell and Funk 1986) . Boulder areas in deep water (>180 m) are the most densely populated habitat type, and juveniles prefer shallow-zone broken-rock habitat (O'Connell and Carlile 1993). They also reportedly occur around steep cliffs and offshore pinnacles (Rosenthal, *et al.* 1982). The presence of refuge spaces is an important factor affecting their occurrence (O'Connell and Carlile 1993).

Yelloweye rockfish are ovoviviparous and give birth to live young in June off Washington (Hart 1988). The age of first maturity is estimated at six years and all are estimated to be mature by eight years (Wyllie

Echeverria 1987). They can grow to 91 cm (Eschmeyer, *et al.* 1983; Hart 1988) and males and females probably grow at the same rates (Love 1996; O'Connell and Funk 1986). The growth rate levels off at approximately 30 years of age (O'Connell and Funk 1986) but they can live to be 118 years old (Love, *et al.* 2002). Yelloweye rockfish are a large predatory reef fish that usually feeds close to the bottom (Rosenthal, *et al.* 1982). They have a widely varied diet, including fish, crabs, shrimps and snails, rockfish, cods, sand lances, and herring (Love, *et al.* 2002). Yelloweye rockfish have been observed underwater capturing smaller rockfish with rapid bursts of speed and agility. Off Oregon the major food items of the yelloweye rockfish include cancroid crabs, cottids, righteye flounders, adult rockfishes, and pandalid shrimps (Steiner 1978). Quillback and yelloweye rockfish have many trophic features in common (Rosenthal, *et al.* 1982).

Stock Status and Management History

The first yelloweye rockfish stock assessment on the U.S. west coast was conducted in 2001 (Wallace 2002). This assessment incorporated two area assessments: one from Northern California using CPUE indices constructed from Marine Recreational Fisheries Statistical Survey (MRFSS) sample data and CDFG data collected on board commercial passenger fishing vessels, and the other from Oregon using Oregon Department of Fish and Wildlife (ODFW) sampling data. The assessment concluded yelloweye rockfish stock biomass in 2001 was at about 7 percent of unexploited biomass in Northern California and 13 percent of unexploited biomass in Oregon. The assessment revealed a thirty-year declining biomass trend in both areas with the last above average recruitment occurring in the late 1980s. The assessment's conclusion that yelloweye rockfish biomass was well below the 25 percent of unexploited biomass threshold for overfished stocks led to this stock being declared overfished in 2002. Until 2002, yelloweye rockfish were listed in the "remaining rockfish" complex on the shelf in the Vancouver, Columbia, and Eureka INPFC areas and the "other rockfish" complex on the shelf in the Monterey and Conception areas. As with the other overfished stocks, yelloweye rockfish harvest is now tracked separately and managed against a species-specific ACL.

In June 2002 the SSC recommended that managers should conduct a new assessment incorporating Washington catch and age data. This recommendation was based on evidence that the biomass distribution of yelloweye rockfish on the west coast was centered in waters off Washington and that useable data from Washington were available. Based on that testimony, the Council recommended completing a new assessment in the summer of 2002, before a final decision was made on 2003 management measures. Methot et al. (Methot, *et al.* 2003) did the assessment, which confirmed the overfished status (24 percent of unfished biomass) and provided evidence of higher stock productivity than originally assumed. The assessment also treated the stock as a coastwide assemblage. The 2002 rebuilding analysis (Methot and Piner 2002a) informed the yelloweye rockfish rebuilding plan adopted under FMP Amendment 16-3 in 2004. The rebuilding plan established a target rebuilding year of 2058 and a harvest control rule of F = 0.0153.

A coastwide 2006 yelloweye rockfish assessment estimated a stock depletion of 17.7 percent of the unfished level at the start of 2006 (Wallace, *et al.* 2006). New data sources in the assessment included WDFW 2002 submersible survey and the International Pacific Halibut Commission annual longline survey. Further revisions in the assessment included reducing natural mortality from 0.045 to 0.036 and increasing steepness from 0.437 to 0.45.

The 2006 rebuilding analysis (Tsou and Wallace 2006) was used to inform a revision of the yelloweye rebuilding plan under FMP Amendment 16-4. Given the significant negative socioeconomic impacts associated with the projected OYs under the constant harvest rate modeled in the rebuilding analysis, the Council elected to gradually ramp down the harvest rate beginning in 2007 before resuming a constant harvest rate rebuilding strategy in 2011. The harvest rate ramp-down strategy, which projected annual

OYs of 23 mt, 20 mt, 17 mt, and 14 mt, respectively in 2007-2011, was projected to extend rebuilding by less than one year relative to the more conservative constant harvest rate strategy analyzed. The ramp-down strategy afforded more time to consider new Yelloweye Rockfish Conservation Areas and other management measures designed to reduce the harvest rate to prescribed levels. Therefore, the Amendment 16-4 rebuilding plan incorporated the ramp-down strategy before resuming a constant harvest rate (SPR = 71.9%) in 2011. The rebuilding plan also specified a target rebuilding year of 2084.

The 2007 updated stock assessment for yelloweye rockfish estimated a stock depletion of 16.4 percent of initial, unfished biomass (Wallace 2008a). The long-term biomass trajectory in the 2007 updated assessment was very similar to that in the 2006 assessment. The 2007 rebuilding analysis (Wallace 2008b) indicated rebuilding progress was on track under the ramp-down strategy; therefore, no revisions were made to the rebuilding plan.

The benchmark 2009 yelloweye assessment estimated a stock depletion of 20.3 percent of initial, unfished biomass at the start of 2009 (Stewart, *et al.* 2009). The resource was modeled as a single stock, but with three explicit spatial areas: Washington, Oregon and California. Each area was modeled simultaneously with its own unique catch history and fishing fleets (recreational and commercial), with the stocks linked via a common stock-recruit relationship with negligible adult movement among areas. The assumed level of historical removals and estimated steepness were identified as the main axes of uncertainty.

The 2009 yelloweye rebuilding analysis (Stewart 2009b) was used to inform a revised rebuilding plan that was implemented under FMP Amendment 16-5. The revised rebuilding plan implemented in 2011 specified a constant harvest rate (SPR = 76%) strategy (the ramp-down strategy was abandoned) and a target year to rebuild the stock of 2074.

The 2011 yelloweye assessment (Taylor and Wetzel 2011), an update of the 2009 assessment, estimated stock depletion at 21.4 percent of initial, unfished biomass at the start of 2011 (Figure 20). The update assessment results were very similar to those in the previous assessment. The 2011 yelloweye rebuilding analysis (Taylor 2011) indicated rebuilding progress was on schedule and no revisions were made to the rebuilding plan.

A yelloweye catch report was provided in 2013 (Agenda Item F.5.a, Attachment 11, June 2013), which indicated 2010-2012 total catches were below specified ACLs/OYs.

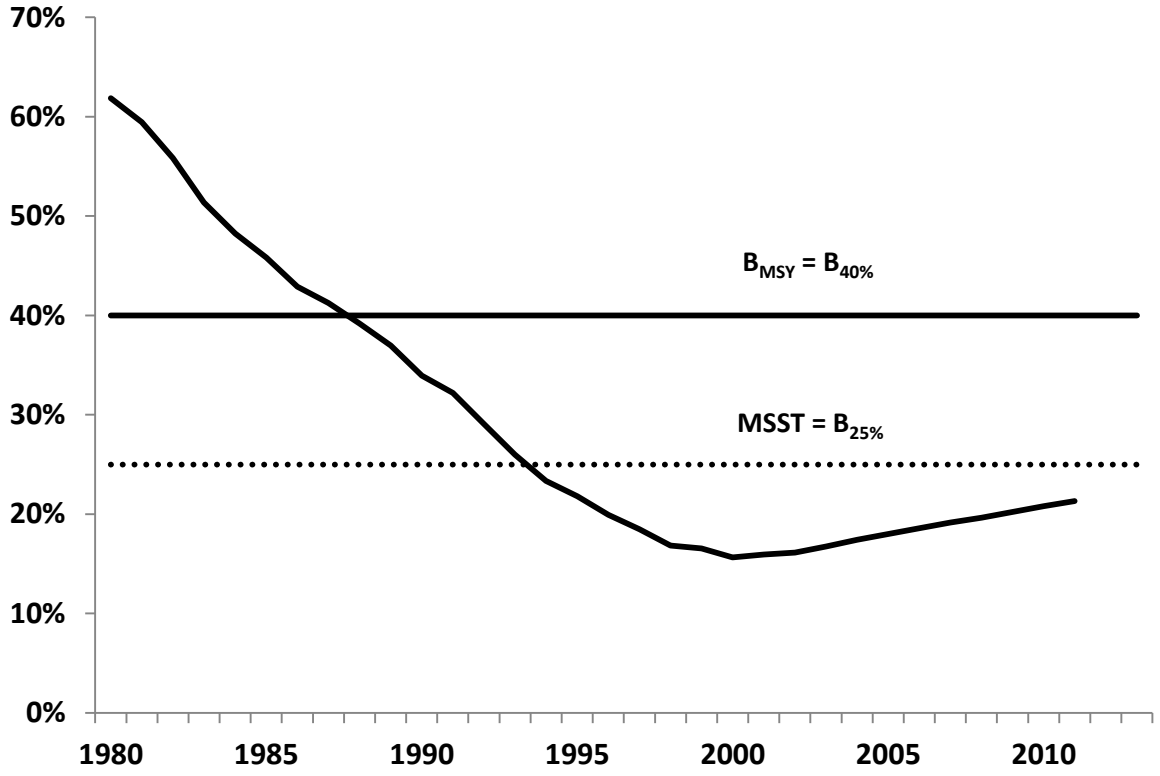

Figure 20. Relative depletion of yelloweye rockfish from 1980 to 2011 based on the 2011 stock assessment update.

Stock Productivity Relative to Rebuilding Success

Yelloweye year class strength is modeled as a deterministic process in the 2011 assessment with no estimation of the size of individual year classes. Therefore, the decline in estimated recruitment tracks closely to that of the spawning output (Figure 21). The decline is especially pronounced given the low (and likely imprecise) estimate for steepness of the stock-recruit relationship in the base-case model (0.441). The low estimated steepness in the assessment results in a prediction of very little surplus production and consequently estimates of low yields at B_{MSY} (MSY is estimated to be 58 mt under the F_{MSY} proxy SPR harvest rate of 50 percent). This relatively low stock productivity also predicts a long mean generation time of 46 years and a slow recovery rate under the very low harvest rate specified in the yelloweye rebuilding plan.

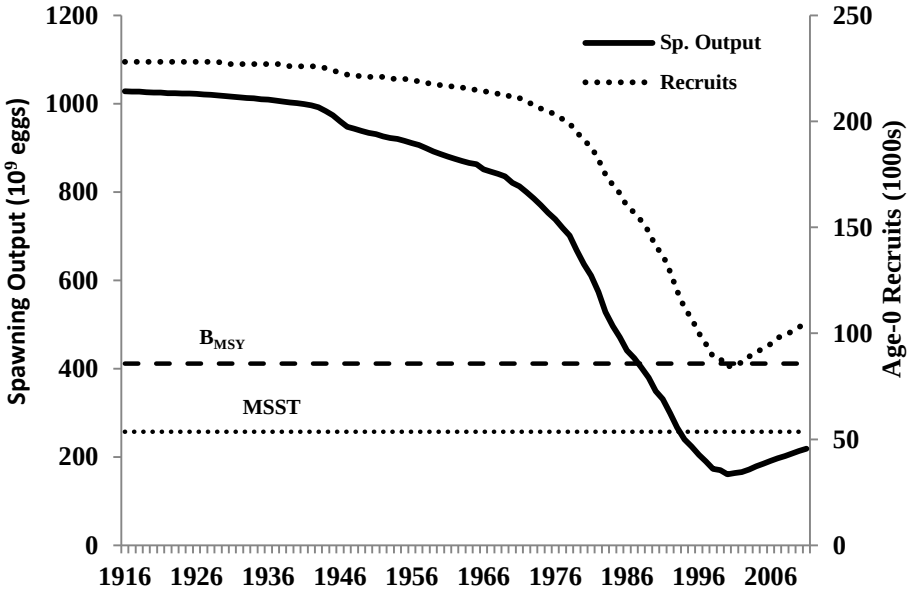

Figure 21. Time series of estimated yelloweye rockfish spawning output and recruitments for the base-case model in the 2011 assessment (Taylor and Wetzel 2011).

Fishing Mortality

Yelloweye rockfish are caught coastwide in all sectors of the fishery. Yelloweye are particularly vulnerable to hook-and-line gears, which are effective in the high relief habitats yelloweye reside. The current non-trawl RCA and the recreational depth closures are primarily configured based on yelloweye distribution and projected impacts in these hook-and-line fisheries. Small footrope trawls, including selective flatfish trawls, do not have the rollers and anti-chafing protection needed to fish in the high relief habitats yelloweye are found. Mandating these gears for trawl efforts on the shelf shoreward of the trawl RCA, the configuration of the trawl RCA, and a small IFQ allocation of yelloweye are the primary strategies currently used to minimize trawl impacts on yelloweye. Yelloweye are also a bycatch species in the Pacific halibut fishery (Love, *et al.* 2002).

Yelloweye rockfish are mostly encountered north of 36º N lat. Yelloweye occur in depths from 25 to 475 m and are most commonly found at depths from 91 to 180 m (Love, *et al.* 2002).

Fishing mortality rates estimated in the 2011 assessment have been in excess of the current F_{MSY} harvest rate for rockfish (SPR = 50 percent) from 1976 through 1999 (Figure 22). Relative exploitation rates (catch/biomass of age-8 and older fish) are estimated to have peaked at 12.7 percent in 1992, but have been at or less than 1.1 percent after 2001. The F_{MSY} exploitation rate assuming the proxy SPR of 50 percent is 2.2 percent. Annual yelloweye harvest rates in the 1976-1999 period averaged over five times the estimated F_{MSY} and spawning biomass declined rapidly during that period.

The commercial RCAs substantially reduce yelloweye impacts. North of 40º10' N lat., the highest bycatch rates of yelloweye rockfish occur in waters less than 100 fm. Yelloweye rockfish have a patchy distribution and as such, using fleetwide bycatch rates over a large area (north and south of 40º10' N lat.) may misrepresent actual catch rates. North of Cape Alava, yelloweye bycatch rates are lowest inside of the 60 fm line; bycatch rates would increase substantially if shoreward RCAs were moved from the 60 fm line to the 75 fm line. The seaward boundary of the non-trawl RCA extends out to 150 fm year round

south of 40º10' N lat. The seaward boundary of the non-trawl RCA north of 40º10' N lat. is at 100 fm year round with a few exceptions where the seaward boundary is at 125 fm. Between 45º03.83' to 43º N lat. the seaward is at 125 fm year round.

Area closures and a prohibition on retention are the main strategies used to minimize recreational yelloweye impacts. The California recreational fishery is subject to depth restrictions that are more restrictive in the northern management areas where yelloweye are more prevalent. CDFG evaluated and has available four potential YRCAs which include habitat in both state and Federal waters where high yelloweye encounter rates have been documented. If implemented, YRCAs are anticipated to reduce yelloweye impacts during the open fishing seasons in both the Northern Groundfish Management Area and the North-Central North of Pt. Arena Groundfish Management Area, possibly allowing for a longer fishing season. To date, these YRCAs have not been implemented but would remain available management measures that can be routinely implemented inseason if needed. Depth management is the main tool used for controlling yelloweye rockfish fishing mortality in the Washington and Oregon recreational fisheries.

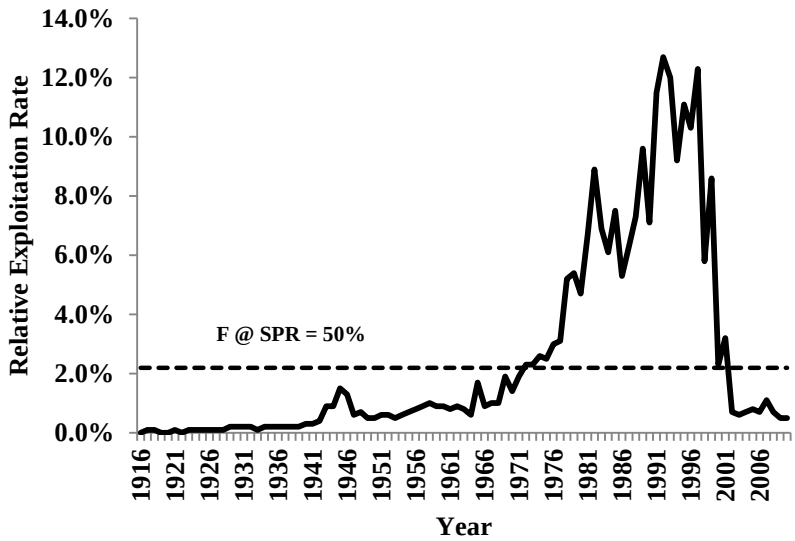

Figure 22. Time series of estimated relative exploitation rates (catch/biomass of age 8+ fish) of yelloweye rockfish, 1916-2010 (Taylor and Wetzel 2011).

Catch monitoring uncertainty is high given the relatively small contribution of yelloweye to rockfish market categories and the relatively large scale of recreational removals. In addition, since 2001, management restrictions have required nearly all yelloweye rockfish caught by recreational and commercial fishermen to be discarded at sea. Precisely tracking recreational catch inseason, especially in the California recreational fishery, has been a challenge.

Rebuilding Duration and Probabilities

Rebuilding under the SPR harvest rate specified in the rebuilding plan has a predicted P_{MAX} of 72.9 percent and a probability of rebuilding by the target year of 2074 of 62.1 percent.

1.1.4 Non-Overfished Groundfish Stocks

1.1.4.1 Arrowtooth Flounder

Distribution and Life History

Arrowtooth flounder (*Atheresthes stomias*) range from the southern coast of Kamchatka to the northwest Bering Sea and Aleutian Islands to San Simeon, California. Arrowtooth flounder is the dominant flounder species on the outer continental shelf from the western Gulf of Alaska to Oregon. They are members of the family Pleuronectidae, the right eyed flounders. Arrowtooth reach sizes of nearly 90 cm and can live to 27 years. Eggs and larvae are pelagic; juveniles and adults are demersal (Garrison and Miller 1982; NOAA 1990). Juveniles and adults are most commonly found on sand or sandy gravel substrates, but occasionally occur over low-relief rock-sponge bottoms. 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 (Garrison and Miller 1982; NOAA 1990; Rickey 1995).

Arrowtooth flounder are oviparous with external fertilization and eggs are about 2.5 mm in diameter. Spawning may occur deeper than 500 m off Washington (Rickey 1995). Arrowtooth are batch spawners (Rickey 1995). They spawn in the deeper continental shelf waters (>200 m) in the late fall through early spring and appear to move inshore during the summer (Zimmerman and Goddard 1996). The larvae spend approximately four weeks in the upper 100 m of the water column (Fargo and Starr 2001) and settle to the bottom in the late winter and early spring. Larvae eat copepods, their eggs, and copepod nauplii (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 1988; NOAA 1990).

Arrowtooth flounder exhibit two feeding peaks, at noon and midnight. Arrowtooth are piscivorous, but they also eat shrimp, worms, and euphausiids (Love 1996). Buckley et al. (1999) analyzed 380 arrowtooth stomachs that were collected in 1989 and 1992 from Oregon and Washington and found that hake (*Merluccius productus*) and unidentified gadids dominate their stomach contents (45 percent and 22 percent respectively) followed by herring (19 percent; *Clupea pallasi*), mesopelagics (0.5 percent), rex sole (1 percent; *Glyptocephalus zachirus*), slender sole (*Lyopsetta exilis*) and other small flatfish (3 percent), other arrowtooth (1.5 percent), other unidentified flatfish (1 percent), pandalid shrimp (~3 percent), and euphausiids (3 percent). Yang (1995) analyzed 1,144 stomachs from arrowtooth collected in the Gulf of Alaska, and found that walleye pollock (*Theragra chalcogramma*) composed 66 percent of the arrowtooth diet, although arrowtooth smaller than 40 cm primarily feed on capelin (*Mallotus villosus*), herring, and shrimp. Gotshall (1969) examined 425 arrowtooth stomachs from northern California throughout the 1960s and found that pandalid shrimp made up nearly 40 percent of the prey by volume, along with other shrimps, crabs, euphausiids, Pacific sanddabs (*Citharichthys sordidus*), and slender sole. However, Gotshall's samples were taken directly from shrimp beds, so higher concentrations of shrimp would be expected. It is clear that arrowtooth have a broad diet, consuming most of the common fish and invertebrates found on soft bottom substrate and in the water column.

Predators of juvenile arrowtooth include skates, dogfish, shortspine thornyhead, halibut, coastal sharks, orcas, toothed whales, and harbor seals (Field, *et al.* 2006). Adult arrowtooth are likely to be vulnerable only to the largest of these predators.

Female arrowtooth off Oregon reach 50 percent maturity at 8 years of age, and males at four years (Hosie 1976). Rickey (1995) found that the arrowtooth reach 50 percent maturity at lengths of 36.8 cm for females and 28 cm for males off Washington, and 44 cm for females and 29 cm for males off Oregon. As

a comparison, female length at 50 percent maturity is 47 cm in the Gulf of Alaska (Turnock, *et al.* 2005) and 38 cm in British Columbia (Fargo and Starr 2001).

Stock Status and Management History

Arrowtooth are commonly caught by trawl fleets off Washington and Oregon, but they are frequently discarded due to low flesh quality. For this reason, the market for arrowtooth has been fairly limited over the last 50 years. It is likely that the stock off the U.S. west coast is linked to the population off British Columbia and, possibly, to the stock in the Gulf of Alaska. However, for assessment purposes it is assumed that the U.S. west coast population is a unit stock.

The west coast stock of arrowtooth flounder was assessed in 1993 (Rickey 1993), and a full stock assessment was done in 2007 (Kaplan and Helser 2008). Three components of the arrowtooth fishery were used in modeling: the mink food fishery in the 1950s-1970s; a targeted fillet/headed-and-gutted fishery that began around 1981; and a "bycatch fleet" that represents west coast trawl effort with arrowtooth bycatch, but no landings. Estimates of historical catch are highly uncertain. The model contains assumed fixed values for natural mortality and steepness of the stock-recruitment relationship. Likelihood profiles suggest that the estimates of biomass and depletion are not sensitive to values of steepness. Assumed values of natural mortality have a small effect on estimated depletion, but strongly influence the estimates of absolute biomass.

The base model shows a period of moderate depletion through the 1950s and 1960s, followed by a rebuilding of the stock beginning in the late 1970s. Strong year classes, in particular the 1999 year class, have led to an increase in the stock since the late 1990s. The spawning biomass at the beginning of 2007 was estimated to be 63,302 mt and 79 percent of the estimated unfished spawning biomass. Total biomass at the start of 2007 was estimated to be 85,175 mt. The 2007 stock assessment estimated that the arrowtooth stock has never fallen below the overfished threshold.

Stock Productivity

Arrowtooth flounder are a very productive stock with high growth rates, high natural mortality rates, and a high stock-recruitment steepness. A mean flatfish steepness of 0.8 was determined in a 2010 meta-analysis conducted by the SSC and described in the 2011-2012 specifications FEIS (PFMC and NMFS 2011). A steepness of 0.902 was assumed in the 2007 arrowtooth flounder assessment based on a flatfish meta-analysis conducted by Dorn (2002a). Arrowtooth received a relatively high productivity score of 1.95 in the PSA analysis (Table 2).

The 2007 assessment estimated strong recruitments for most years between 1998 and 2007, with a particularly strong recruitment of the 1999 year class. That year class has dominated the population and fishery for the last ten years but is now diminished through high natural mortality. However, the 2007 assessment projects a very healthy stock through 2018 under catch streams much higher than has been realized since then.

Fishing Mortality

The target F_{MSY} SPR harvest rate for arrowtooth is 30 percent. The 2007 assessment estimated annual SPR harvest rates between 1997 and 2006 of 49-75 percent, substantially lower than the target. The arrowtooth ACL/OY has never been exceeded.

Arrowtooth flounder are a trawl-dominant species and are not particularly valuable. Given that arrowtooth are caught on the northern shelf where Pacific halibut, darkblotched rockfish, and yelloweye

rockfish are caught incidentally to arrowtooth, this is not a species with a high attainment since valuable quota for these highly constraining species would have to be invested to target arrowtooth. About 20 percent of the arrowtooth quota was attained in the 2012 fishery (cite). Management uncertainty is low with the 100 percent observer coverage for the trawl fleet under trawl rationalization. The PSA vulnerability score of 1.21 indicates a low concern of overfishing.

1.1.4.2 Black Rockfish off California and Oregon

Distribution and Life History

Black rockfish (*Sebastes melanops*) are found from Southern California (San Miguel Island) to the Aleutian Islands (Amchitka Island) and they occur most commonly from San Francisco northward (Hart 1988; Miller and Lea 1972; Phillips 1957; Stein and Hassler 1989). Black rockfish occur from the surface to greater than 366 m; however, they are most abundant at depths less than 54 m (Stein and Hassler 1989). Off California, black rockfish are found along with the blue, olive, kelp, black-and-yellow, and gopher rockfishes (Hallacher and Roberts 1985). 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). Off Oregon, larger fish seem to be found in deeper water (20 m to 50 m) (Stein and Hassler 1989). 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. 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 1988; Stein and Hassler 1989). Black rockfish larvae and young juveniles (<40 mm to 50 mm) are pelagic, but are benthic at larger sizes (Laroche and Richardson 1980).

Black rockfish have internal fertilization and annual spawning (Stein and Hassler 1989). Parturition occurs from February through April off British Columbia, January through March off Oregon, and January through May off California (Stein and Hassler 1989). Spawning areas are unknown, but spawning may occur in offshore waters because gravid (egg-carrying) females have been caught well offshore (Dunn and Hitz 1969; Hart 1988; Stein and Hassler 1989). Black rockfish can live to be more than 20 years in age. The maximum length attained by the black rockfish is 60 cm (Hart 1988; Stein and Hassler 1989). Off Oregon, black rockfish primarily prey on pelagic nekton (anchovies and smelt) and zooplankton such as salps, mysids, and crab megalops. Off Central California, juveniles eat copepods and zoea, while adults prey on juvenile rockfish, euphausiids, and amphipods during upwelling periods. During periods without upwelling they primarily consume invertebrates. Black rockfish feed almost exclusively in the water column (Culver 1986). Black rockfish are known to be eaten by lingcod and yelloweye rockfish (Stein and Hassler 1989).

Stock Status and Management History

A black rockfish assessment was completed in 2003 and pertained to the portion of the coastwide stock occurring off the coasts of Oregon and California (Ralston and Dick 2003) or the southern stock unit. Alternative harvest levels in the 2003 assessment were ranged to capture the major uncertainty of historical landings prior to 1978. Black rockfish catches prior to 1945 were assumed to be zero in the assessment. Many gaps in historical landings of black rockfish since 1945 were evident, and these landings were reconstructed using a variety of data sources. The base model assumed cumulative landings of black rockfish from all fisheries was 17,100 mt from 1945 to 1977. The 2003 assessment concluded the southern California-Oregon stock of black rockfish was in healthy condition with a 2002 spawning output estimated to be at 49 percent of its unexploited level.

The southern stock of black rockfish was again assessed in 2007 (Sampson 2008) using a similar approach and structure as the 2003 assessment. The 2007 assessment estimated the southern stock was at 70 percent of its unfished level at the start of 2007. The 2007 assessment was structured into six fisheries: a set of trawl, commercial non-trawl, and recreational fisheries for Oregon and California, respectively. The fisheries for each state were based on fish capture location rather than where they were landed and therefore represented separate geographic areas. The model in the 2007 assessment did not include any underlying spatial structure in the population dynamics. Like the previous southern stock assessment, abundance indices for tuning the assessment were based on recreational CPUE data with two independent indices available for each state. The standard research trawl surveys along the U.S. west coast do not operate in shallow enough water to catch appreciable numbers of black rockfish and therefore do not provide any fishery independent index of stock biomass for black rockfish. The 2007 assessment had two additional abundance indices that were not available for the previous assessment: a black rockfish pre-recruit index for 2001-2006 and estimates from a tag-recapture study of exploitable black rockfish abundance off Newport, Oregon for 2003-2005. The 2007 assessment for the southern stock of black rockfish used the same sex- and age-specific formulation for natural mortality (M) that was used in the assessment for northern black rockfish, but there is little evidence to confirm that the assumed formulation is correct. The 2003 assessment for southern black rockfish used much smaller values for M that were more consistent with observed values for the maximum age of southern black rockfish.

Stock Productivity

The 2007 southern black rockfish assessment assumed a steepness of 0.6 based on the Dorn meta-analysis of rockfish steepness done at that time. The revised rockfish steepness meta-analysis now predicts a mean steepness of 0.779. The PSA productivity score of 1.33 indicates a stock of moderate productivity.

The 2007 assessment estimated above-average recruitments in the 1990s (with particularly strong recruitments in 1994 and 1999), 2000, 2001, and 2007; and below-average recruitments during 2002-2006. These recruitments are projected to keep the stock healthy under the 1,000 mt constant catch strategy implemented in 2009.

Fishing Mortality

The nearshore commercial and recreational fisheries that take black rockfish are managed well in California and Oregon, and ACLs/OYs have not been exceeded. The PSA vulnerability score of 1.94 indicates a stock of medium concern for overfishing.

Over most of the stock's history the fishing rate has been less than the 50% SPR target fishing rate. The estimated spawning output has been above the target level during all years except 1991 to 1998, and has never dropped below the overfished level. The southern stock of black rockfish is estimated to be well above the overfished level.

1.1.4.3 Black Rockfish off Washington

Distribution and Life History

See the description of black rockfish distribution and life history in section 1.1.4.2.

Stock Status and Management History

The black rockfish stock found between Cape Falcon, Oregon and the U.S. Canadian border was first assessed in 1994 (Wallace and Tagart 1994). Estimated biomass was 60 percent of the unfished level and female egg production was estimated to be 43 percent of the unfished level. A harvest guideline of 517 mt for this area was specified beginning in 1995 based on assessment results. Catches remained well below the harvest guideline in the years subsequent to the assessment.

The 1999 assessment of the black rockfish stock north of Cape Falcon, Oregon determined the stock was at 45 percent of the unfished level (Wallace, *et al.* 1999). The population was regarded as healthy and stock abundance was estimated to be slightly increasing after a period of low abundance in the late 1980s and early 1990s.

The most recent assessment of the northern stock was done in 2007, which estimated a depletion of 53.4 percent of the unfished level (Wallace, *et al.* 2008). The base model for the 2007 assessment assumed a female natural mortality rate to be age-specific using age at first and full maturity for inflections (10 and 15). A constant natural mortality rate of 0.16 was assumed for males and young females (< 10 years of age), and a rate of 0.2 was assumed for old females (>=15 years of age). Model sensitivity analysis showed that model configurations using higher natural mortality for older females provided better overall fits to the data. In the model, spawning biomass and age 3+ biomass reached the lowest levels in 1995, following poor recruitment and intense fishing in the late 1980s. The population trajectory remained just above minimum stock size threshold, and the model indicated that the stock is currently well above the management target of $B_{40\%}$.

Stock Productivity

The 2007 assessment assumed a steepness 0.6 in the stock-recruitment relationship of the northern black rockfish stock based on the Dorn prior (as was done in the southern black rockfish assessment). Steepness may be even higher based on the revised prior of 0.779. The PSA productivity score of 1.33 indicates a stock of moderate productivity.

The 2007 assessment estimated strong recruitments in the 1990s (including strong recruitments in 1994 and 1999 as also estimated in the southern assessment) and above-average recruitments from 2002-2006.

Fishing Mortality

Total mortality of black rockfish off Washington has consistently been well below established ACLs/OYs. The stock is targeted in the Washington recreational fishery; however, that fishery is tightly regulated to minimize canary and yelloweye rockfish impacts. There is also a relatively low tribal take of black rockfish off Washington. There are no commercial nearshore fisheries off Washington.

Exploitation of black rockfish reached a peak in 1988 of 13 percent of the age 3+ biomass and remained near that level for 7 years, dropping precipitously between 1995 and 2000. In recent years exploitation has been relatively low (4-6 percent). Exploitation rate relative to spawning biomass indicate that harvest rates exceeded management targets between the mid 1980s through the mid 1990s for the northern stock of black rockfish.

The PSA vulnerability score of 1.94 indicates a stock of medium concern for overfishing.

1.1.4.4 Cabezon off California

Distribution and Life History

Cabezon (*Scorpaenichthys marmoratus*) are distributed along the entire west coast of the continental United States. They range from central Baja California north to Sitka, Alaska (Love 1996; Miller and Lea 1972). Cabezon are primarily a nearshore species found intertidally and among jetty rocks, out to depths of greater than 100 m (Love 1996; Miller and Lea 1972).

Cabezon are known to spawn in recesses of natural and manmade objects, and males are reported to show nest-guarding behavior (Garrison and Miller 1982). Spawning is protracted, and there appears to be a seasonal progression of spawning that begins off California in winter and proceeds northward to Washington by spring. Spawning off California peaks in January and February (O'Connell 1953) while spawning in Puget Sound (Washington State) occurs for up to 10 months (November-August), peaking in March–April (Lauth 1987). Laid eggs are sticky and adhere to the surface where deposited. After hatching, the young of the year spend 3–4 months as pelagic larvae and juveniles. Settlement takes place after the young fish have attained 3–5 cm in length (Lauth 1987; O'Connell 1953). It is apparent that females lay multiple batches in different nests, but whether these eggs are temporally distinct enough to qualify for separate spawning events is not understood (Lauth 1987; O'Connell 1953).

Stock Status and Management History

Cabezon in California waters was first assessed in 2003 and it estimated a depletion of 34.7 percent at the start of 2003 (Cope, *et al.* 2004). The assessment delineated two stocks (north and south) at the Oregon-California border, a distinction based on differences in the catch history, CPUE trends and biological parameters (mainly growth) between the two areas. Due to the lack of data for the northern population, the assessment focused on only the southern population. As with most nearshore groundfish stocks, this assessment lacked a fishery-independent index of abundance, and consequently relied on recreational CPUE indices and information about larval abundance.

The 2005 assessment modeled two California substocks north and south of Point Conception (Cope and Punt 2006). Historically, the recreational fishery had been the primary source of removals of cabezon in California; however, commercial catches had become a major source of removals in the ten years preceding the assessment because of the developing live-fish fishery. Removals were reconstructed back to 1916, when the commercial fishery began. The estimated stock depletions of the northern and southern substocks of cabezon at the start of 2005 were 40.1 percent and 28.3 percent, respectively.

The most recent cabezon assessment for cabezon occurring in waters off California, done in 2009, estimated a stock depletion of 48.3 percent of unfished biomass at the start of 2009 (Cope and Key 2009). The 2009 assessment modeled two California substocks, and also evaluated the population as a coastwide California stock. The SSC recommended combining the results of the area models for the two California substocks of cabezon for use in deciding statewide harvest specifications.

Stock Productivity

The 2009 cabezon assessment assumed a steepness of 0.7 for all models. The PSA productivity score of 1.72 indicates a stock of relatively high productivity.

Recruitment deviations were estimated from 1970-2006 for both of the assessed substocks. Recruitment patterns are distinctly different for the substocks occurring north and south of Pt. Conception at 34º27’ N lat. Large recruitment events in the 1970s and 1990s in the north and the south have increased spawning

biomass to healthy levels. Interannual variation in recruitment is greater in the north. The large increase in biomass in the south was driven by a large 1999 recruitment, the largest seen in the time series. Large recruitments in the southern substock were estimated immediately after major El Niño events (e.g., 1984 and 1994 recruitments). Recruitment events for the northern substock appear to lag large recruitments in the south by a year.

Fishing Mortality

Exploitation of the southern cabezon substock began in the 1960s and caused a substantial decline in stock biomass. The large recruitments discussed above and a reduction in exploitation rates in the late 1990s and 2000s caused the substock to rebound to healthy levels. Exploitation in the north also increased in the 1960s, although fishing pressure was not as great. The spawning biomass of the northern substock declined, although not as dramatically as in the south. The stock rebounded with good recruitment and a reduction in fishing pressure.

The cabezon stock(s) off California were first assessed in 2003, and OYs were first specified in 2004. Specified OYs were exceeded in each year through 2006, but a reduction in cumulative landing limits adequately reduced fishing mortality starting in 2007. The percent of OY attainment ranged from 56 to 74 percent in the 2007-2010 period.

The PSA vulnerability score of 1.68 indicates a low risk of overfishing.

1.1.4.5 Cabezon off Oregon

Distribution and Life History

See the description of cabezon distribution and life history in section 1.1.4.4.

Stock Status and Management History

The 2009 assessment of the Oregon substock of cabezon (Cope and Key 2009) was the first for cabezon in Oregon waters; the assessment indicated a healthy stock status for Oregon cabezon at 52.4 percent depletion at the start of 2009. Only one index of abundance was used for modeling the Oregon cabezon substock (the Oregon Recreational Boat Survey or ORBS CPUE index). The Oregon model was robust to almost all data and parameter manipulation trials except the removal of the ORBS survey. Removal of the only abundance index causes the population to drop sharply below the overfished level and absolute biomass to be much smaller than in the base case. Unlike the assessments for the California substocks, the assessment of the Oregon cabezon substock does not show recent increases in spawning biomass. While the uncertainty in the estimated depletion level of the Oregon substock is generally low, uncertainty in the estimated spawning biomass is high.

Stock Productivity

Steepness in the 2009 assessment of the Oregon substock of cabezon was assumed to be 0.7. Recruitment in the Oregon substock of cabezon was estimated to be less dynamic than that for the California substocks. The PSA productivity score of 1.72 indicates a stock of relatively high productivity.

The assessment estimates large recruitments in 1999 and 2004. Uncertainty in estimating recruitment for the Oregon substock is less than the uncertainty in recruitment estimation for the California substocks.

Fishing Mortality

Cabezon exploitation in Oregon started in the 1970s and caused the biomass to decline. However, exploitation was not excessive and the estimated spawning biomass has always been above the B_{MSY} target.

The PSA vulnerability score of 1.68 indicates a low risk of overfishing.

1.1.4.6 California Scorpionfish

Distribution and Life History

California scorpionfish (*Scorpaena guttata*), also known locally as sculpin, is a generally benthic species found from central California to the Gulf of California in depths between the inter-tidal and about 170 m (Eschmeyer, *et al.* 1983; Love, *et al.* 1987). California scorpionfish generally inhabits rocky reefs, but in certain areas and seasons they aggregate over sandy or muddy substrate (Frey 1971; Love, *et al.* 1987). Catch rate analysis and tagging studies show that most, but not all, California scorpionfish migrate to deeper water to spawn during May-September (Love, *et al.* 1987). Tagging data suggest that they return to the same spawning site (Love, *et al.* 1987), but information is not available on non-spawning season site fidelity. California scorpionfish are quite mobile and may not be permanently tied to a particular reef (Love, *et al.* 1987).

California scorpionfish spawn from May through August, peaking in July (Love, *et al.* 1987). The species is oviparous, producing floating, gelatinous egg masses in which the eggs are embedded in a single layer (Orton 1955). California scorpionfish utilize the "explosive breeding assemblage" reproductive mode in which fish migrate to, and aggregate at traditional spawning sites for brief periods (Love, *et al.* 1987). These spawning aggregations have been targeted by fishermen. Few California scorpionfish are mature at one year of age, but over 50 percent are mature by age two and most are mature by age three (Love, *et al.* 1987).

The species feeds on a wide variety of foods, including crabs, fishes, octopi, isopods and shrimp, but juvenile Cancer crabs are the most important prey (Limbaugh 1955; Love, *et al.* 1987).

Stock Status and Management History

California scorpionfish were assessed in 2005 (Maunder, *et al.* 2006) in the southern California Bight south of Point Conception at 34º27' N lat. to the U.S.-Mexico border. The stock assessment indicated the California scorpionfish stock was healthy with an estimated spawning stock biomass of 79.8 percent of its initial, unfished biomass in 2005.

In most years, 99 percent or more of the landings occur in the southern California ports. The California nearshore FMP includes California scorpionfish. The stock is managed by the state under provisions for improved fishery monitoring and research data collection.

Stock Productivity

A steepness value of 0.7 was assumed for California scorpionfish in the 2005 assessment. The PSA productivity score of 1.83 indicates a stock of relatively high productivity, especially for a rockfish.

The assessment noted a high recruitment variation in the stock and recruitments in the 1990s and early 2000s were estimated to be substantially above average. Relatively large recruitment events were estimated starting in 1984.

Fishing Mortality

A substantial but unknown portion of the stock occurs in Mexican waters. The exploitation of the stock in Mexican waters is unknown and the connectivity of that stock with the U.S. stock in the Southern California Bight is also unknown.

Commercial catch records for scorpionfish were available beginning in 1928. Commercial catches were the dominant removals until the 1990s when the recreational catch became dominant. High catches and low recruitments in the 1950s and 1960s precipitated a decline in biomass. Stock biomass has been on an increasing trend since the mid 1970s.

The PSA vulnerability score of 1.41 indicates a low risk of overfishing.

1.1.4.7 Chilipepper Rockfish South of 40°10' N Lat.

Distribution and Life History

Chilipepper rockfish (*Sebastes goodei*) are found from Magdalena Bay, Baja California, Mexico, to as far north as the northwest coast of Vancouver Island, British Columbia (Allen 1982; Hart 1988; Miller and Lea 1972). The region of greatest abundance is found between Point Conception and Cape Mendocino, California. Chilipepper have been taken as deep as 425 m, but nearly all in survey catches were taken between 50 and 350 m (Allen and Smith 1988). Adults and older juveniles usually occur over the shelf and slope; larvae and small juveniles are generally found near the surface. In California, chilipepper are most commonly found associated with deep, high relief rocky areas and along cliff drop-offs (Love, *et al.* 1990), as well as on sand and mud bottoms (MBC 1987). They are occasionally found over flat, hard substrates (Love, *et al.* 1990). Love (1996) does not consider this to be a migratory species. Chilipepper may travel as far as 45 m off the bottom during the day to feed (Love 1996). Chilipepper rockfish are described as an elongate fish with reduced head spines similar in appearance to both shortbelly rockfish (at smaller sizes, although shortbelly tend to be slimmer) and bocaccio rockfish (bocaccio tend to have larger mouths).

Chilipeppers are ovoviviparous and eggs are fertilized internally (Reilly, et al. 1992). Chilipepper school by sex just prior to spawning (MBC 1987). In California, fertilization of eggs begins in October and spawning occurs from September to April (Oda 1992) with the peak occurring during December to January (Love, *et al.* 2002). Chilipepper may spawn multiple broods in a single season (Love, *et al.* 2002). Females of the species are significantly larger, reaching lengths of up to 56 cm (Hart 1988). Males are usually smaller than 40 cm (Dark and Wilkins 1994). Males mature at two years to six years of age, and 50 percent are mature at three years to four years. Females mature at two years to five years with 50 percent mature at three years to four years (MBC 1987). Females may attain an age of about 27 years, whereas the maximum age for males is about 12 years (MBC 1987).

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 anchovies, lanternfish, and young Pacific whiting (Hart 1988; Love, *et al.* 2002). Chilipepper are found with widow rockfish, greenspotted rockfish, and swordspine rockfish (Love, *et al.* 2002). Juvenile chilipepper compete for food with bocaccio, yellowtail rockfish, and shortbelly rockfish (Reilly, *et al.* 1992). Pelagic juveniles are preyed upon by a wide range of predators, including seabirds, salmon, lingcod and marine mammals. Larger piscivorous fishes, marine mammals, and in recent years jumbo squid are among the predators of larger adults.

Stock Status and Management History

Chilipepper have been one of the most important commercial target species in California waters since the 1880s and were historically an important recreational target in Southern California waters. With the exception of excluding foreign fishing effort from the U.S. EEZ in the late 1970s, management actions were modest (and usually general to all rockfish and other groundfish) prior to the implementation of the Groundfish FMP in 1982. When the FMP was implemented, management for the groundfish trawl fishery was based on individual vessel trip limits, which were set at 40,000 lbs per trip on the Sebastes (all rockfish species) complex. These limits were maintained until 1991, when they were reduced to 25,000; in 1993 the trip limit system was revised from daily to biweekly trip limits, which were set at 50,000 lbs (south of Cape Mendocino). The trip limit regime continued to evolve in their absolute amounts and temporal duration (monthly, bimonthly) throughout the 1990s, with a general trend towards lower limits as conservation concerns arose for other rockfish species (particularly bocaccio rockfish in the region south of Mendocino). The chilipepper catch in the bottom trawl fishery has been managed under an IFQ system since 2011.

Chilipepper rockfish were assessed in 1998 (Ralston, *et al.* 1998), at which time the stock south of 40º10' N lat. was estimated to be at 46 percent to 61 percent of unfished biomass.

A full chilipepper assessment was conducted in 2007 (Field 2008). The 2007 assessment estimated a substantial increase in the spawning biomass of chilipepper rockfish in recent years, due to a strong 1999 year class as well as greatly reduced harvest rates in commercial and recreational fisheries. The 2007 assessment's base model result suggests a spawning biomass of 23,889 tons in 2006, corresponding to approximately 70 percent of the unfished spawning biomass of 33,390 tons and representing a near tripling of spawning biomass from the estimated low of 8,696 mt (26 percent of unfished) in 1999. The strong 1999 year class represents the largest estimated historical recruitment, and is the primary cause for the current population trajectory. There are no obvious signs of strong year classes since 1999, and coastwide pelagic juvenile surveys suggested average to low recruitment in years immediately preceding the assessment, suggesting that the stock may dip slightly in the near term.

The 2007 assessment was first used in 2008 to decide 2009 and 2010 chilipepper harvest specifications. The Council consideration for 2011 and 2012 was whether or not to remove chilipepper rockfish from the Shelf Rockfish North complex and manage it coastwide. Chilipepper rockfish are predominantly found south of 40°10' N lat. Prior to 2007 they were only assessed in the area south of 40°10' N lat. To date, chilipepper rockfish have been managed with stock-specific harvest specifications south of 40°10' N lat. and within the Shelf Rockfish North complex north of 40°10' N lat. When the stock assessment area was extended for the 2007 chilipepper stock assessment, it was extended to the stock's entire west coast range through waters off Oregon (chilipepper rockfish are not believed to occur in waters off Washington). However, it was decided to continue to manage chilipepper rockfish south of 40º10' N lat. with stock-specific harvest specifications and as part of the Shelf Rockfish complex north of 40°10' N lat.

Stock Productivity

Steepness in the 2007 assessment was fixed at 0.57, which was the mean of the prior probability distribution in the base model. Since steepness was thought to be poorly specified in the model, this parameter was chosen as the major axis of uncertainty. The decision table projected outcomes for a low productivity and a high productivity model using steepness values of 0.34 and 0.81, respectively. The PSA productivity score of 1.83 indicates a stock of relatively high productivity, especially for a rockfish.

There have been strong recruitments estimated for the stock in the late 1960s, early 1970s, and very strong recruitments in 1984 and 1999. The 1999 year class was the biggest recruitment event in the

assessment time series, causing spawning biomass to increase substantially in the ten years preceding the assessment.

Fishing Mortality

Chilipepper rockfish have been one of the most important commercial target species in California since the late 1800s and was also a recreational target in southern California waters. Catches and exploitation rate has declined substantially since the early 1990s. While chilipepper has always been an important target species in California, the exploitation rate has rarely exceeded the F_{MSY} target of a 50 percent SPR. Exploitation rates declined substantially since the late 1990s with the implementation of more restrictive management measures to rebuild depleted stocks.

Throughout most of the past three decades, domestic landings have ranged between approximately 2,000 and 3,000 mt; however, since 2002 landings have averaged less than 100 mt per year. The highest exploitation rates occurred from the late 1980s through the mid 1990s, when they were above target levels and the stock was approaching its lowest estimated historical levels. From the late 1990s through the present, exploitation rates have been declining significantly down to incidental levels, as a result of management measures implemented to rebuild co-occurring depleted rockfish species (particularly bocaccio, but including canary, widow, cowcod and yelloweye). Discards are assumed to be negligible in the historical period; however, regulatory discards have been substantial in recent years, more than doubling the total catch relative to landings since 2002.

The PSA vulnerability score of 1.35 indicates a low risk of overfishing.

1.1.4.8 Dover Sole

Distribution and Life History

Dover sole (*Microstomus pacificus*) are distributed from the Navarin Canyon in the northwest Bering Sea and westernmost Aleutian Islands to San Cristobal Bay, Baja California, Mexico (Hagerman 1952; Hart 1988; NOAA 1990). Dover sole are a dominant flatfish on the continental shelf and slope from Washington to Southern California. Adults are demersal and are found from 9 m to 1,450 m, with highest abundance below 200 m to 300 m (Allen and Smith 1988). Adults and juveniles show a high affinity toward soft bottoms of fine sand and mud. Juveniles are often found in deep nearshore waters. Dover sole are considered to be a migratory species. In the summer and fall, mature adults and juveniles can be found in shallow feeding grounds, as shallow as 55 m off British Columbia (Westrheim and Morgan 1963). By late fall, Dover sole begin moving offshore into deep waters (400 m or more) to spawn. Although there is an inshore-offshore seasonal migration, little north-south coastal migration occurs (Westrheim and Morgan 1963).

Spawning occurs from November through April off Oregon and California in waters 80 m to 550 m depth at or near the bottom (Hagerman 1952; Hart 1988; NOAA 1990; Pearcy, *et al.* 1977). Dover sole are oviparous and fertilization is external. Larvae are planktonic and are transported to offshore nursery areas by ocean currents and winds for up to two years. Settlement to benthic living occurs mid-autumn to early spring off Oregon, and February through July off California (Markle, *et al.* 1992). Juvenile fish move into deeper water with age and begin seasonal spawning and feeding migrations upon reaching maturity.

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 1988; NOAA 1990). Dover sole larvae are eaten by 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).

Stock Status and Management History

Dover sole have been the target of trawl operations along the west coast of North America since World War II and were almost certainly caught prior to the war as incidental take in directed fisheries for English sole and petrale sole. Almost all of the harvests have been taken by groundfish trawl, and in particular as part of the Dover sole, shortspine thornyhead, longspine thornyhead, and sablefish (DTS) trawl fishery. Annual landings from U.S. waters averaged 6,700 mt during the 1960s, 12,800 mt during the 1970s, 18,400 mt during the 1980s, 12,400 mt during the 1990s, and 7,200 mt since 2000.

The 1997 Dover sole stock assessment (Brodziak, *et al.* 1997) treated the entire population from the Monterey area through the U.S.-Vancouver area as a single stock based on research addressing the genetic structure of the population. Under a range of harvest policies and recruitment scenarios, the 1997 model projected that spawning biomass would increase from the estimated year-end level in 1997 through the year 2000 due to growth of the exceptionally large 1991 year class and to the lower catches observed in the fishery since 1991.

Dover sole were next assessed in 2001, resulting in an estimated spawning stock size of 29 percent of the unexploited biomass (Sampson and Wood 2001). Although there was no clear trend in abundance, stocks steadily declined from the 1950s until the mid-1990s. The 1991 year class was the last strong one, consistent with the 1997 assessment.

The 2005 Dover sole assessment indicated the stock was above target levels and had an increasing abundance trend (Sampson 2005). The final base model estimated the unexploited spawning stock biomass to be slightly less than 300,000 mt and spawning biomass at the start of 2005 was estimated to be about 189,000 mt, equivalent to 63 percent of the unexploited level. Spawning biomass and age 5+ biomass (roughly corresponding to the exploitable biomass) were estimated to have reached their lowest points in the mid-1990s and rose steadily since. The estimated increases in biomass since the mid-1990s was due primarily to strong year classes in 1990 and 1991, and exceptionally strong year classes in 1997 and 2000.

A new Dover sole assessment was done in 2011, which indicated the stock was healthy with a 2011 spawning stock biomass depletion of 83.7 percent of unfished biomass (Hicks and Wetzel 2011).

Stock Productivity

Steepness in the 2011 Dover sole assessment was fixed at 0.8, the mean steepness estimated in the SSC's 2010 meta-analysis of flatfish productivity (PFMC and NMFS 2011). While the 2011 assessment was considered data-rich, estimates of steepness are uncertain partly because the stock has not been fished to low levels to understand potential recruitment at low spawning biomass. The PSA productivity score of 1.8 indicates a stock of relatively high productivity.

There is little information regarding recruitment prior to 1960. Estimates of recruitment appear to oscillate between periods of low recruitment and periods of high recruitment. The five largest recruitments were predicted in the years 2000, 1992, 1988, 1965, and 1991. The five smallest recruitments were predicted in 2003, 2002, 2004, 2006, and 1974.

Larger than average recruitments in the early 1960s resulted in an increase in the Dover sole spawning biomass. A period of smaller than average recruitments in the late 1970s and early 1980s, along with the highest catches on record caused a decline in spawning biomass throughout the 1980s. More recently, spawning biomass has been increasing. However, a recent increase in Dover sole catches and low estimated recruitment in the early 2000s seem to be resulting in a slight downward trend in spawning biomass.

Fishing Mortality

The spawning biomass of Dover sole reached a low in the mid-1990s before beginning to increase throughout the last decade. The estimated depletion has remained above the 25 percent biomass target and it is unlikely that the stock has ever fallen below this threshold. Throughout the 1970s, 1980s, and 1990s the exploitation rate and SPR generally increased, but never exceeded the SPR 30 percent F_{MSY} target. Recent exploitation rates on Dover sole have been much lower than F_{MSY}, even after management increased catch levels in 2007.

Given the productivity of the stock and constraints on fishing, projections assuming a 25,000 mt constant annual catch predict the stock would remain above the target B_{MSY} level in the next ten years even under the more pessimistic and less likely low state of nature in the assessment decision table. Higher ACLs than the preferred No Action ACL were initially considered but rejected from more detailed analysis since the current market is projected to limit the take of Dover sole in the next management cycle to less than 25,000 mt. Higher ACLs are predicted to be sustainable; future mortalities as high as the OFL (above the allowable ACL maximum of the ABC) would maintain the stock above the target level of $B_{25\%}$ under the most likely base case model in the 2011 assessment. The effective limit of Dover sole in the 2013 and 2014 shorebased IFQ fishery is likely to be driven by the sablefish allocation, which is decreasing relative to No Action. Sablefish quota is needed to target Dover sole and the other DTS species using trawl gear. Sablefish IFQ quota is also used in a single-species target fishery using fixed gears. The competition and price for sablefish quota is affected by Asian sablefish demand and supply from north Pacific fisheries outside the west coast EEZ (e.g., BC and the Gulf of Alaska fisheries). It may be the case that the supply and demand of west coast Dover sole will remain limited until there is an increased harvestable surplus of sablefish above the levels provided under the No Action and preferred ACLs.

Dover sole is a trawl-dominant species managed using IFQs in the rationalized fishery. Despite Dover sole being an important target species, only 35 percent of the 2011 quota was attained in the IFQ fishery.

The PSA vulnerability score of 1.54 indicates a low risk of overfishing.

1.1.4.9 English Sole

Distribution and Life History

English sole (*Parophrys vetulus*) are found from Nunivak Island in the southeast Bering Sea and Agattu Island in the Aleutian Islands, to San Cristobal Bay, Baja California Sur, Mexico (Allen and Smith 1988). In research survey data, nearly all occurred at depths greater than 250 m (Allen and Smith 1988). Adults and juveniles prefer soft bottoms composed of fine sands and mud (Ketchen 1956), but also occur in eelgrass habitats (Pearson and Owen 1992). English sole use nearshore coastal and estuarine waters as nursery areas (Krygier and Pearcy 1986; Rogers, *et al.* 1988). 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).

Spawning occurs over soft-bottom mud substrates (Ketchen 1956) from winter to early spring, depending on the stock. Eggs are neritic and buoyant, but sink just before hatching (Hart 1988); juveniles and adults are demersal (Garrison and Miller 1982). 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. Large juveniles commonly occur up to depths of 150 m. Although many postlarvae may settle outside of estuaries, most will enter estuaries during some part of their first year of life (Gunderson, et al. 1990). Some females mature as three-year-olds (26 cm), but all females over 35 cm long are mature. Males mature at two years (21 cm).

Larvae are planktivorous. Juveniles and adults are carnivorous, eating copepods, amphipods, cumaceans, mysids, polychaetes, small bivalves, clam siphons, and other benthic invertebrates (Allen 1982; Becker 1984; Hogue and Carey 1982; Simenstad, *et al.* 1979). English sole feed primarily by day, using sight and smell, and sometimes dig for prey (Allen 1982; Hulberg and Oliver 1979). 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.

Stock Status and Management History

English sole have been captured by the bottom trawl fishery operating off the western coast of North America for over a century. Stewart (2006) found that peak catches from the southern area occurred in the 1920s with a maximum of 3,976 mt of English sole landed in 1929, and peak catches from the northern area occurred in the 1940s to the 1960s with a maximum of 4,008 mt landed in 1948. Landings from both areas have generally declined since the mid-1960s and have been at nearly historical lows in recent years

The most recent stock assessment of English sole prior the current 2005 assessment was performed in 1993 (Sampson and Stewart 1993). That assessment considered the female portion of the stock off Oregon and Washington during the years 1977-1993. The English sole spawning biomass was found to be increasing and it was concluded that the fishery was sustainable at (then) contemporary harvest levels.

The 2005 assessment of English sole (Stewart 2006) modeled a single coastwide stock, although both commercial and fishery independent data sources were treated separately for a southern (INPFC Conception and Monterey) and a northern (INPFC Eureka, Columbia and U.S. Vancouver) area. The assessment found that English sole spawning biomass had increased rapidly over the last decade after a period of poor recruitments from the mid-1970s to the mid-1990s, which left the stock at nearly historically low levels. Strong year classes were estimated for 1995, 1996, and 1999. The data indicated that the 1999 year class may be the largest in the time-series. There was substantial uncertainty related to certain parameters in the assessment, specifically biomass, recruitment, and relative depletion, as indicated by the wide confidence intervals for those parameters. Nevertheless, sensitivity analyses indicated that the conclusion that current spawning biomass exceeds the target level ($B_{40\%}$) was robust to all three of these sources of uncertainty. The spawning biomass at the beginning of 2005 was estimated to be 31,379 mt, which corresponds to 91.5 percent of the unexploited equilibrium level. Total catches for 2004 were estimated to be 1,341 mt, of which 950 mt were landed.

The 2007 update assessment (Stewart 2008c) confirmed the magnitude of increased biomass through a large quantity of age data through 2006, which became available. The 2007 assessment also included data on fishery length and age (primarily from Washington) that was previously unavailable. These new data provided substantially improved information regarding recent year class strengths and current stock

status. The spawning biomass at the beginning of 2007 was estimated to be 41,906 mt, which corresponded to 116 percent of the unexploited equilibrium level.

Cope et al. (2013) assessed English sole using the data-moderate exSSS model platform.

Stock Productivity

There is little evidence for a strong stock-recruitment relationship, with some of the largest recruitments occurring at moderate levels of spawning biomass. This corresponds to the relatively high estimate of steepness of 0.80 in the assessment. In general, recruitment deviations are well-informed by the data between 1940 and 2000.

Following two decades of low recruitments, strong year classes were estimated for 1995, 1998-2000, and 2002. The data indicate that the 1999 year class was the largest in the time-series.

The PSA productivity score of 2.25 indicates a very productive stock, which is true for most nearshore and shelf flatfishes.

Fishing Mortality

The estimated SPR for English sole has never been below the proxy target of 30 percent for flatfish. Exploitation rates were highest from the late 1940s to the early 1990s. Since 1992, the intensity of exploitation has been substantially less, resulting in higher SPR levels. This corresponds to a relative exploitation rate (catch/biomass of age 3 and older fish) history that is high from the late 1940s to the early 1990s, and steadily declining to very low levels over the last 15 years.

English sole are a trawl-dominant species. Management uncertainty is low with the 100 percent observer coverage for the trawl fleet under trawl rationalization. Very small amounts of English sole were landed in the 2011 IFQ fishery with only 1 percent of the quota attained. This is due to low trawl effort on the shelf since such efforts require investment of limited quota for Pacific halibut, darkblotched rockfish, and yelloweye rockfish.

The PSA vulnerability score of 1.19 shows a very low concern of overfishing on the stock.

1.1.4.10 Lingcod North and South of 40°10’ N Lat.

Distribution and Life History

Lingcod (*Ophiodon elongatus*), a top order predator of the family Hexagrammidae, ranges from Baja California, Mexico, to Kodiak Island in the Gulf of Alaska. Lingcod are demersal at all life stages (Allen and Smith 1988; NOAA 1990; Shaw and Hassler 1989). Adult lingcod prefer two main habitat types: slopes of submerged banks 10 m to 70 m below the surface with seaweed, kelp, and eelgrass beds and channels with swift currents that flow around rocky reefs (Emmett, *et al.* 1991; Giorgi and Congleton 1984; NOAA 1990; Shaw and Hassler 1989). Juveniles prefer sandy substrates in estuaries and shallow subtidal zones (Emmett, *et al.* 1991; Hart 1988; NOAA 1990). As the juveniles grow they move to deeper waters. Adult lingcod are considered a relatively sedentary species, but there are reports of migrations of greater than 100 km by sexually immature fish (Jagielo 1990; Mathews and LaRiviere 1987; Matthews 1992; Smith, *et al.* 1990).

Mature females live in deeper water than males and move from deep water to shallow water in the winter to spawn (Forrester 1969; Hart 1988; Jagielo 1990; LaRiviere, *et al.* 1980; Mathews and LaRiviere 1987;

Matthews 1992; Smith, *et al.* 1990). 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; LaRiviere, *et al.* 1980; Shaw and Hassler 1989). Spawning generally occurs over rocky reefs in areas of swift current (Adams 1986; Adams and Hardwick 1992; Giorgi and Congleton 1984; LaRiviere, *et al.* 1980). After the females leave the spawning grounds, the males remain in nearshore areas to guard the nests until the eggs hatch. Hatching occurs in April off Washington, but as early as January and as late as June at the geographic extremes of the lingcod range. Males begin maturing at about two years (50 cm), whereas females mature at three plus years (76 cm). In the northern extent of their range, fish mature at an older age and larger size (Emmett, *et al.* 1991 Adams, 1992 #438; Hart 1988; Mathews and LaRiviere 1987; Miller and Geibel 1973; Shaw and Hassler 1989). The maximum age for lingcod is about 20 years (Adams and Hardwick 1992).

Lingcod are a visual predator, feeding primarily by day. Larvae are zooplanktivores (NOAA 1990). Small demersal juveniles prey upon copepods, shrimps, 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 1988; Miller and Geibel 1973; Shaw and Hassler 1989). Lingcod 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).

Stock Status and Management History

Lingcod have been a target of commercial fisheries since the early 1900s in California, and since the late 1930s in Oregon and Washington waters. Recreational fishermen have targeted lingcod since the 1920s in California. A smaller recreational fishery has taken place in Washington and Oregon since at least the 1970s. Although historically the catches of lingcod have been greater in the commercial sector than in the recreational sector, this pattern has been reversed since the late 1990s.

In 1997, Jagielo, et al. (1997) assessed the size and condition of the portion of the stock in the Columbia and Vancouver areas (including the Canadian portion of the Vancouver management area), and concluded the stock had fallen to below ten percent of its unfished size at 8.8 percent of its unfished biomass. The Council responded by imposing substantial harvest reductions coastwide, reducing the harvest targets for the Eureka, Monterey, and Conception areas by the same percentage as in the north.

In 1999, Adams, et al. (1999) assessed the southern portion of the stock and concluded the condition of the southern stock was similar to the northern stock with a depletion of $B_{15\%}$, thus confirming the Council had taken appropriate action to reduce harvest coastwide. Based on these assessments, the lingcod stock was declared overfished in 1999. A rebuilding plan establishing a target year of 2009 and harvest rates of $F = 0.0531$ and $F = 0.0610$ for fisheries in the northern and southern areas, respectively was adopted and implemented in 2000.

Jagielo et al. (2000) conducted a coastwide lingcod assessment and determined the total biomass increased from 6,500 mt in the mid-1990s to about 8,900 mt in 2000. In the south, the population had also increased slightly from 5,600 mt in 1998 to 6,200 mt in 2000. In addition, the assessment concluded previous aging methods portrayed an older population; whereas new aging efforts showed the stock to be younger and more productive. Therefore, the ABC and OY were increased in 2001 on the basis of the new assessment. A revised rebuilding analysis of coastwide lingcod (Jagielo and Hastie 2001) confirmed the major conclusions of the 2000 assessment and rebuilding analysis, but slightly modified recruitment projections to stay on the rebuilding trajectory to reach target biomass in 2009.

The lingcod rebuilding plan was formally adopted by the Council and incorporated into the FMP under Amendment 16-2. The rebuilding plan established a target rebuilding year of 2009 and the harvest control rule of F = 0.0531 for fisheries in the northern areas and F = 0.0610 for fisheries in the southern areas (with a P_{MAX} of 60 percent). Depth-based restrictions and a winter season fishing closure to protect nest-guarding males were also implemented as part of the rebuilding plan.

Jagielo et al. (2004) conducted a coastwide assessment for lingcod in 2003 that indicated the lingcod stock had achieved the rebuilding objective of $B_{40\%}$ in the north with a 68 percent depletion, but was at a 31 percent depletion in the south. The Council's SSC, working in concert with the lead assessment author, recalculated the coastwide lingcod stock status in March 2004 using actual 2003 harvests (the assessment, which was completed during 2003, assumed harvest would be equal to the specified OY in 2003). Their calculations indicated that the spawning biomass at the start of 2004 was within 99.3 percent of B_{MSY} ($B_{40\%}$) on a coastwide basis. The harvest control rule was recalculated to be F = 0.17 for fisheries in the northern areas and F = 0.15 for fisheries in the southern areas.

The 2005 coastwide assessment (Jagielo and Wallace 2006) again modeled two populations of lingcod north and south of 40º10' N. lat. On a coastwide basis, the lingcod population was concluded to be fully rebuilt, with the spawning biomass in 2005 estimated to be 64 percent of its unfished level. Within the separate area models current biomass was estimated to be closer to unfished biomass in the north ($B_{87\%}$) than in the south ($B_{24\%}$). Given that the lingcod stock is managed on a coastwide basis, the Council announced the lingcod stock to be fully rebuilt in 2005, which is four years earlier than the target rebuilding year established in the rebuilding plan.

The 2009 lingcod assessment modeled two populations north and south of the California-Oregon border at 42º N. lat. (Hamel, *et al.* 2009). Both populations were healthy with stock depletion estimated at 62 and 74 percent for the north and south, respectively.

The Council and NMFS elected to maintain the management line for lingcod at 40º10' N lat. by specifying separate ACLs north and south of that line. This action was intended to not overly encumber the commercial fishing industry, which is required to fish within a single management area within one trip. Specifying the lingcod management line at 42º N lat. would create two management areas stratified at 40º10' N lat. and 42º N lat. This would especially burden vessels home ported out of Brookings, Crescent City, Eureka, and Ft. Bragg, since they would have to restructure their current fishing practices to avoid a violation of the management line crossover provisions. It is stated in the 2009 assessment that a management break at Cape Mendocino would be likely more biologically accurate than stratifying the assessment north and south of 42º N lat. In general, given the crossover provisions and the other regulations that foster area management strategies, the fewer latitudinal management lines there are, the less burdened the offshore commercial fishery will be. Two major biogeographic breaks occur on the west coast at Pt. Conception at 34º27' N lat. and Cape Mendocino approximately at 40º10' N lat., and many stocks show differences north and south of these latitudes. These biogeographic breaks are probably the more appropriate latitudes to specify management lines, given how north-south physical processes such as current patterns tend to be different, creating stock differences for species affected by these different physical processes.

The lingcod STAT evaluated the swept area biomass estimates calculated annually (2003-2010) from the NMFS NWFSC trawl survey, which indicated that 48 percent of the lingcod biomass for the stock south of 42º N lat. occurred between 40º10' N lat. and 42º N lat. Therefore, 48 percent of the 2013 and 2014 OFLs projected in the 2009 lingcod assessment for the southern lingcod stock were added to OFLs proposed for the stock north of 40º10' N lat. Likewise, 48 percent of the projected OFLs for the southern stock were subtracted from the OFLs proposed for the stock south of 40º10' N lat. Given that the trawl survey is the main fishery-independent tuning index of biomass in the assessment, using swept area

biomass from the trawl survey to estimate relative biomass north and south of 40º10' N lat. was considered appropriate.

Stock Productivity

Steepness was fixed at 0.8 in the 2009 assessment. The PSA productivity score of 1.75 indicates a stock of relatively high productivity.

Recruitments in the north were estimated from 1928-2007, with bias correction ramping in from 1950 to 1964 as data became informative. The base model indicated a very strong recruitment event in 1964, a secondary event in 1970, and recent relatively strong recruitments in 1999-2002, with fairly high recruitment in 2006 as well. Recruitments in the south were estimated from 1928-2007, with bias correction ramping in from 1960 to 1974 as data became informative. The base model indicated relatively strong recruitment events in 1976, 1983, and 1999-2003, similar to the period of increased recruitment in the north, with a very high but uncertain recruitment in 2007.

Fishing Mortality

Lingcod exploitation coastwide was above the target rate for most of the 1970s through the 1990s, driving the stock below the MSST and into an overfished condition. The stock was successfully rebuilt by 2006 based on good recruitments and very low fishing mortality rates. The SPR for northern lingcod has been above the proxy target of 45 percent since 1998, and in recent years has been far above that level. The SPR for the southern lingcod stock has been above the proxy target of 45 percent since 2001, and in recent years has been far above that level.

The PSA vulnerability score for lingcod is 1.55, indicating a low risk of overfishing of the stock.

1.1.4.11 Longnose Skate

Distribution and Life History

Skates are the largest and most widely distributed group of batoid fish with approximately 245 species ascribed to two families (Ebert and Compagno 2007; McEachran 1990). Skates are benthic fish that are found in all coastal waters but are most common in cold temperatures and polar waters (Ebert and Compagno 2007).

There are about eleven species of skates from either of three genera (Amblyraja, Bathyraja, and Raja) present in the Northeast Pacific Ocean off California, Oregon and Washington (Ebert 2003). Of that number, just three species (longnose skate *Raja rhina*, big skate *Raja binoculata*, and sandpaper skate *Bathyraja interrupta*) make up over 95 percent of survey catches in terms of biomass and numbers, with the longnose skate leading in both categories (62% of biomass and 56% of numbers). Species compositions of fishery landings also show that longnose skate are the predominant skates in commercial catches. On average, longnose skate represents 75 percent of total skate landings in Oregon for the last 20 years and 45 percent in Washington for the last 10 years. There are no species composition data available for commercial landings in California, but anecdotal evidence suggests that the majority of skates landed there are longnose skates.

The distribution of the longnose skate is limited to the eastern Pacific Ocean. It is found from the southeastern Bering Sea to just below Punta San Juanico, southern Baja California, and Gulf of California at depths of 9-1,069 m (Love, *et al.* 2005). Longnose skates do not exhibit a size-specific pattern in distribution relative to bottom depth; average fish size does not vary greatly with depth.

Currently, there is no information available that indicates the existence of multiple breeding units in the Northeast Pacific Ocean. Several tagging studies have found that elasmobranchs, such as sharks and skates, can undertake extensive migrations within their geographic range (Martin and Zorzi 1993; McFarlane and King 2003). This behavior suggests the likelihood that there is a high degree of genetic mixing within the population, across its range. As a result, the longnose skate population off California, Oregon and Washington is modeled in this assessment as a single stock.

The life history of skates is characterized by late maturity, low fecundity and slow growth to large body size (King and McFarlane 2003; Moyle and Cech 1996; Walker and Hislop 1998). Skates invest considerable energy in developing a few large, well-protected embryos. These characteristics are associated with a K-type reproductive strategy, as opposed to r-type strategy, wherein reproductive success is achieved by high productivity and early maturity (Hoenig and Gruber 1990).

The longnose skate is oviparous. After fertilization, the female forms tough, but permeable egg cases that surround eggs and then deposits these egg cases onto the sea floor at daily to weekly intervals for a period of several months or longer (Hamlett and Koob 1999). The eggs within egg cases incubate for several months in a benthic habitat. Inside the egg cases, the embryos develop with nourishment provided by yolk. The longnose skate is known to have only a single embryo per egg case (David Ebert, Moss Landing Marine Laboratories, pers. com. as cited by Gertseva and Schirripa (2008)). When the yolk is depleted and the juvenile is fully formed, it exits in the egg case. Once hatched, the young skate is similar in appearance to an adult, but smaller in size. Upon reaching maturity, skates enter the reproductive stage, which lasts for the remainder of their lives (Frisk, *et al.* 2002; Pratt and Casey 1990). On average off the continental US Pacific Coast, female longnose skates mature between 11-18 years, which corresponds to 75-125 cm in total length (Thompson 2006). The life span of the longnose skate is not well known, although individuals up to 23 years of age have been found (Thompson 2006). Longnose skates attain a maximum length of about 145 cm, although individuals as large as 180 cm have been reported off the U.S. west coast (Thompson 2006).

The reproductive cycle of oviparous skates has been observed for a few species but not for longnose skate. These studies indicate that egg production generally occurs throughout the year although there have been some instances where seasonality in egg laying was observed (Hamlett and Koob 1999). Information on fecundity of longnose skate is extremely limited. Holden (1974) found that species of the family Rajidae are the most fecund of all elasmobranches and can lay 100 egg cases per year, although eggs may not be produced every year. Frisk et al. (2002) estimated that annual fecundity for skates similar in size with longnose may be less than 50 eggs per year; however, those eggs exhibit high survival rates due to the large parental investment. Overall, little is known about breeding frequency, egg survival, hatching success and other early life history characteristics of longnose skate.

Stock Status and Management History

Longnose skate was managed in a complex of dissimilar species, the Other Fish complex, from 1982, when the Groundfish FMP was implemented through 2008. In 2009, longnose skate was removed from the Other Fish complex and managed with stock-specific harvest specifications.

Gertseva and Schirripa (2008) assessed the west coast longnose skate stock in 2007. The spawning stock biomass was estimated to be at 66 percent of its unfished biomass at the start of 2007. Based on that assessment, a constant catch strategy (OY = 1,349 mt) was implemented in 2009 based on a 50 percent increase in the average 2004-2006 landings and discard mortality. The constant catch strategy was revised in 2013 by implementing an ACL of 2,000 mt to provide greater access to the stock and to limit disruption of current fisheries. This level of harvest was projected to maintain the population at a healthy

level as projected in the 10-year forecast for longnose skate in the 2007 assessment (Gertseva and Schirripa 2008).

The SSC recommended changing the proxy F_{MSY} rate for longnose skate and other elasmobranchs from an SPR of 45% to an SPR of 50% beginning in 2015. This recommendation, driven primarily by conservation concerns for spiny dogfish (see section 1.1.4.18), was heeded by the Council when they adopted 2015 and 2016 OFLs consistent with this lower harvest rate.

Stock Productivity

Steepness of the stock-recruitment curve was fixed at a value of 0.4 in the 2007 assessment to reflect the K-type reproductive strategy of the longnose skate. Recruitments were deterministically provided using this steepness value and a Beverton-Holt stock-recruitment relationship since the data in the 2007 assessment was not informative of relative year-class strength. In general, elasmobranchs have relatively low productivity given the K-type reproductive strategy of producing few eggs per female with a significant parental energy investment to increase survival of those few eggs (e.g., production of egg cases and relatively large yolk masses).

Fishing Mortality

Historically, skates in general, and longnose skate in particular, have not been high-priced fishery products. They are taken mostly as bycatch in other commercially important fisheries (Bonfil 1994). Although skates are caught in almost all demersal fisheries and areas off the U.S. west coast, the vast majority (almost 97%) are caught with trawl gear.

Landing records indicate that skates have been retained on the U.S. Pacific Coast at least since 1916 (Martin and Zorzi 1993). Little is known about the species composition of west coast skate fisheries, particularly prior to 1990. With few exceptions, longnose skate landings have been reported, along with other skate species, under the market category “unspecified skates”, until 2009 when a sorting requirement for longnose skate was required.

Historically, only the skinned pectoral fins or “wings” were sold, although a small portion of catch would be marketed in the round (whole). The wings were cut onboard the boat and the remainder discarded. Currently, west coast skates are marketed both whole and as wings. Skates wings are sold fresh or fresh-frozen, as well as dried or salted and dehydrated, for sale predominantly in Asian markets (Bonfil 1994; Martin and Zorzi 1993). It appears that the demand for whole skates did increase greatly during the mid-1990s, as evidenced by the increase in the number of trips where skates were landed. While skates were encountered predominantly as bycatch previously, landings data from this period reveal greater targeting of skates by some vessels. After a few years, the whole-skate market cooled due to downturns in Asian financial markets (Peter Leipzig, Fishermen's Marketing Association, pers. com. as cited by Gertseva and Schirripa (2008).

Historically, the exploitation rate for the longnose skate has been low. It reached its maximum level of 4.02% in 1981 (Gertseva and Schirripa 2008). An exploitation rate of 1.25% was estimated in 2006.

A vulnerability score of 1.68 indicates a low concern for overfishing the stock.

1.1.4.12 Longspine Thornyhead

Distribution and Life History

Longspine thornyhead occur from the southern tip of Baja, California, to the Aleutian Islands (Jacobson and Vetter 1996; Orr, *et al.* 1998). There appears to be no distinct geographic breaks in stock abundance along the west coast (Fay 2006; Rogers, *et al.* 1997). Adult longspine thornyhead are bottom dwellers, and inhabit the deep waters of the continental slope throughout their range.

Longspine occur at depths greater between 201 and 1,756 m, most typically between 500 and 1,300 m (Love, *et al.* 2002), and a peak in abundance and spawning biomass in the oxygen minimum zone (OMZ) at about 1,000 m depth (Jacobson and Vetter 1996; Wakefield 1990). Longspine are better adapted to deep water than shortspine (Siebenaller 1978; Siebenaller and Somero 1982). Wakefield (Wakefield 1990) estimated that in Central California, 83% of the longspine population resides within an area of the continental slope bounded by 600 and 1,000 m depth.

Unlike shortspine thornyhead, the mean size of longspines is similar throughout the depth range of the species (Jacobson and Vetter 1996). Camera sled observations indicate that longspines do not school or aggregate, and are distributed relatively evenly over soft sediments (Wakefield 1990). Differences in density of individuals at depth do occur with latitude, with higher densities of longspine in deep water (1,000-1,400 m) off Oregon than off central California (Jacobson and Vetter 1996).

The strong relationship between depth and size found in shortspine thornyhead (Jacobson and Vetter 1996 is not observed for longspines, with the distribution of longspines being relatively uniform with depth {Rogers, 1997 #271). Unlike shortspines, longspine do not undergo an ontogenetic migration to deeper waters (Wakefield 1990).

Longspine thornyheads prefer muddy or soft sand bottoms in deep-water environments characterized by high pressure and low oxygen concentrations. These are low productivity (Vetter and Lynn 1997) and low diversity (Haigh and Schnute 2003) habitats where food availability is limited. Longspines have adapted to this environment with an extremely slow metabolism that allows it to wait up to 180 days between feedings (Vetter and Lynn 1997). They are not territorial, and do not school. They have no swim bladders; instead oil in the bones and spines provides floatation. Video observations from submersibles and ROVs indicate that thornyhead are sit-and-wait predators that rest on the bottom and remain motionless for extended periods (John Butler, NOAA Fisheries, Southwest Fisheries Science Center, CA, as cited in Jacobson and Vetter (1996)).

The spawning season for longspine thornyheads appears to be extended, and occurs over several months during February, March and April (Best 1964; Moser 1974; Pearcy 1962; Wakefield and Smith 1990). Both thornyhead species produce a bi- lobed jellied egg mass that is fertilized at depth and which then floats to the surface where final development and hatching occur (Pearcy 1962). An extended larval and pelagic juvenile phase follows, which is thought to be 18-20 months long (Jacobson and Vetter 1996; Moser 1974; Wakefield 1990). Juvenile longspine settle on the continental slope at depths between 600 and 1,200 m (Wakefield 1990). Moser (1974) reports a mean length at settlement of 4.2-6.0 cm, although pelagic juveniles up to 69 mm in length have been collected in midwater trawls off Oregon (J. Siebenaller unpublished data, as cited in Wakefield and Smith (1990)).

Following settlement, longspine thornyhead are strictly benthic (Jacobson and Vetter 1996). No apparent pulse in recruitment during the year was observed by Wakefield and Smith (1990), perhaps due to the long (4-5 months) spawning season, variation in growth rates, and variation in the duration of the pelagic

period (Wakefield and Smith 1990). There is potential for cannibalism because juveniles settle directly on to the adult habitat (Jacobson and Vetter 1996).

Adult females release between 20,000 and 450,000 eggs over a 4-5 month period (Best 1964; Moser 1974). Wakefield (1990) and Cooper et al. (2005) both found linear relationships between fecundity and somatic weight. The data analyzed by Cooper et al. (2005) indicated that fecundity of longspine between 20 and 30 cm in length ranged from 20,000 to 50,000 eggs.

There is considerable uncertainty regarding age and growth of thornyheads (Jacobson and Vetter 1996), although data indicate that longspine thornyhead are long lived. Age estimates of over 40 years have been obtained from otoliths using thin-section and break- and-burn techniques (Ianelli, *et al.* 1994). High frequencies of large longspine thornyheads may be due to a strongly asymptotic growth pattern, with accumulation of many age groups in the largest size-classes (Jacobson and Vetter 1996).

Size-at-age data (Ianelli, *et al.* 1994) indicate that longspine grow to a maximum size of about 30cm TL at ages of about 25-45 years, with little or no sexual dimorphism in length at age – longspines in British Columbia, Canada also display no sexual dimorphism (Starr and Haigh 2000). Orr et al. (1998) report a maximum length for longspines of 38 cm, although individuals of this size are rare in both trawl surveys and commercial landings. Growth increments on otoliths suggest that juveniles reach 80 mm after 1 year of life as demersal juveniles {Wakefield unpublished data, as cited in Wakefield and Smith, \1990 #462}, which would correspond to an age of 2.5 - 3 years old.

Longspine thornyhead are ambush 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). 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. Sablefish and shortspine thornyhead commonly prey on longspine thornyhead (Buckley, *et al.* 1999).

Stock Status and Management History

Longspine thornyhead are exploited in the limited entry deep-water trawl fishery operating on the continental slope that also targets shortspine thornyhead, Dover sole and sablefish (i.e., the DTS fishery). A very small proportion of longspine landings is due to non-trawl gears (gillnets, hook and line). Longspine and shortspine thornyhead make up a single market category; however, they were managed under separate harvest specifications since 1992. Beginning in 2011, trawl catches of longspine north of 34º27' N lat. have been managed using individual fishing quotas.

The thornyhead fishery developed in Northern California during the 1960s. The fishery then expanded north and south, and the majority of the landings of longspine thornyhead have since been in the Monterey, Eureka, and Columbia INPFC areas, with some increase in landings from the Conception (southern CA) and Vancouver (northern WA) INPFC areas in recent years (Fay 2006).

The most recent stock assessment of west coast longspine thornyhead was done in 2013. This was the fifth assessment done for longspines, but only the second in which it was assessed individually (earlier assessments were of longspine and shortspine thornyheads in combination). Previous assessments were conducted by Jacobson (Jacobson 1990; 1991), Ianelli et al. (1994), Rogers et al. (1997), and Fay (2006). The 1990 and 1991 assessments were very similar. Important features included reviews of available biological data, and analyses of trends in mean lengths from port samples and catch rates calculated from logbook data. Swept-area and video biomass estimates were used to estimate average biomass levels and

exploitation rates in the Monterey to US-Vancouver management areas. The available data were used to conduct per-recruit analyses of yield, revenue, and spawning biomass, and to develop estimates of the then target level of $F_{35\%}$.

Ianelli et al. (1994) assessed the coastwide abundance of longspine and shortspine thornyheads based on slope survey data, an updated analysis of the logbook data, and fishery length-composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The Rogers et al. (1997) assessment used a length-based version of Stock Synthesis 1 to fit an age-structured model to data for the Monterey, Eureka, Columbia and Vancouver INPFC areas. Models were fitted to biomass estimates and length data from the AFSC slope surveys (1988-1996), a logbook CPUE index, discarded proportions by year, and length composition data from California and Oregon. Sensitivity to discard rates based on changes in prices and minimum size were explored.

The 2005 assessment of longspine thornyhead estimated spawning biomass in 2005 was approximately 71 percent of unfished spawning biomass (Fay 2006). The model assumed one coastwide stock with one coastwide trawl fishery. Results from the base model suggested that the length compositions from the slope surveys were influencing recruitment in the model, such that the model estimated slightly higher recruitment in the early 1990s, which then declined in the mid to late 1990s.

The 2013 longspine thornyhead assessment indicated a stock depletion of 75 percent at the start of 2013 (Stephens and Taylor 2013).

Stock Productivity

Stephens and Taylor (2013) estimated annual longspine recruitment using a Beverton-Holt stock-recruitment function and assuming a steepness value of 0.6. Most 2013 rockfish assessments used a steepness prior of 0.779, estimated from a meta-analysis of rockfish assessment results. This value might be expected in the 2013 longspine assessment; however, rockfish ecology and reproduction are quite different from those of thornyheads, which (for example) do not give birth to live young but rather spawn floating egg masses.

Steepness in the shortspine thornyhead assessment was fixed at 0.6 both in the 2005 and 2013 models (Hamel 2006c; Taylor and Stephens 2013). This value was justified based on consistency between the modeling approach and management targets, in addition to being within a range of biologically reasonable values. For consistency, therefore, steepness for the longspine model was also fixed at 0.6.

Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates. The 2013 longspine assessment is relatively uninformative of relative year class strength since ages were not used in the model (thornyheads are notoriously difficult to age). Therefore, a length-based assessment with an assumed steepness is used to determine recruitment.

Fishing Mortality

The estimated exploitation rate of longspine thornyheads was above the current F_{MSY} harvest rate through much of the 1990s and, in hindsight, given the current target harvest rate, overfishing was occurring. However, stock biomass was estimated to have never dropped below the target B_{MSY} level. There is very little risk of overexploitation of longspines given their deep distribution beyond the 700 fm limit to west coast bottom trawling implemented under Amendment 19.

The PSA vulnerability score of 1.54 for longspine thornyheads also indicates a low concern for potential overfishing of the stock.

1.1.4.13 Pacific Cod

Distribution and Life History

Stock Status and Management History

The west coast population of Pacific cod has never been formally assessed. Targetable amounts of Pacific cod occur off northern Washington infrequently since the west coast EEZ is at the southern limit of their distribution. The Pacific cod OFL has been set at the highest annual historical catch observed for the stock and ACLs/OYs have been set at half that amount.

Pacific cod is the only unassessed, data-poor groundfish stock currently managed with stock-specific harvest specifications on the west coast.

Stock Productivity

The PSA vulnerability score of 1.34 for Pacific cod indicates a low concern for potential overfishing of the stock.

Fishing Mortality

1.1.4.14 Pacific Whiting

Distribution and Life History

Stock Status and Management History

Stock Productivity

Fishing Mortality

Pacific whiting is managed consistent with the Agreement with Canada on Pacific Hake/Whiting. OYs, now called TACs (total allowable catches), for Pacific whiting are adopted on an annual basis after a stock assessment is completed just prior to the Council's March meeting . The most recent assessment was conducted in 2013 Hicks 2013 and was used to determine stock status and 2013 harvest specifications.

1.1.4.15 Sablefish

Distribution and Life History

Sablefish, or black cod, (*Anoplopoma fimbria*) are distributed in the northeastern Pacific ocean from the southern tip of Baja California, northward to the north-central Bering Sea and in the Northwestern Pacific ocean from Kamchatka, southward to the northeastern coast of Japan. Although few studies have critically evaluated issues regarding the stock structure of this species, it appears there may exist at least three different stocks of sablefish along the west coast of North America: (1) a stock that exhibits relatively slow growth and small maximum size that is found south of Monterey Bay (Cailliet, *et al.* 1988; Phillips and Inamura 1954); (2) a stock that is characterized by moderately fast growth and large maximum size that occurs from northern California to Washington; and (3) a stock that grows very quickly and contains individuals that reach the largest maximum size of all sablefish in the northeastern Pacific ocean, distributed off British Columbia, Canada and in the Gulf of Alaska (Mason, *et al.* 1983; McFarlane and Beamish 1983a). Large adults are uncommon south of Point Conception (Hart 1988; Love 1996; McFarlane and Beamish 1983b; NOAA 1990). Adults are found as deep as 1,900 m, but are most abundant between 200 m and 1,000 m (Beamish and McFarlane 1988; Kendall and Matarese 1987; Mason, *et al.* 1983). Off southern California, sablefish are abundant to depths of 1,500 m (MBC 1987). Adults and large juveniles commonly occur over sand and mud (McFarlane and Beamish 1983a; NOAA 1990) in deep marine waters. They were also reported on hard-packed mud and clay bottoms in the vicinity of submarine canyons (MBC 1987).

Spawning occurs annually in the late fall through winter in waters greater than 300 m (Hart 1988; NOAA 1990). Sablefish are oviparous with external fertilization (NOAA 1990). Eggs hatch in about 15 days (Mason, *et al.* 1983; NOAA 1990) and are demersal until the yolk sac is absorbed (Mason, *et al.* 1983). Age-zero juveniles become pelagic after the yolk sac is absorbed. Older juveniles and adults are benthopelagic. Larvae and small juveniles move inshore after spawning and may rear for up to four years (Boehlert and Yoklavich 1985; Mason, *et al.* 1983). Older juveniles and adults inhabit progressively deeper waters. Estimates indicate that 50 percent of females are mature at five years to six years (24 inches) and 50 percent of males are mature at five years (20 inches).

Sablefish larvae prey on copepods and copepod nauplii. Pelagic juveniles feed on small fishes and cephalopods—mainly squids (Hart 1988; Mason, *et al.* 1983). Demersal juveniles eat small demersal fishes, amphipods, and krill (NOAA 1990). Adult sablefish feed on fishes like rockfishes and octopus (Hart 1988; McFarlane and Beamish 1983a). Larvae and pelagic juvenile sablefish are heavily preyed upon by seabirds 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 1988; 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).

Stock Status and Management History

Formal stock assessments of sablefish began in 1984. The first coastwide assessment established regulations on the sablefish fishery off the U.S. Pacific coast which were implemented as trip limits in October 1982. Since 1982, the sablefish fishery has been managed intensively, with limited entry and open access programs used in various manners to limit catches.

In 2001, two assessments were completed and reviewed by a STAR Panel: one by NMFS (Schirripa and Methot 2001) and one by the Pacific Groundfish Conservation Trust (Hilborn, *et al.* 2001). The two assessments were in agreement, and the Council adopted the NMFS assessment for management purposes. Schirripa and Methot (2001) focused on evaluating the sensitivity of the model and the outcomes to changes in the survey data. These changes included the combining of the AFSC slope survey data and the NWFSC Industry Co-operative Survey data using a statistical Generalized Linear Models (GLM) procedure. This analysis made it possible to extend the southern boundary of the assessment south to Point Conception at 34°27' N lat. rather than 36° N lat., used in previous assessments. The assessment indicated a normal decline in biomass since the late 1970s due to the fishing down of the unfished stock and an unexpected decline in recruitment during the early 1990s. It introduced for the first time, the possibility that sablefish recruitment may be linked to environmental factors. A seemingly meaningful relationship was demonstrated between changes in northern and southern copepod abundances and sablefish recruitment. Conditions and projections in the model considered two competing "states of nature" to calculate the mean virgin recruitment: a "density-dependent" state that used the average of 1975-1991 recruitments, and a "regime shift" state that used the 1975-2000 recruitments. To account for this uncertainty, the Council adopted a 2002 ABC based on the proxy harvest rate ($F_{45\%}$) adjusted to reflect the distribution north and south of 36° N latitude. This was done because a plan amendment would be needed to change the management area since Groundfish FMP Amendment 14 specified only the area north of 36° N lat.

The Council also wanted to verify industry reports of a large abundance of juvenile sablefish, an observation that was confirmed to some extent by preliminary results from the 2001 NMFS slope survey. Based on these considerations, the Council recommended a new expedited assessment be done in 2002. This update assessment (Schirripa 2002), by definition, sought to document changes in the estimates of the status of the stock by only considering newly available data for 2001 while not considering any new changes in the model structure or model assumptions. The expedited assessment confirmed fishermen's anecdotal reports of a large 1999 year class, which was also apparent in the preliminary results of the 2001 slope survey.

The 2005 sablefish assessment estimated stock depletion at 34.3 percent of unfished biomass (Schirripa and Colbert 2006). The assessment fit a relationship between sea level and recruitment deviations for the period 1973-2003 and used that relationship to hindcast recruitment variability back to 1925. The 2005 assessment found that spawning stock biomass had steadily declined since 1900 and suggested that there was little evidence that recruitment from 2001-2005 was as high as that for the strong 1999 and 2000 year classes. As a result, the assessment's biomass projections indicate a short-term increase, followed by a continued decline.

The 2007 updated sablefish assessment estimated spawning depletion to be 38.3 percent of unfished biomass at the start of 2007 (Schirripa 2008). This increase from 2005 was attributed in part to the continued recruitment of the strong 1999 and 2000 year classes into the spawning stock biomass. The assessment also estimated a series of poor recruitments in the mid- to late-1990s, and if fished at the full OY level, depletion was forecasted to decrease for the next five years.

The 2011 sablefish assessment estimated spawning stock biomass to be at 33 percent of its unfished biomass at the beginning of 2011 (Stewart, *et al.* 2011). The resource was modeled as a single stock; however, there is some dispersal to and from offshore seamounts and along the coastal waters of the continental U.S., Canada, Alaska, and across the Aleutian Islands to the western Pacific which was not explicitly accounted for in this analysis. Environmental time-series including both sea-surface height (used in previous sablefish assessments) and zooplankton abundance were also investigated. These environmental indices were not used in the 2011 assessment in the interest of parsimony since they did not affect results.

Stock Productivity

It was not possible to estimate the steepness parameter of the Beverton-Holt stock-recruitment relationship in the 2011 sablefish assessment, so this quantity was fixed at a value of 0.6 and explored via sensitivity analyses.

Stewart et al. (2011) estimated sablefish were exploited at a modest level through the first half of the 20th century. Following a period of above-average recruitments, the spawning stock biomass increased to nearly unexploited levels. Large harvests in the 1970s and 1980s were believed to have caused the stock biomass to decline. Estimates of the stock's productivity were highly uncertain due to lack of information on mortality, absolute stock size, and productivity. Sablefish recruitment was estimated to be variable over the historical record, with substantial uncertainty in individual recruitment events. Recruitments during the 1980s were, on average, roughly an order of magnitude higher than the very poor recent cohorts estimated between 2002 and 2007.

Fishing Mortality

The sablefish fishery has been managed with a rich history of seasons, size-limits, trip-limits, and a complex permit system. Coastwide yield targets have been divided among the different gears (hook-and-line, pot and trawl), fishery sectors (including both limited entry and open access) as well as north and south of 36º N lat. Peak catches occurred in the late 1970s just prior to the imposition of the first catch limits. Since 2001, the total estimated dead catch has been only 79 percent of the sum of the OFLs (ABCs at the time) and 87 percent of the ACLs (OYs at the time). In only one year of the last 10, 2008, did the estimated dead catch exceed the ACL (and OFL) by 5% (3%).

The PSA vulnerability score of 1.64 indicates a relatively low concern for potential overfishing.

1.1.4.16 Shortbelly Rockfish

Distribution and Life History

Shortbelly rockfish (*Sebastes jordani*) range from Punta Baja in Baja California (Klingbeil 1976) as far north as La Perouse Bank off of British Columbia, and as far west as the Cobb seamount off the southern Washington coast (Pearson, *et al.* 1993). However, they are most abundant along the continental shelf break between the northern end of Monterey Bay and Point Reyes, California (particularly in the regions of Ascension Canyon and the Farallon Islands), and around the Channel Islands in the Southern California Bight (Love, *et al.* 2002; Moser, *et al.* 2000; Pearson, *et al.* 1991; Phillips 1964). Although stock structure is poorly understood, genetic analysis of fish collected between San Diego and Cape Mendocino suggest a single coastwide stock, with slight differences in allele frequencies across Point Conception (Constable 2006). The shortbelly rockfish is one of the most abundant rockfish species in the California Current and is a key forage species for many piscivorous fish, birds, and marine mammals.

Shortbelly rockfish feed primarily on juvenile and adult euphausiids, and are an important prey item to a wide range of piscivorous fishes, seabirds and marine mammals (Chess, *et al.* 1988; Lowry and Carretta 1999; Sydeman, *et al.* 2001). Merkel (1957) reported that juvenile shortbelly rockfish were important prey of Chinook salmon along the central California coast in late spring and summer, accounting for more than 60% of those identified to species. For many breeding California seabirds, as much as 90% of their diet is comprised of pelagic stages of juvenile (age 0) rockfish during the late spring and early summer breeding seasons, and unexploited species (such as shortbelly) generally account for more than two thirds of the juvenile rockfish identified (Ainley, *et al.* 1993; Miller and Sydeman 2004; Sydeman, *et al.* 2001). However there is considerable interannual and interdecadal variability in the frequency of rockfish in seabird diets. Throughout the 1990s, foraging rates on juvenile rockfish by central California seabirds declined for both exploited and unexploited rockfish species primarily in response to changes in ocean conditions associated with poor recruitment for rockfish (Miller and Sydeman 2004; Mills, *et al.* 2007; Sydeman, *et al.* 2001). Although rockfish have rarely been identified to the species level in the diets of many California Current marine mammals (Antonelis and Fiscus 1980; Morejohn, *et al.* 1978; Perez and Bigg 1986; Stroud, *et al.* 1981), shortbelly were among the five most significant prey items for California sea lion (*Zalophus californianus*) in the Channel Islands (Lowry and Carretta 1999) and are frequently encountered in sea lion food habits samples off of Central California (Weise and Harvey 2005). Shortbelly rockfish are also described as important prey to thresher sharks (Preti, *et al.* 2004), longnose skate (Robinson, *et al.* 2007), and jumbo squid (Field, *et al.* 2007), among others. Consequently, shortbelly rockfish are an important forage species to a wide range of predators throughout the California Current ecosystem, and generally have a trophic position and life history traits more similar to forage fishes than most other *Sebastes*.

Stock Status and Management History

The expectation of eventual development of a domestic commercial fishery (Kato 1981) led to past efforts to estimate stock abundance and productivity (Lenarz 1980, Pearson et al. 1989, Pearson et al. 1991) as well as evaluations of commercial potential. The first ABC for shortbelly rockfish was set by the Council at 10,000 mt for 1983 through 1989. A stock assessment by Pearson et al. (Pearson, *et al.* 1991) estimated that allowable catches for shortbelly might range from 13,900 to 47,000 mt per year, based on life history data and hydroacoustic survey estimates of abundance. Subsequently, the Council established an ABC of 23,500 mt, which was reduced to 13,900 mt in 2001 based on observations of poor recruitment throughout the 1990s and the continued lack of a targeted fishery. Yet despite several attempts to develop a commercial fishery for shortbelly, domestic fishery landings have never exceeded 80 mt per year along the west coast.

A shortbelly rockfish assessment was done as an academic exercise in 2007 to understand the potential environmental determinants of fluctuations in the recruitment and abundance of an unexploited rockfish population in the California Current ecosystem (Field, *et al.* 2008). The results of the assessment indicated the shortbelly stock was healthy with an estimated spawning stock biomass of 67 percent of its unfished biomass in 2005.

Shortbelly rockfish is an abundant species that is not targeted in any commercial or recreational fisheries or caught in substantial amounts. However, shortbelly rockfish is a valuable forage fish species in the California Current ecosystem with fluctuations in stock recruitment and biomass driven by environmental conditions. The consequence of fisheries, including high and low estimates of plausible discards, were estimated to be negligible ($P<0.01$) in all years with the exception of the foreign fisheries of the mid-1960s (Field, *et al.* 2008). Shortbelly rockfish were initially considered for an Ecosystem Component (EC) species categorization under Amendment 23. Rather than classifying shortbelly rockfish as an EC species, the Council chose to recommend a very restrictive ACL of 50 mt for 2011 and beyond. This ACL is a level of harvest meant to accommodate unavoidable incidental bycatch of shortbelly rockfish

while allowing most of the harvestable surplus of the stock to be available as forage for species in the California Current ecosystem. Such ecological considerations are made when setting ACLs for west coast groundfish species.

Stock Productivity

Field et al. (Field, *et al*. 2008) assumed a steepness of 0.65 in a Mace-Doonan stock-recruitment relationship (Mace and Doonan 1988) in the 2007 shortbelly assessment. The data in the assessment model were insufficient for estimating steepness; therefore, an assumed value was used based on the Dorn (2002b) meta-analysis of rockfish steepness available at the time the assessment was conducted.

Recruitment deviations of shortbelly from 1960-2005 were estimated in the 2007 assessment; however, there was greater confidence in relative year class strength from 1975-2005. The model suggested a long period of poor recruitment through most of the 1990s, associated with a significant decline in biomass. The interesting conclusion of the 2007 shortbelly assessment was how apparent environmental determinants of shortbelly recruitment and not fishing mortality affected biomass and stock status.

Fishing Mortality

Shortbelly rockfish are not targeted in any west coast fisheries and are incidentally caught in very small amounts. Love et al. (2002) reported that shortbelly rockfish were commonly caught incidentally with trawl gear in the San Francisco-Monterey region during the development of the trawl fishery in the 1930s and 1940s when they were often referred to as steamer rockcod, as they tended to be common in the steamer lanes south of San Francisco. However, as a result of the small size and poor marketability, only modest domestic landings (1 to 65 mt per year) have been reported in the last 25 years. Historical landings were almost certainly less. Phillips (1939) reported that *S. jordani* accounted for 1 lb out of 332,630 lbs examined in Monterey wholesale fish markets between 1937 and 1938. Nitsos (1965) reported trace amounts (approximately 1,000 lbs out of 1,920,000 lbs landed) of *S. jordani* landed in Monterey ports from trawlers in 1962-1963, but none were reported from ports other than Monterey. There was historically a short period in which large numbers of shortbelly were caught during the foreign fisheries of the 1960s and 1970s (Rogers 2003b). These landings (nearly 15,000 mt through 1976, over half of which was taken in 1966) were presumably incidental to the targeting of other rockfish and Pacific hake. Only in the early days of the foreign fisheries (the mid-1960s) were Pacific hake pursued in large numbers south of Cape Mendocino, which is when the bulk of documented historical landings of shortbelly occurred. Since the early 1970s the Pacific hake fishery has been prosecuted primarily off of Oregon and Washington, and to a lesser extent off of Northern California (generally north of Cape Mendocino).

The available data for historical bycatch rates of shortbelly rockfish are extremely sparse. Shortbelly have been caught incidentally, at times in large numbers, by trawlers targeting other semi-pelagic rockfish (usually chilipepper and widow rockfish). As large hauls of shortbelly are not marketable but occasionally foul the mesh of typical groundfish trawls, more experienced fishermen generally recognize shortbelly sign (as well as habitat preferences) on their acoustics, and work to actively avoid schools. Bycatch monitoring programs conducted north of Cape Mendocino in the mid-1980s suggested very negligible levels of bycatch, such that shortbelly were less than 0.25% of total catches in all fishing strategies (which included nearshore flatfish, bottom rockfish, midwater rockfish and whiting, shrimp and the deepwater complex), including less than 0.05% for midwater trawl whiting and rockfish (Pikitch 1988). Very little contemporary information is available for the region south of Mendocino. However, all of these data were collected far north of the usual range of shortbelly. Data processed from the West Coast Groundfish Observer Program suggests that approximately one mt of shortbelly rockfish were caught and discarded in trawl fisheries south of Mendocino. As regulatory measures have closed the vast

majority of habitat optimal to adult shortbelly, such trace landings are to be expected in recent years, and comparable data prior to these closures does not exist.

Field et al. (2007) acknowledged the uncertain historical estimates of shortbelly bycatch and therefore explored higher and lower bycatch streams in the 2007 assessment. Varying the historical catch assumptions in the assessment did not result in meaningful deviations from the base model results; therefore, they concluded it was unlikely fishing mortality had any substantive impact on the stock since the days of the foreign fisheries.

1.1.4.17 Shortspine Thornyhead

Distribution and Life History

Shortspine thornyhead (*Sebastolobus alascanus*) are found in the waters off of the West Coast of the United States from northern Baja California to the Bering Sea. They are found from 20 to over 1,500 m in depth. The majority of the spawning biomass occurs in the oxygen minimum zone between 600 and 1,400 m, where longspine thornyheads are most abundant (Bradburn, *et al.* 2011; Jacobson and Vetter 1996). The distribution of the smallest shortspine thornyheads suggests that they tend to settle at around 100–400 m and are believed to have ontogenetic migration down the slope, although large individuals are found across the depth range.

Shortspine thornyhead do not appear to be distributed evenly across the west coast, with higher densities of thornyheads in shallower areas (under 500 m) off of Oregon and Washington, and higher densities in deeper areas off of California. The mean latitude of the largest shortspine is slightly further north than of the medium sizes, suggesting the possibility of either a J-shaped migration, differential patterns of recruitment, or regional differences in exploitation history.

Although their densities vary, shortspine thornyheads are present in almost all trawlable areas below 500 m. They are caught in 91% of the trawl survey hauls below 500 m and 94% of the commercial bottom trawl hauls below 500 m. In camera tows, thornyheads are seen to be spaced randomly across the sea floor (Wakefield 1990), indicating a lack both of schooling and territoriality.

Genetic studies of stock structure do not suggest separate stocks along the west coast. Siebenaller (1978) and Stepien (1995) found few genetic differences among shortspine thornyheads along the Pacific coast. Stepien (1995), however, did suggest that there may be a separate population of shortspine thornyhead in the isolated area around Cortes Bank off San Diego, California. Stepien (1995) also suggested that juvenile dispersion might be limited in the area where the Alaska and California currents split. This occurs towards the northern boundary of the assessment area, near 48° N lat.

Stepien et al. (2000), using a more discerning genetic material (mtDNA), found evidence of a pattern of genetic divergence corresponding to geographic distance. However, this study, which included samples collected from southern California to Alaska, did not identify a clear difference between stocks even at the extremes of the range. No such pattern was seen in longspine thornyhead, which suggests that the shorter pelagic stage (~1 yr vs. ~2 yrs) of shortspine may contribute to an increased genetic separation with distance.

Shortspine thornyheads along the west coast spawn pelagic, gelatinous masses between December and May (Erickson and Pikitch 1993; Pearson and Gunderson 2003; Wakefield 1990). Juveniles settle at around 1 year of age (22- 27 mm in length), likely in the range of 100-200 m (Vetter and Lynn 1997), and migrate down the slope with age and size, although large individuals are found across the depth range.

Shortspine thornyhead grow very slowly, but may continue growing throughout their lives, reaching maximum lengths of over 70 cm. Females appear to reach larger sizes than do males. Maturity in females has been estimated as occurring near 18 cm, at 8-10 years of age (Pearson and Gunderson 2003), although new information suggests that patterns of maturity may be more complex.

Shortspine and longspine thornyheads have historically been caught with each other and with Dover sole and sablefish, making up the DTS fishery. Other groundfish species that frequently co-occur in these deep waters include a complex of slope rockfishes, rex sole, longnose skate, roughtail skate, Pacific grenadier, giant grenadier, Pacific flatnose as well as non-groundfish species such as Pacific hagfish and a diverse complex of eelpouts. Shortspine thornyheads typically occur in shallower water than the shallowest longspine thornyheads, and migrate to deeper water as they age. When shortspines have reached a depth where they overlap with longspines, they are typically larger than the largest longspines. Shortspine thornyhead stomachs have been found to include longspine thornyheads, suggesting a predator-prey linkage between the two species.

Thornyheads spawn gelatinous masses of eggs which float to the surface. This may represent a significant portion of the upward movement of organic carbon from the deep ocean (Wakefield 1990). Thornyheads have been observed in towed cameras beyond the 1,280 m limit of the current fishery and survey, but their distribution, abundance, and ecosystem interactions in these deep waters are relatively unknown.

Stock Status and Management History

Beginning in 1989, both thornyhead species were managed as part of the deepwater complex with sablefish and Dover sole (DTS). In 1991, the Council first adopted separate ABC levels for thornyheads and catch limits were imposed on the thornyhead group. Harvest guidelines (HGs) were instituted in 1992 along with an increase in the minimum mesh size for bottom trawl fisheries. In 1995 separate landing limits were placed on shortspine and longspine thornyheads and trip limits became more restrictive. Trip limits (predominantly 2-month limits on cumulative vessel landings) have often been adjusted during the year since 1995 in order to not exceed the HG or OY for that year. At first, the HG for shortspine thornyhead was set higher than the ABC (1,500 vs. 1,000 mt in 1995-1997) in order to allow a greater catch of longspine thornyhead, which was considered a relatively underutilized and healthy stock. In 1999 the OY was set at less than 1,000 mt and remained close to that level through 2006. As a result of the 2005 shortspine assessment, catch limits increased to about 2,000 mt per year and have remained near that level to the present.

Since early 2011, trawl harvest of each thornyhead species has been managed under the PFMC's catch share, or individual fishing quota (IFQ), program. Whereas the trip limits previously used to limit harvest restricted only the amount of fish each vessel could land, individual vessels fishing under the catch-share program are now held accountable for all of the quota-share species they catch.

The most recent stock assessment of west coast longspine thornyhead was done in 2013. This was the fifth assessment done for longspines, but only the second in which it was assessed individually (earlier assessments were of longspine and shortspine thornyheads in combination). Previous assessments were conducted by Jacobson (Jacobson 1990; 1991), Ianelli et al. (1994), Rogers et al. (1997), and Fay (2006). The 1990 and 1991 assessments were very similar. Important features included reviews of available biological data, and analyses of trends in mean lengths from port samples and catch rates calculated from logbook data. Swept-area and video biomass estimates were used to estimate average biomass levels and exploitation rates in the Monterey to US-Vancouver management areas. The available data were used to conduct per-recruit analyses of yield, revenue, and spawning biomass, and to develop estimates of the then target level of $F_{35\%}$.

Ianelli et al. (Ianelli, *et al.* 1994) assessed the coastwide abundance of longspine and shortspine thornyheads based on slope survey data, an updated analysis of the logbook data, and fishery length-composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The assessment of thornyheads in 1997 covered the area from Central California at 36° N lat. to the U.S.-Canada border (Rogers, *et al.* 1997). The STAR Panel expressed concern that management requires more detailed information on thornyheads than could be obtained from the available data. In 1998, two separate stock assessments covering the area north of 36° N lat. were prepared and accepted by the Council (NMFS and OT 1998; Rogers, *et al.* 1998). A synthesis of these two assessments was used to set the harvest specifications 1999 and 2000. Given that the synthesis estimated 1999 depletion at 32 percent of virgin biomass, the Council used the precautionary 40-10 policy to set the OYs for those two years.

There were a range of uncertainties in the 2001 assessment of shortspine thornyhead, in 2001, not the least of which was the estimated biomass (Piner and Methot 2001). The assessment was extended south to Point Conception (in contrast to past surveys, which were limited to stocks north of the 36° N latitude management area boundary). The authors concluded the 2001 spawning biomass ranged between 25 percent and 50 percent of unexploited spawning biomass. As was also the case in the 1998 assessment, the uncertainty in abundance largely revolved around the uncertainty in recruitment and survey q, or catchability, of shortspine thornyhead in slope surveys. The authors also concluded that the trend in stock biomass was increasing and the stock was not depleted. Based on estimated biomass and application of the GMT-recommended F=0.75M principle (which approximated an $F_{50\%}$ proxy harvest rate for shortspine thornyhead), the assessment authors and GMT recommended a slight increase in the ABC and OY for 2002. They also recommended that the harvest specifications be set for two areas divided by Point Conception at 34º27' N lat., rather than the previous policy to separate the management areas at the Conception-Monterey border (36º N lat.). Despite the uncertainty in biomass estimates and determination of whether shortspine thornyhead should be treated as a "precautionary zone" stock, these recommendations did treat the stock as such by applying the 40-10 adjustment.

The 2005 stock assessment estimated the shortspine thornyhead spawning stock biomass to be at 62.9 percent of its initial, unfished biomass in 2005 (Hamel 2006c). The 2005 assessment extended the southern border of the assessment area from Point Conception to the Mexican border (32.5º N latitude). Including the entire Conception area resulted in a larger basis for unfished biomass, given that this area was estimated to contain nearly half of the stock's total west coast biomass. It was noted that there could be regional management concerns with this stock because while the assessment OY was coastwide, there are differences in historic exploitation rates north and south of Point Conception. It was also noted the biomass estimate south of Pt. Conception was more uncertain than that in the north.

The 2013 stock assessment estimated the shortspine thornyhead spawning stock biomass to be at 74.2 percent of its initial, unfished biomass in 2013 (Taylor and Stephens 2013). A longer time series of the coastwide NWFSC trawl survey biomass estimates were included in this assessment relative to the 2005 assessment. Therefore, the STAT concluded there was no greater uncertainty in the biomass south of Pt. Conception relative to estimates for the rest of the coast. As in the previous assessment, no age data were used in the 2013 assessment and growth parameters were fixed at the same values used in 2005.

Stock Productivity

Taylor and Stephens (2013) estimated annual shortspine recruitment using a Beverton-Holt stock-recruitment function and assuming a steepness value of 0.6. Most 2013 rockfish assessments used a steepness prior of 0.779, estimated from a meta-analysis of rockfish assessment results. This value might be expected in the 2013 longspine assessment; however, rockfish ecology and reproduction are quite different from those of thornyheads, which (for example) do not give birth to live young but rather spawn floating egg masses.

Steepness in the shortspine thornyhead assessment was fixed at 0.6 both in the 2005 and 2013 models (Hamel 2006c; Taylor and Stephens 2013). This value was justified based on consistency between the modeling approach and management targets, in addition to being within a range of biologically reasonable values.

Annual deviations about this stock-recruitment curve were estimated for the years 1944 through 2012. Estimated recruitments do not show high variability, and the uncertainty in each estimate is greater than the variability between estimates. The 2013 shortspine assessment is relatively uninformative of relative year class strength since ages were not used in the model (thornyheads are notoriously difficult to age). Therefore, a length-based assessment with an assumed steepness is used to determine recruitment.

Fishing Mortality

Landings of shortspine were estimated to have risen to a peak of 4,815 mt in 1989, followed by a sharp decline during a period of trip limits and other management measures imposed in the 1990s. Since the institution of separate trip limits for shortspine and longspine thornyheads, the fishery had more moderate removals of between 1,000 and 2,000 mt per year from 1995 through 1998. Landings fell below 1,000 mt per year from 1999 through 2006, then rose to 1,531 in 2009 and have declined since that time.

Exploitation rates in terms of spawning potential ratio indicates that the exploitation slightly exceeded the F_{MSY} target for a single year in 1985 and then for the period 1989-1994. However, the stock status is estimated to have never fallen below the $B_{40\%}$ management target.

1.1.4.18 Spiny Dogfish

Distribution and Life History

In the Northeast Pacific, spiny dogfish (*Squalus suckleyi*) occur from the Gulf of Alaska, with isolated individuals found in the Bering Sea, southward to San Martin Island, in southern Baja California. They are extremely abundant in waters off British Columbia and Washington, but decline in abundance southward along the Oregon and California coasts (Ebert 2003; Ebert, *et al.* 2010).

The U.S. west coast spiny dogfish stock likely has interaction and overlap with dogfish observed off British Columbia. About 1,300 dogfish were tagged along the coast of Washington from 1942-1946, during the period of the strong directed fishery for dogfish. Only 50 of these fish were recaptured and had tags returned (4%), of which 54% were recaptured within U.S. coastal waters, while 32% were recaptured in coastal Canada and 12% in the inside waters of Puget Sound and the Strait of Georgia. One fish was recaptured in coastal Japanese waters (7 years after being tagged). Because many of the releases were close to the U.S.-Canada border, and the fractions do not take into account the relative fishing pressure within each area, this study is of limited use in providing reliable information about dogfish movement rates.

A spatial population dynamics model (Taylor 2008), which included these tagging data (along with much larger tagging experiments conducted in Canada and inside U.S. waters of Puget Sound) estimated movement rates of about 5% per year between the U.S. coastal sub-population of dogfish and that found along the west coast of Vancouver Island in Canada. The model also estimated movement rates of less than 1% per year between the U.S. coastal sub-population of dogfish and that in the Puget Sound.

These sharks appear to prefer areas in which the water temperature ranges from 5 to 15° C, often making latitudinal and depth migrations to follow this optimal temperature gradient (Brodeur, *et al.* 2009). There is also evidence of seasonal movement along the coast based on both tagging data and timing of historical fisheries (Ketchen 1986). One estimate of the seasonal movement along the Pacific coast is a North-South shift of about 600 km from winter to summer (Taylor 2008). This seasonal pattern is not as extreme as that found among spiny dogfish in Atlantic waters of the U.S., which are likely due to larger fluctuations in temperature. Dogfish have also been captured in high-seas salmon gillnets across the North Pacific between about 40° and 50° N lat. (Nakano and Nagasawa 1996), but the extent of these wide-ranging pelagic movements is poorly understood.

The biology and life history of spiny dogfish are relatively well studied (Campana, *et al.* 2009; Di Giacomo, *et al.* 2009; Taylor 2008; Tribuzio 2009; Tribuzio, *et al.* 2009; Tribuzio, *et al.* 2010; Vega, *et al.* 2009). This species is an opportunistic feeder that consumes a wide range of prey (whatever is abundant). Schooling pelagic fish, such as herring, make up the majority of its diet. They also feed on invertebrates such as shrimp, crab and squid. In turn, dogfish are preyed upon by larger cod, hake, and other spiny dogfish (Beamish, *et al.* 1992; Brodeur, *et al.* 2009; Tanasichuk, *et al.* 1991). Larger species of sharks, as well as seals and killer whales, also feed on dogfish.

Spiny dogfish have internal fertilization and ovoviviparous development. The internal development takes place over 22-24 months, the longest gestation period known for sharks. The number of pups in each litter ranges between 5 and 15 individuals depending on the size of the female (larger females bearing more pups). The size at birth is generally between 20 and 30 cm for both genders. Male spiny dogfish are reported to grow faster than females, but females reach larger sizes. This species is the latest maturing (with 50% female maturity reported at 35.5 years) and longest lived of all elasmobranchs (Cortes 2002; Saunders and McFarlane 1993; Smith, *et al.* 1998; Taylor 2008). Life history traits of spiny dogfish make the species highly susceptible to overfishing and slow to recover from stock depletion since its slow growth, late maturation, and low fecundity are directly related to recruitment and spawning stock biomass (Holden 1974; King and McFarlane 2003).

Stock Status and Management History

Spiny dogfish on the U.S. west coast have been utilized for almost a thousand years, with those in Puget Sound first used by Native Americans (Bargmann 2009). The exploitation of spiny dogfish in coastal waters, however, started in the 20th century. Even though the history of spiny dogfish utilization on the U.S. west coast included a brief but intense commercial fishery in the 1940s, in general this species is not highly prized and is mostly taken as bycatch in other fisheries.

Prior to 1936, coastal catches of spiny dogfish were extremely minimal, but in 1936, shortly after it was discovered that livers of spiny dogfish have high level of vitamin A, a large scale fishery for dogfish developed in the Pacific Northwest. Before World War II, Northeast Pacific dogfish livers could not compete with the cheaper and more potent sources of vitamin A from Europe. But when World War II started and European supplies were cut, dogfish shark livers became the major source of vitamin A in the United States, and the spiny dogfish fishery grew rapidly along the Pacific coast. The processed liver oils were used in pharmaceuticals, food processing, and animal feed (Bargmann 2009; Ketchen 1986).

During the liver fishery, dogfish were targeted by three major gear groups, including setlines, set nets, and bottom trawls. The timing of the dogfish liver fishery coincided with the development of bottom trawling in the U.S. Northwest, and though at the onset of the fishery the catches by trawl were low, by the mid-1940s trawling was the dominant type of fishing for dogfish.

In 1945, a sharp decline in spiny dogfish catches began. This decline occurred despite continued strong demand for vitamin A and high prices for dogfish livers, but because of decreased availability of the species in the Northeast Pacific (Bargmann 2009; Ketchen 1986). In 1950, with the advent of synthetic vitamins, demand for spiny dogfish livers declined and catches in the Northeast Pacific virtually ended.

Between 1950 and 1974, the landings of spiny dogfish remained minimal. By the late 1950s it was reported that species availability had increased. Also, in the late 1950s-early 1960s, dogfish earned a bad reputation among fishermen. They were blamed for driving off commercially valuable species such as herring and mackerel, while consuming large numbers of them. Spiny dogfish have also been observed biting through nets to get to their fish prey, releasing many of them and damaging fishing gear in the process. They were also reported damaging gear when become entangled in commercial nets. As a result, fishermen were trying to avoid areas with higher chances of dogfish catches (such as soft bottoms, for example) to prevent encountering dogfish and potentially damaging their gear.

A market opportunity for dogfish developed in the mid-1970s. In Europe, spiny dogfish has long been used an inexpensive source of human food, for fish and chips in particular. A decline in the European dogfish supply provided an opportunity for developing an export dogfish food fishery on the U.S. west coast. Also, during the late 1970s, shark cartilage started to be used in cancer treatment, and a portion of spiny dogfish catches have since been sold for medical research and treatment (Gregory Lippert, WDFW, pers. com. as cited by Gertseva and Taylor (2011)). As before, three types of gear were involved in catching dogfish (bottom trawl, setlines, and sunken gill nets), but since the mid-1980s catches by gillnets have been minimal.

Spiny dogfish is a common bycatch species, often caught in other fisheries and largely discarded. For instance, it has long been incidentally caught in the hake fishery, which is almost exclusively conducted with mid-water trawls. Large-scale harvesting of Pacific hake in the U.S. began in 1966, when factory trawlers from the Soviet Union and other countries began targeting this stock. After the 200-mile U.S. EEZ was declared in 1977, a joint-venture fishery was initiated between U.S. trawlers and Soviet factory trawlers acting as motherships (larger, slower ships for fish processing and storage while at sea). By 1989 the U.S. fleet capacity had grown to a level sufficient to harvest the entire quota, and no further foreign fishing was allowed. The Pacific hake fishery is currently 100% observed at sea and data on bycatch species, including spiny dogfish, is being routinely collected.

Spiny dogfish on the U.S. west coast has been managed under the Other Fish complex since implementation of the Groundfish FMP by the Council in 1982. In 2005, reduction in the Other Fish ABC was implemented due to removal of the California substock of cabezon from the Other Fish complex. The same year, a 50% precautionary OY reduction was implemented to accommodate uncertainty associated with managing unassessed stocks. In 2006, a trip limit for spiny dogfish was imposed for U.S. west coast waters which varied between 45 and 91 mt per two months for all gears. In 2009, another ABC reduction was implemented due to removal of longnose skate from the Other Fish complex and the 50% OY reduction was maintained.

In 2011, reduction in the Other Fish OFL was implemented due to removal of the Oregon substock of cabezon from the Other Fish complex. The 50% precautionary reduction to the ACL was maintained; however, a scientific uncertainty buffer was specified as an ABC of 7,742 mt under the Amendment 23 framework.

Gertseva and Taylor (2011) estimated the spawning stock output of spiny dogfish to be 44,660 thousands of fish (95% confidence interval: 8,937-80,383), which represents 63% of the unfished spawning output level. While this depletion level indicates the stock is currently healthy, fishing at the target SPR of 45% is expected to severely reduce the spawning output over the long term because of the extremely low productivity and other reproductive characteristics of the stock. The Council partially addressed this by setting a more conservative spiny dogfish ABC for 2013 by specifying a P* of 0.3.

The Council further decided to manage spiny dogfish with stock-specific harvest specifications beginning in 2015. The SSC also investigated establishing a more conservative F_{MSY} harvest rate for spiny dogfish and other elasmobranchs in recognition of their lower productivity. The SSC recommended and the Council adopted a more conservative proxy 50% SPR harvest rate as an interim measure for elasmobranchs. The 50% SPR was based on an SSC meta-analysis of Chondrichthyes species using the posterior distribution for F_{MSY}/M values as reported by Zhou et al. (2012). The SSC said they may further investigate sustainable harvest rates for Council-managed elasmobranchs as more information becomes available in the future.

Stock Productivity

Spiny dogfish have a relatively low stock productivity due to slow growth, late maturation, and low fecundity. The fecundity of dogfish in the Northeast Pacific Ocean has been well studied, with pregnant females having relatively few pups per litter (5 to 15), and with relatively little variability among individuals. Unlike fish producing millions of eggs, the low fecundity of dogfish suggests both low productivity in general and a more direct connection between spawning output and recruitment than for many species.

Gertseva and Taylor (2011) modeled the spiny dogfish spawner-recruit relationship using a new functional form that was recently added to the Stock Synthesis platform, which allowed a more explicit modeling of pre-recruit survival between the stage during which embryos can be counted in pregnant females to their recruitment as age 0 dogfish. This new method may be useful for a variety of low fecund species, as well as providing additional flexibility in the spawner-recruit relationship that may be explored for any stock. The method is an expansion and improvement on similar approaches previously applied to dogfish (Taylor 2008; Wood, *et al.* 1979), which assumed a linear decline in age 0 survival as a function of population density. While steepness was not estimated or assumed in the conventional sense of a Beverton-Holt stock-recruitment relationship, a value for steepness can be calculated using a formula provided by Gertseva and Taylor (2011). The calculated value of steepness is 0.28, indicating a great degree of compensation or density-dependent recruitment.

Fishing Mortality

During the last 10 years, relative exploitation rates (catch/summary biomass) are estimated to have hovered around 1% and SPR is estimated to be well above pre-2015 management target of SPR 45%. The 2011 assessment identified a period during the vitamin A fishery in the 1940s when the exploitation rate exceeded the current F_{MSY} proxy harvest rate.

1.1.4.19 Splitnose Rockfish South of 40°10’ N Lat.

Distribution and Life History

Splitnose rockfish (*Sebastes diploproa*) are distributed from the northern Gulf of Alaska (Prince William Sound) to central Baja California and occur at depths between 91-795 meters. Adults are the most

abundant between British Columbia and southern California at depths from 215 to 350 meters (Alverson, *et al.* 1964; Gunderson and Sample 1980; Love, *et al.* 2002). The species is distinguished by having a deeply notched upper jaw, which inspired its Greek name diploproa, meaning "double prow". Splitnose rockfish are commonly seen on low-relief mud fields of the continental shelf and upper slope, often near isolated rock, cobble or shell debris. Solitary individuals are often found resting on the seafloor, although they occasionally form schools that move more than 100 meters in the water column (Love, *et al.* 2002; Rogers 1994).

Splitnose rockfish co-occur with an assemblage of slope rockfish, including Pacific ocean perch (*Sebastes alutus*), darkblotched rockfish (*Sebastes crameri*), yellowmouth rockfish (*Sebastes reedi*), and sharpchin rockfish (*Sebastes zacentrus*) off Washington and Oregon, and stripetail rockfish (*Sebastes saxicola*), darkblotched rockfish and shortspine thornyhead (*Sebastolobus alascanus*) off central California. Pacific ocean perch and darkblotched rockfish are the most abundant members of that assemblage off the coasts of Oregon and Washington, but splitnose rockfish and darkblotched rockfish dominate off the northern coast of California. Lesser amounts of splitnose have also been noted in the deepwater DTS assemblage and with shrimp catch (Rogers 1994; Rogers and Pikitch 1992; Weinberg 1994).

There are no clear stock delineations for splitnose rockfish in the U.S. waters. No molecular markers have yet been developed for this species, and no genetic data are currently available to suggest the presence of several stocks (Waples, *et al.* 2008). No distinct breaks are seen in the fishery landings and catch distributions. Survey catches imply a continuous distribution. The spatial dynamic cluster analysis of the Northwest Fisheries Science Center (NWFSC) survey abundance indices (Cope and Punt 2009) provided no evidence of spatial stock structure for splitnose rockfish off Washington, Oregon, and California.

Splitnose rockfish are documented in the literature to live to at least 86 years (Bennett, *et al.* 1982), although a fish encountered in a NMFS survey was aged at 103 years old. This is a small species – the maximum size reported in the literature is 46 cm (Love, *et al.* 2002); the vast majority of individuals caught in NMFS surveys were under 44 cm in fork length, although a few fish larger than this were caught.

Splitnose rockfish exhibit sexual dimorphism in growth. Although the males grow to their maximum lengths earlier than females, females reach larger sizes than males (Boehlert 1980; Love, *et al.* 2002). It was hypothesized that life history characteristics may vary with latitude, but that is uncertain. Boehlert and Kappenman (1980) detected greater size-at-age with increasing latitude and suggested more rapid growth of fish in the northern end of their range. Analysis of the NWFSC shelf-slope survey data did not show a distinct gradient in growth rate between north and south, although the asymptotic length (Linf) exhibits a latitudinal gradient (Gertseva, *et al.* 2009). Growth of splitnose rockfish was found to correlate with climate and environmental variables, including sea surface temperature, the El Niño Southern Oscillation (ENSO) index, and the Pacific Decadal Oscillation (PDO) (Black 2009; Black, *et al.* 2008); more information is needed to develop climate-growth relationships for stock assessment purposes.

Female splitnose rockfish off California mature at 6-9 years old (18-23 cm long) (Echeverria 1987), and their fecundity increases with size (Phillips 1964). Splitnose rockfish mature somewhat later off British Columbia - both males and females reach 50% maturity at size of 27 cm (Westrheim 1975). Like other rockfishes, splitnose utilize internal fertilization and bear live young (Love, *et al.* 2002). This species can exhibit a long reproductive season, with young larvae found in all months off southern California, from January to September off central California, from March to September in Oregon, and in July off Washington (Love, *et al.* 2002; Moser, *et al.* 2000).

Young juveniles live at the surface for several months, then go through a transitory midwater residence, and finally settle to benthic habitats near the end of their first year of life (Love, *et al.* 2002). During their first year, splitnose have been found living among drifting vegetation in Puget Sound and southern California, and under floating objects in Queen Charlotte Sound, British Columbia (Shaffer, *et al.* 1995). Pelagic juvenile splitnose feed on calanoid copepods and amphipods (Shaffer, *et al.* 1995), while benthic juveniles and adults eat krill, copepods, sergestid shrimps and amphipods. Splitnose are prey of Steller sea lions and other pinnipeds (Love, *et al.* 2002).

Size-composition data for splitnose rockfish show a strong gradient of body size with depth, with smaller fish in shallow waters, suggesting ontogenetic movements of splitnose rockfish to deeper waters with increasing size and age, a common phenomenon in the genus *Sebastes* (Boehlert 1980).

Stock Status and Management History

Limits on domestic rockfish catches were first instituted in 1983, with splitnose rockfish managed as a part of the *Sebastes* complex, which included around 50 species. The ABC for the *Sebastes* complex was estimated for each International North Pacific Fisheries Council (INPFC) area along the coast based on historic landings. In 1994, the *Sebastes* complex was divided into southern and northern management areas, and harvest guidelines were established for the complex in each area. The southern area included Conception, Monterey and Eureka INPFC areas, and the northern area included Columbia and U.S.-Vancouver INPFC areas.

In response to a concern that deepwater species off Oregon and Washington might have been overharvested, Rogers (1994) conducted a preliminary assessment of splitnose rockfish, which focused on compiling and reviewing the available data. However, since the data were sparse and no evident trends in biomass or mean size were detected, the results were inconclusive. In 1996 the status of several rockfish species, which were part of the *Sebastes* complex, were assessed (Rogers, *et al.* 1996), and ABCs for splitnose rockfish in the southern area were calculated to be 868 mt for the southern management area and 274 mt for the northern management area. These amounts were not specified individually, but included in the total ABCs for the *Sebastes* complex.

In 1998, unusually high splitnose rockfish landings drove *Sebastes* complex harvests in the southern management area sharply upward. In 1999, for the first time, splitnose rockfish were individually separated from the southern *Sebastes* complex. Individual ABCs and OYs for splitnose rockfish in that area have been specified along with splitnose-specific trip limits since then. The ABC for the southern management area was set at 868 mt, as estimated in the 1996 assessment of the remaining rockfish in the *Sebastes* complex (Rogers, *et al.* 1996).

Additionally in 1999, the general *Sebastes* complex was divided into nearshore, shelf, and slope assemblages, and the dividing line between the northern and southern management areas was shifted southward to 40º10’ N lat., near Cape Mendocino. Since that time, in the northern area, splitnose has been managed under trip limits for minor slope rockfish. In 2000, harvest specifications for splitnose rockfish were set for the Conception and Monterey areas only, and 48 mt for the Eureka area were added to the northern minor rockfish ABC. Also, a precautionary adjustment of the OY (reduced from the ABC by 25%) was specified to account for the limited nature of the assessment. In 2000, the ABC and OY for splitnose rockfish south of 40º10’ N lat. were reduced based on the revised F_{MSY} harvest rate policy. During the last 10 years, the coastwide landings and total catch of splitnose rockfish were relatively low, and the limits established for the area south of 40º10’ N lat. have not been exceeded.

Gertseva et al. (2009) assessed splitnose rockfish coastwide and determined the stock was healthy with a depletion of 66 percent at the start of 2009. Since 1999, the splitnose spawning output was estimated to

have been increasing in response to below-average removals and above-average recruitment during the last decade. At the beginning of 2009 the estimated spawning stock output was 8,426 million eggs. Uncertainty in the model was explored though asymptotic variance estimates and sensitivity analyses. Asymptotic confidence intervals were estimated within the model and reported throughout the assessment for key model parameters and management quantities. Uncertainty in recent recruitment was used to define alternative states of nature and develop the decision table.

Stock Productivity

Steepness of the stock-recruitment curve was fixed at a value of 0.58 in the 2009 splitnose rockfish assessment, as estimated by a meta-analysis for unassessed rockfish. Recruitment deviations were estimated for each year between 1960 and 2006, which was the period best informed by the data based on evaluation of the variance of the recruitment deviations. Prior to 1960 and after 2006, recruits were taken deterministically from the stock-recruit curve. The model estimated above-average recruitments in the most recent years beginning 1999 (), which along with low catches during the last decade determine a population increase in recent and early forecast years. Uncertainty in recent recruitment was used to define alternative states of nature and develop the decision table.

Fishing Mortality

Splitnose rockfish have been taken incidentally in fisheries such as the trawl fisheries targeting POP, mixed slope rockfish, and other deepwater targets, but have not been a commercial target species. Splitnose rockfish were lightly exploited until the 1940s, when the trawl fishery for rockfish first became important. With the development of the POP fishery (a species with which splitnose rockfish co-occur), spawning output of splitnose rockfish began to decline. A sharp drop in the 1960s was associated with large harvests of POP by foreign trawl fleets operating in the U.S. EEZ. Another drop occurred in 1998 when the increased availability of splitnose rockfish led to high removals off California. Since 1999, the splitnose spawning output was estimated to have been increasing in response to below-average removals and above-average recruitment during the last decade.

It was decided to continue management of splitnose rockfish with stock-specific specifications south of 40°10’ N lat. and under the Slope Rockfish complex north of 40°10’ N lat. when the coastwide splitnose rockfish assessment was first used to inform management in 2011. A north-south apportionment based on the average 1916-2008 assessed area catch resulting in 64.2 percent stock-specific specification in the southern area and 35.8 percent for the contribution of splitnose rockfish to the Slope Rockfish North complex was used to apportion harvest specifications since 2011. The Council recommended continuing this management strategy largely due to the implications of determining the uncertain catch history by trawl permit to initially allocate trawl splitnose quota shares (QS) under Amendment 20. Since splitnose rockfish are not targeted and predominantly discarded at sea, little data would be available to determine catch history.

1.1.4.20 Starry Flounder

Distribution and Life History

Starry flounder (*Platichthys stellatus*) have a very broad geographic distribution around the rim of the North Pacific Ocean and have been recorded from Los Angeles to the Aleutian Islands, although they are rare south of Point Conception (Kramer and O'Connell 1995; Orcutt 1950). Off the U.S. west coast starry flounder are found commonly in nearshore waters, especially in the vicinity of estuaries (Baxter 1999; Kimmerer 2002; NOAA 1990; Orcutt 1950; Pearson 1989; Sopher 1974). It has quite a shallow bathymetric distribution, with most individuals occurring in waters less than 80 m, although specimens

have been collected off the continental shelf in excess of 350 m (Kramer and O'Connell 1995; Orcutt 1950). They are most often found on gravel, clean shifting sand, hard stable sand, and mud substrates.

Spawning occurs primarily during the winter months of December and January, at least in central California (Orcutt 1950); it may occur somewhat later in the year (February-April) off British Columbia and Washington (Hart 1988; Love 1996). Egg/larval development apparently takes about 2-3 months to occur. Offspring principally remain within the estuaries until age two, when many have migrated to the adjacent ocean habitats (Baxter 1999; Kimmerer 2002; Orcutt 1950). Reproductive maturity occurs at age two years for males and age three years for females, when the fish are 28 cm and 35 cm, respectively. Tagging studies have shown that fish are relatively sedentary and move little during their adult lives (Love 1996); however, there is little information on regional variation in stock structure.

Starry flounder consume crabs, shrimps, worms, clams and clam siphons, other small mollusks, small fish, nemertean worms, and brittle stars (Hart 1988).

Stock Status and Management History

The U.S. west coast starry flounder stock was assessed in 2005 (Ralston 2006). The assessment was based on the assumption of separate biological populations north and south of the California-Oregon border. The assessment used catch data, relative abundance indices derived from trawl logbook data, and an index of age-1 abundance from trawl surveys in the San Francisco Bay and Sacramento-San Joaquin River estuary. Unlike most other groundfish stock assessments, no age- or length-composition data were directly used in the assessment. Both the northern and southern populations were estimated to be above the target level of 40 percent of virgin spawning biomass (44 percent in Washington-Oregon and 62 percent in California), although the status of this data-poor species remained fairly uncertain compared to that of many other groundfish species. One of the most significant areas of uncertainty in the assessment was the estimate of natural mortality rate, which was quite high (0.30 for females and 0.45 for males).

Starry flounder were managed in the Other Flatfish complex until 2007, when the stock was removed from the complex and managed with stock-specific specifications determined from the assessment. Starry flounder have never been overfished or subject to overfishing.

Stock Productivity

Recruitment deviations were estimated in both the northern and southern starry flounder assessment models, although selectivity patterns were fixed external to the model after analysis of trawl length composition information from the PacFIN-BDS data base and sport length composition information from the RecFIN data base. Growth and other life history parameters were also fixed, largely based on a detailed study of starry flounder by Orcutt (1950). Finally, spawner-recruit steepness ($h = 0.80$) and recruitment variability ($\sigma r = 1.00$) were also held constant.

Starry flounder is a relatively productive stock with a PSA productivity score of 2.15. They are also not vulnerable to potential overfishing ($V = 1.04$).

Fishing Mortality

Starry flounder are mostly caught in nearshore recreational fisheries. Historically, they were also caught in nearshore trawl efforts; however, this catch is rare today given that Washington and California have closed their state nearshore waters to trawling. Both the northern and southern stocks were estimated to be well above the $B_{25\%}$ B_{MSY} threshold ($B_{44\%}$ in Washington-Oregon and $B_{62\%}$ in California). In addition,

recent exploitation rates have been well below the F_{MSY} proxy for flatfish. Recent landings in both areas have been less than 20% of the calculated ABC/OFL.

1.1.4.21 Widow Rockfish

Distribution and Life History

Widow rockfish (*Sebastes entomelas*) range from Albatross Bank off Kodiak Island to Todos Santos Bay, Baja California, Mexico (Eschmeyer, *et al.* 1983; Miller and Lea 1972; NOAA 1990). They occur over hard bottoms along the continental shelf (NOAA 1990) and prefer rocky banks, seamounts, ridges near canyons, headlands, and muddy bottoms near rocks. Large widow rockfish concentrations occur off headlands such as Cape Blanco, Cape Mendocino, Point Reyes, and Point Sur. Adults form dense, irregular, midwater and semi-demersal schools deeper than 100 m at night and disperse during the day (Eschmeyer, *et al.* 1983; NOAA 1990; Wilkins 1986). All life stages are pelagic, but older juveniles and adults are often associated with the bottom (NOAA 1990). All life stages are fairly common from Washington to California (NOAA 1990). Pelagic larvae and juveniles co-occur with yellowtail rockfish, chilipepper, shortbelly rockfish, and bocaccio larvae and juveniles off Central California (Reilly, *et al.* 1992).

Widow rockfish are ovoviviparous, have internal fertilization, and brood their eggs until released as larvae (NOAA 1990; Reilly, *et al.* 1992). Mating occurs from late fall-early winter. Larval release occurs from December through February off California, and from February through March off Oregon. Juveniles are 21 mm to 31 mm at metamorphosis, and they grow to 25 cm to 26 cm over three years. Age and size at sexual maturity varies by region and sex, generally increasing northward and at older ages and larger sizes for females. Some mature in three years (25 cm to 26 cm), 50 percent are mature by four years to five years (25 cm to 35 cm), and most are mature in eight years (39 cm to 40 cm) (NOAA 1990). The maximum age of widow rockfish is 28 years, but rarely over 20 years for females and 15 years for males (NOAA 1990). The largest size is 53 cm and about 2.1 kg (Eschmeyer, *et al.* 1983; NOAA 1990).

Widow rockfish are carnivorous. Adults feed on small pelagic crustaceans, midwater fishes (such as age-one or younger Pacific whiting), salps, caridean shrimp, and small squids (Adams 1987; NOAA 1990). 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 euphausiids (Reilly, *et al.* 1992).

Stock Status and Management History

Widow rockfish are an important commercial species from British Columbia to central California, particularly since 1979, when Oregon trawl fisherman demonstrated the ability to make large catches at night using midwater trawl gear. Many more participants have entered the fishery since that time, and landings of widow rockfish have increased rapidly (Love, *et al.* 2002). Widow rockfish are a minor component of the recreational groundfish fisheries.

Williams et al. (2000) assessed the coastwide stock of widow rockfish in 2000. The spawning output level (8,223 mt eggs), based on that assessment and a revised rebuilding analysis (Punt and MacCall 2002) adopted by the Council in June 2001, was at 23.6 percent of the unfished level (33,490 mt eggs) in 1999. The widow rockfish stock was declared overfished in 2001 based on this assessment result.

It was concluded in the 2003 assessment (He, *et al.* 2003) that the widow rockfish stock size was at 24.7 percent of the unfished biomass and that stock productivity was considerably lower than previously

thought. Data sparseness was a significant problem in this widow rockfish assessment. Results from the 2003 widow rockfish rebuilding analysis were used to develop the first widow rockfish rebuilding plan, which was adopted in April 2004 under Amendment 16-3 to the groundfish FMP. The rebuilding plan established a target rebuilding year of 2038 and a harvest control rule of F = 0.0093 (with a P_{MAX} of 60 percent).

A full assessment was completed in 2005 for widow rockfish (He, *et al.* 2006a). In addition to including the new data from 2003 to 2004, this assessment added an index of relative abundance based on the triennial survey data and estimated the power coefficient of the midwater juvenile survey index instead of using a fixed value. The base model estimated that spawning biomass declined steadily since the early 1980s and that spawning output in 2004 was 31 percent of the unexploited level, above the Council's overfished threshold. Further, spawning output in the base model was estimated to have never dropped below the 25 percent overfished threshold. Alternative model runs, which were considered to be only slightly less plausible than the base model, however, indicated that the stock had been below $B_{25\%}$. The 2005 rebuilding analysis indicated that the stock was much closer to reaching a rebuilt biomass than previously estimated: under the 2005 rebuilding analysis (He, *et al.* 2006b), T_{MIN} was estimated to be 2013, compared to a T_{MIN} of 2026 in the 2003 analysis (He, *et al.* 2003). This rebuilding analysis was used to modify the widow rockfish rebuilding plan, which was adopted under Amendment 16-4 in 2006. The target rebuilding year under the modified rebuilding plan was 2015 and the harvest control rule was an SPR harvest rate of 95 percent.

An updated assessment was done in 2007 (He, *et al.* 2008) using the same age-based model (written in ADMB) and data compiling procedures used in the previous assessment. New data from 2005 and 2006, including catches, age composition, and a CPUE time series, were included in the 2007 assessment. Sources of uncertainty include a questionable source of information (Oregon bottom trawl logbook data); the validity of the fixed natural mortality rate used; the estimation of stock-recruitment relationships, which also led to uncertainty in the rebuilding analysis; the appropriateness of using the Santa Cruz juvenile survey data; and stock structure issues including relationship to the Canadian stock. The estimated total biomass in 2006 was 120,132 mt and the estimated 2006 spawning biomass was 47,478 mt. Spawning biomass in the 2007 assessment is higher than in the 2005 assessment primarily because of the relatively strong recruitment in 2003 by the 2000 cohort. The estimated current depletion rate is 35.5 percent of the unfished spawning output. The ABC for 2007 is 5,334 mt and the harvest guideline is 368 mt. It is estimated that the population will recover to the target in 2009, which is six years earlier than the target year in the rebuilding plan. Based on these results, the SSC recommended no changes to the rebuilding plan.

Future research needs include reliable abundance indices, continue the long-term recruitment index and midwater juvenile trawl survey, ability to infer direct and indirect estimates of year class strengths, better understand the relationship between environmental conditions in the California Current Ecosystem, improve short-term forecasts of productivity, biomass levels and allowable catches from stock assessments, new discard data, evaluate the utility of hydro-acoustic surveys, increase age-collection programs to increase sample size, and determination of age-composition for the triennial survey.

A full assessment of widow rockfish was conducted in 2011 (He, *et al.* 2011), which indicated the spawning stock biomass was successfully rebuilt with a depletion of 51 percent at the start of 2011. However, there is considerable uncertainty regarding the new stock assessment’s finding that the stock has rebuilt. Productivity and status of this stock are highly uncertain because the available biomass indices are not informative. Nonetheless, the SSC considered the base model of the new widow rockfish assessment to be the best available science.

Stock Productivity

The major axis of uncertainty in the new widow rockfish assessment is steepness, which defines the relative productivity of the stock. The SSC recommended fixing the steepness parameter at 0.76 in the assessment, due to the lack of information to reliably estimate steepness. The steepness parameter of 0.76 is the median value in the distribution of steepness parameters of assessed rockfish species in the Dorn (2002b) meta-analysis. The decision table in the assessment was developed to bracket model uncertainty in widow rockfish productivity with alternative values of steepness. The 12.5 percent and 87.5 percent quantiles from the prior distribution on h translate into steepness values of 0.54 and 0.95, respectively. This range was considered reasonable to account for the uncertainty associated with steepness. It was, however, agreed by the STAT and the SSC to shift this range to a lower steepness value to (a) take account of the data which, while not greatly informative, did provide some evidence for a lower steepness value, and (b) provide continuity by considering the value of steepness used in the 2009 assessment (0.41). As a result, steepness values of 0.41 and 0.90 were used for the low and high states of nature in the assessment decision table.

The high uncertainty in the steepness of the stock-recruitment relationship and the lack of recent strong recruitments compels a precautionary approach to managing widow rockfish. If the pessimistic state of nature is correct (h = 0.41), then annual constant catches of up to 1,500 mt are projected to maintain spawning stock biomass above the MSST during the 10-year projection period (i.e., 2013-2022).

The base model in the 2011 widow assessment estimated a time series of recruitment of age-0 fish from 1948 to 2009. The highest recruitment occurred in 1970 (Figure 23). Recruitments remained generally low in the early 1990s and have been very low since 2001, as compared to the long-term average. As in the past widow assessments, uncertainties in estimation of recruitment remain high.

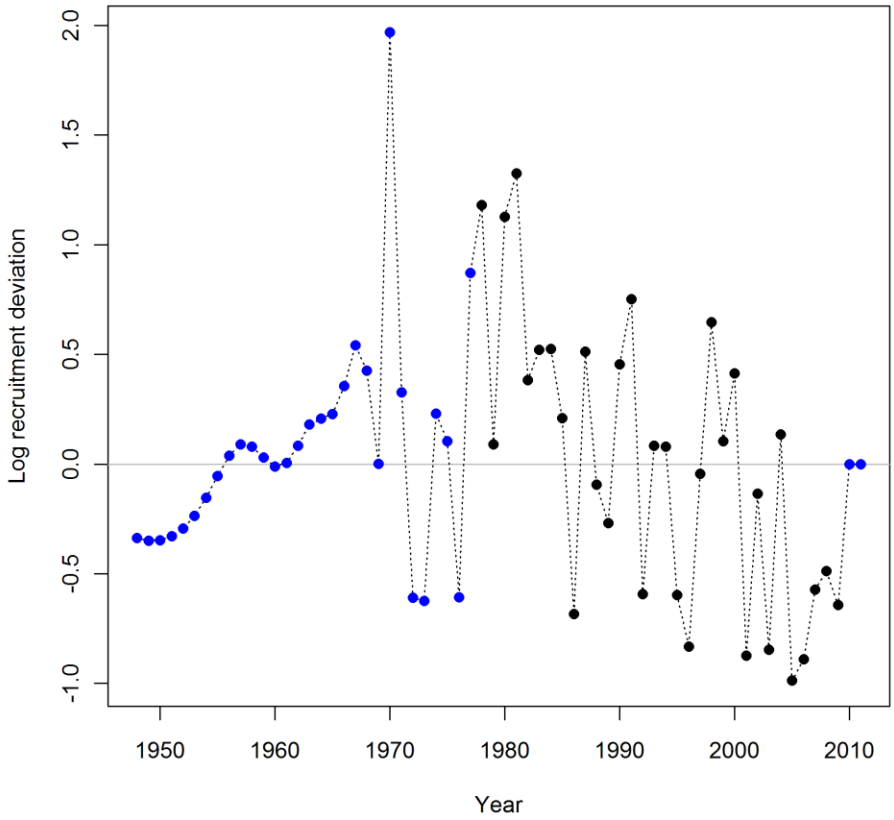

Figure 23. Time series of estimated recruitments from the base model in the 2011 widow rockfish assessment.

Fishing Mortality

Widow rockfish are caught mostly in midwater trawls used to target Pacific whiting and, before 2002, used to target widow and yellowtail rockfish. The exploitation rate was above the target SPR of 50 percent (i.e., $F<F_{MSY}$) until the late 1970s when trawl catches in the target midwater fishery increased to rates beyond the target. This continued until the stock was declared overfished and managed under a rebuilding plan. Harvest declined dramatically and the estimated SPR harvest rates increased rapidly above target F_{MSY}. The increase in biomass during the past decade was the result of reduced catches rather than strong year-classes.

Lower OYs specified in 2005-2010 were not exceeded as the fishery was managed to avoid widow bycatch and the percent of OY attainment decreased with time during that period. The percent attainment of the 2011 IFQ allocation was 40 percent. The at-sea whiting sectors have been better able to avoid widow rockfish in recent years with the lowest bycatch rates (widow catch/whiting catch) observed in the past couple of years.

Management uncertainty is low since widow rockfish is a trawl-dominant species and there is mandatory 100 percent observer coverage in trawl fisheries.

1.1.4.22 Yellowtail Rockfish North of 40º10' N lat.

Distribution and Life History

Yellowtail rockfish (*Sebastes flavidus*) range from San Diego, California, to Kodiak Island, Alaska (Fraidenburg 1980; Gotshall 1981; Lorz, *et al.* 1983; Love, *et al.* 2002; Miller and Lea 1972; Norton and MacFarlane 1995). The center of yellowtail rockfish abundance is from Oregon to British Columbia (Fraidenburg 1980). Yellowtail rockfish are a common, demersal species abundant over the middle shelf (Carlson and Haight 1972; Fraidenburg 1980; Tagart 1991; Weinberg 1994). Yellowtail rockfish are most common near the bottom, but not on the bottom (Love, *et al.* 2002; Stanley, *et al.* 1994). Yellowtail rockfish adults are considered semi-pelagic (Stanley, *et al.* 1994; Stein, *et al.* 1992) or pelagic, which allows them to range over wider areas than benthic rockfish (Pearcy 1992). Adult yellowtail rockfish occur along steeply sloping shores or above rocky reefs (Love, *et al.* 2002). They can be found above mud with cobble, boulder and rock ridges, and sand habitats; they are not, however, found on mud, mud with boulder, or flat rock (Love, *et al.* 2002; Stein, *et al.* 1992). Yellowtail rockfish form large (sometimes greater than 1,000 fish) schools and can be found alone or in association with other rockfishes (Love, *et al.* 2002; Pearcy 1992; Rosenthal, *et al.* 1982; Stein, *et al.* 1992; Tagart 1991). These schools may persist at the same location for many years (Pearcy 1992).

Yellowtail rockfish are viviparous (Norton and MacFarlane 1995) and mate from October to December. Parturition peaks in February and March and from November to March off California (Westrheim 1975). 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, *et al.* 2002; Tagart 1991). Male yellowtail rockfish are 34 cm to 41 cm in length (five years to nine years) at 50 percent maturity, females are 37 cm to 45 cm (six years to ten years) (Tagart 1991). Yellowtail rockfish are long-lived and slow-growing; the oldest recorded individual was 64 years old (Fraidenburg 1980; Tagart 1991). Yellowtail rockfish have a high growth rate relative to other rockfish species (Tagart 1991). They reach a maximum size of about 55 cm in approximately 15 years (Tagart 1991). Yellowtail rockfish 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 Pacific whiting, Pacific herring, smelt, anchovies, lanternfishes, and others), along with squid, krill, and other planktonic organisms (euphausiids, salps, and pyrosomes) (Love, *et al.* 2002; Phillips 1964; Rosenthal, *et al.* 1982; Tagart 1991).

Stock Status and Management History

Until the late 1990s, yellowtail rockfish were harvested as part of a directed midwater trawl fishery. Yellowtail rockfish are common in both commercial and recreational fisheries throughout its range and commonly occur with canary and widow rockfishes (Cope and Haltuch 2012). Despite historically large removals and its popularity in commercial and recreational fisheries, its association with those highly regulated species has greatly decreased removals over the last decade. From the end of 2002 through 2010, implementation of the RCAs and small landings limits designed to only accommodate incidental bycatch eliminated directed mid-water fishing opportunities for yellowtail rockfish in non-tribal trawl fisheries. A limited opportunity to target yellowtail rockfish in the trawl fishery has been available since 2011 under the trawl rationalization program, yet low quotas for widow rockfish, canary rockfish, and for other constraining stocks has continued to limit mid-water targeting of yellowtail rockfish.

Yellowtail rockfish are currently managed with stock-specific harvest specifications north of 40º10' N lat. and within the southern Shelf Rockfish complex south of 40º10' N lat. There has never been an assessment of the southern stock and the OFL contribution of yellowtail rockfish to the southern Shelf Rockfish complex is based on a DB-SRA estimate.

Yellowtail rockfish on the U.S. west coast north of 40º10' N lat. were assessed in 1984 (Weinberg, *et al.* 1984), 1986 (Coleman 1986), 1988 (Tagart 1988), 1993 (Tagart 1993), 1996 (Tagart and Wallace 1996), and 1997 (Tagart, *et al.* 1997) to determine harvest specifications for the stock. A full assessment in 2000 (Tagart, *et al.* 2000) was the first that estimated stock status with an estimated depletion of 60.5% at the start of 2000. Lai et al. (2003) updated the 2000 assessment and estimated stock depletion was 46% at the start of 2003. Another assessment update was prepared in 2005 (Wallace and Lai 2006) with an estimated depletion of 55% at the start of 2005.

A new data-moderate assessment of yellowtail rockfish north of 40º10' N lat. was conducted in 2013 (Cope and Dick 2014). The estimated depletion at the start of 2013 was 69% and the spawning biomass was estimated to be 38,168 mt. This was a large biomass increase relative to previous estimates and largely due to low removals in the last 10 years.

Stock Productivity

The posterior median estimate of steepness in the 2013 yellowtail rockfish assessment is 0.79, indicating a relatively productive stock. However, this estimate may not be as informative of relative stock productivity. Due to the low susceptibility of yellowtail rockfish to fisheries removals, the vulnerability to overfishing of yellowtail rockfish is relatively low (V = 1.88), though the productivity of this species is also relatively low (P = 1.33) based on other life history traits, including a longevity to almost 70 years.

Fishing Mortality

Fishing mortality of yellowtail rockfish north of 40º10' N lat. was relatively high in the 1980s and 1990s with direct targeting by mid-water trawl gear of yellowtail and widow rockfish. The elimination of that fishery in 2003 to reduce impacts on widow rockfish (and canary rockfish to some degree), coupled with RCA implementation, significantly reduced fishing mortality of yellowtail rockfish. The decision table in the 2013 assessment predicts the stock will keep building under the average annual catch estimated in the assessment (1,376 mt) and would remain at a healthy level in the next 10 years (i.e., above B_{MSY}) at catch levels over 4 times that amount.

1.1.5 Groundfish Stock Complexes

There are eight stock complexes for which ACLs were specified through the 2013-2014 management cycle. These complexes are the Nearshore, Shelf, and Slope Rockfish complexes north and south of 40°10' N lat., the Other Flatfish, and the Other Fish complexes.

Most of the component stocks comprising the stock complexes are unassessed category 3 stocks with OFLs that are determined using data-poor methods such as DBSRA, DCAC, or average historical catch (see Section 1.1.1). In cases where assessments were used to inform OFLs for component stocks managed in stock complexes, the OFLs were projected from those assessments using proxy F_{MSY} harvest rates. A more detailed description of the assessed stocks managed in stock complexes follows.

1.1.5.1 Nearshore Rockfish North and South of 40°10' N Lat.

The nearshore rockfish complexes north and south of 40º10' N lat. are comprised of both assessed and unassessed species. Of the stocks managed in the nearshore rockfish complexes, only blue rockfish in California north of Pt. Conception, brown rockfish, China rockfish, copper rockfish, and gopher rockfish in California north of Pt. Conception have been assessed. The following section defines these complexes

in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Nearshore Rockfish complex north of 40°10' N lat. is composed of the following species: black and yellow rockfish (*Sebastes chrysomelas*); blue rockfish (*S. mystinus*); brown rockfish (*S. auriculatus*); calico rockfish (*S. dalli*); China rockfish (*S. nebulosus*); copper rockfish (*S. caurinus*); gopher rockfish (*S. carnatus*); grass rockfish (*S. rastrelliger*); kelp rockfish (*S. atrovirens*); olive rockfish (*S. serranoides*); quillback rockfish (*S. maliger*); and treefish (*S. serriceps*). These stocks are all unassessed with the exception of brown rockfish, blue rockfish in California, China rockfish, and copper rockfish.

The Nearshore Rockfish complex south of 40°10' N lat. is further subdivided into the following management categories: 1) shallow nearshore rockfish [comprised of black and yellow rockfish (*Sebastes chrysomelas*), China rockfish (*S. nebulosus*), gopher rockfish (*S. carnatus*), grass rockfish (*S. rastrelliger*), and kelp rockfish (*S. atrovirens*)], and 2) deeper nearshore rockfish [comprised of black rockfish (*S. melanops*), blue rockfish (*S. mystinus*), brown rockfish (*S. auriculatus*), calico rockfish (*S. dalli*), copper rockfish (*S. caurinus*), olive rockfish (*S. serranoides*), quillback rockfish (*S. maliger*), and treefish (*S. serriceps*)]. With the exception of the blue rockfish stock occurring in waters off California north of Point Conception (i.e., 34°27' N lat. to 40°10' N lat.) and gopher rockfish north of Point Conception (34°27' N lat.), all of the Nearshore Rockfish South stocks are unassessed. The blue rockfish stock was estimated to be at 29.7 percent of its unfished biomass in 2007; therefore, the stock is considered to be in the precautionary zone. Spawning biomass depletion of gopher rockfish north of Point Conception was estimated to be at 97 percent of its unfished biomass in 2005.

Blue Rockfish in California

<u>Distribution and Life History</u>

Blue rockfish (*Sebastes mystinus*) range from the Gulf of Alaska to northern Baja California, although they are most commonly found between Oregon and central California (Love, *et al.* 2002). They inhabit kelp forests and rocky reefs in relatively shallow depths usually to about 90 meters (50 fm) (Miller and Lea 1972; Reilly 2001), but have been landed as deep as 549 meters (300 fm) (Love, *et al.* 2002). Blue rockfish are residential, with their movements restricted to a small area, usually near the kelp canopy or pinnacles for shelter and spatial orientation (Jorgensen, *et al.* 2006; Lea, *et al.* 1999; Miller and Geibel 1973). Genetic evidence suggests distinct subpopulations of blue rockfish with a biogeographic barrier at Cape Mendocino, California (Cope 2004). More recently, evidence suggests the presence of two genetically distinct cryptic species in central California (Burford, *et al.* 2011).

Blue rockfish are primarily "selective opportunity" planktivores (Gotshall, *et al.* 1965; Love and Ebeling 1978). As juveniles, they feed on planktonic crustacea, hydroids, and algae (Miller and Geibel 1973). Adults also consume fish, squid, tunicates, scyphozoids, bull kelp nori, and pelagic gastropods (Hobson, *et al.* 1996; Lea, *et al.* 1999; Love, *et al.* 2002). Many of these prey items are made available from the relaxation of upwelling or southerly winds, explaining high blue rockfish numbers in the summer off central and northern California, where these conditions are well developed (Hobson and Chess 1988; Love, *et al.* 2002). Due to their great abundance in kelp forests, blue rockfish juveniles are recognized as a key species in the piscivore trophic web of these ecosystems (Hallacher and Roberts 1985).

Stock Status and Management History

The blue rockfish stock in California waters north of Pt. Conception was assessed in 2007 and the stock's depletion was estimated to be 29.7% of its unfished spawning output at the start of 2007 (Key, *et al.* 2008). Blue rockfish were not a highly sought species historically, but an increase in catches in the 1970s resulted in a continuous decline in spawning biomass through the early 1990s. The abundance of blue rockfish was at the management target (SB40%) in 1980 and at the overfished threshold in 1982., Spawning biomass reached a minimum (10% of unexploited) in 1994 and 1995; however, there has been a constant increase since then.

During the 2009 and 2010 biennial specifications process, the Council contemplated removing blue rockfish from the Nearshore Rockfish complexes. Blue rockfish was managed within the Nearshore Rockfish complexes because of scientific uncertainty and management needs, given the interaction of blue rockfish with other nearshore species. When blue rockfish occur offshore they can be targeted separately from other nearshore rockfish, but those that occur inshore mix with other nearshore rockfish stocks. Blue rockfish are managed under the California nearshore management plan which has mandatory sorting requirements for landed catch. Landings are routinely tracked and monitored, thereby reducing management uncertainty. For more efficient state management, blue rockfish remains a component stock within the Nearshore Rockfish complexes. The OFL contribution of blue rockfish is projected from the 2007 assessment using the proxy $F_{50\%}$ F_{MSY} harvest rate and apportioning 87.3 percent of the OFL based on average catches of the assessed stock south of 40°10' N lat. (Key, *et al.* 2008). The OFL contribution of blue rockfish south of 34º27' N lat. is based on DCAC. The assessed portion of the blue rockfish stock is categorized as a category 2 stock, and the unassessed portion south of 34º27' N lat. is categorized as a category 3 stock. The Council has implemented precautionary management of the California population of blue rockfish since 2009 by setting a harvest guideline for California fisheries based on the sum of the 40-10 adjusted ACL contribution north of Pt. Conception and the ABC contribution south of Pt. Conception. This HG has not been exceeded since then.

Stock Productivity

A Beverton-Holt steepness of 0.58 was assumed in the 2007 blue rockfish assessment based on the median steepness in the rockfish meta-analysis done at that point in time. The GMT's PSA analysis indicates a relatively high vulnerability to potential overfishing (V = 2.01) due partly to a relatively low relative productivity (P = 1.22) (Table 2).

Recruitment is variable and highly uncertain for blue rockfish. There was little information other than the pre-recruitment index in the recent years to inform the 2007 assessment model about recruitments. Recruitment appeared to be high in the 1960s, and more recently strong year classes appeared in 1993 and 1998. The late 1970s showed all time low recruitment, with 2006 among the 3 lowest recruitment years estimated.

Fishing Mortality

Blue rockfish have been an important part of the recreational fishery in California since the late 1950s (Mason 1998; Reilly, *et al.* 1993; Wilson-Vandenberg, *et al.* 1996). Commonly taken by Commercial Passenger Fishing Vessels (CPFVs, aka partyboats), skiffs, and divers, it is among the most frequently caught species north of Point Conception (Karpov, *et al.* 1995). However, since the mid-1980s the California recreational catch has declined significantly, especially in the south. This may be a result of overfishing from the more heavily populated southern coast (Love, *et al.* 1998), where there is more angling opportunity due to more favorable access and ocean conditions (Bennett, *et al.* 2004); poor recruitment resulting from a long-term shift away from preferred cold, productive waters (Jarvis, *et al.*

2004; Love, *et al.* 2002); or the effect of increasingly strict fishing regulations. Fishing mortality exceeded current target levels from the mid 1970s through the late 1990s, but has been close to target levels since 2000.

The California blue rockfish catch has played a relatively minor role in the commercial fishery compared to the recreational fishery. This has remained true, even with the advent of the live-fish fishery in the late 1980s, although the contribution of blue rockfish has been increasing in recent years. Since the preferred dinner plate-sized catch for this fishery results in immature fish being targeted in many cases, there is concern over the potential implications of the increasing effort in this fishery. Selection of younger, smaller individuals has led to lower lifetime egg production and consequently, threatened population viability (O'Farrell and Botsford 2005; O'Farrell and Botsford 2006).

Brown Rockfish

Distribution and Life History

Brown rockfish (*Sebastes auriculatus*) are distributed from Prince William Sound to southern Baja California in Mexico, but are most abundant on the U.S. west coast south of Bodega Bay, California (Love, *et al.* 2002). They occur from very shallow inshore waters out to 135 m (74 fm). Brown rockfish are a sedentary rockfish found in shallow water and bays (Eschmeyer, *et al.* 1983), among sheltering weed-covered rocks or around pilings (Lamb and Edgell 1986). Brown rockfish show distinct genetic differentiation by distance in coastal populations off California (Buonaccoursi, *et al.* 2005), though no distinct break is obvious to define substocks. Life history information is not spatially resolved. While coastwide populations may be subject to localized depletion because of reef-specific associations and small home ranges, no subpopulations have been distinguished.

Brown rockfish have been aged to 34 years (Love, *et al.* 2002).

Stock Status and Management History

Brown rockfish are managed in the northern and southern Nearshore Rockfish complexes. A single coastwide data-moderate assessment of brown rockfish was conducted in 2013 (Cope, *et al.* 2014). The assessment estimated the brown rockfish stock to be healthy with a depletion of 42% of its unfished biomass at the start of 2013. The brown rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003 and an observer-based recreational CPUE index from California Party Fishing Vessels (CPFV; i.e., charter boats) during 1999-2011 as indices of abundance. No indices were constructed for north of 40º10’ N lat. since this is a rare species north of Cape Mendocino. While coastwide landings were used in the assessment, only about 1% of the cumulative coastwide landings of brown rockfish were from fisheries north of 40º10’ N lat. It was assumed that the population in the north followed the same trends as the southern population.

Stock Productivity

Brown rockfish has a notably elevated vulnerability to overfishing (V = 1.99) but a relatively high productivity score for a rockfish (P = 1.72) in the GMT’s PSA analysis (Table 2).

Fishing Mortality

China Rockfish

Distribution and Life History

China rockfish (*Sebastes nebulosus*) range from Kachemak Bay in the Gulf of Alaska to Redondo Beach and Nicholas Island in the Southern California Bight but are most abundant from Prince William Sound to northern California (Love, *et al.* 2002). They occur primarily in nearshore and shelf waters in depths ranging from 3 to 128 m. Chinas are a solitary species associated with high relief habitats, especially boulder fields with many crevices. They are territorial and a study off Vancouver Island indicates that individuals are likely to move 10 m or less within their territories.

China rockfish are long-lived with the oldest age reported at 79 years (Love, *et al.* 2002). Males and females mature at about the same size and age with some fish mature at 26 cm and all fish mature at 30 cm. The maximum size is reported to be 45 cm. Larval release occurs off California from January to June peaking in January. Larvae are released later in the season in the Gulf of Alaska during April to August with peak release in May.

Chinas prey on benthic organisms including brittle stars, crabs, shrimps, chitons, and small fishes. Nudribranchs, octopi, snails, and red abalone were observed prey for China rockfish off central and northern California.

Stock Status and Management History

China rockfish are managed in the northern and southern Nearshore Rockfish complexes. Separate data-moderate assessments of China rockfish north and south of 40º10' N lat.[6] were conducted in 2013 (Cope, *et al.* 2014). The China rockfish population south of 40º10' N lat. was estimated to be healthy with a depletion of 66% of its unfished biomass at the start of 2013. However, the population north of 40º10' N lat. was estimated to be more depleted and in the precautionary zone with a depletion ratio of 37% at the start of 2013. The southern China rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003, as well as an observer-based recreational CPUE index from CPFVs during 1999-2011 as indices of abundance. The northern China rockfish assessment used a CPUE index of the Oregon and northern California recreational fisheries derived from dockside intercept surveys during 1980-2003 and an Oregon onboard charter boat index during 2001-2012 as indices of abundance and assumed the population off Washington followed the same trends.

The Council decided to continue to manage China rockfish in the Nearshore Rockfish complexes in 2015-2016. The Council expressed interest in conducting a full assessment of China rockfish with greater focus on modeling state-specific indices of abundance. There was also the suggestion of exploring an Oregon nearshore commercial index which can be theoretically constructed given Oregon's logbook program (an effort metric can be derived from logbook data). Available age and length composition data may also help inform some of the China rockfish dynamics.

[6] Separate China rockfish data-moderate assessments were also conducted north and south of the California-Oregon border at 42º N lat. at the Council's request. The SSC recommended the Council's choice of a management line for China rockfish should dictate which assessments should be used to set harvest specifications. The Council's decision to continue to manage the stock within the Nearshore Rockfish complexes north and south of 40º10' N lat. in 2015 and beyond rendered the second set of assessments stratified at 42º N lat. moot.

Stock Productivity

The productivity score for China rockfish is relatively low (P = 1.33) and there is a major vulnerability to potential overfishing (V = 2.23).

Fishing Mortality

China rockfish are an important species in the nearshore recreational and commercial fisheries on the west coast. They are particularly valuable in the commercial live-fish fishery where their unique coloration and high quality flesh commands the highest prices for rockfish delivered as a live product on the west coast. California and Oregon allow nearshore commercial fisheries while Washington does not.

Fishing mortality of China rockfish south of 40º10' N lat. has been well below the F_{MSY} harvest rate. The XDB-SRA base model estimates that median MSY for southern China rockfish is 32 mt per year (Table 6), and the fishing mortality rate in 2012 was 28% of F_{MSY}. However, that is not the case for the population north 40º10' N lat. The XDB-SRA base model estimates that median MSY for northern China rockfish is 9 mt per year, and the fishing mortality rate in 2012 was 191% of F_{MSY}. Figure 24 depicts total estimated catch of China rockfish north of 40º10' N lat. relative to the 2015 OFL and ACL contributions to the complex. The cumulative 2004-2012 total estimated catch of China rockfish north of 40º10' N lat. was 191% and 221% of the cumulative 2015 OFL and ACL contributions, respectively. Maintaining these catch levels is predicted to lead to continued stock decline.

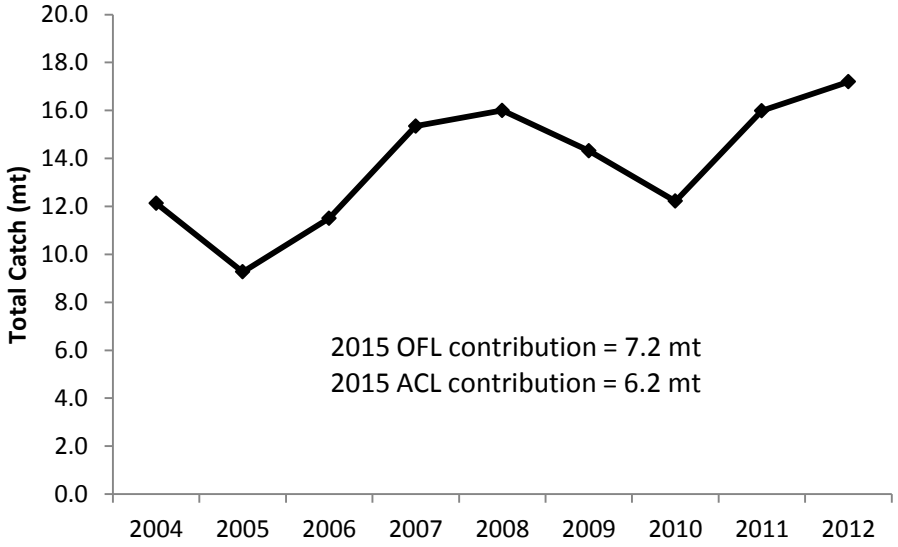

Figure 24. Estimated total catch of China rockfish north of 40º10' N lat. in 2004-2012 relative to the preferred 2015 OFL contribution and ACL contribution.

Copper Rockfish

Distribution and Life History

Copper rockfish (*Sebastes caurinus*) are a deep bodied and spiny rockfish that range from Kachemak Bay in the Gulf of Alaska to Isla San Benito in central Baja California and are common from Port Valdez, Alaska to northern Baja California (Love, *et al.* 2002). They range in depth from the subtidal zone to 183 m. Subadult and adult copper rockfish are found primarily in boulder fields and over high relief rocks, although they also inhabit low relief rock substrata. They perch on the substrata or hover a few meters

above the bottom in aggregations and as solitary individuals (Love, *et al.* 2002). Depending on the habitat and the geographic location, coppers are often found with vermilion, brown, black, dusky, silvergray, yelloweye, quillback, or tiger rockfishes. Coppers have small home ranges in high relief habitats (<10 m^2) and large home ranges in low relief habitats (<4,000 m^2).

Stock Status and Management History

Copper rockfish are managed in the northern and southern Nearshore Rockfish complexes. Separate data-moderate assessments of copper rockfish north and south of 34º27' N lat. were conducted in 2013 (Cope, *et al.* 2014). Both copper rockfish populations were estimated to be healthy with depletions of 76% and 48% of unfished biomass at the start of 2013 in the southern and northern populations, respectively. The southern copper rockfish assessment used a CPUE index of the California recreational fisheries derived from dockside intercept surveys during 1980-2003, as well as an observer-based recreational CPUE index from CPFVs during 1999-2011 as indices of abundance. The northern copper rockfish assessment used the same CPUE indices as in the southern model with the addition of an Oregon onboard charter boat index during 2001-2012 as indices of abundance and assumed the population off Washington followed the same trends.

Stock Productivity

Fishing Mortality

Gopher Rockfish

Distribution and Life History

Gopher rockfish (*Sebastes carnatus*) range from Eureka, California, to San Roque, central Baja California (Miller and Lea 1972), but are most common from Mendocino County to Santa Monica Bay, California (Love 1996). Gopher rockfish is a residential and demersal species, associated with kelp beds or rocky reefs, from the intertidal to about 264 ft (80 m), most commonly between 30 and 120 ft (9-37 m) (Eschmeyer, *et al.* 1983; Love 1996; Love, *et al.* 2002). One tagging study off central California (Lea, *et al.* 1999) revealed that gopher rockfish exhibit minor patterns of movement (<1.5 nm, 2.8 km) with all fish being recaptured on the same reef system where they were tagged. Another study, conducted by Matthews (1986), reported movements up to 1.2 km (0.65 nm) by gopher rockfish that traveled from a low-relief natural reef to a high-relief artificial reef. The change in substrate type may have been a factor in the movement in the Matthews study.

Gopher rockfish settle out of the plankton as large larvae (2 cm. or less in length) primarily in the canopies of giant and bull kelp (*Macrocystis pyrifera* and *Nereocystis luetkeana*, respectively) where they remain close to the fronds (Love, *et al.* 2002). Settlement occurs primarily in June and July. With growth, older individuals move down the kelp stipes to the bottom where they take up residence in rocks and crevices. They are largely territorial with home ranges of 10-12 m^2 (Love, *et al.* 2002).

Gopher rockfish are closely related to black-and-yellow rockfish (*Sebastes chrysomelas*) and kelp rockfish (*Sebastes atrovirens*). Gopher and black-and-yellow rockfish are distinct morphologically by color and inhabit different depth ranges (gopher have a deeper depth range), but cannot be distinguished

genetically (Love, *et al.* 2002). This presents an interesting phenomenon in how speciation in rockfish may occur. There are theories that interbreeding may be lessened by individuals only breeding with others of the same color. If it is determined the two species are actually one, then the name *S. carnatus* will prevail since it was described first (Love, *et al.* 2002).

Stock Status and Management History

Gopher rockfish was assessed for the first time in 2005 and estimated stock depletion under the base model was 97% of its unfished biomass at the start of 2005 (Key, *et al.* 2006). Although the distribution of gopher rockfish extends south into the Southern California Bight, the assessment was restricted to the stock north of Point Conception. The assessment is based on landings and length composition data from commercial and recreational fisheries (primarily hook and line gear) and an index of relative abundance (CPUE) from the CPFV Sportfish Survey database. These data sources were used to estimate population trends from 1965 to 2004. There are no fishery-independent indices of stock biomass for gopher rockfish. Assessment results indicate an upward trend in gopher rockfish biomass since the 1980s and estimates of 2005 abundance ranged between 60 percent and 110 percent of average unfished stock size; this range of depletion levels is the result of alternative emphases in the model given to the CPFV in the CPUE index, a data element identified as a major source of uncertainty.

During the 2007-2008 biennial specifications process, the Council decided to continue managing gopher rockfish within the Nearshore Rockfish South complex since there was adequate resource protection under the California nearshore management plan and managing gopher rockfish with stock-specific harvest specifications could disrupt that plan. The OFL contribution of gopher rockfish north of 34º27' N lat. is projected from the 2005 assessment (Key, *et al.* 2006) using the proxy $F_{50\%}$ F_{MSY} harvest rate. The OFL contribution of gopher rockfish south of 34º27' N lat. is based on DCAC. The assessed portion of the gopher rockfish stock is categorized as a category 1 stock and the unassessed portion south of 34º27' N lat. is categorized as a category 3 stock.

Stock Productivity

Recruitments were modeled in the 2005 assessment assuming a Beverton-Holt relationship, with steepness fixed at h=0.65 and recruitment variability fixed at sigma r = 0.5. Recruitment deviations were estimated for the period 1965-2000. This stock showed evidence of weak recruitment in the 1970s, with peaks in the mid-1980s and mid-1990s. Recruitment estimates in the 1970s are not reliable since length information was not available until the 1980s. Overall, recruitment has been variable throughout the entire time series.

The PSA productivity score of 1.56 for gopher rockfish indicates a moderate relative productivity among rockfish species. There is a relatively low vulnerability of potential overfishing (V = 1.76) for the stock.

Fishing Mortality

Gopher rockfish have been a minor component of the commercial and recreational rockfish fishery since at least the late 1960s. In 1980, an estimated 63 mt of gopher rockfish were landed commercially north of Point Conception, with a decrease in landings in the mid-1980s. Landings then began to increase, with a peak in the fishery occurring in 1992 when approximately 74 mt were landed. Since then, landings have slightly decreased over time. Lower recent landings in 2003 and 2004 (13 and 15 mt, respectively) are in part due to more restrictive federal limits placed on rockfishes. Hook-and-line gears have been the dominant gear type used during the 1969 to 2004 period accounting for 98% of commercial landings.

The recreational gopher rockfish fishery for California ports north of Point Conception peaked during a five-year period in the early 1990s, with 2001 and 2003 also being productive years. Since 1983, anglers

caught the greatest proportion of gopher rockfish from private and rental boats (71%), followed next by party and charter boats (27%). However, in more recent years (1997 to 2004) these proportions have changed, with the private and rental boats taking 59% of gopher rockfish in the recreational fishery and 41% by the party and charter boats. Also since 1983, gopher rockfish have ranked 25th in northern California recreational fishery landings, accounting for approximately 1% of the total harvest for all recreationally caught fishes. However, gopher rockfish made up approximately 50% of the estimated take of the shallow nearshore rockfishes and 6% of all nearshore rockfish species combined. Additionally, recent catches have been influenced by size and bag limits.

Starting in the late 1980s the premium quality live- fish market developed (Larson and Wilson-Vandenberg 2001). Currently, nearly all gopher rockfish are landed in this condition due to a more lucrative high-demand market. As a result of the increasing demand for live- fish the average price per pound has risen steadily from a low of less than $2.00/lb at the inception of the live- fish market to approximately $6.15/lb in 2004 (unadjusted for inflation).

Recent exploitation rates are estimated to have been well below the F_{MSY} proxy for rockfish.

1.1.5.2 Shelf Rockfish North and South of 40°10’ N Lat.

The shelf rockfish complexes north and south of 40º10’ N lat. are comprised of both assessed and unassessed species. Of the stocks managed in the shelf rockfish complexes, chilipepper rockfish north of 40º10’ N lat. (the assessment for the northern stock only covers the area from 40º10’ N lat. to Cape Blanco, OR at 43º N lat. – see section 1.1.4.7 for more details), greenspotted rockfish, greenstriped rockfish, and stripetail rockfish have been assessed. The following section defines these complexes in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Shelf Rockfish complex north of 40°10' N lat. is comprised of the following species: bronzespotted rockfish (*Sebastes gilli*); bocaccio (*Sebastes paucispinis*); chameleon rockfish (*S. phillipsi*); cowcod (*S. levis*); dusky rockfish (*S. ciliatus*); dwarf-red rockfish (*S. rufianus*); flag rockfish (*S. rubrivinctus*); freckled rockfish (*S. lentiginosus*); greenblotched rockfish (*S. rosenblatti*); greenspotted rockfish (*S. chlorostictus*); greenstriped rockfish (*S. elongatus*); halfbanded rockfish (*S. semicinctus*); harlequin rockfish (*S. variegatus*); honeycomb rockfish (*S. umbrosus*); Mexican rockfish (*S. macdonaldi*); pink rockfish (*S. eos*); pinkrose rockfish (*S. simulator*); pygmy rockfish (*S. wilsoni*); redstripe rockfish (*S. proriger*); rosethorn rockfish (*S. helvomaculatus*); rosy rockfish (*S. rosaceus*); silvergray rockfish (*S. brevispinis*); speckled rockfish (*S. ovalis*); squarespot rockfish (*S. hopkinsi*); starry rockfish (*S. constellatus*); stripetail rockfish (*S. saxicola*); swordspine rockfish (*S. ensifer*); tiger rockfish (*S. nigrocinctus*); and vermilion rockfish (*S. miniatus*).

The Shelf Rockfish complex south of 40°10’ N lat. is composed of the following species: bronzespotted rockfish (*Sebastes gilli*); chameleon rockfish (*S. phillipsi*); dusky rockfish (*S. ciliatus*); dwarf-red rockfish (*S. rufianus*); flag rockfish (*S. rubrivinctus*); freckled rockfish (*S. lentiginosus*); greenblotched rockfish (*S. rosenblatti*); greenspotted rockfish (*S. chlorostictus*); greenstriped rockfish (*S. elongatus*); halfbanded rockfish (*S. semicinctus*); harlequin rockfish (*S. variegatus*); honeycomb rockfish (*S. umbrosus*); Mexican rockfish (*S. macdonaldi*); pink rockfish (*S. eos*); pinkrose rockfish (*S. simulator*); pygmy rockfish (*S. wilsoni*); redstripe rockfish (*S. proriger*); rosethorn rockfish (*S. helvomaculatus*); rosy rockfish (*S. rosaceus*); silvergray rockfish (*S. brevispinis*); speckled rockfish (*S. ovalis*); squarespot rockfish (*S. hopkinsi*); starry rockfish (*S. constellatus*); stripetail rockfish (*S. saxicola*); swordspine rockfish (*S. ensifer*); tiger rockfish (*S. nigrocinctus*); vermilion rockfish (*S. miniatus*); and yellowtail rockfish (*S. flavidus*).

Greenspotted Rockfish

Distribution and Life History

Greenspotted rockfish (*Sebastes chlorostictus*) are found in waters off the west coast of North America, ranging from Copalis Head, Washington to Isla Cedros, Baja California (approximately 25º to 47º N lat.). Abundance of this species is greatest from northern Baja California to Mendocino County in California. Greenspotted rockfish associate with several benthic habitat types between depths of 30-363 m, although adults are most common between 60 and 240 m (Love, *et al.* 2002).

Greenspotted rockfish are a long-lived and slow growing species, with sedentary adults associating with a wide variety of benthic habitats. Maximum reported age is 51 years (Benet, *et al.* 2009). Estimates of maximum length for greenspotted rockfish are in the vicinity of 50 cm. Benet et al. (2009) report maximum fork length as 48 cm for central California. Miller and Gotshall (1965) report 51 cm total length for the same area, but did not attempt to distinguish between greenspotted rockfish and pink rockfish (*Sebastes eos*), which grow to 56 cm (Love, *et al.* 2002). Commercial port samplers in California have reported individuals larger than 50 cm fork length (up to 57 cm), although fish of this size appear to be rare (CALCOM, 2011). In southern California, Love et al. (1990) report maximum length as 50 cm total length. Sexual dimorphism is not apparent in greenspotted rockfish (Benet, *et al.* 2009; Lenarz and Wyllie Echeverria 1991; Mason 1998), although latitudinal differences in weight-at-length, length-at-age, and size-at-maturity have been observed.

Seasonal maturation and size at maturity vary with latitude, a trend commonly seen in rockfishes (Benet, *et al.* 2009; Love, *et al.* 1990). In central and northern California, spawning months have been reported from March to September, with peak parturition from April to June (Benet, *et al.* 2009; Wyllie Echeverria 1987). In southern California spawning months begin in February and extend through July, with peak parturition in April (Love, *et al.* 1990). Benet et al. (2009) estimate length at 50% maturity for female greenspotted as 26 cm, consistent with a previous estimate of 27 cm (Wyllie Echeverria 1987) based on females from the same area. In southern California, Love et al. (1990) report length at 50% maturity as 22 cm (converted to fork length from total length). Love et al. (1990) detected evidence of multiple broods in females from southern California (ovaries containing eyed larvae and large numbers of fertilized or unfertilized eggs). No evidence of multiple broods was found in studies of greenspotted rockfish north of Point Conception (Benet, *et al.* 2009; Wyllie Echeverria 1987).

Several studies have reported on habitat associations for greenspotted rockfish. Yoklavich et al. (2000) quantified deep, rocky habitat in Monterey Bay. They observed smaller greenspotted rockfish in shallow depths (75-174 m), and reported strong associations with heterogeneous habitats (cobble-mud, mud-boulder, rock-mud, and rock-ridge). Laidig et al. (2009) studied habitat associations of demersal fishes from a manned submersible in central California, observing 809 greenspotted rockfish. They mainly encountered immature individuals (86% of greenspotted were <25 cm), identifying positive associations with all habitat types (boulder, brachiopod beds, cobble) other than mud. The predominance of juvenile rockfish in the study area suggests that the areas and depths surveyed may be nursery grounds for juvenile rockfish and/or transitional zones as individuals move toward adult habitats (Laidig, *et al.* 2009). Juvenile greenspotted rockfish are commonly seen in traps targeting spot prawn in Monterey Bay, usually in low-relief habitats (Dick, *et al.* 2011).

Adult greenspotted rockfish are generally sedentary, and associate with a wide range of habitat types. Yoklavich et al. (2000) observed 426 greenspotted rockfish (fourth highest abundance of observed species) in Monterey Bay, noting that adults were common near rocky outcrops, ridges, caves, and overhangs. Anderson et al. (2009) described greenspotted rockfish as characteristic of transition zones between hard and soft sediments, based on in situ observations across Cordell Bank in central California.

They classified habitat for greenspotted rockfish over a range of spatial scales. At the finest scale (1-10s of m), greenspotted were found to have weak associations with four of five possible categories: mud, boulders, cobbles, and rock (sand being the fifth category). At intermediate scales (10-100s of m) Anderson et al. (2009) characterized greenspotted habitat as depths between 100-300 m and soft and mixed sediment types.

Movements of greenspotted rockfish have been monitored using acoustic tagging experiments. Starr et al. (2002) implanted acoustic tags in six adults in Monterey Bay, finding that adults exhibit limited horizontal movement and almost no vertical movement. They also identified two movement patterns. In the first pattern, 94% of time was spent within a 0.58 km2 area. The second pattern involved larger movements, with excursions up to 3 km, but 60% of time was spent within the 1.6 km^2 study area. Lowe et al. (2009) monitored 4 adult greenspotted rockfish near oil platforms in southern California using acoustic tags. Probabilities of detection near the release sites dropped by 14% in one year of monitoring. Two individuals returned to their release sites after a 7-month absence.

Williams and Ralston (2002) studied the distribution and co-occurrence of rockfishes over continental shelf and slope habitats using fishery-independent trawl survey data. Greenspotted rockfish were consistently caught (>80% co-occurrence) with bocaccio, chilipepper, stripetail (*S. saxicola*), and shortbelly rockfish. Williams and Ralston (2002) proposed species assemblages for management purposes, including greenspotted in a "southern shelf" assemblage along with bocaccio, chilipepper, shortbelly, stripetail, greenstriped, and cowcod. Since greenspotted rockfish is not a primary target of commercial fisheries, its association with other desirable shelf rockfish species (e.g., bocaccio and chilipepper) is likely a driving force behind historical exploitation of this species.

Molecular systematic studies (Hyde and Vetter 2007) report that greenspotted rockfish are closely related to pink rockfish and greenblotched rockfish (*S. rosenblatti*). Greenspotted rockfish can be distinguished from pink and greenblotched rockfishes by a smooth lower jaw, lacking scales found on the lower mandibles of the other two species (Love, *et al.* 2002).

Stock Status and Management History

The 2011 greenspotted rockfish assessment conducted for the portion of the stock off California was modeled as two area assessments north and south of Point Conception at 34º27' N lat. The assessment indicates the stock is in the precautionary zone with spawning biomass depletions of 30.6 percent and 37.4 percent for the stocks north and south of Point Conception, respectively. The stocks have shown substantial biomass increases since implementation of the RCAs in 2003. Shelf rockfish are particularly well protected by the RCAs, and greenspotted rockfish catches have been negligible since 2003. The Council recommended continuing to manage greenspotted rockfish within the Shelf Rockfish complexes since catch histories were too uncertain to allocate QS in the IFQ fishery. The OFL contribution of greenspotted rockfish to the Shelf Rockfish North complex was based on apportioning 22.2 percent of the projected OFLs from the assessment for the stock north of Point Conception, which is the average estimated catch proportion in the assessment for the stock occurring in the area between 40°10' N lat. and the California-Oregon border at 42° N lat. The OFL contribution for the portion of the stock occurring north of 42° N lat. was derived using DBSRA. The SSC categorized the assessed portion of the stock as a category 2 stock since recruitments were not estimated. The unassessed portion of the stock was categorized as a category 3 stock.

Stock Productivity

Length and age composition data available for the 2011 greenspotted rockfish assessment contained insufficient information to reliably resolve year-class strength. Both base models assumed that recruitment

followed a deterministic Beverton-Holt stock-recruitment relationship, so trends in recruitment reflected trends in estimated spawning output.

While the productivity score for greenspotted rockfish is relatively low (P = 1.39), the susceptibility score is sufficiently low to estimate a medium vulnerability to potential overfishing (V = 1.98).

Fishing Mortality

Greenspotted rockfish are not usually a primary target of commercial or recreational fisheries. Regulations affecting this species are typically intended to alter fishing mortality of primary targets and/or overfished species. For example, implementation of RCAs statewide and CCAs in southern California has greatly reduced fishing mortality for greenspotted rockfish in the past decade.

Historical harvest rates for greenspotted rockfish peaked in the mid-1980s in southern California, but continued to rise in northern California until about a decade later. SPR harvest rates exceeded the current proxy MSY value in northern California from 1973-2000, and from 1969-1998 in southern California. Biomass in both regions is currently below target (<40% unfished spawning output), but above the MSST, and equilibrium SPR harvest rates have been below the proxy MSY level since 2001 in the north and since 1999 in the south.

Greenstriped Rockfish

Distribution and Life History

Greenstriped rockfish (*Sebastes elongatus*) can be found in abundance from British Columbia to Northern Baja California, but range from Chirikof Island in the Aleutian Islands (Gulf of Alaska) to central Baja California (Love, *et al.* 2002). Adults may inhabit depths between 12 and 500 meters, but are more commonly found between 100 and 250 m, and adults typically move to deeper water as they mature (Love, *et al.* 2002; Shaw and Gunderson 2006). This species of rockfish is found with other congeners or alone in a wide range of habitats, which include rocky outcroppings. However, unlike most other species of rockfish they seem to prefer mud or sand bottoms (Love, *et al.* 2002; Shaw and Gunderson 2006).

A genetic study of greenstriped rockfish was recently undertaken by Jon Hess (pers. comm., NWFSC, NOAA as cited in by Hicks et al. (2009)) to study the stock structure of greenstriped rockfish. The genetic variability was remarkably low and showed less variability than most other rockfish species, even when including samples from Puget Sound. However, latitudinal differences in life-history traits have been observed.

Typical of other species of the genus *Sebastes*, greenstriped rockfish are long-lived with maximum observed ages greater than 50 years (Love, *et al.* 2002). Females grow larger than males, but typically mature at about the same length, between 18 and 24 cm, which corresponds to an age between 7 and 10 years. A latitudinal cline in maturity has been observed with fish maturing at a smaller size in the southern areas (Wyllie Echeverria 1987).

Greenstriped rockfish give birth to live young and the fecundity of a 0.5 kilogram female is on average around 200,000 eggs (Dick 2009), although a wide range of fecundity has been reported (Love, *et al.* 2002). The reproductive development of males and females is slightly offset with mating occurring in December through February, fertilization occurring in early spring, and parturition occurring about a month later in late spring (Shaw and Gunderson 2006). Females have the ability to store sperm during the time between copulation and fertilization to ensure the availability of spermatozoa when oocyte maturation has occurred (Shaw and Gunderson 2006). However, in southern latitudes, parturition may

occur from January to July and females in Southern California may release two broods during this time (Love, *et al.* 2002). Juveniles settle to the bottom at about 3 cm in length in autumn and are commonly found along the interface of fine sand and clay. Maturing adults typically move to deeper water (Love, *et al.* 2002).

A wide range of prey items make up the diet of greenstriped rockfish. They will feed from the water column or the bottom on such things as fish, krill, shrimps, copepods, amphipods, and squid. Other fish species may prey on greenstriped rockfish. They have been found in the stomachs of king salmon (Love, *et al.* 2002). Reefs with small numbers of piscivorous rockfish had much higher numbers of small rockfish, such as greenstriped rockfish, than reefs with high numbers of piscivorous rockfish (PFMC 2006).

Stock Status and Management History

Greenstriped rockfish are a bycatch species with little market value mainly due to its small size, and it has been reported that fillets from this species have a short shelf life (Love, *et al.* 2002). As a result, there has not been a long-term directed fishery for this species. However, greenstriped rockfish are often observed in landings from various fisheries, although in small proportions. The most common occurrence of greenstriped rockfish is in trawl fisheries, but they are often caught in recreational fisheries, especially when fishing vessels drift off of the rocks.

After many attempts to start trawl fisheries off the west coast of the United States in the late 1800s, the availability of the otter trawl and the diesel engine in the mid-1920s helped the trawl fisheries expand (Douglas 1998). The trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1960). Foreign fleets began fishing for rockfish in the mid 1960s until the EEZ was implemented in 1977 (Rogers 2003b). Since 1977, landings of rockfish were high until management restrictions were implemented in 2000.

Greenstriped rockfish are often caught in bottom trawls, but a long-term directed fishery has not occurred for this species and historical discarding rates are not well known. There have been many reports of greenstriped rockfish occurring in various fisheries, even as early as 1884 (Goode 1884). Fishermen report that greenstriped rockfish are ubiquitous, but are rarely if ever caught in great numbers.

A coastwide assessment of greenstriped rockfish was done in 2009, which indicated stock depletion was at 81% of its unfished biomass at the start of 2009 (Hicks, *et al.* 2009). The coastwide greenstriped harvest specifications were apportioned beginning in 2011 using the mean of the 2003-2008 swept area biomass estimates north of 40°10’ N lat. (84.5 percent) from the NMFS trawl survey. This stock has continued to be managed within the Shelf Rockfish complexes due to the complications associated with managing this species with IFQs. Species pulled out of a complex managed with IFQs must be converted into an IFQ management unit under the Amendment 20 rules. Greenstriped rockfish is a trawl-dominant bycatch species that is rarely landed due to their diminutive size and low market desirability. An initial allocation of quota share for greenstriped would be less than straightforward given the unreliable catch history. The SSC rated the greenstriped stock as category 2 on the basis of the very uncertain catch history in the 2009 assessment that prevented the estimation of discrete year classes.

Stock Productivity

Recruitment deviations were estimated in the 2009 assessment starting in 1970. The estimates showed that recruitment was highly variable for greenstriped rockfish with high values in 1971, 1984, 1993, and 1998, and low estimates of recruitment in the 1990s, early 1970s, and 2006. The age data from the

NWFSC trawl survey were very consistent with these estimates and precisely showed a very strong 1993 cohort.

While the greenstriped productivity score is relatively low (P = 1.28), the susceptibility to high exploitation was also low leading to a medium vulnerability to potential overfishing (V = 1.88).

Fishing Mortality

The spawning output of greenstriped rockfish reached a low in the late 1990s before beginning to increase throughout the last decade. The estimated depletion has remained above the 40% of unfished spawning output target and it is unlikely that the stock has ever fallen below this threshold. Throughout the 1970s, 1980s, and 1990s the exploitation rate and SPR have generally increased and occasionally exceeded current estimates of the harvest rate limit (SPR = 50%). Recent exploitation rates on greenstriped rockfish have been very small, which is primarily due to management actions in the late 1990s and early 2000s to rebuild other species.

Stripetail Rockfish

Distribution and Life History

Stripetail rockfish (*Sebastes saxicola*) are found from Yakutat Bay in the eastern Gulf of Alaska to Bahia Sebastian Vizcaino in central Baja California, but are more common from coastal British Columbia to southern California (Love, *et al.* 2002). They occur in depths ranging from 25 to 547 m but are most abundant between 100 and 200 m. Adult stripetail are benthically oriented and are most often associated mud, sand, and other low relief habitats. Stripetails are found in the same habitats as splitnose rockfish, greenstriped rockfish, Dover sole, and thornyheads.

Stripetail rockfish live at least 38 years and females grow faster (after reaching maturity) and achieve a larger size than males. Stripetail rockfish are relatively small-sized rockfish with a maximum size of 41 cm and 1 kg (Love, *et al.* 2002). Female stripetails along the California coast are mature by 18 cm or about 9 years of age. Off California, larval release occurs from November to March with peak release occurring off central and northern California in February and in December in the Southern California Bight (Love, *et al.* 2002). Females produce between 15,000 and 230,000 eggs.

Stripetails are primarily water column planktivores feeding mainly on krill and copepods. They are preyed on by a number of predators including Chinook salmon.

Stock Status and Management History

Stripetail rockfish are managed in the northern and southern Shelf Rockfish complexes. They are a relatively minor component stock to these complexes since stripetail are not targeted nor landed in large amounts.

A new data-moderate assessment of stripetail rockfish was conducted in 2013, which indicated the stock was healthy with a depletion exceeding 77.5% (Cope, *et al.* 2014). The 2013 assessment did not produce a reliable estimate of the scale of the stock's biomass; therefore, the SSC did not recommend using the OFL estimates in the assessment. However, the SSC did recommend the available data in the assessment provided strong evidence that the stock was well above the target B_{MSY} and that the assessment results could be used for status determination. Given that the assessment-based OFLs were not endorsed by the SSC, the OFL continues to be based on a DBSRA methodology and the stock is therefore categorized as a category 3 stock.

Stock Productivity

Two recruitment events reported in trawl studies off California from 1973-1993 occurred during El Nińos (Love, *et al.* 2002). It is not clear from the literature whether this is a representative recruitment pattern for the stock.

The PSA productivity score of 1.39 for stripetail rockfish indicates a relatively low productivity among rockfish species. There is a moderate vulnerability of potential overfishing (V = 1.8) for the stock.

Fishing Mortality

Stripetail rockfish are not targeted in commercial or recreational fisheries due to their small size. However, they are caught incidentally in bottom trawl fisheries due to their occurrence in low relief, trawlable habitats. They are rarely landed in current trawl fisheries although they were frequently landed and sold for animal food in the 1950s and 1960s. The stock has never experienced overfishing with the exploitation rate remaining well below the proxy SPR = 50% F_{MSY} harvest rate for rockfish.

1.1.5.3 Slope Rockfish North and South of 40°10' N Lat.

The slope rockfish complexes north and south of 40º10' N lat. are comprised of both assessed and unassessed species. Of the stocks managed in the slope rockfish complexes, aurora rockfish, blackgill rockfish south of 40º10' N lat., rougheye rockfish (and blackspotted rockfish), and sharpchin rockfish have been assessed. There is an older assessment of bank rockfish that was done in 2000 (Piner, *et al.* 2000) that was limited in area and is not used in current management. The following section defines these complexes in terms of their component stocks and provides further detail on those component stocks that have been assessed.

The Slope Rockfish complex north of 40°10' N lat. is comprised of the following species: aurora rockfish (*Sebastes aurora*); bank rockfish (*S. rufus*); blackgill rockfish (*S. melanostomus*); blackspotted rockfish (*S. melanostictus*); redbanded rockfish (*S. babcocki*); rougheye rockfish (*S. aleutianus*); sharpchin rockfish (*S. zacentrus*); shortraker rockfish (*S. borealis*); splitnose rockfish (*S. diploproa*); and yellowmouth rockfish (*S. reedi*).

The Slope Rockfish complex south of 40°10' N lat. is composed of the following species: aurora rockfish (*Sebastes aurora*), bank rockfish (*S. rufus*), blackgill rockfish (*S. melanostomus*), POP (*S. alutus*), redbanded rockfish (*S. babcocki*), rougheye rockfish (*S. aleutianus*), sharpchin rockfish (*S. zacentrus*), shortraker rockfish (*S. borealis*), and yellowmouth rockfish (*S. reedi*).

Aurora Rockfish

Distribution and Life History

Aurora rockfish (*Sebastes aurora*) are encountered between the Queen Charlotte Islands (British Columbia, Canada) south to mid-Baja California (Mexico). Off of the United States, they are common from northern Oregon to southern California, and are most abundant in the area around Point Conception, California. They occur at depths from 200 to 700 m (~100 to 400 fm) with the median depth increasing to the south, such that they are most abundant from 350 to 550 m in the north and 400 to 600 m in the south.

While there are areas of greater abundance off of northern Oregon and especially off of Point Conception, California, the population appears continuous over the entire coast, so that there is no clear point for stock delineation. Survey catches exhibit a continuous distribution along the entire coast, though with areas of higher and lower abundances along the coast.

Aurora rockfish is a long-lived rockfish species, with maximum observed age of 125 years on the U.S. west coast based upon otoliths aged in the 2013 assessment (Hamel, *et al.* 2013). This is slightly greater than the maximum of 118 years seen by Thompson and Hannah (2010) and consistent with a maximum age greater than 75 as reported by Love et al. (2002). As with many rockfish species, aurora rockfish exhibit both spatially varying and sexually dimorphic growth, with females reaching a slightly larger size than males. Off of Oregon, females reached an asymptotic length of 36.9 cm, while males reached only 33.6 cm (Thompson and Hannah 2010). Asymptotic size and size at age decreases with latitude, and since the bulk of the stock is south of Oregon, the average asymptotic lengths are quite a bit lower than those reported above.

Thompson and Hannah (2010) found the age at 50% maturity for female aurora rockfish to be 12.56 years and the length at 50% maturity to be 25.54 cm. Maturity data collected coastwide during the 2012 NWFSC trawl survey found similar values, though with more evidence of atresia in older and larger fish than observed in the Thomson and Hannah study.

Aurora rockfish larvae have been collected off of California in months ranging from November to August, with abundance peaking in May and June, corresponding to the observation of females with developed embryos from March to May off of California and in May in Oregon (Love, *et al.* 2002). Thompson and Hannah (2010) also found that parturition peaked in May off of Oregon. Auroras settle on the bottom when they reach a length of about 3.3 cm (Love, *et al.* 2002).

Aurora rockfish display ontogenetic movement, with smaller fish found in shallower waters (below 400-450 m). They are distributed over both hard and soft substrates (Love, *et al.* 2002).

Aurora rockfish co-occurs with many prominent groundfish targets such as Dover sole, sablefish, thornyheads and hake, though are most reported in the catch of splitnose rockfish. Aurora rockfish contributes to the overall California Current ecosystem as both predator on crustaceans and small fishes, and as prey to larger fishes, marine mammals, and large squid. Juvenile aurora rockfishes are preyed on by salmon, birds, and other fishes (Love 2011).

Several aspects of aurora rockfish population biology are affected by the ecosystem. The recruitment of many species of rockfish appears to be high in 1999, suggesting that environmental conditions influence the spawning success and survival of larvae and juvenile rockfish, including aurora rockfish. The mechanism behind this observation is not well understood, but zooplankton abundance, changes in water temperature and currents, distribution of prey and predators, and amount and timing of upwelling are all possible linkages. Changes in the environment may also directly influence age-at-maturity, fecundity, growth, and survival, which can affect stock status determination and its susceptibility to fishing. Thompson and Hannah (2010) found variations in growth corresponding to individual years based upon dendrochronological techniques and otoliths, and found a correlation between an observed growth anomaly in otoliths and sea level in individual years.

Stock Status and Management History

Aurora rockfish reside in deep waters below 200 m. The primary gear type that has been used to catch aurora rockfish and other deepwater rockfish has been trawl gear. The use of trawls off the west coast of the United States dates to the late 1800s, though there was little fishery expansion until the availability of

the otter trawl and the diesel engine in the mid-1920s (Douglas 1998). Trawl fisheries were mainly conducted on the shelf and became more established during World War II when demand increased for groundfish. Mink farms were also a major destination of groundfish removals in the 1940s and 1950s (Jones and Harry 1960). Foreign fleets began fishing for rockfish, including deeper waters of the slope, in the mid-1960s, with declining participation until the 200-mile EEZ was implemented in 1977 (Rogers 2003b). Peaks in the foreign catch have typically been seen in the mid-1960s for rockfishes, but for aurora rockfish, the largest catches were taken in the early 1970s. Foreign fishing was limited in the northern regions by 1970, shifting effort southward and more into aurora rockfish habitat. After 1977, domestic landings of rockfish increased rapidly until about 1990. Subsequent declines in rockfish landings were driven by declining biomass levels and implementation of new, more restrictive management practices, particularly between 1997 and 2002.

Documented and estimated removals of aurora rockfish do not reach consistently large levels until the 1980s. Aurora rockfish are and have been historically most commonly taken from central California to Oregon, tightly coupled with catches of splitnose rockfish. The term "rosefish" was often used to describe either splitnose or aurora rockfish and has been used as a reporting category in California since 1982. Aurora rockfish remains largely a non-targeted member of the slope rockfish complexes.

Limits on select rockfishes, which included the co-occurring species splitnose, were established in 1982. The first imposed catch limits on a coastwide *Sebastes* complex (aurora being one of the 50 rockfishes in the complex) were instituted in 1983. This complex was divided into two management areas north and south of 43º N lat. (separating the Eureka and Columbia INPFC areas) in 1994. Ongoing concern that shelf and slope rockfishes may be undergoing overfishing led the attempt by Rogers et al. (1996) to describe the status of most rockfishes contained in the *Sebastes* complex. Aurora rockfish information content was low, so only estimates of exploitation rates were provided, indicating the stock was undergoing very high exploitation rates relative to biomass estimates in both management areas.

The *Sebastes* complex was subsequently divided into nearshore, shelf, and slope complexes effective in the year 2000, and the dividing line between the northern and southern management areas was shifted to 40º10' N. lat. Aurora rockfish has been managed under trip limits for the minor slope rockfish complex in both the north and south management areas from 2000-2010. Beginning in 2011, bottom trawl catches of slope rockfish north and south of 40º10' N lat. have been managed under an IFQ system.

The first assessment of the west coast stock of aurora rockfish was conducted in 2013 (Hamel, *et al.* 2013); the assessment estimated stock depletion was at 64 percent of its unfished equilibrium at the start of 2013 and had never dropped below its B_{MSY} target (Figure 25). The assessment was a length-based full assessment with natural mortality identified as the major axis of uncertainty. The SSC categorized aurora rockfish as a category 1 stock based on the assessment. However, the uncertainty in estimated biomass in the 2013 assessment was greater than for other category 1 assessments resulting in a higher sigma value for defining the ABC buffer (see section 1.2.2 for more details).

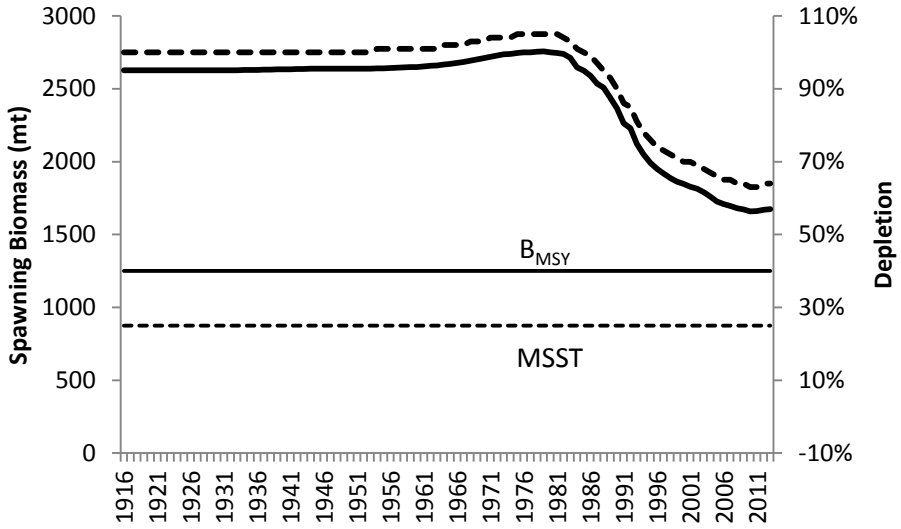

Figure 25. Time series of estimated spawning biomass and depletion of aurora rockfish, 1916-2013.

Stock Productivity

Steepness was fixed to the mean of the most recent rockfish steepness prior (h = 0.779; Thorson, 2013) in the 2013 assessment. Recruitment deviations were estimated from 1916 (the beginning of the modeling period), with a ramp towards bias correction beginning in 1962, full-bias adjustment beginning in 1970 and ending in 2008, and a ramping back down to no bias correction in 2012. Two of the largest contemporary recruitment events are found in 1999 and 2007 (Figure 26). Despite the inclusion of estimated ageing error, discerning individual year classes remains difficult and significant correlation exists between the estimated strength of adjacent year classes, which may be primarily due to ageing error rather than actual correlation in recruitment strength.

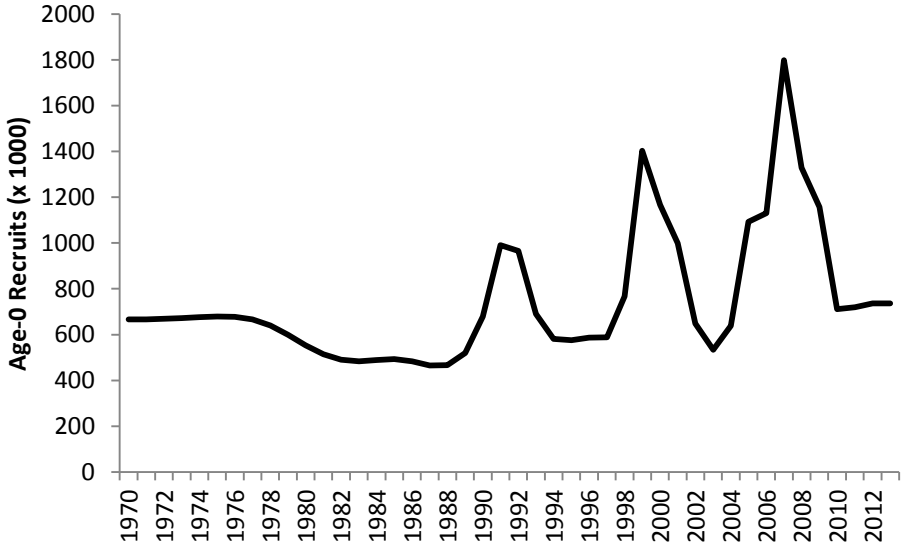

Figure 26. Time series of estimated age-0 recruits of aurora rockfish on the U.S. west coast, 1970-2013.

Fishing Mortality

The 2013 estimates that exploitation of aurora rockfish has been relatively low, with total catch estimated to have exceeded the current management harvest-rate limits in only 2 years, during the early peak in trawl catch (1990 and 1992) (Figure 27). Recent levels of removals have remained moderate. There seems to be very low risk that current removals are causing overfishing.

While stock-specific OFLs/ABCs were not historically set for aurora rockfish specifically, the reauthorized Magnuson-Stevens Act of 2006 and FMP Amendment 23 required OFLs for all species in a management plan, including those managed in stock complexes. The first OFL contributions were calculated using DB-SRA and provided in 2011. The 2015 and beyond OFLs are projected from the 2013 assessment. Recent catches since 2002 have been below the new 2015 OFL and ABC (Figure 28).

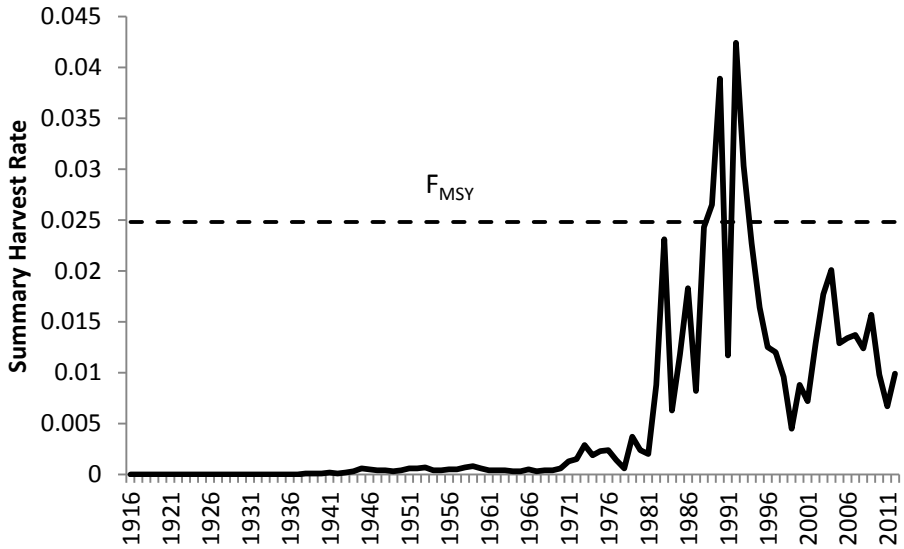

Figure 27. Time-series of estimated summary harvest rate for the west coast stock of aurora rockfish, 1916-2012. The dashed line is the harvest rate at the overfishing F_{MSY} proxy.

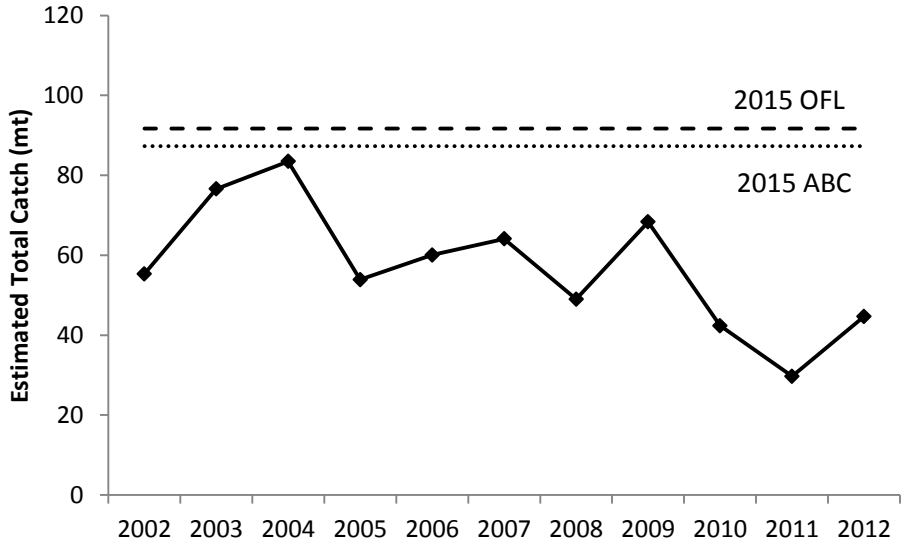

Figure 28. Estimated coastwide total annual catch of aurora rockfish in 2002-2012 relative to the proposed 2015 OFLs and 2015 ABCs (summed north and south of 40°10' N lat. to compare to coastwide catches).

Blackgill Rockfish

Distribution and Life History

Blackgill rockfish (*Sebastes melanostomus*), also known at times as blackmouth rockfish or deepsea rockfish, range from at least central Vancouver Island to central Baja California (Love, *et al.* 2002). However, the species is relatively uncommon north of Cape Mendocino and occurs in the greatest densities in the Southern California Bight (SCB). The name very accurately describes the most identifying characteristic of adult blackgill rockfish, in that they have black pigmentation on the rear edge of their gill cover, as well as in the fold above the upper jaw and inside of the mouth. The rest of the fish appears pink with brown and white blotches underwater, or reddish with distinct brown saddles upon capture. It is a medium-sized (to about 62 cm maximum length) and deep bodied species. Additional descriptions and meristics can be found in Love et al. (2002) for adults and Moser (1996) for larvae and juveniles.

Hyde and Vetter (2007) did not find any evidence for close molecular or evolutionary relationships between blackgill and other rockfish species. Blackgill were found to be moderately related with several other slope or deep shelf species (*S. aurora*, *S. phillipsi*, *S. gilli*, *S. diploproa*, and *S. melanosema*) as well to a suite of mostly rare and poorly known species from the Gulf of California (*S. sinensis*, *S. peduncularis*, and *S. cortezi*) or southern California.

Blackgill are a slope rockfish species, and are generally rare in waters less than 100 meters and most abundant in waters between 300 and 500 meters depth. Love et al. (2002) report a depth distribution of 87 to 768 meters; however, from ten years of data from the NWFSC combined trawl survey, only one haul greater than 600 meters encountered blackgill (that tow was at 647 meters) and the shallowest fish was encountered at 133 meters. Survey data suggest that smaller fish tend to be encountered in shallower water and larger fish in deeper water; survey data also suggest few small fish in waters north of Cape Mendocino. Juveniles are often seen over soft bottom habitats with low relief. Adults are usually associated with high relief rocky outcrops, canyons or deep rock pinnacles, although fishermen often report taking them in midwater (Kronman 1999; Love, *et al.* 2002).

Little is known about the population structure of blackgill rockfish. Like most rockfish, larvae and juveniles circulate in the plankton for 3-4 months. Love et al. (2002) report that some juveniles may be pelagic for up to 7 months; however, this may be atypical. Thus, like most shelf and slope species, blackgill likely disperse over fairly long distances before settling to the bottom. Abundance south of the U.S./Mexico border is uncertain, but there appear to be substantial numbers and catches of blackgill in many areas, and pelagic juveniles have been found as far south as Punta Abreojos, in southern Baja California (Moser and Ahlstrom 1978). The CalCOFI Ichthyoplankton survey has been used to develop or explore indices of relative abundance for several rockfish species for which larvae can be morphologically identified to species (Moser, *et al.* 2000), and such indices have been used as relative abundance indices for assessments of bocaccio (Field, *et al.* 2009) and shortbelly rockfish (Field, *et al.* 2008) as well as northern anchovy (Jacobson and Lo 1994), Pacific sardine (Hill, *et al.* 2008), and California sheephead (Alonzo, *et al.* 2008). Unfortunately, blackgill rockfish are not among the species that have been historically sorted to the species level using morphological methods, although recent developments have led to the potential to use genetic methods to identify historical and contemporary Sebastes from the ichythyoplankton archives (e.g., (Taylor, *et al.* 2004), J. Hyde, FRD/SWFSC, unpublished data). Thus, it is possible that these collections could provide relative abundance information from past and contemporary monitoring programs.

Moser and Ahlstrom also found that blackgill represented approximately 16% of the total number of rockfish specimens encountered in a series of midwater trawls for late larvae and juvenile stage rockfish done in the early 1970s (prior to most historical exploitation). By contrast, from ongoing pelagic juvenile surveys run by the Fisheries Ecology Division used to develop juvenile (pre-recruit) indices for some species, blackgill rockfish comprised only about 3% of juveniles collected from the southern California region from 2004 through 2010 (K. Sakuma and J. Field, unpublished data as cited in Field and Pearson (2011)). However, these results are not likely to be comparable unless seasonal and depth of survey efforts are accounted for; the Moser and Ahlstrom (1978) study in particular fished depths ranging from 0 to 600 meters using an Isaacs-Kidd midwater trawl, while the FED survey uses a considerably larger (modified Cobb) midwater trawl and typically only fishes at 30 meters headrope depth. There is at least some potential to consider relative abundance indices of age-0 juveniles from the FED/SWFSC survey in the future, although given the very slow growth and difficulty in ageing of blackgill rockfish, it is unlikely that validation of survey indices or improved understandings of high frequency variation in year class strength will be of substantial near term benefit to the model.

Nearly 2/3rds of all U.S. landings are from waters south of Point Conception, for which blackgill accounted for as much as 20 to 30% of total *Sebastes* landings in the SCB during the 1980s, when deep water fixed gear fisheries rapidly expanded (more details in catch history section). Nearly all of the remaining landings took place between Conception and Cape Mendocino, such that less than 1.3% of historical California landings have come from waters north of Cape Mendocino. Landings in Oregon waters are even less, and only trace landings of blackgill are reported from Washington waters. Trawl survey abundance data (discussed later in the document) are consistent with these results, although they represent the period following the greatest extent of exploitation: surveys that took place from the 1970s through the late 1990s had virtually no coverage in southern waters where blackgill are the most abundant.

Blackgill rockfish have among the deepest distribution of all of the California Current *Sebastes* (although the three *Sebastolobus* species are common at considerably greater depths), and live at the edge of the low oxygen (hypoxic) conditions that characterize the slope waters of the California Current. Below these depths, species diversity declines to a smaller suite of species that have adapted to cope with low oxygen waters, notably the DTS complex species (Dover sole, thornyheads and sablefish), which have evolved a range of adaptive strategies including metabolic suppression, slow growth rates, late ages at maturity, and ambush (rather than active searching) predation methods (Childress and Seibel 1998; Jacobson and Vetter 1996; Koslow, *et al.* 2000; Vetter and Lynn 1997). These low oxygen waters, known as the oxygen minimum zone (OMZ), are a natural feature of the Eastern Pacific Rim and other regions characterized by high surface productivity and/or the upwelling of oxygen-poor source waters (Helly and Levin 2004). The California Current has a relatively deeper OMZ than the Equatorial Eastern Tropical Pacific (ETP) or the Humboldt Current (Helly and Levin 2004), with the zone starting at approximately 500 to 600 meters depth in the waters off of southern and central California. The observation that blackgill are likely the most deeply distributed medium-size Sebastes (at least in southern California Current waters) suggests that they have adapted to live on the edge of the OMZ, where oxygen availability is rapidly declining relative to shelf waters, although no Sebastes species appears able to tolerate the very low oxygen conditions within the OMZ itself.

Seibel (2011) describes two oxygen thresholds that are temperature dependent (as opposed to species or situation-specific), one in which virtually all species are capable are of physiologically adjusting or adapting to declining oxygen availability, and a second for which no further adjustment or adaptation in aerobic O2 utilization is possible. Seibel (2011) describes this latter threshold as one at which "organisms that are not specifically adapted to low O2 will suffer physiological stress and eventual death." Importantly, this threshold falls just below the currently observed oxygen levels throughout the slope

waters of much of the California Current, inferring that any expansion of the OMZ in this region is likely to have tremendous impacts on the vertical distribution of populations and the species composition of ecosystems. Equally importantly, there is already some evidence of a shoaling (shallowing) of the depth of the OMZ throughout the California Current (Bograd, *et al.* 2008; Whitney, *et al.* 2007), with Bograd et al. (2008) reporting oxygen declines of 20-30% at depths of approximately 300 to 500 meters in the waters of the Southern California Bight, the region in which most of the blackgill biomass resides. A shoaling of the OMZ has been predicted to be a likely or plausible response to global climate change due to the fact that oxygen is less soluble in warmer waters, and warming is also expected to increase stratification in the upper ocean, which will both reduce oxygen supply and increase oxygen demand at depth (Keeling, *et al.* 2010; Sarmiento, *et al.* 1998; Seibel 2011).

For blackgill rockfish, it is the shoaling of the OMZ at depth that is likely to be the greatest long-term threat, as such a shoaling would likely represent a severe compression of the available habitat for this species. McClatchie et al. (2010) evaluated potential scenarios for hypoxia to impact the habitat of cowcod (Sebastes levis), a rebuilding shelf species that is a focus of management in the SCB. They found that as much as 37% of deep (240-350 m) cowcod habitat is currently affected by hypoxia, but that if the current trends of a shoaling OMZ continue for 20 years, this could increase to 55% of deep habitat, as well as an additional 18% of habitat in the 180 to 240 m depth range. These numbers would presumably differ substantially for blackgill rockfish, which have a very different (considerably deeper) distribution; due to their proximity to the OMZ, they may be at considerably greater risk to the longer-term impacts of shoaling. Moreover, changes in the characteristics and dynamics of the OMZ could lead to changes in the forage base for blackgill, which are described as foraging primarily on mesopelagic fishes which undergo dial migrations from the edge of the OMZ to surface waters in order to feed.

As previously mentioned, blackgill have been described as having a strong affinity for deep water habitat, particularly around offshore banks, canyons and areas of high depth gradients. They have been described as feeding on small mesopelagic fishes, such as myctophids and bathylagids (Love, *et al.* 2002). Isaacs and Schwartzlose (1965), Genin et al. (1988), Koslow (2000) and Genin (2004) describe the mechanisms by which vertical migrants, such as zooplankton and mesopelagic fishes, become trapped by topographic features. High densities of deepwater adapted resident species are consequently found in the relatively small, confined areas where these diurnally-migrating prey become aggregated. Such observations are consistent with the reports by fishermen of isolated deep banks, pinnacles or other habitat features often hosting very large numbers of fish over a relatively small spatial range, such that vertical hook and line gear (which can be more precisely targeted at small habitat features) is the gear of choice for targeting these species (as opposed to horizontal, or set, hook and line gear often used to target species in deeper slope waters, such as sablefish and thornyheads, which tend to be more widely dispersed).

With respect to predators and predation mortality, it is likely that sablefish and shortspine thornyheads are among the most important predators of blackgill rockfish. Both species are large (up to 100 and 75 cm, respectively, although individuals greater than 80 or 65 cm of either species are uncommon) and largely piscivorous ambush predators that are typically (along with longspine thornyhead and Dover sole) the most abundant and commercially important groundfish in the continental slope ecosystem (Lauth 2000). Food habits information for adult sablefish found that *Sebastolobus* and *Sebastes* species, particularly Sebastolobus altivelis, are key prey items, representing 15% to 30% of total prey by volume (Buckley, *et al.* 1999; Laidig, *et al.* 1997). Similarly, shortspine thornyhead preyed heavily on S. altivelis, unidentified *Sebastes*, and other fishes (Buckley, *et al.* 1999). Although no *S. melanostomus* were conclusively identified in either study, other slope rockfish species (*S. crameri*, *S. diploproa*, and *S. alutus*) were. The lack of specimens is likely due to both studies' focused sampling in northern California, Oregon and Washington slope waters, rather than the south-central and southern California waters in which *S. melanostomus* are most abundant.

Length data for both of these predators (sablefish and shortspine thornyheads) and their prey suggest that predation is low on fishes smaller than 5 cm, high on fishes ranging from 5 cm through 20 cm, and drops off notably for larger prey. However, the diet data summarized here were largely of smaller (40-60 cm) predators, and larger predators likely consume (or consumed) a broader range of prey. In the most recent stock assessment for longspine thornyhead (Sebastolobus altivelis), the base model suggested a declining or stable population (Fay 2006); however, it was noted that an ecosystem model of the northern California Current indicated that abundance of longspines should be increasing due to declines in predation mortality associated with declines in their primary predators (Field, *et al.* 2006). Survey biomass trends for longspine thornyheads, while limited to a relatively narrow time period and associated with considerable uncertainty, also suggested an increasing biomass trend. These observations led to exploration of both time and age-varying natural mortality rates for *S. altivelis* as informed by changes in predator biomass and estimates of predator consumption (Fay and Field, unpublished data as cited in Field and Pearson (2011)). Results suggest that, for this species, predation-related factors should be taken into account for future single-species stock assessments. Comparable evaluations could, and probably should, be done for blackgill rockfish and other slope species, for which their likely most important sources of predation mortality have themselves undergone significant changes in abundance.

Stock Status and Management History

Blackgill rockfish have historically represented a minor part of California rockfish landings north of Point Conception, but a substantial fraction of landings occur south of Conception. Based on consultations with fishery participants, Butler et al. (1999a) and Kronman (1999) defined the southern California targeted fishery for blackgill rockfish as being a relatively recent phenomenon. Although longline fishing had long been the primary means of catching rockfish in southern California waters, increased participation and declines in the catches of many highly desired shelf species (such as vermilion rockfish and cowcod) contributed to a gradual shift in effort towards deeper and more offshore waters. Moreover, improvements in technology and gear (such as loran, affordable acoustic systems, electric line haulers) helped ease the difficulties of fishing (and relocating good fishing sites) in deeper waters. Additionally, set nets (gillnets) also began to be deployed at a larger scale in southern California in the 1970s and 1980s, often targeting deep reefs for large bocaccio, cowcod, blackgill, bank and other rockfish species.

Such developments seem to have been associated with a geographic expansion of the regions fished, such that fishing locations were sequentially depleted and new fishing locations discovered and developed over time. The first stock assessment for blackgill rockfish (Butler, *et al.* 1999a) noted that there was significant evidence for sequential depletion of blackgill rockfish in localized areas. This included reports from fishery participants that many pinnacles or other fishing sites that routinely yielded 20,000 pounds of blackgill per trip in the early days of the fishery were now only yielding 500 or so pounds per trip and were often covered with lost gear. Similarly, in a review of historical southern California fisheries, Kronman (1999) also documented the rapid growth and development of the blackgill fishery specifically as one in which fishermen would often "completely decimate" rockfish spots with deep fishing vertical line gear, based on the accounts of the participants themselves. Consequently, there was an ongoing shift to newer fishing spots, generally further offshore and to greater depths, as well as greater experimentation with alternative gears and target species.

These observations suggest the potential for a situation in which the stock may have undergone the "sequential depletion" of biomass from available habitat patches. If so, this would suggest that a traditional (non-spatial) stock assessment assumption of evenly distributed fishing mortality across space is substantially flawed. In fact, if the fishery were sequentially depleting specific areas, the length frequency information would not be likely to suggest a shift to smaller fish over time as the length frequencies could essentially reflect "unfished" population structure for the duration over which the new habitats were discovered and exploited. The consequences of failing to recognize such patterns can lead

to overexploitation and collapse, and such processes have been described for several marine invertebrate populations (Karpov et al. 2000, Orensanz et al. 2000) as well as temperate water reef fishes (Epperly and Dodrill 1995, Rudershausen et al. 2008). Ongoing efforts to analyze historical block summary data have the potential to identify such shifts and consider whether such factors are likely to be important for west coast groundfish species such as blackgill, as well as to determine whether there is sufficient data to estimate spatial effects or develop spatially-explicit models more capable of accounting for such factors.

Management of blackgill rockfish has generally not been to the species level, but rather as part of the "*Sebastes* complex" in the Pacific Fishery Management Council era (prior to which management was under the direction of the California Department of Fish and Game). The PFMC allowable biological catches (ABC) of blackgill have historically been grouped together with eleven other species of minor rockfishes called "remaining rockfish" and all "other" rockfish. The PFMC historically used trip limits, and later cumulative trip limits (over set time periods), to slow the pace of harvest based on allowable biological catch and to promote a year-round fishery. For all commercial gear types, the limits were initiated in 1983 when the PFMC imposed a monthly limit of 40,000 pounds per trip for the entire coastwide *Sebastes* complex, a limit that stayed in place through 1990. After recognizing the differential spatial distribution of the remaining rockfishes and the fisheries that target them, harvest limits on both open access and limited entry fisheries were divided between the northern and southern *Sebastes* complexes, and trip limits began to be implemented at variable levels over both time (month and year) and space (north and south of Mendocino), often with species-specific limits in addition to the overall limit on *Sebastes* catches. Although early limits applied to both trawl and fixed gears, beginning in 1995 fixed gear limits (hook and line and pot, primarily, as gill nets were phased out through the 1990s) were set to 10,000 lbs of *Sebastes* per trip, which persisted through the 1990s.

Consequently, prior to 1999 cumulative trip limits had been historically high relative to landings of blackgill rockfish from individual trips, and unlikely to have impacted fishing for blackgill and catches. Limits were dramatically reduced in 1999 for the southern *Sebastes* complex; 2-month cumulative limit of 3,500 pounds for limited entry and 3,600 pounds per month for open access. Since 2000, blackgill has been managed as part of the Minor Slope Rockfish sub-group, with limits ranging from 3,000-50,000 pounds per 2 months; Tables 1-3 show the trip limits implemented since 2000 for this complex for the limited entry trawl, limited entry fixed gear and open access fixed gear fisheries. Table 4 shows the total estimated catches of blackgill (including discards) south of 40° 10' for the period since 2001, during which time catches have typically ranged well below allowable levels.

In 2001 the Cowcod Conservation area was established outside of 20 fathoms and directly excludes directed groundfish fishing from an expansive area in the Conception and southern Monterey INPFC areas.[7] This regulation has had a tremendous impact on the southern fixed gear fleet that targets blackgill, as the deep offshore banks and features that characterize the CCAs in deep water are optimal habitat for this species. By contrast, the shelf closures (rockfish conservation areas) implemented to protect rebuilding shelf species (such as bocaccio, cowcod, canary and widow rockfish) have presumably had a negligible direct effect, as the depths closed in the RCAs do not encompass the depths at which most blackgill are encountered. Such measures may have had an indirect effect, by virtue of shifting trawl effort to deeper waters, although for much of California the overall effect has been a sharp decline in active participation in the trawl fishery more generally.

The first assessment for blackgill rockfish was conducted in 1998 and estimated stock depletion was between 40 and 54 percent of its unfished equilibrium at the start of 1998 (Butler, *et al.* 1999a). That assessment assumed a unit stock in southern and central California (Conception INPFC area) and was

7 As the current trawl survey also excludes this region from trawl gear impacts, the area of the CCAs is shown in later maps of survey CPUE for blackgill rockfish, in Figure 13

based on a stock reduction analysis assuming constant recruitment. The dynamics of the simple model were tuned to average mortality rates from catch curves and landings data. Fishery selectivity was assumed to mirror maturity at size/age; trends in fishable/mature biomass were then estimated.

A second blackgill rockfish stock assessment was completed in 2005 indicating a stock depletion of 52 percent (Helser 2006). This assessment expanded the geographic range of that in Butler et al. (1999a), including both the Monterey and Conception INPFC areas, where over 90 percent of the landings have occurred. The assessment was based on catch and length composition data from commercial fisheries and indices of relative abundance and size composition from the AFSC shelf trawl survey and the AFSC slope survey. The modeling approach included fishery and survey length compositions to explicitly estimate selectivity. The assumed natural mortality rate was identified as a key axis of uncertainty for this stock.

The most recent blackgill rockfish assessment, conducted in 2011 for the stock south of 40º10' N lat. (Field and Pearson 2011), estimated the stock was below target with a depletion of 30 percent of its unfished biomass at the start of 2011 (Figure 29). The spawning output of blackgill rockfish was at high levels in the mid-1970s, but began to decline steeply in the late 1970s through the 1980s, consistent with the rapid development and growth of the targeted fishery. The biomass reached a low of approximately 18 percent of the unfished level in the mid-1990s. Since that time, catches have declined and spawning output has increased. The estimated depletion level in 2011 is 30.2 percent.

Catch data used in the assessment are generally reliable throughout the time period, although there is a lot of uncertainty in catch data prior to the early 1980s. Ageing is very difficult for this species, which appears to have highly variable size at age, as well as apparent regional differences in growth rates and potentially other life history traits. The lack of a reliable, long-term, fishery-independent survey index that reflects abundance from the entire range of the stock is problematic. In general, natural mortality and growth parameters comprised the greatest contribution to model uncertainty.

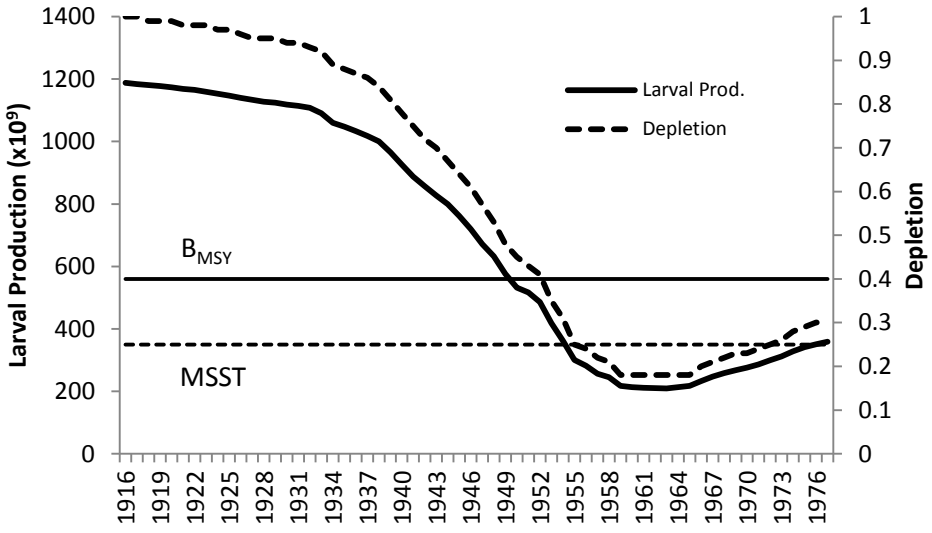

Figure 29. Time series of estimated spawning output and depletion of blackgill rockfish south of 40º10' N lat., 1950-2011.

Stock Productivity

In the 2013 assessment, the Beverton-Holt model was used to describe the stock-recruitment relationship. The log of the unexploited recruitment level was treated as an estimated parameter; recruits were taken deterministically from the stock-recruit curve. Recruitment deviations were not estimated, as the lack of obvious cohorts in either age or length data and the high degree of ageing uncertainty make plausible estimates unlikely. The estimated recruitment is projected to be at relatively high levels due to the fixed value of steepness (h = 0.76); this trend, however, is consistent with the trends from the survey data.

Blackgill rockfish have a relatively high potential vulnerability to overfishing (V = 2.08) driven by a combination of low productivity (P = 1.22) and relatively high susceptibility to being caught in the fishery (Table 2). The low productivity is due to the stock being long-lived (max. age = 87 yrs; (Love, *et al.* 2002)), with late maturation, and relatively low natural mortality (Table 5).

Fishing Mortality

Catches of blackgill rockfish primarily occur in the Southern California Bight south of Point Conception (34º27' N. lat.) where the species is caught in both directed fixed gear (hook-and-line) and historically, gillnet fisheries. Landings of this species are estimated to have risen slowly from very low levels (approximately 20-30 mt) in the 1950s, and then climbed rapidly in the 1970s and 1980s as improvements in technology and declines in other target species led fishermen to target blackgill rockfish in deeper and more offshore waters. Landings peaked in the mid-1980s at just over 1,000 mt, but have declined to approximately 100 mt to 150 mt in recent years.

The 2011 depletion estimate indicated the stock was in the precautionary zone compelling the Council to reduce impacts to prevent overfishing and allow the stock to rebuild back to its target biomass. The Council and NMFS implemented stringent harvest guidelines of 106 and 110 mt for 2013 and 2014, respectively corresponding to calculated 40-0 reductions. Specifying HGs created a sorting requirement for the stock allowing better inseason catch monitoring. The Council further established an apportionment of the non-trawl allocation of 60 percent to limited entry and 40 percent to open access fixed gears, which reflects the historical distribution of catch between the limited entry and open access fixed gear sectors from 2005-2010. Non-trawl landing limits for blackgill south of 40º10’ N lat. were reduced beginning in 2013 to prevent targeting of the stock. Cumulative landing limits for blackgill south of 40º10’ N lat. were reduced from 40,000 lbs/2 months for slope rockfish including blackgill to 40,000 lbs/ 2 months with a sublimit of 1,375 lbs/2 months for blackgill for the limited entry fixed gear sector. Open access cumulative landing limits south of 40º10’ N lat. were reduced from 10,000 lbs/2 months for slope rockfish including blackgill to 10,000 lbs/ 2 months with a sublimit 475 lbs/2 months for blackgill. While final catch accounting of groundfish in 2013 groundfish fisheries will not be available until the end of 2014, landed catch of blackgill has been reduced significantly and fishermen report blackgill targeting is no longer occurring.

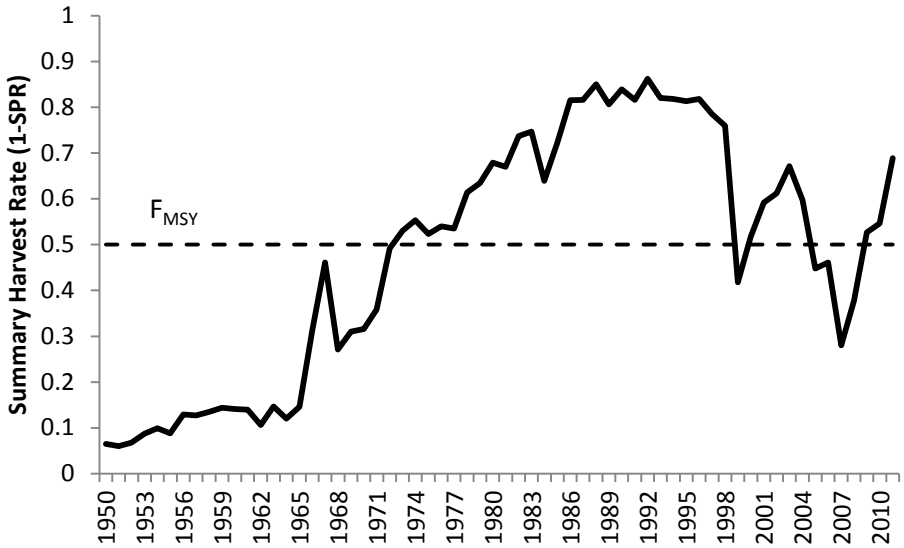

Figure 30. Time series of estimated summary harvest rate for the blackgill rockfish south of 40º10' N lat., 1950-2011. The dashed line is the harvest rate at the overfishing F_{MSY} proxy.

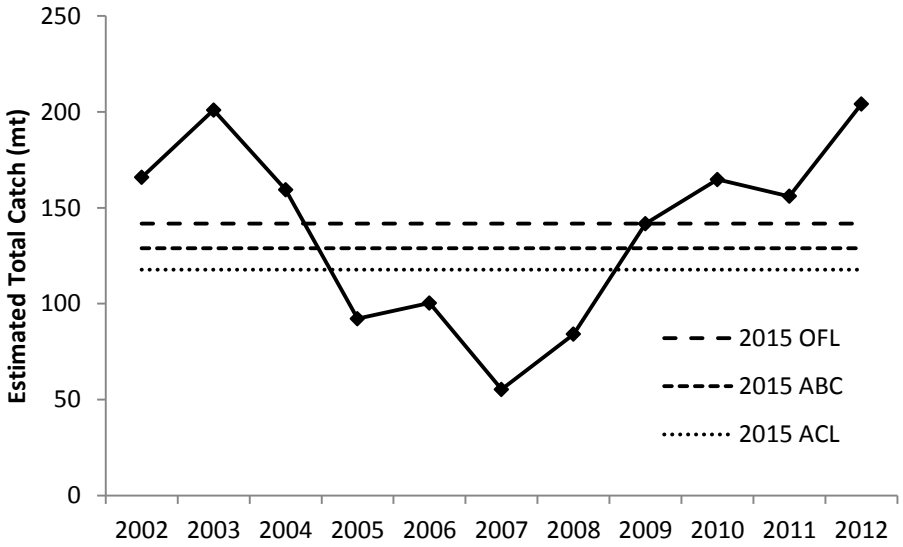

Figure 31. Estimated coastwide total annual catch of blackgill rockfish in 2002-2012 relative to the proposed 2015 OFLs, 2015 ABCs, and 2015 ACLs (summed north and south of 40º10' N lat. to compare to coastwide catches).

Rougheye/Blackspotted Rockfish

Distribution and Life History

Rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) are slope rockfish that share broad overlap in their depth and geographic distributions from the Eastern Aleutian Islands along the North American continental margin to southern Oregon, with blackspotted rockfish's range extending east beyond the Aleutian chain to the Pacific Coast of Japan (Gharrett, *et al.* 2005; Hawkins, *et al.* 2005; Orr and Hawkins 2008). It is very difficult to visually distinguish between the two species and

they have been persistently confused in surveys and catches. It has only been from recent genetic studies in the early 2000s that the two separate species have been identified and described (Orr and Hawkins 2008).

Both species are encountered at depths shallower than 100 m to at least 439 m, however, blackspotted rockfish tend to be more prevalent in deeper waters (Hawkins et al. 2005, Orr and Hawkins 2008). Genetic information is not available to provide positive species identification in historical survey and landings information, but these data indicate that density of the nominal rougheye rockfish complex decreases sharply south of the Oregon-California border at 42° N lat. Studies suggest that rougheye rockfish account for a greater proportion of the species complex along the coast of Washington and Oregon than in Alaskan waters (Gharrett, *et al.* 2005; Hawkins, *et al.* 2005; Orr and Hawkins 2008). Recent discussions with port samplers in southern Oregon suggest that both rougheye and blackspotted rockfish are encountered with some regularity in the commercial trawl and fixed-gear landings in Charleston, Port Orford, and Brookings, with blackspotted rockfish composing approximately one third to one half of identified specimens (C. Good and N. Wilsman, ODFW, pers. comm. as cited in Hicks et al. 2013).

The west coast of the U.S. is the southern portion of the range of rougheye rockfish, and it is likely that the population north of the U.S.-Canada border is not a separate stock. The connectivity of rougheye populations throughout its range is unknown.

Compared with other rockfish species on the west coast of the U.S., rougheye rockfish life-history is poorly described and the recent resurrection of two species (rougheye and blackspotted rockfishes) has further complicated the understanding of life-history characteristics. Rougheye rockfish are often associated with boulders and steep habitats, and are typically found alone or in small aggregations (Love, *et al.* 2002). Younger fish may school and are often found in shallower waters on the shelf, and larger fish may form larger aggregations in the Pacific Northwest during the autumn and winter.

Rougheye rockfish give birth to live young with larvae released between February and June and at lengths between 4.5-5.3 mm (Love, *et al.* 2002). There are no studies on the fecundity of rougheye rockfish on the west coast of the U.S.

A wide range of prey items make up the diet of rougheye rockfish. Crangid and pandalid shrimps make up the majority of their diets, and larger individuals, greater than 30 cm, feeding upon other fishes (Love 2011). They are also known to feed upon gammarid amphipods; mysids, crabs, polychaetes, and octopuses (Love 2011; Love, *et al.* 2002).

Stock Status and Management History

Rougheye and blackspotted rockfish (henceforth denoted as rougheye) are landed as part of the minor slope rockfish complexes north and south of 40º10' N lat.; however, they are rarely caught in the south. The historical reconstruction of landings for rougheye rockfish suggests that fixed gear fisheries have caught rougheye rockfish since the turn of the 20th century and landings in the trawl fishery are estimated to have increased into the 1940s. Landings remained relatively constant throughout the 1950s and into the 1960s before the foreign trawl fleet increased catches into the 1970s. The declaration of the EEZ resulted in the buildup of a domestic fleet and landings increased rapidly into the late 1980s and early 1990s. Subsequently, landings declined in the late 1990s and have been between 100 and 200 mt in recent years. Trawl, longline, and Pacific whiting at-sea trawl fisheries make up the majority of the catch.

Rougheye rockfish are a desirable market species and discarding has been low, historically. However, management restrictions (e.g., trip limits) have resulted in increased discarding since 2000. Trawl

rationalization was introduced in 2011, and since then very little discarding of rougheye rockfish has occurred.

Hicks et al. (2013) conducted the first assessment of the U.S. west coast stock of rougheye and blackspotted rockfish as a complex of two species. The coastwide population was modeled assuming parameters for combined sexes (a single-sex model) and assuming removals beginning in 1916. The predicted spawning biomass from the base model generally showed a slight decline over the entire time series with a period of steeper decline during the 1980s and 1990s. Since 2000, the spawning biomass has stabilized and possibly increased because of reduced catches and above average recruitment in 1999. The 2013 spawning biomass relative to unfished equilibrium spawning biomass was estimated to be 47 percent of its unfished equilibrium at the start of 2013. The stock has been estimated to be healthy throughout the time series in the new assessment (Figure 32).

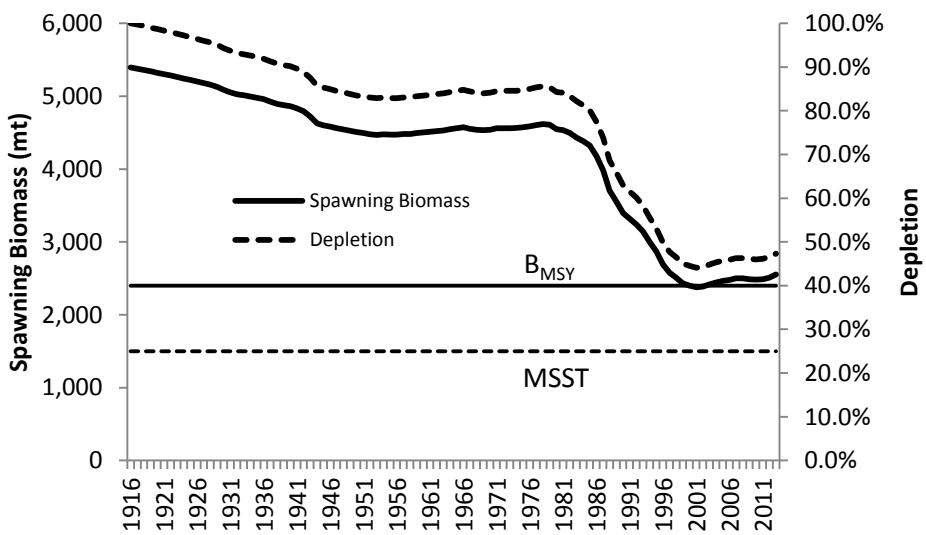

Figure 32. Time series of estimated spawning biomass and depletion of rougheye/blackspotted rockfish, 1916-2013 (from Hicks et al. 2013).

Stock Productivity

A steepness parameter was fixed at 0.779 in the 2013 assessment based on a steepness meta-analysis for west coast rockfishes (Jim Thorson, NWFSC). There is little information regarding recruitment prior to 1980, and the uncertainty in these estimates is expressed in the assessment. Estimates of recruitment appear to oscillate between periods of low and high recruitment. The four largest recruitments were estimated in 1999, 1998, 2001, and 1988, and the four smallest recruitments were estimated in 2002, 2006, 2005, and 1995 (Figure 33).

Rougheye rockfish have the highest potential vulnerability to overfishing (V = 2.27) driven by a combination of low productivity (P = 1.17) and relatively high susceptibility to being caught in the fishery (Table 2). The low productivity is due to the stock being long-lived (max. age = 205 yrs; (Love, *et al.* 2002)), with late maturation, and relatively low natural mortality (Table 5).

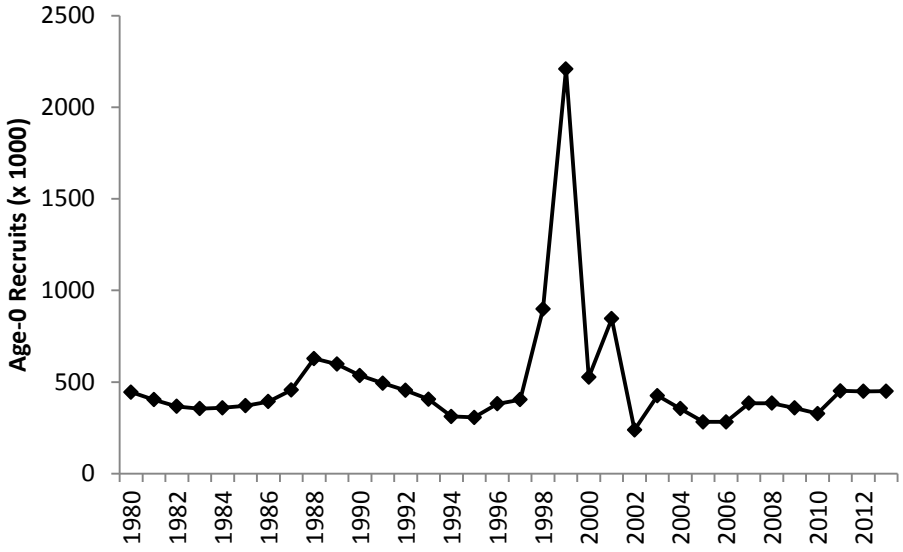

Figure 33. Time series of estimated age-0 recruits of rougheye/blackspotted rockfish on the U.S. west coast, 1980-2013(from Hicks et al. 2013).

Fishing Mortality

Rougheye rockfish are not often targeted by a specific fishery, but are desirable and marketable, thus are typically retained when captured. They are often captured in bottom trawl, mid-water trawl, and longline fisheries. Small numbers have been observed in pot, shrimp, and recreational fisheries.

After many attempts to start trawl fisheries off the west coast of the United States in the late 1800s, the availability of the otter trawl and the diesel engine in the mid-1920s helped the trawl fisheries expand (Douglas 1998). Trawl fisheries really became established during World War II when demand increased for shark livers and bottomfish. A mink food fishery also developed during World War II (Jones and Harry 1960). Foreign fleets began fishing for rockfish in the mid-1960s until the EEZ was implemented in 1977 (Rogers 2003b). Since 1977, landings of rockfish were high until management restrictions were implemented in 2000. Longline catches of rougheye rockfish are present from the turn of the century and continue in recent years, targeting sablefish and halibut.

A long-term directed fishery has not occurred for rougheye rockfish and historical discarding practices are not well known. Rougheye rockfish inhabit deeper water as adults, which were fished less often historically.

Throughout the 1980s and 1990s exploitation rates (1-SPR) were mostly above target levels (Figure 34). Recent exploitation rates on rougheye rockfish were predicted to be near target levels.

While stock-specific OFLs/ABCs were not historically set for rougheye rockfish specifically, the reauthorized Magnuson-Stevens Act of 2006 and FMP Amendment 23 required OFLs for all species in a management plan, including those managed in stock complexes. The first OFL contributions were calculated using DB-SRA and provided in 2011. The 2015 and beyond OFLs are projected from the 2013 assessment. Recent catches since 2002 have been above the new 2015 OFL since 2008 (Figure 35).

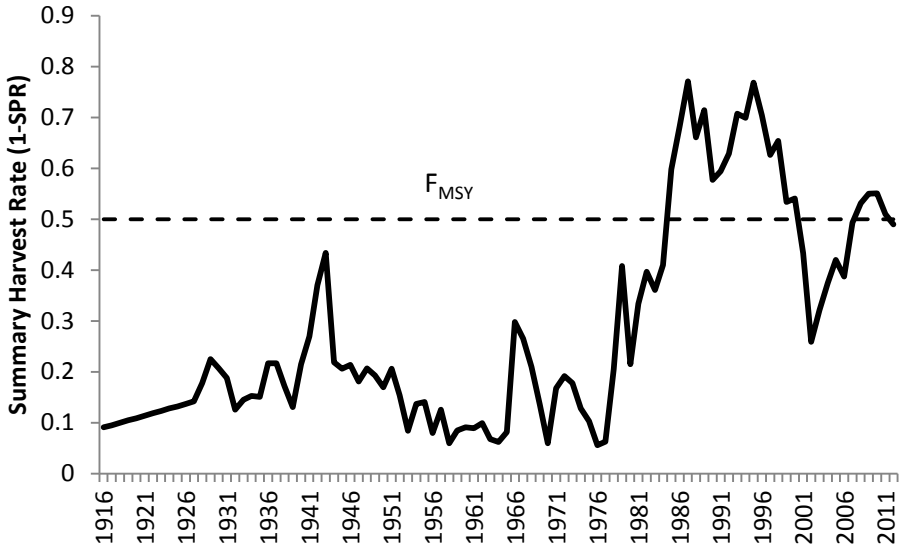

Figure 34. Time-series of estimated summary harvest rate for the west coast stocks of rougheye and blackspotted rockfish, 1916-2012. The dotted line is the harvest rate at the overfishing F_{MSY} proxy.

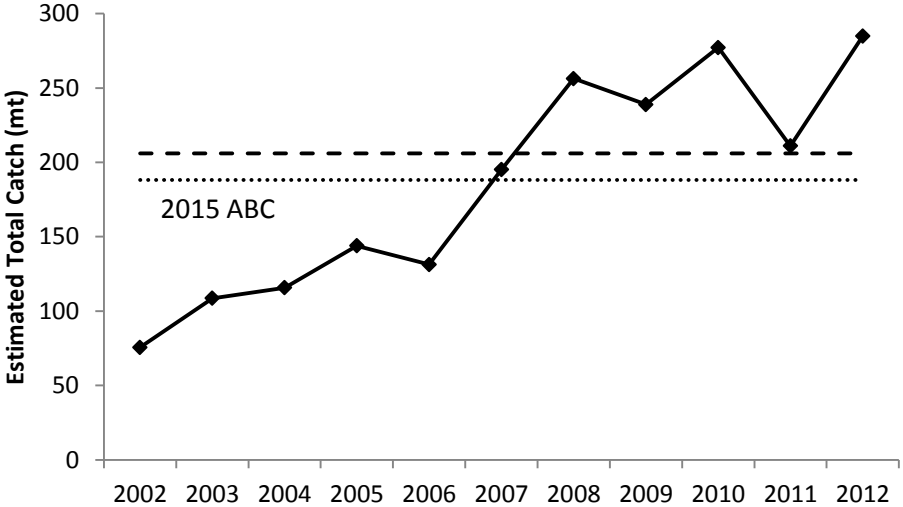

Figure 35. Estimated coastwide total annual catch of rougheye and blackspotted rockfish in 2002-2012 relative to the proposed 2015 OFLs and 2015 ABCs (summed north and south of 40º10' N lat. to compare to coastwide catches).

Sharpchin Rockfish

Distribution and Life History

Sharpchin rockfish (*Sebastes zacentrus*) range from the western Aleutian Islands (Attu Is.) to Southern California, though the core range is northern California to the Gulf of Alaska in waters between 100 m and 300 m (Love, *et al.* 2002). There is no indication of population structure in sharpchin rockfish. Sharpchin rockfish is a smaller-sized rockfish that inhabits waters up to 500 m, typically over muddy-rock habitats.

Mitochondrial DNA analyses indicate sharpchins are related mostly to harlequin, Puget Sound, and pygmy rockfishes (Love, *et al.* 2002).

Sharpchin rockfishes live to at least 58 years (Love, *et al.* 2002). Females attain a larger size than males with a reported maximum size of 45 cm (Love, *et al.* 2002). Off Oregon and Washington, the size at 50% maturity for females is 22cm with all females being mature at 30 cm. The size at 50% maturity is larger for samples farther north with 25 cm and 28 cm reported off British Columbia and the Gulf of Alaska, respectively. Larval releases occur from March to June off California and Oregon and during July off British Columbia.

Sharpchin eat a variety of prey including krill, shrimps, gammarid amphipods, copepods, and small fishes.

Stock Status and Management History

Sharpchin rockfish are managed in the northern and southern Slope Rockfish complexes.

A new data-moderate assessment of sharpchin rockfish was conducted in 2013, which indicated the stock was healthy with a depletion of 89% at the start of 2013 (Cope, *et al.* 2014). The SSC recommended the 2013 assessment be used for setting harvest specifications and upgraded the stock from a category 3 to a category 2 stock. The 2015 and 2016 OFLs are 382 and 372 mt, respectively. The coastwide OFLs were apportioned 80% to the north of 40º10' N lat. and 20% to the south to determine the OFL contributions to the Slope Rockfish complexes based on swept area biomass estimates from the triennial survey.

Stock Productivity

A high steepness of 0.95 was estimated in the 2013 sharpchin rockfish assessment, which is particularly high for a rockfish.

Sharpchin have a relatively low productivity (P = 1.36) and a relatively high vulnerability (V = 2.05) to overfishing based on the PSA scores derived prior to the 2013 assessment (Table 2).

Fishing Mortality

Sharpchin are not a major commercial target, though they are taken in large numbers and commonly seen in trawls that target Pacific ocean perch. They are taken most commonly of Oregon and Washington with POP, darkblotched, splitnose, and yellowmouth rockfish. While they are common in west coast bottom trawl catches, their smaller size makes them less valuable than the larger rockfish species. They are rarely taken in recreational fisheries.

1.1.5.4 Other Flatfish

The Other Flatfish complex contains most of the flatfish species managed in the Groundfish FMP (with the exception of arrowtooth flounder, Dover sole, English sole, petrale sole, and starry founder). These species include butter sole (*Isopsetta isolepis*), curlfin sole (*Pleuronichthys decurrens*), flathead sole (*Hippoglossoides elassodon*), Pacific sanddab (*Citharichthys sordidus*), rex sole (*Glyptocephalus zachirus*), rock sole (*Lepidopsetta bilineata*), and sand sole (*Psettichthys melanostictus*).

Pacific Sanddabs

Distribution and Life History

Pacific sanddab (*Citharichthys sordidus*) is a left-eyed flounder of the family Paralichthyidae and is widely distributed along the Pacific west coast from the Bering Sea to Cabo San Lucas, Baja California (Arora 1951; Hart 1988; Kramer and O'Connell 1995; Love, *et al.* 2005; Miller and Lea 1972; Rackowski and Pikitch 1989). Early studies reported that the species is the most abundant in the north-central portion of California from Eureka to San Francisco, but were also fairly common in southern California (Rackowski and Pikitch 1989). Early studies also reported that the species is usually found at depths between 18m and 275m and most commonly found at depths between 35m and 95m (Arora 1951; Demory 1971; Hart 1988; Miller and Lea 1972; Roedel 1953). On Oregon's continental shelf, Pacific sanddab is the most abundant small flatfish on sandy-bottom in the depths between 74 and 102 m (Pearcy 1978). Young Pacific sanddab (ages 0 and 1) are also found to be concentrated in the same depth range (Donohoe 2000). Pacific sanddab was also found to be relatively more abundant in shallow waters at higher latitudes (Chamberlain 1979).

Pacific sanddab are generally not considered a primary target for commercial fisheries along the U.S. west coast, but they are nevertheless highly prized by the commercial and recreational fisheries for their excellent edibility (CDFG 2001), and have long been an important component of the nearshore flatfish fishery, commanding a high price in fresh fish markets (Arora 1951). Commercial catches of Pacific sanddab were mostly from bottom trawl fisheries, and there is a long history of catches. Recreational catches of Pacific sanddab are from the hook and line fishery and most of this catch is from southern California waters. Some recreational anglers target Pacific sanddab in southern California, mostly from small boats and CPFVs (CDFG 2001).

Pacific sanddabs can growth to 35cm in length. They are sexually dimorphic, with females attaining larger sizes than males. Analysis of growth rates for both sexes between the southern and northern areas (divided at the California-Oregon border at 42º N lat.) showed no significant difference in growth rates for both sexes between the two areas.

There are no genetic or tagging studies informing stock structure of Pacific sanddab along the U.S. Pacific coast. Bottom trawl surveys in recent years (both NWFSC and triennial surveys) showed that Pacific sanddab are commonly caught along the coastal areas of all U.S. waters.

Pacific sanddabs play an important role in the coastal ecosystems in the U.S. waters, particularly because they are a relatively abundant species and are important prey items to a wide range of marine predators, including piscivorous fishes, sea mammals, and sea birds (Field, *et al.* 2006; Levin, *et al.* 2006).

Stock Status and Management History

Pacific sanddabs have been under federal management since the implementation of the groundfish FMP in 1982 and managed within the Other Flatfish complex of unassessed flatfish species. The management performance in recent years for Pacific sanddab has been good; the average 2005-2012 total annual catch has been about 23% of the stock's ACL/OY contribution to the Other Flatfish complex.

A coastwide assessment of Pacific sanddab was done in 2013 indicating the stock was at 95.5% of its unfished biomass (He, *et al.* 2013). The SSC recommended in 2013 that this assessment not be used for deciding harvest specifications since the scale of the stock's biomass could not be adequately estimated. However, the status estimate was precise enough to conclude the stock was well above the B_{MSY} proxy of $B_{25\%}$. The SSC recommended the stock continue to be categorized as a category 3 stock given the OFL

estimate from the assessment depends on the biomass estimate, which was not estimated with adequate precision. The OFL estimate is therefore based on the DBSRA method used since 2011. The 2015 and 2016 OFL contribution of Pacific sanddab to the Other Flatfish complex is 4,801 mt.

Stock Productivity

A steepness prior of 0.8 was used in the 2013 assessment. Annual recruitment deviations were estimated between 1966 and 2011. Annual recruitment deviations were treated in a log-normal distribution with σ_R fixed at 0.45. Low recruitments occurred from the early 2000s to the mid-2000s. Recruitments in recent years have been at or above the long term average, with a strong recruitment in 2010.

The PSA productivity score of 2.4 indicates a very high relative productivity of Pacific sanddabs. This leads to a very low vulnerability (V = 1.25) of potential overfishing for the stock.

Fishing Mortality

There is a long history of commercial catches on Pacific sanddab (Barss 1976). Sette and Fiedler (1928) reported that landings of flatfish in California waters were first reported in 1892. The first available landings of Pacific sanddab in Oregon waters were in 1942 (Karnowski, *et al.* 2012). There were also commercial catches for mink foods in both California and Oregon waters in the 1950s and 1960s (Best 1959; Best 1961; Nitsos and Reed 1965). Reported total catches of Pacific sanddab were high in the late 1920s. And there was an increasing trend from the 1960s and reached the highest catch level in the late 1990s. Discards of Pacific sanddab in commercial trawl fisheries were high, primarily due to its small size (Sampson 2002). Catches of the species in recent years were in the range of 200 mt and 400 mt, well below the OFL contribution of the stock to the Other Flatfish complex of 4,801 mt.

Rex Sole

Distribution and Life History

Stock Status and Management History

Stock Productivity

Fishing Mortality

1.1.5.5 Other Fish

The Other Fish stock complex contains all the unassessed groundfish FMP species that are neither rockfish (family *Scorpaenidae*) nor flatfish, except for spiny dogfish which was newly assessed in 2011. These species include big skate (*Raja binoculata*), California skate (*Raja inornata*), leopard shark (*Triakis semifasciata*), soupfin shark (*Galeorhinus zyopterus*), spiny dogfish (*Squalus acanthias*), finescale codling (*Antimora microlepis*), Pacific grenadier (*Coryphaenoides acrolepis*), ratfish

(*Hydrolagus colliei*), cabezon (*Scorpaenichthys marmoratus*) (off Washington), and kelp greenling (*Hexagrammos decagrammus*).

A new assessment of spiny dogfish was done in 2011 indicating a healthy status with a spawning biomass depletion of 63% of its unfished biomass in 2011 (Gertseva and Taylor 2011). The spiny dogfish contribution to the complex 2013 and 2014 OFLs were projected from the new assessment using the proxy $F_{45\%}$ F_{MSY} harvest rate. The SSC categorized the stock as a category 2 stock since recruitments were not estimated.

The Other Fish complex is currently an aggregation of species with different life history characteristics and depth distributions. The historical catch of many of the component stocks is poorly understood with some stocks missing any record of landings on the west coast. The SSC recommended in 2012 this complex be re-evaluated for the next management cycle and to give consideration to adding new species related to the component species of the complex into the FMP and re-grouping species with similar vulnerabilities, ecological interactions, and distributions.

The Council proposes reconfiguring the Other Fish complex for 2015 and beyond to be comprised only of kelp greenling stocks coastwide, the Washington stock of cabezon, and leopard shark. The other species currently managed in the Other Fish complex are proposed to be designated as Ecosystem Component species.

1.1.6 Ecosystem Component Species

1.2 The Groundfish Harvest Specification Framework and Harvest Specifications for Fisheries in 2015 and Beyond

West coast groundfish stocks are managed under a harvest specification framework that considers scientific and management uncertainties. The first specification decided is the overfishing limit (OFL), which is the maximum sustainable yield (MSY) estimated for the stock and the legal harvest limit beyond which constitutes overfishing. The OFL is determined either by applying the harvest rate estimated to result in a biomass capable of sustaining MSY (i.e., F_{MSY}) recommended by the Council's Scientific and Statistical Committee (SSC) to an estimate of exploitable biomass in the case of assessed stocks or through an approved data-poor method (e.g., depletion-corrected average catch (DCAC) or depletion-based stock reduction analysis (DBSRA)) in the case of unassessed stocks. Regardless of the method or data informing the calculation of an OFL, there is scientific uncertainty in the estimation of an OFL. The Pacific Coast Groundfish Fishery Management Plan (FMP) mandates a precautionary buffer to address this uncertainty by prescribing an acceptable biological catch (ABC) harvest level that is less than the OFL. A further reduction from the ABC can be specified when setting an annual catch limit (ACL) that accounts for management uncertainty, socioeconomic considerations, ecological considerations, conservation objectives, and/or other considerations the Council and NMFS wish to address. Since the ACL can be set equal to the ABC, the ABC is the highest harvest level that can be considered for west coast groundfish stocks.

The following sections describe in detail the science informing 2015 and 2016 harvest specification decisions. Table 8 summarizes the 2014, 2015, and 2016 harvest specifications for west coast groundfish stocks.

Table 8. Status quo 2014 harvest specifications and final preferred overfishing limits (OFLs in mt), acceptable biological catches (ABCs in mt), annual catch limits (ACLs in mt), and ecosystem component species designations for west coast groundfish stocks and stock complexes in 2015 and 2016 (stocks with new assessments in bold).

Stock	2014			2015			2016		
	OFL	ABC	ACL	OFL	ABC	ACL	OFL	ABC	ACL
OVERFISHED STOCKS									
BOCACCIO S. of 40^{0}10'	**881**	**842**	**337**	**1,444**	**1,380**	**349**	**1,351**	**1,291**	**362**
CANARY	741	709	119	733	701	122	729	697	125
COWCOD S. of 40^{0}10'	**12**	**9**	**3**	**67**	**60**	**10**	**66**	**59**	**10**
DARKBLOTCHED	**553**	**529**	**330**	**574**	**549**	**338**	**580**	**554**	**346**
PACIFIC OCEAN PERCH	838	801	153	842	805	158	850	813	164
PETRALE SOLE	**2,774**	**2,652**	**2,652**	**2,946**	**2,816**	**2,816**	**3,044**	**2,910**	**2,910**
YELLOWEYE	51	43	18	52	47	18	52	47	19
NON-OVERFISHED STOCKS									
Arrowtooth Flounder	6,912	5,758	5,758	6,599	5,497	5,497	6,396	5,328	5,328
Black Rockfish (OR-CA)	1,166	1,115	1,000	1,176	1,124	1,000	1,183	1,131	1,000
Black Rockfish (WA)	428	409	409	421	402	402	423	404	404
Cabezon (CA)	165	158	158	161	154	154	158	151	151
Cabezon (OR)	49	47	47	49	47	47	49	47	47
California scorpionfish	122	117	117	119	114	114	117	111	111
Chilipepper S. of 40º10'	1,722	1,647	1,647	1,703	1,628	1,628	1,694	1,619	1,619
Dover Sole	77,774	74,352	25,000	66,871	63,929	50,000	59,221	56,615	50,000
English Sole	**5,906**	**5,646**	**5,646**	**12,092**	**11,040**	**11,040**	**8,493**	**7,754**	**7,754**
Lingcod N of 40º10'	3,162	2,878	2,878	3,010	2,830	2,830	2,891	2,719	2,719
Lingcod S. of 40º10'	1,276	1,063	1,063	1,205	1,004	1,004	1,136	946	946
Longnose skate	2,816	2,692	2,000	2,449	2,341	2,000	2,405	2,299	2,000
Longspine Thornyhead (coastwide)	**3,304**	**2,752**	**NA**	**5,007**	**4,171**	**NA**	**4,763**	**3,968**	**NA**
Longspine Thornyhead N of 34°27'	**NA**	**NA**	**1,958**	**NA**	**NA**	**3,170**	**NA**	**NA**	**3,015**
Longspine Thornyhead S. of 34°27'	**NA**	**NA**	**347**	**NA**	**NA**	**1,001**	**NA**	**NA**	**952**
Pacific Cod	3,200	2,221	1,600	3,200	2,221	1,600	3,200	2,221	1,600

Stock	2014			2015			2016		
	OFL	**ABC**	**ACL**	**OFL**	**ABC**	**ACL**	**OFL**	**ABC**	**ACL**
Sablefish (coastwide)	7,158	6,535	NA	7,857	7,173	NA	8,526	7,784	NA
Sablefish N of 36°	NA	NA	4,349	NA	NA	4,793	NA	NA	5,241
Sablefish S. of 36°	NA	NA	1,560	NA	NA	1,719	NA	NA	1,880
Shortbelly	6,950	5,789	50	6,950	5,789	50	6,950	5,789	50
Shortspine Thornyhead (coastwide)	**2,310**	**2,208**	**NA**	**3,203**	**2,668**	**NA**	**3,169**	**2,640**	**NA**
Shortspine Thornyhead N of 34°27'	**NA**	**NA**	**1,525**	**NA**	**NA**	**1,745**	**NA**	**NA**	**1,726**
Shortspine Thornyhead S. of 34°27'	**NA**	**NA**	**393**	**NA**	**NA**	**923**	**NA**	**NA**	**913**
Spiny dogfish	2,950	2,024	NA	2,523	1,912	1,912	2,503	1,897	1,897
Splitnose S. of $40^{0}10'$	1,747	1,670	1,670	1,794	1,715	1,715	1,826	1,746	1,746
Starry Flounder	1,834	1,528	1,528	1,841	1,534	1,534	1,847	1,539	1,539
Widow	4,435	4,212	1,500	4,137	3,929	2,000	3,990	3,790	2,000
Yellowtail N of $40^{0}10'$	**4,584**	**4,382**	**4,382**	**12,281**	**11,213**	**11,213**	**11,647**	**10,634**	**10,634**
STOCK COMPLEXES									
Nearshore Rockfish North	110	94	94	90	79	69	90	79	69
Shelf Rockfish North	2,195	1,932	968	2,208	1,944	1,944	2,217	1,953	1,952
Slope Rockfish North a/	1,553	1,414	1,160	1,804	1,669	1,669	1,818	1,683	1,683
Nearshore Rockfish South	1,160	1,001	990	1,309	1,165	1,114	1,317	1,163	1,006
Shelf Rockfish South	1,913	1,620	714	1,914	1,625	1,624	1,915	1,626	1,625
Slope Rockfish South a/	685	622	622	806	698	687	807	699	689
Other Flatfish	10,060	6,982	4,884	11,298	8,620	8,620	9,948	7,496	7,496
Other Fish	6,802	4,697	4,697						
Cabezon (WA)	*b/*	*b/*	*b/*	*4.5*	*3.7*	*3.7*	*4.8*	*4.0*	*4.0*
Kelp greenling (CA)	*118.9*	*82.5*	*NA*	*118.9*	*99.2*	*99.2*	*118.9*	*99.2*	*99.2*
Kelp greenling (OR)	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*
Kelp greenling (WA)	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*	*b/*
Leopard shark	*167.1*	*139.4*	*139.4*	*167.1*	*139.4*	*139.4*	*167.1*	*139.4*	*139.4*

Stock	2014			2015			2016		
	OFL	ABC	ACL	OFL	ABC	ACL	OFL	ABC	ACL
ECOSYSTEM COMPONENT SPECIES									
Big skate	*458.0*	*317.9*	*NA*	No harvest specifications for an EC species					
California skate	*86.0*	*59.7*	*NA*	No harvest specifications for an EC species					
Aleutian skate	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
Roughtail/black skate	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
Bering/sandpaper skate	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
All other skates	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
Pacific grenadier	*1,519.0*	*1,054.2*	*NA*	No harvest specifications for an EC species					
Giant grenadier	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
All other grenadiers	*c/*	*c/*	*c/*	No harvest specifications for an EC species					
Ratfish	*1,441.0*	*1,000.1*	*NA*	No harvest specifications for an EC species					
Soupfin shark	*61.6*	*42.8*	*NA*	No harvest specifications for an EC species					
Finescale codling	*b/*	*b/*	*b/*	No harvest specifications for an EC species					

a/ 2015 and 2016 harvest specifications assume the status quo stock complex structure. See "Slope RF" worksheet for stock complex alternatives.

b/ No OFL or ABC contribution for these stocks given the lack of an approved method.

c/ No harvest specifications adopted since these species are not currently managed in the FMP.

1.2.1 Overfishing Limits

The OFL is the MSY harvest level associated with the current stock abundance and is the estimated or proxy MSY harvest level, which is the harvest threshold above which overfishing occurs. The methods for determining OFL are based on the best available science and the recommendation of the SSC; therefore, alternatives are not developed for this reference point.

Amendment 23, which was adopted in December 2010 and implemented in 2011, revised the descriptions of species categories used in the development of harvest specifications. The first category (category 1) includes those species with relatively data-rich quantitative stock assessments that are developed on the basis of catch-at-age, catch-at-length, or other data. Recruitments are estimated for category 1 stocks. OFLs and overfished/rebuilding thresholds can generally be calculated for these species. The second category (category 2) includes species for which some biological indicators are available yet data informing an assessment are limited. Category 2 assessments include a new class of data-moderate assessments where catch data and one or more indices of abundance inform the status and estimated biomass of the stock, but age and length compositional data are excluded. This type of assessment allows for a more expeditious assessment review than the category 1 benchmark assessments, which require a rigorous review process[8], thus enabling more stocks to be assessed in an assessment cycle. Two data-moderate assessment models were approved for the 2013 assessment cycle (which informs management decision-making for 2015 and beyond): extended depletion-based stock reduction analysis (XDBSRA) and extended simple stock synthesis (exSSS). The third category (category 3) includes minor species which are caught and where the only available information is catch-based data. When setting the 2015 and 2016 OFLs for category 1 or 2 species, the F_{MSY} harvest rate or a proxy was applied to the estimated exploitable biomass. A policy of using a default harvest rate as a proxy for the fishing mortality rate that is expected to achieve MSY is also referred to as the F_{MSY} control rule or maximum fishing mortality threshold (MFMT) harvest rate. Catch-based methods are generally used to determine the OFL for category 3 species.

New stock assessments, stock assessment updates and rebuilding analyses recommended by the SSC as the "best available science" and suitable for use in setting biennial harvest specifications were approved by the Council for setting the 2015 and 2016 biennial harvest specifications. Eight full stock assessments, eight data-moderate stock assessments, and one stock assessment update were prepared to inform the 2015 and 2016 harvest specifications. Full stock assessments, those that consider the appropriateness of the assessment model and that revise the model as necessary, were prepared for the following stocks: aurora rockfish, cowcod south of 34º27' N lat., darkblotched rockfish, longspine thornyhead, petrale sole, Pacific sanddabs, rougheye/blackspotted rockfish (analyzed as a complex of two stocks), and shortspine thornyhead. These were the first west coast assessments for aurora rockfish, rougheye/blackspotted rockfish, and Pacific sanddabs. OFLs were estimated for seven of these eight stocks; the exception being Pacific sanddabs where the assessment was recommended to inform stock status but not estimates of current biomass or OFL. Eight stocks were assessed using the approved data-moderate models: brown rockfish, China rockfish, copper rockfish, English sole, rex sole, sharpchin rockfish, stripetail rockfish, and yellowtail rockfish north of 40º10' N lat. OFLs were estimated for seven of these eight stocks; the exception being stripetail rockfish where the assessment was recommended to inform stock status but not estimates of current biomass or OFL. A stock assessment update, which incorporates new data through existing models without changing the model, was prepared for bocaccio. For stocks that did not have new assessments or an update prepared, the Council considered OFLs projected in the most recent stock assessment or update or estimated using historical landings data.

[8] The review process for new benchmark assessments includes a Stock Assessment Review (STAR) panel review and a subsequent review by the Council's Scientific and Statistical Committee (SSC). Only those assessments that are endorsed by the SSC are considered for formal adoption in the Council process.

Two data-poor methods, depletion-corrected average catch (DCAC) and depletion-based stock reduction analysis (DBSRA), used to determine most of the category 3 OFLs since 2011 were recommended for use in determining 2015 and 2016 OFLs for unassessed stocks, where there was enough harvest data to use these methods. Average historical catch was used to determine OFLs for stocks where the historical catches were too sparse to use DCAC or DBSRA methods.

For 2015 and 2016, default harvest rates were used as a proxy for the fishing mortality rate that is expected to achieve the MSY (F_{MSY}). A proxy is used because there is insufficient information for most Pacific Coast groundfish stocks to establish a species-specific F_{MSY}. In 2015 and 2016, the following default harvest rate proxies, based on SSC recommendations, were used: $F_{30\%}$ for assessed flatfish, $F_{40\%}$ for Pacific whiting, $F_{50\%}$ for rockfish (including thornyheads), $F_{50\%}$ for spiny dogfish, and $F_{45\%}$ for other groundfish such as sablefish and lingcod. The FMP allows default harvest rate proxies to be modified as scientific knowledge improves for a particular species.

Table 9 compares the 2015 and 2016 OFLs with the 2014 OFL for stocks managed with stock-specific harvest specifications. The OFLs are specified for all the stocks and stock complexes actively managed in the fishery, as required by the FMP. The 2014 OFLs in Table 9 were projected from stock assessments done in 2011 or earlier. The 2015 and 2016 OFLs in Table 9 include the results of stock assessments done in 2013. The OFL contributions for the cowcod stock south of 40º10' N lat. are shown as area-specific OFL contributions because they were derived using different methodologies. The Conception area OFLs for cowcod were projected from the 2013 rebuilding analysis (Dick and MacCall 2013a) and the Monterey area OFLs were derived using DBSRA. Although the area-specific OFL contributions for cowcod are displayed in Table 9, the OFL is specified for the entire stock south of 40°10' N lat. and not for each area. The 2014 OFL and 2015 and 2016 OFL contributions of individual stocks within the six Rockfish complexes, the Other Flatfish complex, and the Other Fish complex are shown in italics in **Error! Reference source not found.**. The OFL contributions for the individual stocks were summed to derive the complex OFLs. **Error! Reference source not found.** assumes the status quo stock complex structure for the slope rockfish complexes. However, the Council is contemplating a restructuring of these complexes. The Council also recommended restructuring the status quo Other Fish complex by removing spiny dogfish and managing that stock with stock-specific harvest specifications (Table 9), designating the skates, grenadiers, soupfin shark, finescale codling, and ratfish stocks as Ecosystem Component species, and managing kelp greenling, the Washington stock of cabezon, and leopard shark in a reconfigured Other Fish complex.

The preferred 2015 and 2016 OFLs for west coast groundfish stocks and stock complexes used the same policies (e.g., F_{MSY} harvest rates and methodologies) used to determine the 2014 OFLs (i.e., No Action) with the following exceptions:

- The spiny dogfish F_{MSY} proxy harvest rate was changed from $F_{45\%}$ to $F_{50\%}$;
- Spiny dogfish is recommended to be removed from the Other Fish complex and managed with stock-specific harvest specifications;
- The skates, Pacific grenadier, finescale codling, soupfin shark, and ratfish stocks are removed from the Other Fish complex and designated as Ecosystem Component species;
- Those endemic skate and grenadier species not previously managed in the FMP are recommended to be added to the FMP and designated as Ecosystem Component species; and
- Kelp greenling, the Washington stock of cabezon, and leopard shark are recommended for management in a new Shallow Roundfish complex (there is also an alternative to manage these stocks individually with stock-specific harvest specifications).

Table 9. Specified 2014 OFLs (i.e., No Action alternative) (mt) and preferred 2015 and 2016 OFLs (mt) for stocks managed with stock-specific harvest specifications (overfished stocks in CAPS, stocks with new assessments in bold, substock contributions to a stock OFL in italics (i.e., cowcod)).

Stock	2014 OFL	Category	2015 OFL	2016 OFL
OVERFISHED STOCKS				
BOCACCIO S. of 40^{0}10' N. lat.	**881**	**1**	**1,444**	**1,351**
CANARY	741	1	733	729
COWCOD S. of 40^{0}10' N. lat.	12		**66.6**	**66.1**
COWCOD (Conception)	**7**	**2**	***55.0***	***54.1***
COWCOD (Monterey)	5	3	*11.6*	*12.0*
DARKBLOTCHED	**553**	**1**	**574**	**580**
PACIFIC OCEAN PERCH	838	1	842	850
PETRALE SOLE	**2,774**	**1**	**2,946**	**3,044**
YELLOWEYE	51	2	52	52
NON-DEPLETED STOCKS				
Arrowtooth Flounder	6,912	2	6,599	6,396
Black Rockfish (OR-CA)	1,166	1	1,176	1,183
Black Rockfish (WA)	428	1	421	423
Cabezon (CA)	165	1	161	158
Cabezon (OR)	49	1	49	49
California scorpionfish	122	1	119	117
Chilipepper S. of 40^{0}10' N. lat.	1,722	1	1,703	1,694
Dover Sole	77,774	1	66,871	59,221
English Sole	**5,906**	**2**	**12,092**	**8,493**
Lingcod N. of 40º10' N. lat.	3,162	1	3,010	2,891
Lingcod S. of 40º10' N. lat.	1,276	2	1,205	1,136
Longnose skate	2,816	1	2,449	2,405
Longspine Thornyhead (coastwide)	**3,304**	**2**	**5,007**	**4,763**
Pacific Cod	3,200	3	3,200	3,200
Sablefish (coastwide)	7,158	1	7,857	8,526
Shortbelly	6,950	2	6,950	6,950
Shortspine Thornyhead (coastwide)	2,310	**2**	**3,203**	**3,169**
Spiny dogfish	2,950	2	2,523	2,503
Splitnose S. of 40^{0}10' N. lat.	1,747	1	1,794	1,826
Starry Flounder	1,834	2	1,841	1,847
Widow	4,435	1	4,137	3,990
Yellowtail N. of 40^{0}10' N. lat.	**4,584**	**2**	**12,281**	**11,647**
STOCK COMPLEXES				
Nearshore Rockfish North	110		88	88
Black and yellow	*0.01*	3	*0.01*	*0.01*
Blue (CA)	*27.4*	2	*27.4*	*27.7*
Blue (OR & WA)	*32.3*	3	*32.3*	*32.3*
Brown	***5.5***	**2**	***1.9***	***1.9***
Calico	-	3	-	-
China	***9.8***	**2**	***7.2***	***7.4***
Copper	***26.0***	**2**	***10.6***	***10.3***
Gopher	-	3	-	-
Grass	*0.7*	3	*0.7*	*0.7*
Kelp	*0.01*	3	*0.01*	*0.01*

Stock	2014 OFL	Category	2015 OFL	2016 OFL
Olive	*0.3*	3	*0.3*	*0.3*
Quillback	*7.4*	3	*7.4*	*7.4*
Treefish	*0.2*	3	*0.2*	*0.2*
Shelf Rockfish North	2,195		2,209	2,218
Bronzespotted	-	3	-	-
Bocaccio	*284.0*	3	*284.0*	*284.0*
Chameleon	-	3	-	-
Chilipepper	*129.6*	3	*128.2*	*127.5*
Cowcod	-	3	*0.4*	*0.4*
Flag	*0.1*	3	*0.1*	*0.1*
Freckled	-	3	-	-
Greenblotched	*1.3*	3	*1.3*	*1.3*
Greenspotted 40°10' to 42° N. lat.	*9.4*	2	*10.0*	*9.9*
Greenspotted N. of 42 N. lat. (OR & WA)	*6.1*	3	*6.1*	*6.1*
Greenstriped	*1,268.3*	2	*1,281.9*	*1,292.0*
Halfbanded	-	3	-	-
Harlequin	-	3	-	-
Honeycomb	-	3	-	-
Mexican	-	3	-	-
Pink	*0.004*	3	*0.004*	*0.004*
Pinkrose	-	3	-	-
Puget Sound	-	3	-	-
Pygmy	-	3	-	-
Redstripe	*269.9*	3	*269.9*	*269.9*
Rosethorn	*12.9*	3	*12.9*	*12.9*
Rosy	*3.0*	3	*3.0*	*3.0*
Silvergray	*159.4*	3	*159.4*	*159.4*
Speckled	*0.2*	3	*0.2*	*0.2*
Squarespot	*0.2*	3	*0.2*	*0.2*
Starry	*0.004*	3	*0.004*	*0.004*
Stripetail	*40.4*	3	*40.4*	*40.4*
Swordspine	*0.0001*	3	*0.0001*	*0.0001*
Tiger	*1.0*	3	*1.0*	*1.0*
Vermilion	*9.7*	3	*9.7*	*9.7*
Slope Rockfish North	1,553		1,804	1,818
Aurora	***15.4***	**1**	***17.4***	***17.5***
Bank	*17.2*	3	*17.2*	*17.2*
Blackgill	*4.7*	3	*4.7*	*4.7*
Redbanded	*45.3*	3	*45.3*	*45.3*
Rougheye/Blackspotted	***71.1***	**2**	***201.9***	***206.8***
Sharpchin	***214.5***	**2**	***305.6***	***297.6***
Shortraker	*18.7*	3	*18.7*	*18.7*
Splitnose	*974.1*	1	*1,000.6*	*1,018.2*
Yellowmouth	*192.4*	3	*192.4*	*192.4*
Nearshore Rockfish South	1,160		1,313	1,288
Shallow Nearshore Species	NA	NA	NA	NA
Black and yellow	*27.5*	3	*27.5*	*27.5*
China	***16.6***	**2**	***55.2***	***52.7***

Stock	2014 OFL	Category	2015 OFL	2016 OFL
Gopher (N of Pt. Conception)	*153.0*	1	*148.0*	*144.0*
Gopher (S of Pt. Conception)	*25.6*	3	*25.6*	*25.6*
Grass	*59.6*	3	*59.6*	*59.6*
Kelp	*27.7*	3	*27.7*	*27.7*
Deeper Nearshore Species	NA	NA	NA	NA
Blue (assessed area)	*187.8*	2	*188.6*	*190.3*
Blue (S of 34 ^{0}27' N. lat.)	*72.9*	3	*72.9*	*72.9*
Brown	***204.6***	**2**	***163.8***	***160.2***
Calico	-	3	-	-
Copper	***141.5***	**2**	***301.1***	***284.3***
Olive	*224.6*	3	*224.6*	*224.6*
Quillback	*5.4*	3	*5.4*	*5.4*
Treefish	*13.2*	3	*13.2*	*13.2*
Shelf Rockfish South	1,912.9		1,917.9	1,918.9
Bronzespotted	*3.6*	3	*3.6*	*3.6*
Chameleon	-	3	-	-
Flag	*23.4*	3	*23.4*	*23.4*
Freckled	-	3	-	-
Greenblotched	*23.1*	3	*23.1*	*23.1*
Greenspotted	*80.3*	2	*82.8*	*82.0*
Greenstriped	*232.7*	2	*235.1*	*237.0*
Halfbanded	-	3	-	-
Harlequin	-	3	-	-
Honeycomb	*9.9*	3	*9.9*	*9.9*
Mexican	*5.1*	3	*5.1*	*5.1*
Pink	*2.5*	3	*2.5*	*2.5*
Pinkrose	-	3	-	-
Pygmy	-	3	-	-
Redstripe	*0.5*	3	*0.5*	*0.5*
Rosethorn	*2.1*	3	*2.1*	*2.1*
Rosy	*44.5*	3	*44.5*	*44.5*
Silvergray	*0.5*	3	*0.5*	*0.5*
Speckled	*39.4*	3	*39.4*	*39.4*
Squarespot	*11.1*	3	*11.1*	*11.1*
Starry	*62.6*	3	*62.6*	*62.6*
Stripetail	*23.6*	3	*23.6*	*23.6*
Swordspine	*14.2*	3	*14.2*	*14.2*
Tiger	*0.04*	3	*0.04*	*0.04*
Vermilion	*269.3*	3	*269.3*	*269.3*
Yellowtail	*1,064.4*	3	*1,064.4*	*1,064.4*
Slope Rockfish South	685		806	807
Aurora	***26.1***	**1**	***74.3***	***74.3***
Bank	*503.2*	3	*503.2*	*503.2*
Blackgill	*134.0*	2	*137.0*	*140.0*
Pacific ocean perch	-	3	-	-
Redbanded	*10.4*	3	*10.4*	*10.4*
Rougheye/Blackspotted	***0.4***	**2**	***4.1***	***4.2***
Sharpchin	***9.8***	**2**	***76.4***	***74.4***

Stock	2014 OFL	Category	2015 OFL	2016 OFL
Shortraker	*0.1*	3	*0.1*	*0.1*
Yellowmouth	*0.8*	3	*0.8*	*0.8*
Other Flatfish	10,060		11,298	9,948
Butter sole	*4.6*	3	*4.6*	*4.6*
Curlfin sole	*8.2*	3	*8.2*	*8.2*
Flathead sole	*35.0*	3	*35.0*	*35.0*
Pacific sanddab	*4,801.0*	**3**	*4,801.0*	*4,801.0*
Rex sole	***4,371.5***	**2**	***5,609.0***	***4,259.0***
Rock sole	*66.7*	3	*66.7*	*66.7*
Sand sole	*773.2*	3	*773.2*	*773.2*
Other Fish a/	6,802	3	291	291
Cabezon (WA)	*b/*	3	*4.5*	*4.8*
Kelp greenling (CA)	*118.9*	3	*118.9*	*118.9*
Kelp greenling (OR)	*b/*	3	*b/*	*b/*
Kelp greenling (WA)	*b/*	3	*b/*	*b/*
Leopard shark	*167.1*	3	*167.1*	*167.1*

a/ Values for these specifications are the sum of known contributions of component stocks. The 2014 OFL is not comparable to the 2015 and 2016 OFLs since the Other Fish complex was restructured by designating most of the component species as Ecosystem Component species.

b/ No OFL contribution for these stocks given the lack of an approved method.

1.2.2 Acceptable Biological Catches

Scientific uncertainty in stock assessments is taken into consideration when setting harvest specifications. The ABC is an annual catch specification that is the stock or stock complex's OFL reduced by an amount associated with scientific uncertainty in estimating the OFL, which is calculated as the estimated exploitable biomass multiplied by FMSY. The SSC considers the uncertainty in estimating stock biomass and provided recommendations to the Council for quantifying this source of scientific uncertainty in groundfish stock assessments. A conceptual framework that factors in scientific uncertainty for stocks with quantitative assessments was implemented under Amendment 23. Under the framework, scientific uncertainty associated with estimating an OFL (sigma (σ)) is quantified by the SSC, and the percentage reduction that defines the scientific uncertainty buffer and the ABC can be determined by translating the estimated σ to a range of overfishing probability (P*) values. Each P* value is then mapped to its corresponding buffer fraction. The Council then determines the preferred level of risk aversion by selecting an appropriate P* value, accordingly. In cases where the P* approach is used, the upper limit of P* values considered is 0.45.

The 2014, 2015, and 2016 ABCs are annual catch specifications that are the stock or stock complex's OFL reduced by an amount associated with the scientific uncertainty in estimating the OFL. Under the FMP harvest specification framework, scientific advice that is relatively uncertain will result in ABCs that are relatively lower, all other things being equal (i.e., a precautionary reduction in catch will occur due purely to scientific uncertainty in estimating the OFL). The ABC is the catch level that ACLs may not exceed. As explained in more detail below, the SSC recommended a two-step approach referred to as the P* approach for determining ABCs. In the P* approach, the SSC determines the amount of scientific uncertainty associated with estimating the OFL in stock assessments, referred to as the sigma (σ) value. Since the OFL is estimated by applying the harvest rate estimated or assumed to produce MSY (i.e., F_{MSY}) to the exploitable biomass and since assumed proxy F_{MSY} harvest rates by taxa are currently used to estimate the OFL, the variance in estimating biomass is the metric used for determining sigma. The Council chooses its preferred level of risk of overfishing, which is designated as the overfishing probability[9] (P*) (see Section 1.2.2.1). The scientists then apply the P* value to the sigma value to determine the amount by which the OFL is reduced to establish the ABC. The SSC's recommendations for sigma and the reductions from OFL associated with different P* values are science-based recommendations; therefore, alternatives to these values are not analyzed.

The SSC assigned each species in the groundfish fishery to one of three categories based on the level of information available about the species. Table 10 shows the criteria used by the SSC to categorize stocks. The SSC's recommended sigma value for category 1 stocks is based on a statistical analysis of the variance within and among stock assessments. The meta-analysis used stock assessments from 17 data-rich stocks to determine the proxy sigma value for category 1 stocks. The general methodology used by the SSC subcommittees to assess among-assessment uncertainty was to compare previous stock assessments and stock assessment updates[10], and consider the logarithms of the ratios of the biomass estimates for each pair of assessments and their reciprocals using the last 20 years from an assessment. This provides a distribution of stock size differences in log-space and, if this variation is averaged over species, provides a general view of total biomass variation (represented as sigma - σ) that emerges among repeat assessments of stocks, while embracing a wide range of factors that affect variability in results.

[9] The overfishing probability (P*) is the probability of overfishing a stock or stock complex (i.e., exceeding the specified OFL) based solely on the scientific uncertainty in estimating the OFL.

[10] Stock assessment updates were excluded from the meta-analysis unless they were the most recent assessment conducted (in which case the original full assessment upon which the update was based was excluded from the meta-analysis) because of constraints imposed by the Terms of Reference for groundfish stock assessments on how much update assessments could change from the last full assessment.

The SSC indicated that biomass is most likely the dominant source of uncertainty; however, it is anticipated that other factors will need to be considered in the future.

Table 10. Criteria used by the SSC to categorize stocks based on the quantity and quality of data informing the estimate of OFL. Stock categories are used in deciding 2015 and 2016 ABCs that accommodate the uncertainty in estimating OFLs.

Category	Sub-category	Criteria
Category 1 - Data rich stocks. OFL based on F_{MSY} or F_{MSY} proxy from model output. ABC based on P* buffer.		
1	a	Reliable compositional (age and/or size) data sufficient to resolve year-class strength and growth characteristics. Only fishery-dependent trend information available. Age/size structured assessment model.
1	b	As in 3a, but trend information also available from surveys. Age/size structured assessment model.
1	c	Age/size structured assessment model with reliable estimation of the stock-recruit relationship.
Category 2 - Data moderate. OFL derived from model output (or natural mortality).		
2	a	M*survey biomass assessment (as in Rogers 1996).
2	b	Historical catches, fishery-dependent trend information only. An aggregate population model is fit to the available information.
2	c	Historical catches, survey trend information, or at least one absolute abundance estimate. An aggregate population model is fit to the available information.
2	d	Full age-structured assessment, but results are substantially more uncertain than assessments used in the calculation of the P* buffer. The SSC will provide a rationale for each stock placed in this category. Reasons could include that assessment results are very sensitive to model and data assumptions, or that the assessment has not been updated for many years.
Category 3 - Data poor. OFL derived from data-poor methods using historical catch.		
3	a	No reliable catch history. No basis for establishing OFL.
3	b	Reliable catch estimates only for recent years. OFL is average catch during a period when stock is considered to be stable and close to B_{MSY} equilibrium on the basis of expert judgment.
3	c	Reliable aggregate catches during period of fishery development and approximate values for natural mortality. Default analytical approach DCAC.
3	d	Reliable annual historical catches and approximate values for natural mortality and age at 50% maturity. Default analytical approach DBSRA.

Based on this analysis, the SSC recommended using the biomass variance statistic of $\sigma = 0.36$ for category 1 stocks. In cases where the stock biomass estimated in the most recent assessment has a variance greater than the variance estimated for that stock's category, the assessment's estimated biomass variance is used instead. The stock biomass estimated in the 2011 widow rockfish assessment was judged to have a greater variance than the sigma of 0.36 used for other category 1 stocks. In this case, the SSC recommended using a sigma value of 0.41 for deciding the widow rockfish ABC. Likewise, the 2013

assessment for aurora rockfish also indicated a greater variance than the sigma of 0.36 used for other category 1 stocks. In that case, a sigma value of 0.39 was chosen for deciding the aurora rockfish ABC. Each P* is mapped to its corresponding buffer fraction. The Council then recommends an appropriate P* value. When the P* approach is used, the upper limit of P* allowed by the FMP is 0.45.

Since there is greater scientific uncertainty for category 2 and 3 stocks relative to category 1 stocks, the scientific uncertainty buffer is generally greater than that recommended for category 1 stocks. The SSC recommended sigma values for category 2 and 3 stocks of 0.72 and 1.44, respectively (i.e., two and four times the sigma for category 1 stocks). The specific values of 0.72 and 1.44 were recommended by the SSC and considered to be the best available scientific information; however, the values are not based on a formal analysis of assessment outcomes and could change substantially when the SSC reviews additional analyses in future management cycles.

Table 11 shows the relationship between the values for sigma and the buffer for a range of values for P*.

1.2.2.1 Considerations for Deciding the Overfishing Probability (P*) When Specifying an Acceptable Biological Catch

The overfishing probability metric (P*) is technically defined as the probability of overfishing a stock based on the scientific uncertainty in estimating the OFL. This definition has generated much debate in the Council's harvest specification decision-making process. One side of the debate maintains the literal definition of the overfishing probability. The counter argument is that P* is the Council's level of risk tolerance that the OFL will be exceeded. Both arguments have merit but the latter argument is more tractable in the Council process and is a more accurate representation of how the P* value is decided.

The one problem with the literal definition of P* is that not all assessments are alike. The SSC recognizes this and has recommended a proxy value of sigma (0.36) for category 1 stocks, which are stocks that have assessments with estimated recruitment deviations (i.e., the strength of individual year classes is estimated). However, the SSC acknowledges that the proxy sigma for category 1 stocks may not represent the relative uncertainty of all category 1 stocks. For this reason, sigma is estimated in new category 1 assessments. If the estimated sigma is greater than the proxy value of 0.36, then the estimated sigma is used rather than the proxy value. However, the true scientific uncertainty is not estimated well in this process. Assessments vary greatly in the amount of uncertainty that is characterized in the assessment model. It is common that one or more parameters are either estimated outside the model or assumed based on the assessment scientist's best judgment. In such cases, the uncertainty associated with that parameter is also not estimated nor characterized in any way within the assessment. For instance, the 2011 sablefish assessment (Stewart, *et al.* 2011) appears to estimate current biomass with significant uncertainty. However, within that assessment many of the key parameters that affect the estimated biomass such as growth and natural mortality are explicitly estimated within the model[11]. The confidence interval associated with the ending year biomass estimate appears quite large relative to other assessments since the uncertainties associated with estimated growth and natural mortality are included within the overall assessment uncertainty. This compares to many other assessments, such as splitnose rockfish in 2009 (Gertseva, *et al.* 2009) or longspine thornyhead in 2013 (Stephens and Taylor 2013) where many parameters are assumed and fixed (e.g., natural mortality and steepness) and the estimated biomass variance appears smaller. However, this is not necessarily the case; more of the true uncertainty in estimated biomass is characterized in the sablefish assessment.

The spectrum of assessment approaches vary between fully Bayesian models with most key parameters estimated (e.g., sablefish in 2011) to deterministic models with most parameters fixed (e.g., longspine thornyhead in 2013). Within the spectrum are parameter estimations using informed or diffuse priors. Given this variety of approaches and the degree to which uncertainty is characterized, it is hard to pursue a formulaic approach where the P* decision hinges on the scientific uncertainty associated with estimating the OFL. For the most part, the relative uncertainty in estimating the OFL is addressed with the SSC's sigma specification. The Council's P* decision is therefore most appropriately considered as a risk assessment given many sources of uncertainty regarding the true state of nature for a stock.

1.2.2.2 Preferred 2015 and 2016 Acceptable Biological Catches

The ABCs for actively-managed stock complexes were determined by summing ABC values of the component stocks. Table 12 and Table 13 depict the potential alternative 2015 and 2016 ABCs, respectively for stocks and stock complexes across a range of P* values from 0.25 to 0.45. The Council

[11] Stock-recruitment steepness (h), another parameter that affects the estimate of biomass, is fixed at an assumed 0.6 in the 2011 sablefish assessment.

selected a P* value of 0.45 for most category 1 stocks. With a P* value of 0.45, a sigma value of 0.36 corresponds with a reduction of 4.4 percent from the OFL when deriving the ABC. For sablefish, the thornyheads, and assessed flatfish stocks, the Council selected a P* value of 0.4. The preferred 2015 and 2016 ABCs used the same policies (i.e., stock categories, sigma and P* values) used to determine the 2014 No Action ABCs with the following exceptions:

- Aurora rockfish was changed from a category 3 to a category 1 stock based on the new benchmark stock assessment adopted in 2013 (Hamel, *et al.* 2013). Therefore, the sigma of 1.44 for category 3 stocks was used to determine the 2014 ABC and a stock-specific sigma of 0.39 estimated for aurora rockfish was used to determine the 2015 and 2016 ABCs. The same P* of 0.45 was used to determine 2014, 2015, and 2016 ABCs;

- Rougheye/blackspotted rockfish was changed from a category 3 (for rougheye alone) to a category 2 stock based on the new benchmark stock assessment adopted in 2013 (Hicks, *et al.* 2013). The SSC decided to designate the rougheye/blackspotted assemblage of stocks as category 2 since the assessment was for the complex of these two hard to distinguish stocks;

- English sole and yellowtail rockfish north of 40º10' N lat. were changed from category 1 to category 2 stocks based on their new data-moderate assessments;

- Brown rockfish, China rockfish, copper rockfish, rex sole, and sharpchin rockfish were changed from category 3 stocks to category 2 stocks based on new data-moderate assessments for these stocks in 2013; and

- Shortspine thornyhead was changed from a category 1 stock to a category 2 stock based on the lack of age data in the new benchmark assessment for this stock in 2013 (Taylor and Stephens 2013). The same P* value of 0.4 was used to determine the 2014, 2015, and 2016 ABCs.

Table 11. Relationship between P* and the percent reduction of the OFL for deciding the 2015 and 2016 ABCs for category 1, aurora rockfish, widow rockfish, category 2, and category 3 stocks based on σ values of 0.36, 0.39, 0.41, 0.72, and 1.44, respectively.

P*	Assessment Uncertainty (σ)				
	Cat. 1	Aurora	Widow	Cat. 2	Cat. 3
	0.36	0.39	0.41	0.72	1.44
0.5	0	0	0	0	0
0.45	4.4%	4.8%	5.0%	8.7%	16.6%
0.44	5.3%		6.0%	10.3%	19.5%
0.43	6.2%		7.0%	11.9%	22.4%
0.42	7.0%		7.9%	13.5%	25.2%
0.41	7.9%		8.9%	15.1%	27.9%
0.4	8.7%	9.4%	9.9%	16.7%	30.6%
0.39	9.6%		10.8%	18.2%	33.1%
0.38	10.4%		11.8%	19.7%	35.6%
0.37	11.3%		12.7%	21.3%	38.0%
0.36	12.1%		13.7%	22.7%	40.3%
0.35	13.0%	14.0%	14.6%	24.2%	42.6%
0.34	13.8%		15.6%	25.7%	44.8%
0.33	14.6%		16.5%	27.1%	46.9%
0.32	15.5%		17.4%	28.6%	49.0%
0.31	16.3%		18.4%	30.0%	51.0%
0.3	17.2%	18.5%	19.3%	31.4%	53.0%
0.29	18.1%		20.3%	32.9%	54.9%
0.28	18.9%		21.3%	34.3%	56.8%
0.27	19.8%		22.2%	35.7%	58.6%
0.26	20.7%		23.2%	37.1%	60.4%
0.25	21.6%	23.1%	24.2%	38.5%	62.1%
0.24	22.5%		25.1%	39.9%	63.8%
0.23	23.4%		26.1%	41.3%	65.5%
0.22	24.3%		27.1%	42.6%	67.1%
0.21	25.2%		28.2%	44.0%	68.7%
0.2	26.1%	28.0%	29.2%	45.4%	70.2%
0.19	27.1%		30.2%	46.9%	71.8%
0.18	28.1%		31.3%	48.3%	73.2%
0.17	29.1%		32.4%	49.7%	74.7%
0.16	30.1%		33.5%	51.1%	76.1%
0.15	31.1%	33.2%	34.6%	52.6%	77.5%
0.14	32.2%		35.8%	54.1%	78.9%
0.13	33.3%		37.0%	55.6%	80.2%
0.12	34.5%		38.2%	57.1%	81.6%
0.11	35.7%		39.5%	58.7%	82.9%
0.1	37.0%	39.3%	40.9%	60.3%	84.2%
0.09	38.3%		42.3%	61.9%	85.5%
0.08	39.7%		43.8%	63.6%	86.8%
0.07	41.2%		45.4%	65.4%	88.1%
0.06	42.9%		47.1%	67.4%	89.3%
0.05	44.7%	47.3%	49.1%	69.4%	90.6%

Table 12. 2014 ABCs (mt) and a range of alternative 2015 ABCs (mt) varied by the probability of overfishing (P*) for west coast groundfish stocks (overfished stocks in CAPS; stocks with new assessments in bold; component stocks in stock complexes in italics).

Stock	Status Quo 2014 ABC	Range of Alternative 2015 ABCs				
		Overfishing Probability (P*)				
		0.45	0.40	0.35	0.30	0.25
OVERFISHED STOCKS						
BOCACCIO S. of 40^{0}10' N lat.	842	**1,380**	**1,318**	**1,256**	**1,195**	**1,132**
CANARY	709	701	669	638	607	575
COWCOD S. of 40^{0}10' N lat.	9	60	60	60	60	60
COWCOD (Conception)	*6*	***50***	***50***	***50***	***50***	***50***
COWCOD (Monterey)	*3*	*10*	*10*	*10*	*10*	*10*
DARKBLOTCHED	529	**549**	**524**	**499**	**475**	**450**
PACIFIC OCEAN PERCH	801	805	769	733	697	660
PETRALE SOLE	2,652	**2,816**	**2,690**	**2,563**	**2,439**	**2,310**
YELLOWEYE	43	47	43	39	35	32
NON-OVERFISHED STOCKS						
Arrowtooth Flounder	5,758	6,025	5,497	5,002	4,527	4,058
Black Rockfish (OR-CA)	1,115	1,124	1,074	1,023	974	922
Black Rockfish (WA)	409	402	384	366	349	330
Cabezon (CA)	158	154	147	140	133	126
Cabezon (OR)	47	47	45	43	41	38
California scorpionfish	117	114	109	104	99	93
Chilipepper S. of 40^{0}10' N lat.	1,647	1,628	1,555	1,482	1,410	1,335
Dover Sole	74,352	63,929	61,053	58,178	55,369	52,427
English Sole	5,646	**11,040**	**10,073**	**9,166**	**8,295**	**7,437**
Lingcod N of 42º N lat. (OR & WA)	1,897	1,814	1,733	1,651	1,572	1,488
Lingcod S. of 42º N lat. (CA)	2,044	2,115	1,930	1,756	1,589	1,425
Lingcod N of 40º10' N lat.	2,878	2,830	2,659	2,494	2,334	2,172
Lingcod S. of 40º10' N lat.	1,063	1,100	1,004	913	827	741
Longnose skate	2,692	2,341	2,236	2,130	2,027	1,920
Longspine Thornyhead (coastwide)	2,752	**4,571**	**4,171**	**3,795**	**3,435**	**3,079**
Pacific Cod	2,221	2,669	2,221	1,837	1,504	1,213
Sablefish (coastwide)	6,535	7,511	7,173	6,836	6,506	6,160
Shortbelly	5,789	6,345	5,789	5,268	4,768	4,274
Shortspine Thornyhead (coastwide)	2,208	**2,924**	**2,668**	**2,428**	**2,197**	**1,970**
Spiny dogfish	2,024	2,303.2	2,101.4	1,912.2	1,730.6	1,551.5
Splitnose S. of 40^{0}10' N lat.	1,670	1,715	1,638	1,561	1,485	1,406
Starry Flounder	1,528	1,681	1,534	1,395	1,263	1,132
Widow	4,212	3,929	3,729	3,532	3,337	3,138
Yellowtail N of 40^{0}10' N lat.	4,382	**11,213**	**10,230**	**9,309**	**8,425**	**7,553**

Stock	Status Quo 2014 ABC	Range of Alternative 2015 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
STOCK COMPLEXES						
Nearshore Rockfish North	94	79	69	60	53	45
Black and yellow	*0.0*	*0.011*	*0.009*	*0.008*	*0.006*	*0.005*
Blue (CA)	*25.0*	*25.0*	*22.9*	*20.8*	*18.8*	*16.9*
Blue (OR & WA)	*26.9*	*26.9*	*22.4*	*18.5*	*15.2*	*12.2*
Brown	***4.6***	***1.8***	***1.7***	***1.5***	***1.4***	***1.2***
Calico	*0.0*	-	-	-	-	-
China	***8.2***	***7.5***	***6.8***	***6.2***	***5.6***	***5.0***
Copper	***21.6***	***10.1***	***9.2***	***8.4***	***7.6***	***6.8***
Gopher	*0.0*	-	-	-	-	-
Grass	*0.5*	*0.5*	*0.5*	*0.4*	*0.3*	*0.2*
Kelp	*0.0*	*0.008*	*0.006*	*0.005*	*0.004*	*0.003*
Olive	*0.3*	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
Quillback	*6.2*	*6.2*	*5.1*	*4.2*	*3.5*	*2.8*
Treefish	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*
Shelf Rockfish North	1,932	1,943	1,712	1,505	1,317	1,142
Bronzespotted	*0.0*	-	-	-	-	-
Bocaccio	*236.9*	*236.9*	*197.1*	*163.0*	*133.5*	*107.6*
Chameleon	*0.0*	-	-	-	-	-
Chilipepper	*108.1*	*106.9*	*88.9*	*73.6*	*60.2*	*48.6*
Cowcod	*0.0*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
Flag	*0.1*	*0.06*	*0.05*	*0.04*	*0.03*	*0.03*
Freckled	*0.0*	-	-	-	-	-
Greenblotched	*1.1*	*1.1*	*0.9*	*0.7*	*0.6*	*0.5*
Greenspotted 40°10' to 42° N lat.	9	*8.5*	*7.7*	*7.0*	*6.4*	*5.7*
Greenspotted N of 42 N lat. (OR & WA)	*5.1*	*5.1*	*4.2*	*3.5*	*2.9*	*2.3*
Greenstriped	*1,158*	*1,170.3*	*1,067.8*	*971.7*	*879.4*	*788.3*
Halfbanded	*0.0*	-	-	-	-	-
Harlequin	*0.0*	-	-	-	-	-
Honeycomb	*0.0*	-	-	-	-	-
Mexican	*0.0*	-	-	-	-	-
Pink	*0.0*	*0.003*	*0.003*	*0.002*	*0.002*	*0.001*
Pinkrose	*0.0*	-	-	-	-	-
Puget Sound	*0.0*	-	-	-	-	-
Pygmy	*0.0*	-	-	-	-	-
Redstripe	*225.1*	*225.1*	*187.3*	*154.9*	*126.9*	*102.3*
Rosethorn	*10.8*	*10.8*	*9.0*	*7.4*	*6.1*	*4.9*
Rosy	*2.5*	*2.5*	*2.1*	*1.7*	*1.4*	*1.1*
Silvergray	*133.0*	*133.0*	*110.6*	*91.5*	*74.9*	*60.4*
Speckled	*0.1*	*0.14*	*0.12*	*0.10*	*0.08*	*0.06*
Squarespot	*0.1*	*0.14*	*0.12*	*0.10*	*0.08*	*0.07*
Starry	*0.0*	*0.003*	*0.003*	*0.002*	*0.002*	*0.001*
Stripetail	*33.7*	*33.7*	*28.0*	*23.2*	*19.0*	*15.3*
Swordspine	*0.0*	*0.00008*	*0.00007*	*0.00006*	*0.00005*	*0.00004*

Stock	Status Quo 2014 ABC	Range of Alternative 2015 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
Tiger	*0.8*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*
Vermilion	*8.1*	*8.1*	*6.7*	*5.6*	*4.6*	*3.7*
Slope Rockfish North	1,414	1,669	1,545	1,430	1,322	1,215
Aurora	*12.8*	***16.6***	***15.8***	***15.0***	***14.2***	***13.4***
Bank	*14.4*	*14.4*	*12.0*	*9.9*	*8.1*	*6.5*
Blackgill	*3.9*	*3.9*	*3.3*	*2.7*	*2.2*	*1.8*
Redbanded	*37.7*	*37.7*	*31.4*	*26.0*	*21.3*	*17.2*
Rougheye/Blackspotted	*59.3*	***184***	***168***	***153***	***138***	***124***
Sharpchin	*178.9*	***279.0***	***254.6***	***231.6***	***209.6***	***187.9***
Shortraker	*15.6*	*15.6*	*13.0*	*10.7*	*8.8*	*7.1*
Splitnose	*931.3*	*956.6*	*913.6*	*870.5*	*828.5*	*784.5*
Yellowmouth	*160.5*	*160.5*	*133.6*	*110.5*	*90.4*	*72.9*
Nearshore Rockfish South	1,001	1,165	1,038	924	820	722
Shallow Nearshore Species	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Black and yellow	*23.0*	*23.0*	*19.1*	*15.8*	*12.9*	*10.4*
China	*13.8*	***47.1***	***43.0***	***39.1***	***35.4***	***31.7***
Gopher (N of Pt. Conception)	*146.3*	*141.5*	*135.1*	*128.8*	*122.5*	*116.0*
Gopher (S of Pt. Conception)	*21.4*	*21.4*	*17.8*	*14.7*	*12.0*	*9.7*
Grass	*49.7*	*49.7*	*41.4*	*34.2*	*28.0*	*22.6*
Kelp	*23.1*	*23.1*	*19.2*	*15.9*	*13.0*	*10.5*
Deeper Nearshore Species	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Blue (assessed area)	*171.4*	*172.2*	*157.1*	*142.9*	*129.4*	*116.0*
Blue (S of 34 ^{o}27' N lat.)	*60.8*	*60.8*	*50.6*	*41.8*	*34.3*	*27.6*
Brown	***170.6***	***156.3***	***142.6***	***129.8***	***117.4***	***105.3***
Calico	*0.0*	-	-	-	-	-
Copper	***118.0***	***267.2***	***243.8***	***221.8***	***200.8***	***180.0***
Olive	*187.4*	*187.4*	*155.9*	*128.9*	*105.6*	*85.1*
Quillback	*4.5*	*4.5*	*3.7*	*3.1*	*2.5*	*2.0*
Treefish	*11.0*	*11.0*	*9.2*	*7.6*	*6.2*	*5.0*
Shelf Rockfish South	1,620	1,621	1,372	1,156	967	800
Bronzespotted	*3.0*	*3.0*	*2.5*	*2.1*	*1.7*	*1.4*
Chameleon	*0.0*	-	-	-	-	-
Flag	*19.5*	*19.5*	*16.3*	*13.4*	*11.0*	*8.9*
Freckled	*0.0*	-	-	-	-	-
Greenblotched	*19.3*	*19.3*	*16.1*	*13.3*	*10.9*	*8.8*
Greenspotted	*73.3*	*72.1*	*65.8*	*59.9*	*54.2*	*48.6*
Greenstriped	*212.4*	*214.7*	*195.9*	*178.2*	*161.3*	*144.6*
Halfbanded	*0.0*	-	-	-	-	-
Harlequin	*0.0*	-	-	-	-	-
Honeycomb	*8.2*	*8.2*	*6.8*	*5.7*	*4.6*	*3.7*
Mexican	*4.2*	*4.2*	*3.5*	*2.9*	*2.4*	*1.9*
Pink	*2.1*	*2.1*	*1.8*	*1.5*	*1.2*	*1.0*
Pinkrose	*0.0*	-	-	-	-	-
Pygmy	*0.0*	-	-	-	-	-

Stock	Status Quo 2014 ABC	Range of Alternative 2015 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
Redstripe	*0.4*	*0.4*	*0.3*	*0.3*	*0.2*	*0.2*
Rosethorn	*1.8*	*1.8*	*1.5*	*1.2*	*1.0*	*0.8*
Rosy	*37.1*	*37.1*	*30.9*	*25.5*	*20.9*	*16.9*
Silvergray	*0.4*	*0.4*	*0.4*	*0.3*	*0.3*	*0.2*
Speckled	*32.8*	*32.8*	*27.3*	*22.6*	*18.5*	*14.9*
Squarespot	*9.2*	*9.2*	*7.7*	*6.4*	*5.2*	*4.2*
Starry	*52.2*	*52.2*	*43.4*	*35.9*	*29.4*	*23.7*
Stripetail	*19.7*	*19.7*	*16.4*	*13.6*	*11.1*	*9.0*
Swordspine	*11.9*	*11.9*	*9.9*	*8.2*	*6.7*	*5.4*
Tiger	*0.0*	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*
Vermilion	*224.6*	*224.6*	*186.9*	*154.6*	*126.6*	*102.1*
Yellowtail	*887.7*	*887.7*	*738.7*	*611.0*	*500.3*	*403.4*
Slope Rockfish South	622	698	606	524	452	386
Aurora	*21.7*	***70.7***	***67.3***	***63.9***	***60.6***	***57.1***
Bank	*459.4*	*419.7*	*349.2*	*288.8*	*236.5*	*190.7*
Blackgill	*122.3*	*125.1*	*114.1*	*103.8*	*94.0*	*84.3*
Pacific ocean perch	*0.0*	-	-	-	-	-
Redbanded	*8.7*	*8.7*	*7.2*	*6.0*	*4.9*	*3.9*
Rougheye/Blackspotted	*0.3*	***3.8***	***3.4***	***3.1***	***2.8***	***2.5***
Sharpchin	*8.2*	***69.8***	***63.6***	***57.9***	***52.4***	***47.0***
Shortraker	*0.1*	*0.09*	*0.07*	*0.06*	*0.05*	*0.04*
Yellowmouth	*0.7*	*0.7*	*0.6*	*0.5*	*0.4*	*0.3*
Other Flatfish	6,982	9,865	8,620	7,517	6,521	5,606
Butter sole	*3.2*	*3.9*	*3.2*	*2.7*	*2.2*	*1.8*
Curlfin sole	*5.7*	*6.9*	*5.7*	*4.7*	*3.9*	*3.1*
Flathead sole	*24.3*	*29.2*	*24.3*	*20.1*	*16.5*	*13.3*
Pacific sanddab	*3,331.9*	*4,004.0*	*3,331.9*	*2,755.8*	*2,256.5*	*1,819.6*
Rex sole	*3,033.8*	***5,121.0***	***4,672.3***	***4,251.6***	***3,847.8***	***3,449.5***
Rock sole	*46.3*	*55.6*	*46.3*	*38.3*	*31.3*	*25.3*
Sand sole	*536.6*	*644.8*	*536.6*	*443.8*	*363.4*	*293.0*

Table 13. 2014 ABCs (mt) and a range of alternative 2016 ABCs (mt) varied by the probability of overfishing (P*) for west coast groundfish stocks (overfished stocks in CAPS; stocks with new assessments in bold; component stocks in stock complexes in italics).

Stock	Status Quo 2014 ABC	Range of Alternative 2016 ABCs				
		Overfishing Probability (P*)				
		0.45	0.40	0.35	0.30	0.25
OVERFISHED STOCKS						
BOCACCIO S. of 40^{0}10' N lat.	842	**1,291**	**1,233**	**1,175**	**1,118**	**1,059**
CANARY	709	697	666	634	604	572
COWCOD S. of 40^{0}10' N lat.	9	59	59	59	59	59
COWCOD (Conception)	*6*	***49***	***49***	***49***	***49***	***49***
COWCOD (Monterey)	*3*	*10*	*10*	*10*	*10*	*10*
DARKBLOTCHED	529	**554**	**530**	**505**	**480**	**455**
PACIFIC OCEAN PERCH	801	813	776	740	704	666
PETRALE SOLE	2,652	**2,910**	**2,779**	**2,648**	**2,520**	**2,386**
YELLOWEYE	43	47	43	39	35	32
NON-OVERFISHED STOCKS						
Arrowtooth Flounder	5,758	5,840	5,328	4,848	4,388	3,934
Black Rockfish (OR-CA)	1,115	1,131	1,080	1,029	980	927
Black Rockfish (WA)	409	404	386	368	350	332
Cabezon (CA)	158	151	144	137	131	124
Cabezon (OR)	47	47	45	43	41	38
California scorpionfish	117	111	106	101	97	91
Chilipepper S. of 40^{0}10' N lat.	1,647	1,619	1,547	1,474	1,403	1,328
Dover Sole	74,352	56,615	54,069	51,522	49,035	46,429
English Sole	5,646	**7,754**	**7,075**	**6,438**	**5,826**	**5,223**
Lingcod N of 42º N lat. (OR & WA)	1,897	1,761	1,682	1,603	1,525	1,444
Lingcod S. of 42º N lat. (CA)	2,044	1,995	1,820	1,656	1,499	1,344
Lingcod N of 40º10' N lat.	2,878	2,719	2,555	2,398	2,245	2,089
Lingcod S. of 40º10' N lat.	1,063	1,037	946	861	779	699
Longnose skate	2,692	2,299	2,196	2,092	1,991	1,885
Longspine Thornyhead (coastwide)	2,752	**4,349**	**3,968**	**3,610**	**3,267**	**2,929**
Pacific Cod	2,221	2,669	2,221	1,837	1,504	1,213
Sablefish (coastwide)	6,535	8,151	7,784	7,418	7,060	6,684
Shortbelly	5,789	6,345	5,789	5,268	4,768	4,274
Shortspine Thornyhead (coastwide)	2,208	**2,893**	**2,640**	**2,402**	**2,174**	**1,949**
Spiny dogfish	2,024	2,285.5	2,085.2	1,897.5	1,717.2	1,539.5
Splitnose S. of 40^{0}10' N lat.	1,670	1,746	1,667	1,589	1,512	1,432
Starry Flounder	1,528	1,686	1,539	1,400	1,267	1,136
Widow	4,212	3,790	3,596	3,407	3,218	3,026
Yellowtail N of 40^{0}10' N lat.	4,382	**10,634**	**9,702**	**8,828**	**7,990**	**7,163**

Stock	Status Quo 2014 ABC	Range of Alternative 2016 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
STOCK COMPLEXES						
Nearshore Rockfish North	94	79	69	61	53	46
Black and yellow	*0.0*	*0.011*	*0.009*	*0.008*	*0.006*	*0.005*
Blue (CA)	*25.0*	*25.3*	*23.1*	*21.0*	*19.0*	*17.0*
Blue (OR & WA)	*26.9*	*26.9*	*22.4*	*18.5*	*15.2*	*12.2*
Brown	***4.6***	***1.8***	***1.7***	***1.5***	***1.4***	***1.2***
Calico	*0.0*	-	-	-	-	-
China	***8.2***	***7.5***	***6.8***	***6.2***	***5.6***	***5.0***
Copper	***21.6***	***10.1***	***9.2***	***8.4***	***7.6***	***6.8***
Gopher	*0.0*	-	-	-	-	-
Grass	*0.5*	*0.5*	*0.5*	*0.4*	*0.3*	*0.2*
Kelp	*0.0*	*0.008*	*0.006*	*0.005*	*0.004*	*0.003*
Olive	*0.3*	*0.26*	*0.22*	*0.18*	*0.15*	*0.12*
Quillback	*6.2*	*6.2*	*5.1*	*4.2*	*3.5*	*2.8*
Treefish	*0.2*	*0.18*	*0.15*	*0.12*	*0.10*	*0.08*
Shelf Rockfish North	1,932	1,952	1,720	1,512	1,323	1,148
Bronzespotted	*0.0*	-	-	-	-	-
Bocaccio	*236.9*	*236.9*	*197.1*	*163.0*	*133.5*	*107.6*
Chameleon	*0.0*	-	-	-	-	-
Chilipepper	*108.1*	*106.4*	*88.5*	*73.2*	*59.9*	*48.3*
Cowcod	*0.0*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*
Flag	*0.1*	*0.06*	*0.05*	*0.04*	*0.03*	*0.03*
Freckled	*0.0*	-	-	-	-	-
Greenblotched	*1.1*	*1.1*	*0.9*	*0.7*	*0.6*	*0.5*
Greenspotted 40°10' to 42° N lat.	9	*8.5*	*7.7*	*7.0*	*6.4*	*5.7*
Greenspotted N of 42 N lat. (OR & WA)	*5.1*	*5.1*	*4.2*	*3.5*	*2.9*	*2.3*
Greenstriped	*1,158*	*1,179.6*	*1,076.2*	*979.3*	*886.3*	*794.6*
Halfbanded	*0.0*	-	-	-	-	-
Harlequin	*0.0*	-	-	-	-	-
Honeycomb	*0.0*	-	-	-	-	-
Mexican	*0.0*	-	-	-	-	-
Pink	*0.0*	*0.003*	*0.003*	*0.002*	*0.002*	*0.001*
Pinkrose	*0.0*	-	-	-	-	-
Puget Sound	*0.0*	-	-	-	-	-
Pygmy	*0.0*	-	-	-	-	-
Redstripe	*225.1*	*225.1*	*187.3*	*154.9*	*126.9*	*102.3*
Rosethorn	*10.8*	*10.8*	*9.0*	*7.4*	*6.1*	*4.9*
Rosy	*2.5*	*2.5*	*2.1*	*1.7*	*1.4*	*1.1*
Silvergray	*133.0*	*133.0*	*110.6*	*91.5*	*74.9*	*60.4*
Speckled	*0.1*	*0.14*	*0.12*	*0.10*	*0.08*	*0.06*
Squarespot	*0.1*	*0.14*	*0.12*	*0.10*	*0.08*	*0.07*
Starry	*0.0*	*0.003*	*0.003*	*0.002*	*0.002*	*0.001*
Stripetail	*33.7*	***33.7***	***28.0***	***23.2***	***19.0***	***15.3***
Swordspine	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*

Stock	Status Quo 2014 ABC	Range of Alternative 2016 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
Tiger	*0.8*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*
Vermilion	*8.1*	*8.1*	*6.7*	*5.6*	*4.6*	*3.7*
Slope Rockfish North	1,414	1,683	1,559	1,443	1,334	1,227
Aurora	*12.8*	***16.7***	***15.9***	***15.1***	***14.3***	***13.5***
Bank	*14.4*	*14.4*	*12.0*	*9.9*	*8.1*	*6.5*
Blackgill	*3.9*	*3.9*	*3.3*	*2.7*	*2.2*	*1.8*
Redbanded	*37.7*	*37.7*	*31.4*	*26.0*	*21.3*	*17.2*
Rougheye/Blackspotted	*59.3*	***189***	***172***	***157***	***142***	***127***
Sharpchin	*178.9*	***271.7***	***247.9***	***225.6***	***204.2***	***183.0***
Shortraker	*15.6*	*15.6*	*13.0*	*10.7*	*8.8*	*7.1*
Splitnose	*931.3*	*973.4*	*929.6*	*885.8*	*843.0*	*798.2*
Yellowmouth	*160.5*	*160.5*	*133.6*	*110.5*	*90.4*	*72.9*
Nearshore Rockfish South	1,001	1,163	1,036	922	818	720
Shallow Nearshore Species	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Black and yellow	*23.0*	*23.0*	*19.1*	*15.8*	*12.9*	*10.4*
China	*13.8*	*47.1*	*43.0*	*39.1*	*35.4*	*31.7*
Gopher (N of Pt. Conception)	*146.3*	*137.7*	*131.5*	*125.3*	*119.2*	*112.9*
Gopher (S of Pt. Conception)	*21.4*	*21.4*	*17.8*	*14.7*	*12.0*	*9.7*
Grass	*49.7*	*49.7*	*41.4*	*34.2*	*28.0*	*22.6*
Kelp	*23.1*	*23.1*	*19.2*	*15.9*	*13.0*	*10.5*
Deeper Nearshore Species	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Blue (assessed area)	*171.4*	*173.8*	*158.5*	*144.3*	*130.6*	*117.0*
Blue (S of 34 ^{o}27' N lat.)	*60.8*	*60.8*	*50.6*	*41.8*	*34.3*	*27.6*
Brown	***170.6***	***156.3***	***142.6***	***129.8***	***117.4***	***105.3***
Calico	*0.0*	-	-	-	-	-
Copper	***118.0***	***267.2***	***243.8***	***221.8***	***200.8***	***180.0***
Olive	*187.4*	*187.4*	*155.9*	*128.9*	*105.6*	*85.1*
Quillback	*4.5*	*4.5*	*3.7*	*3.1*	*2.5*	*2.0*
Treefish	*11.0*	*11.0*	*9.2*	*7.6*	*6.2*	*5.0*
Shelf Rockfish South	1,620	1,622	1,373	1,157	968	800
Bronzespotted	*3.0*	*3.0*	*2.5*	*2.1*	*1.7*	*1.4*
Chameleon	*0.0*	-	-	-	-	-
Flag	*19.5*	*19.5*	*16.3*	*13.4*	*11.0*	*8.9*
Freckled	*0.0*	-	-	-	-	-
Greenblotched	*19.3*	*19.3*	*16.1*	*13.3*	*10.9*	*8.8*
Greenspotted	*73.3*	*71.6*	*65.3*	*59.5*	*53.8*	*48.2*
Greenstriped	*212.4*	*216.4*	*197.4*	*179.6*	*162.6*	*145.8*
Halfbanded	*0.0*	-	-	-	-	-
Harlequin	*0.0*	-	-	-	-	-
Honeycomb	*8.2*	*8.2*	*6.8*	*5.7*	*4.6*	*3.7*
Mexican	*4.2*	*4.2*	*3.5*	*2.9*	*2.4*	*1.9*
Pink	*2.1*	*2.1*	*1.8*	*1.5*	*1.2*	*1.0*
Pinkrose	*0.0*	-	-	-	-	-
Pygmy	*0.0*	-	-	-	-	-

Stock	Status Quo 2014 ABC	Range of Alternative 2016 ABCs				
		Overfishing Probability (P*)				
		0.45	**0.40**	**0.35**	**0.30**	**0.25**
Redstripe	*0.4*	*0.4*	*0.3*	*0.3*	*0.2*	*0.2*
Rosethorn	*1.8*	*1.8*	*1.5*	*1.2*	*1.0*	*0.8*
Rosy	*37.1*	*37.1*	*30.9*	*25.5*	*20.9*	*16.9*
Silvergray	*0.4*	*0.4*	*0.4*	*0.3*	*0.3*	*0.2*
Speckled	*32.8*	*32.8*	*27.3*	*22.6*	*18.5*	*14.9*
Squarespot	*9.2*	*9.2*	*7.7*	*6.4*	*5.2*	*4.2*
Starry	*52.2*	*52.2*	*43.4*	*35.9*	*29.4*	*23.7*
Stripetail	*19.7*	*19.7*	*16.4*	*13.6*	*11.1*	*9.0*
Swordspine	*11.9*	*11.9*	*9.9*	*8.2*	*6.7*	*5.4*
Tiger	*0.0*	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*
Vermilion	*224.6*	*224.6*	*186.9*	*154.6*	*126.6*	*102.1*
Yellowtail	*887.7*	*887.7*	*738.7*	*611.0*	*500.3*	*403.4*
Slope Rockfish South	622	699	607	525	452	387
Aurora	*21.7*	***70.7***	***67.3***	***63.9***	***60.6***	***57.1***
Bank	*459.4*	*419.7*	*349.2*	*288.8*	*236.5*	*190.7*
Blackgill	*122.3*	*127.8*	*116.6*	*106.1*	*96.0*	*86.1*
Pacific ocean perch	*0.0*	-	-	-	-	-
Redbanded	*8.7*	*8.7*	*7.2*	*6.0*	*4.9*	*3.9*
Rougheye/Blackspotted	*0.3*	***4***	***4***	***3***	***3***	***3***
Sharpchin	*8.2*	***67.9***	***62.0***	***56.4***	***51.0***	***45.8***
Shortraker	*0.1*	*0.09*	*0.07*	*0.06*	*0.05*	*0.04*
Yellowmouth	*0.7*	*0.7*	*0.6*	*0.5*	*0.4*	*0.3*
Other Flatfish	6,982	8,633	7,496	6,494	5,595	4,775
Butter sole	*3.2*	*3.9*	*3.2*	*2.7*	*2.2*	*1.8*
Curlfin sole	*5.7*	*6.9*	*5.7*	*4.7*	*3.9*	*3.1*
Flathead sole	*24.3*	*29.2*	*24.3*	*20.1*	*16.5*	*13.3*
Pacific sanddab	*3,331.9*	*4,004.0*	*3,331.9*	*2,755.8*	*2,256.5*	*1,819.6*
Rex sole	*3,033.8*	***3,888.5***	***3,547.7***	***3,228.3***	***2,921.7***	***2,619.3***
Rock sole	*46.3*	*55.6*	*46.3*	*38.3*	*31.3*	*25.3*
Sand sole	*536.6*	*644.8*	*536.6*	*443.8*	*363.4*	*293.0*

1.2.3 Annual Catch Limits

Annual catch limits (ACLs) are specified for each stock and stock complex that is "in the fishery" as specified under the FMP framework. An ACL is a harvest specification set equal to the ABC or below the ABC in consideration of conservation objectives, management uncertainty, socioeconomic considerations, ecological considerations, and other factors (e.g. rebuilding considerations) needed to meet management objectives. Sector-specific ACLs may be specified in cases where a sector has a formal, long-term allocation of the harvestable surplus of a stock or stock complex. The ACL counts all sources of fishing-related mortality including landed catch, discard mortalities, research catches, and set-asides for exempted fishing permits (EFPs).

Under the FMP, the biomass level that produces MSY (B_{MSY}) is defined as the precautionary threshold. When the biomass for an assessed category 1 or 2 stock falls below the precautionary threshold, the harvest rate will be reduced to help the stock return to the B_{MSY} level, which is the management target for groundfish stocks. If a stock biomass is larger than B_{MSY}, the ACL may be set equal to or less than ABC. Because B_{MSY} is a long-term average, the true biomass could be below B_{MSY} in some years and above B_{MSY} in other years. Even in the absence of overfishing, biomass may decline to levels below B_{MSY} due to natural fluctuations in recruitment. The minimum stock size threshold (MSST) is the biomass threshold for declaring a stock overfished. When spawning stock biomass falls below the MSST, a rebuilding plan must be developed that determines the strategy for rebuilding the stock in the shortest time possible while considering impacts to fishing-dependent communities and other factors. When spawning stock biomass is below B_{MSY} yet above the MSST, the stock is considered to be in the precautionary zone. The current proxy B_{MSY} and MSST reference points for west coast groundfish stocks are as follows:

- Assessed flatfish stocks: B_{MSY} = 25 percent of initial biomass or $B_{25\%}$; MSST = 12.5 percent of initial biomass or $B_{12.5\%}$ (PFMC and NMFS 2011); and
- All other assessed groundfish stocks: B_{MSY} = 40 percent of initial biomass or $B_{40\%}$; MSST = 25 percent of initial biomass or $B_{25\%}$.

These reference points are only used to manage assessed stocks since they require estimates of spawning stock biomass.

West coast groundfish stocks are managed with harvest control rules that calculate ACLs below the ABCs when spawning biomass is estimated to be in the precautionary zone. These harvest control rules are designed to prevent a stock from becoming overfished. The FMP defines the 40-10 harvest control rule for stocks with a B_{MSY} proxy of $B_{40\%}$ that are in the precautionary zone. The analogous harvest control rule for assessed flatfish stocks is the 25-5 harvest control rule. Both ACL harvest control rules are applied after the ABC deduction is made. The further the stock biomass is below the precautionary threshold, the greater the reduction in ACL relative to the ABC, until at $B_{10\%}$ for a stock with a B_{MSY} proxy of $B_{40\%}$ or $B_{5\%}$ for a stock with a B_{MSY} proxy of $B_{25\%}$, the ACL would be set at zero[12] (Figure 36). These harvest policies foster a quicker return to the B_{MSY} level and serve as an interim rebuilding policy for stocks that are below the MSST. The Council may recommend setting the ACL higher than what the default ACL harvest control rule specifies as long as the ACL does not exceed the ABC, complies with the requirements of the MSA, and is consistent with the FMP and National Standard Guidelines. Additional precautionary adjustments may be made to an ACL if necessary to address management

[12] The lower $B_{10\%}$ and $B_{5\%}$ thresholds in the precautionary ACL harvest control rules are used to establish the slope of the ACL curve in Figure 36. These precautionary ACL control rules only apply for stocks in the precautionary zone ($B_{MSY} > B_{CURRENT} >$ MSST). A rebuilding plan governs the ACL harvest control rule for any stock that falls below the MSST and is designated as overfished.

uncertainty, conservation concerns, socioeconomic concerns, ecological considerations, and the other factors that are considered when setting ACLs.

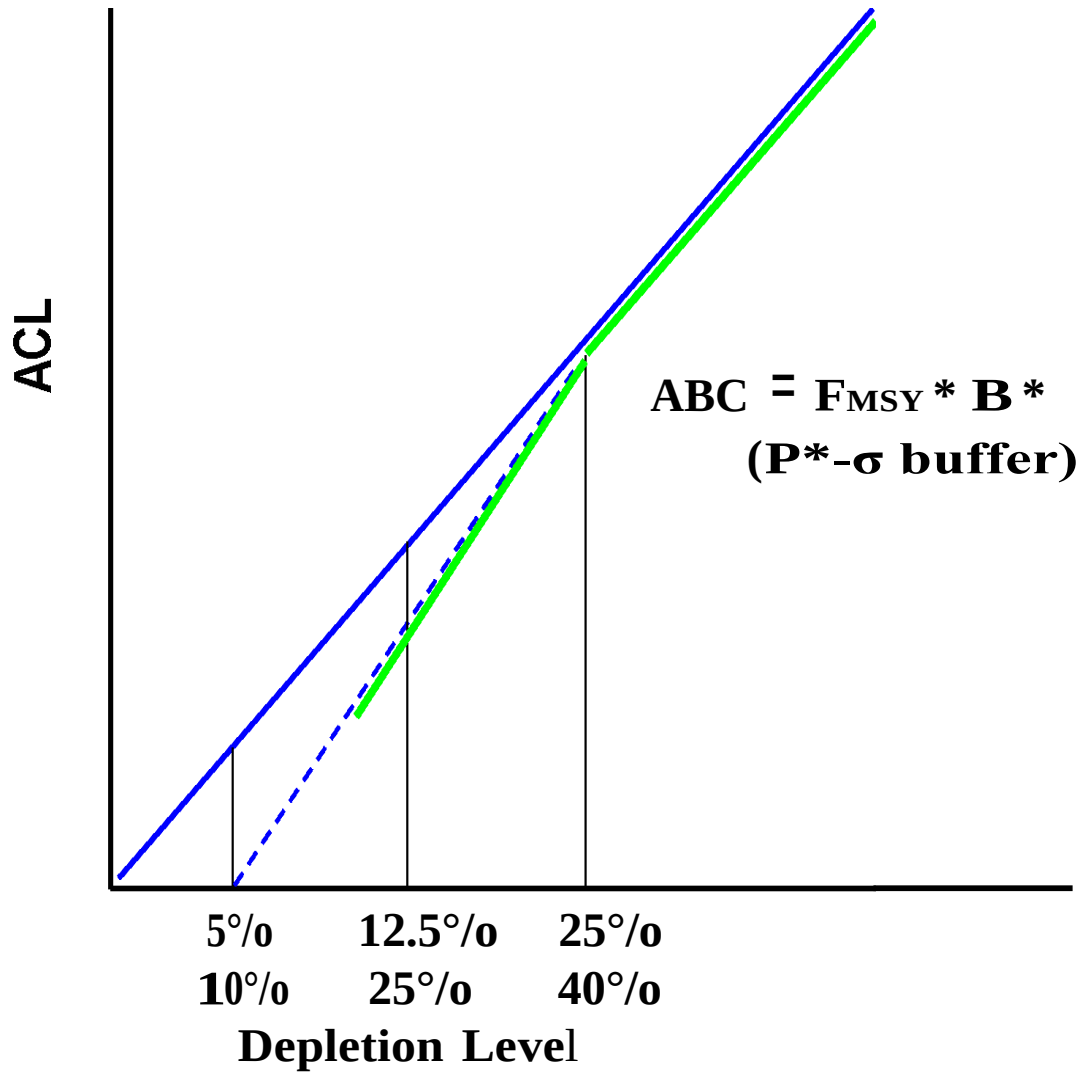

Figure 36. Conceptual diagram of the 25-5 and 40-10 ACL harvest control rules used to manage assessed west coast flatfish and other groundfish species, respectively, that are in the precautionary zone.

The ACL serves as the basis for invoking accountability measures (AMs), which are management measures or mechanisms used to address any management uncertainty that may result in exceeding an ACL. If ACLs are exceeded more often than 1 in 4 years, then AMs, such as catch monitoring and inseason adjustments to fisheries, need to improve or additional AMs may need to be implemented. Additional AMs may include setting an annual catch target (ACT), which is a specified level of harvest below the ACL. The use of ACTs may be especially important for a stock subject to highly uncertain inseason catch monitoring. A sector-specific ACT may serve as a harvest guideline (HG) for a sector or may be used strategically in a rebuilding plan to attempt to reduce mortality of an overfished stock more than the rebuilding plan limits prescribe.

The Council has the discretion to adjust the ACLs for uncertainty on a case-by-case basis. In cases where there is a high degree of uncertainty about the condition of the stock or stocks, the ACL may be reduced accordingly. Most category 3 species are managed in a stock complex (such as the minor rockfish complexes and the Other Flatfish complex) where harvest specifications are set for the complex in its entirety. For stock complexes, the ACL will be less than or equal to the sum of the individual component ABCs. The ACL may be adjusted below the sum of component ABCs as appropriate.

For most stocks and stock complexes, the Council elected to use the same general policies for deciding 2015 and 2016 ACLs as were used for deciding the 2014 ACLs (No Action). The No Action ACLs are the 2014 ACLs specified in Federal regulations.

Section 4.6.3 of the FMP states the Council's general policies on rebuilding overfished stocks. Section 4.6.3.1 of the FMP specifies the overall goals of rebuilding programs are to (1) achieve the population size and structure that will support the MSY within a specified time period that is as short as possible, taking into account the status and biology of the stock, the needs of fishing communities, and the interaction of the stock of fish within the marine ecosystem; (2) minimize, to the extent practicable, the adverse social and economic impacts associated with rebuilding, including adverse impacts on fishing communities; (3) fairly and equitably distribute both the conservation burdens (overfishing restrictions) and recovery benefits among commercial, recreational, and charter fishing sectors; (4) protect the quantity and quality of habitat necessary to support the stock at healthy levels in the future; and (5) promote widespread public awareness, understanding and support for the rebuilding program. These overall goals are derived from and consistent with the requirements of the MSA. The first goal embodies MSA National Standard 1 (NS1) and the requirements for rebuilding overfished stocks found at MSA section 304(e)(4)(A). The third goal is required by MSA section 304(e)(4)(B). The fourth and fifth goals represent additional policy preferences of the Council that recognize the importance of habitat protection to the rebuilding of some fish stocks and the desire for public outreach and education on the complexities—biological, economic, and social issues—involved with rebuilding overfished stocks. Overfished groundfish species are those with spawning biomasses that have dropped below the Council's MSST (i.e., 25 percent of initial spawning biomass or $B_{25\%}$ for all groundfish species other than flatfish where the MSST is $B_{12.5\%}$). The FMP requires these stocks to be rebuilt to a target biomass that supports MSY (i.e., B_{MSY} or $B_{40\%}$ for all groundfish species other than flatfish where the target is $B_{25\%}$).

Rebuilding plans are in place for six overfished rockfish species, as well as petrale sole, where assessments have indicated spawning biomass has declined to below the MSST. New full and updated assessments and rebuilding analyses were done in 2013 inform the 2015 and 2016 harvest specifications for many of the overfished species. New full assessments were conducted for cowcod, darkblotched rockfish, and petrale sole in 2013; however, a new rebuilding analysis was only prepared for cowcod. The results of the new assessments for darkblotched rockfish and petrale sole indicated those stocks would be rebuilt by 2015 and 2014, respectively. The SSC did not recommend new rebuilding analyses for these two stocks given their imminent rebuilding expectation. An update assessment for bocaccio was prepared in 2013. Like darkblotched, the stock is predicted to rebuild by 2015 and the SSC therefore recommended no new rebuilding analysis be prepared. Catch reports for canary rockfish, Pacific ocean perch, and yelloweye rockfish were prepared in 2013. These catch reports indicated total catches were within limits prescribed in these stocks' respective rebuilding plans.

LITERATURE CITED

Adams, P. B. 1986. Status of lingcod (*Ophiodon elongatus*) stocks off the coast of Washington, Oregon and California. Pages 60 *in* Status of Pacific coast groundfish fishery in 1986 and recommended acceptable biological catches for 1987. Pacific Fisheries Management Council, Portland, OR.

Adams, P. B. 1987. The diet of widow rockfish *Sebastes entomelas* in northern California. W. H. Lenarz and D. R. Gunderson, editors. Widow rockfish, proceedings of a workshop. NOAA Tech. Rep. NMFS 48, Tiburon, CA.

Adams, P. B. and J. E. Hardwick. 1992. Lingcod. Pages 161-164 *in* L. W.S, C. M. Dewees, and C. W. Haugen, editors. California's Living Marine Resources and Their Utilization. California Sea Grant Program, Davis, CA.

Adams, P. B., E. H. Williams, K. R. Silberberg, and T. E. Laidig. 1999. Southern lingcod stock assessment in 1999. *in* Appendix to Status of the Pacific Coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000 (SAFE Report). Pacific Fishery Management Council, Portland.

Ainley, D. G., W. H. Sydeman, R. H. Parrish, and W. H. Lenarz. 1993. Oceanic factors influencing distribution of young rockfish (*Sebastes*) in Central California: a predator's perspective. CalCOFI Reports 34(133-139).

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

Allen, L. G., D. J. Pondella II, and M. H. Hom. 2006. The ecology of marine fishes: California and adjacent waters. University of California Press, Los Angeles, CA.

Allen, M. J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D Dissertation. University of California.

Allen, M. J. and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific.

Alonzo, S. H., T. Ish, M. Key, A. D. MacCall, and M. Mangel. 2008. The importance of incorporating protogynous sex change into stock assessments. Bulletin of Marine Science 83:163-179.

Alverson, D. L. and B. M. Chatwin. 1957. Results from tagging experiments on a spawning stock of petrale sole, Eopsetta jordani (Lockington). J.Fish.Res.Board Canada 14:953-974.

Alverson, D. L., A. T. Pruter, and L. L. Ronholt. 1964. A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. Institute of Fisheries, University of British Columbia, Vancouver, British Columbia.

Anderson, T. J., C. Syms, D. A. Roberts, and D. F. Howard. 2009. Multi-scale fish-habitat associations and the use of habitat surrogates to predict the organization and abundance of deep-water fish assemblages. Journal of Experimental Marine Biology and Ecology 379:34-42.

Antonelis, G. A. and C. H. Fiscus. 1980. The pinnipeds of the California Current. CalCOFI Reports 21:68-78.

Archibald, C., P. D. Fournier, and B. M. Leaman. 1983. Reconstruct of stock history and development of rehabilitation strategies for Pacific ocean perch in Queen Charlotte Sound, Canada. N.Amer.J.Fish.Mgmt. 3:283-294.

Arora, H. L. 1951. An investigation of the California sand dab, (*Citharichthys sordidus*) (Girard). California Fish and Game 37:3-42.

Bargmann, G. G. 2009. A history of the fisheries for spiny dogfish along the Pacific Coast from California to Washington. *in* V. F. Gallucci, G. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

Barss, W. H. 1976. The Pacific sanddab. Oregon Department of Fish and Wildlife Informational Report 76-5.

Baxter, R. 1999. Pleuronectiformes. Pages 369-415 *in* E. Interagency Ecological Program for the Sacramento-San Joaquin, editor. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California, volume Technical Report 63. California Department of Fish and Game, Stockton, CA.

Beamish, R. J. 1979. New information on the longevity of Pacific ocean perch (*Sebastes alutus*). J.Fish.Res.Board Canada 36:1395-1400.

Beamish, R. J. and G. A. McFarlane. 1988. Resident and dispersal behavior of adult sablefish (*Anoplopoma fimbria*) in the slope waters off Canada's West Coast. Can.J.Fish.Aquat.Sci. 45:152-164.

Beamish, R. J., G. A. McFarlane, and A. Benson. 2006. Longevity overfishing. Progress in Oceanography 68:289-302.

Beamish, R. J., B. L. Thomson, and G. A. McFarlane. 1992. Spiny dogfish predation on chinook and coho salmon and the potential effects on hatchery-produced salmon. Trans.Am.Fish.Soc. 121(4):444-455.

Becker, D. S. 1984. Resource partitioning by small-mouthed pleuronectids in Puget Sound, Washington. Ph.D Dissertation. University of Washington.

Bence, J. R. and J. E. Hightower. 1990. Status of bocaccio in the Conception/Monterey/Eureka INPFC areas in 1990. *in* Appendix to Status of the Pacific Coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991 (SAFE Report). Pacific Fishery Management Council, Portland.

Benet, D. L., E. J. Dick, and D. E. Pearson. 2009. Life histroy aspects of greenspotted rockfish (*Sebastes chlorostictus*) from central California. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-466:43 pgs.

Bennett, J. T., G. W. Boehlert, and K. K. Turekian. 1982. Confirmation of longevity in *Sebastes diploproa* (Pisces: *Scorpaenidae*) from ^{210}Pb/^{226}Ra measurements in otoliths. Marine Biology 71:209-215.

Bennett, W. A., K. Roinestad, L. Rogers-Bennett, L. Kaufman, D. Wilson-Vandenberg, and B. Heneman. 2004. Inverse regional responses to climate change and fishing intensity by the recreational rockfish (*Sebastes* spp.) fishery in California. Canadian Journal of Fisheries and Aquatic Sciences 61:2499-2510.

Berkeley, S. A. 2004. Maternal age as a determinant of larval grwoth and survival in a marine fish, Sebastes melanops Ecology 85(5):1258-1264.

Berkeley, S. A., M. A. Hixon, R. J. Larson, and M. S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29(8):23-32.

Best, E. A. 1959. Status of the animal food fishery in northern California, 1956 and 1957. California Fish and Game 45(1):5-18.

Best, E. A. 1960. Petrale Sole. Pages 79 *in* California ocean fisheries resources to the year 1960. California Department of Fish and Game.

Best, E. A. 1961. The California animal food fishery, 1958-1960. Bulletin of the Pacific Marine Fisheries Commission 5:5-15.

Best, E. A. 1963. Movements of petrale sole, *Eopsetta jordani*, tagged off of California. Pacific Marine Fisheries Commission Bulletin 6:24-38.

Best, E. A. 1964. Spawning of longspine channel rockfish, *Sebastolobus altivelis*. California Fish and Game 50:265-267.

Beverton, R. J. H. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. Journal of Fish Biology 42(Supplement B):137-160.

Birtwell, I. K., M. Wood, and D. K. Gordon. 1984. Fish diets and benthic invertebrates in the estuary of the Somass River, Port Alberni, British Columbia. Canadian Manuscript Report of Fisheries and Aqautic Sciences 1799:49.

Black, B. A. 2009. Climate-driven synchrony across tree, bivalve, and rockfish growth-increment chronologies of the northeast Pacific. Marine Ecology Progress Series 378:37-46.

Black, B. A., G. W. Boehlert, and M. M. Yoklavich. 2008. Using tree-ring crossdating techniques to validate annual growth increments in long-lived fishes. Canadian Journal of Fisheries and Aquatic Sciences 62:2277-2284.

Bobko, S. J. and S. A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish, Sebastes melanops. . Fish.Bull. 102(3):418-429.

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

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

Bograd, S. J., C. G. Castro, E. D. Lorenzo, D. M. Palacios, H. Bailey, W. Gilly, and coauthors. 2008. Oxygen declines and the shoaling of the hypoxic boundary in the California Current. Geophysical Research Letters 35:L12607.

Bond, C. E. 1979. Biology of fishes. Saunders College Publishing, Philadelphia.

Bonfil, R. 1994. Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper No. 341.

Bradburn, M. J., A. Keller, and B. H. Horness. 2011. The 2003 to 2008 U.S. West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. NOAA Technical Memorandum NMFS-NWFSC-114:323 pgs.

Brodeur, R. D., I. A. Fleming, J. M. Bennett, and M. A. Campbell. 2009. Summer distribution and feeding of spiny dogfish off the Washington and Oregon coasts. *in* V. F. Gallucci, G. A. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

Brodeur, R. D. and W. G. Percy. 1984. Food habits and dietary overlap of some shelf rockfishes (genus Sebastes) from the northeastern Pacific Ocean. Fishery Bulletin 82:262-294.

Brodziak, J., L.Jacobson, R. Lauth, and M. Wilkins. 1997. Assessment of the Dover sole stock for 1997. *in* Appendix to Status of the Pacific Coast groundfish fishery through 1997 and recommended biological catches for 1998 (Stock assessment and fishery evaluation). Pacific Fishery Management Council, Portland, OR.

Buckley, T. W., G. E. Tyler, D. M. Smith, and P. A. Livingston (O. National and A. Atmospheric). 1999. Food habits of some commercially important groundfish off the coasts of California, Oregon, Washington, and British Columbia.

Buonaccoursi, V. P., C. A. Kimbrel, E. A. Lynn, and R. D. Vetter. 2005. Limited realized dispersal and introgressive hybridization influence genetic structure and conservation strategies for brown rockfish, *Sebastes auriculatus*. Conservation Genetics 6:697-713.

Burford, M. O., M. H. Carr, and G. Bernardi. 2011. Age-structured genetic analysis reveals temporal and geographic variation within and between two cryptic rockfish species. Marine Ecology Progress Series 442:201-215.

Butler, J. L., T. Barnes, P. Crone, and R. Conser. 2003. Cowcod rebuilding review. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Butler, J. L., L. D. Jacobson, and J. T. Barnes. 1999a. Stock assessment for blackgill rockfish. *in* Appendix to the status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Butler, J. L., L. D. Jacobson, J. T. Barnes, H. G. Moser, and R. Collins. 1999b. Stock assessment of cowcod. *in* Appendix to Status of the Pacific Coast groundfish fishery through 1998 and

recommended acceptable biological catches for 1999 (SAFE Report). Pacific Fishery Management Council, Portland, OR.

Cailliet, G. M., E. K. Osada, and M. Moser. 1988. Ecological studies of sablefish in Monterey Bay. Calif.Dept.Fish and Game 74:133-153.

Campana, S. E., W. Joyce, and D. W. Kulka. 2009. Growth and reproduction of spiny dogfish off the Eastern Coast of Canada, including inferences on stock structure. *in* V. F. Gallucci, G. A. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

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

Casillas, E., L. Crockett, Y. deReynier, J. Glock, M. Helvey, B. Meyer, and coauthors. 1998. Essential Fish Habitat, West Coast Groundfish. *in* Appendix to Amendment 11 of the Pacific Coast Groundfish Plan, Fishery Management Plan Environmental Impact Statement for the California, Oregon Washington Groundfish Fishery. National Marine Fisheries Service, Seattle.

Castillo, G. C. 1992. Fluctuations of year-class strength of petrale sole (*Eopsetta jordani*) and their relation to environmental factors. Oregon State University, Corvallis, OR.

Castillo, G. C. 1995. Latitudinal patterns in reproductive life history traits of Northeast Pacific flatfish. Pages 51-72 *in* International Symposium on North Pacific Flatfish. University of Alaska Sea Grant College Program, Fairbanks, AK, 1995.

Castillo, G. C., H. W. Li, and J. T. Golden. 1993. Environmental induced recruitment variation in petrale sole, *Eopsetta jordani*. Fisheries Bulletin 92:481-493.

CDFG. 2001. Sanddabs. Pages 201-202 *in* California's Marine Living Resources: A Status Report. California Department of Fish and Game.

Chamberlain, D. W. 1979. Histology of the reproductive systems and comparison of selected morphological characters in four Eastern Pacific species of *Citharichys* (*Pisces: Bothidae*). Ph.D. University of Southern California, Los Angeles, CA.

Chess, J. R., S. E. Smith, and P. C. Fischer. 1988. Trophic relationships of the shortbelly rockfish, *Sebastes jordani*, off central California. CalCOFI Reports 29(129-136).

Childress, J. J. and B. A. Seibel. 1998. Life at stable low oxygen levels: Adaptations of animals to oceanic oxygen minimum layers. Journal of Experimental Biology 201:1223-1232.

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. Canadian Journal of Fisheries and Aquatic Sciences 48:734-750.

Clark, W. G. 2002. F35% revisited ten years later. North American Journal of Fisheries Management 22:251-257.

Coleman, B. A. 1986. The 1980 Pacific West Coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, length and age composition.

Constable, H. 2006. Population genetics of juvenile *Sebastes jordani*, shortbelly rockfish, along the California coast. San Francisco State University, San Francisco, CA.

Cooper, D. W., K. E. Pearson, and D. R. Gunderson. 2005. Fecundity of shortspine thornyhead (*Sebastolobus alascanus*) and longspine thornyhead (*S. altivelis*) (Scorpaenidae) from the northeastern Pacific Ocean, determined by sterological and gravimetric techniques. Fishery Bulletin 103:15-22.

Cope, J., E. J. Dick, A. MacCall, M. Monk, B. Soper, and C. Wetzel. 2014. Data-moderate stock assessments for brown, China, copper, sharpchin, stripetail, and yellowtail rockfishes and English and rex soles in 2013. Pacific Fishery Management Council, Portland, OR.

Cope, J. M. 2004. Population genetics and phylogeography of the blue rockfish (*Sebastes mystinus*) from Washington to California. Canadian Journal of Fisheries and Aquatic Sciences 61:332-342.

Cope, J. M., J. DeVore, E. J. Dick, K. Ames, J. Budrick, D. L. Erickson, and coauthors. 2011. An approach to defining stock complexes for U.S. West Coast groundfishes using vulnerabilities and ecological distributions. N.Amer.J.Fish.Mgmt. 31(4):589-604.

Cope, J. M. and M. A. Haltuch. 2012. Temporal and spatial summer groundfish assemblages in trawlable habitat off the west coast of the USA, 1977 to 2009. Marine Ecology Progress Series 451:187-200.

Cope, J. M. and M. Key. 2009. Status of Cabezon (Scorpaenichthys marmoratus) in California and Oregon waters as assessed in 2009. Pacific Fishery Management Council, Portland, OR.

Cope, J. M., K. Piner, C. V. Minte-Vera, and A. E. Punt. 2004. Status and future prospects for the cabezon (*Scorpaenichthys marmoratus*) as assessed in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2004 and recommended acceptable biological catches for 2005-2006 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Cope, J. M. and A. Punt. 2006. Status of Cabezon (Scorpaenichthys marmoratus) in California Waters as Assessed in 2005. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Cope, J. M. and A. E. Punt. 2009. Drawing the lines: resolving fishery management units with simple fisheries data. Canadian Journal of Fisheries and Aquatic Sciences 66(8):1256-1273.

Cortes, E. 2002. Incorporating uncertainty into demographic modeling: Application to shark populations and their conservation. Conservation Biology 16:1048-1062.

Crone, P. R., R. D. Methot, R. J. Conser, and T. L. Builder. 1999. Status of the canary rockfish resource off Oregon and Washington in 1999. *in* Status of the Pacific Coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999 (SAFE Report). Pacific Fishery Management Council, Portland, OR.

Culver, B. N. 1986. Results of tagging black rockfish (Sebastes melanops) off the Washington and northern Oregon coast. Alaska Sea Grant College Program, Anchorage, Alaska, 1986.

Dark, T. A. and M. E. Wilkins. 1994. Distribution, abundance, and biological characteristics of groundfish off the coast of Washington, Oregon and California, 1977-1986. NOAA.

Demory, R. L. 1971. Depth distribution of some small flatfishes off the northern Oregon-Washington coast. Research Report, Fish Commission of Oregon 3:44-48.

Demory, R. L. 1984. Appendix 12: Progress report on the status of petrale sole in the INPFC Columbia-Vancouver areas in 1984. *in* Status of the Pacific coast groundfish fishery and recommendations for management in 1985. Pacific Fishery Management Council, Portland, OR.

Di Giacomo, E. E., M. R. Perier, and M. Coller. 2009. Reproduction of spiny dogfish in San Matias Gulf, Patagonia. *in* V. F. Gallucci, G. A. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

Dick, E. J. and A. D. MacCall. 2011. Depletion-based stock reduction analysis: a catch-based method for determining sustainable yields for dat-poor fish stocks. Fisheries Research 110:331-341.

Dick, E. J. and A. D. MacCall. 2013a. Cowcod Rebuilding Analysis. Pacific Fishery Management Council, Portland, OR.

Dick, E. J. and A. D. MacCall. 2013b. Status and productivity of cowcod, *Sebastes levis*, in the Southern California Bight, 2013. Pacific Fishery Management Council, Portland, OR.

Dick, E. J., D. Pearson, and S. Ralston. 2011. Status of greenspotted rockfish, *Sebastes chlorostictus*, in U.S. waters off California. Pacific Fishery Management Council, Portland, OR.

Dick, E. J. and S. Ralston. 2007. Cowcod rebuilding analysis. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation.

Dick, E. J., S. Ralston, and D. Pearson. 2007. Status of cowcod, *Sebastes levis*, in the southern California Bight. Pacific Fishery Management Council, Portland, OR.

Dick, E. J., S. Ralston, D. Pearson, and J. Wiedenmann. 2009. Updated status of cowcod, *Sebastes levis*, in the southern Californight bight. Portland, OR.

Donohoe, C. J. 2000. Metamorphosis, growth, and settlement of Pacific sanddab (*Citharichthys sordidus*) to a continental shelf nursery, inferred from otolith microstructure. Ph.D. Oregon State University, Corvallis, OR.

Dorn, M., S. A. Berkeley, R. J. Conser, O. S. Hamel, R. Mohn, K. Piner, and coauthors. 2006. Petrale Sole STAR Panel Meeting Report [September 2005]. *in* Volume 2: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Dorn, M. W. 2002a. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. Pages 22:290-300 *in*. N. Am J. fish. Manage.

Dorn, M. W. 2002b. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. N. Am J. Fish. Manage. 22:290-300.

Douglas, D. A. 1998. Species composition of rockfish in catches by Oregon trawlers, 1963-93.

Dunn, J. R. and C. R. Hitz. 1969. Oceanic occurrence of black rockfish (Sebastes melanops) in the central north Pacific. J.Fish.Res.Bd.Canada 26:3094-3097.

Ebert, D. A. 2003. Sharks, Rays and Chimaeras of California. University of California Press, Berkley, CA.

Ebert, D. A. and L. J. V. Compagno. 2007. Biodiversity and systematics of skates (Chondrichthyes: Rajiformes: Rajoidei). Environ.Biol.Fish. 80(2-3):111-124.

Ebert, D. D., W. T. White, K. J. Goldman, L. J. V. Compagno, T. S. Daly-Engel, and R. D. Ward. 2010. Resurrection and redescription of *Squalus suckleyi* (Girard, 1854) from the North Pacific, with comments on the *Squalus acanthias* subgroup (Squaliformes: Squalidae). Zootaxa 2612:22-40.

Echeverria, T. W. 1987. Thirty-four species of California rockfishes: maturity and seasonality of reproduction. Fish.Bull., U.S. 85(2):229-250.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, Volume II: Species life history summaries. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland.

Erickson, D. L. and E. K. Pikitch. 1993. A histological description of shortspine thornyhead, Sebastolobus alascanus , ovaries: Structures associated with the production of gelatinous egg masses. Environ.Biol.Fish. 36:273-282.

Eschmeyer, W. N., E. S. Herald, and H. Hammon. 1983. A Field Guide to Pacific Coast Fishes of North America. Houghton Mifflin, Boston.

Fargo, J. and P. J. Starr. 2001. Turbot stock assessment for 2001 and recommendation for management in 2002. Canadian Science Advisory Secretariat.

Fay, G. 2006. Stock Assessment and Status of Longspine Thornyhead (Sebastolobus altivelis) off California, Oregon and Washington in 2005. *in* Volume 4: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Field, J. C. 2008. Status of the Chilipepper rockfish, Sebastes goodei , in 2007. Pacific Fishery Management Council, Portland, Oregon.

Field, J. C. 2011a. Rebuilding analysis for bocaccio in 2011. Pacific Fishery Management Council, Portland, OR.

Field, J. C. 2011b. Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas as evaluated for 2011. Pacific Fishery Management Council, Portland, OR.

Field, J. C. 2013. Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas as evaluated for 2013. Pacific Fishery Management Council, Portland, OR.

Field, J. C., K. Baltz, A. J. Phillips, and W. A. Walker. 2007. Range expansion and trophic interactions of the jumbo squid, *Dosidicus gigas*, in the California Current. CalCOFI Reports 48:131-146.

Field, J. C., E. J. Dick, and A. D. MacCall. 2008. Stock Assessment Model for the Shortbelly Rockfish, *Sebastes Jordani*, in the California Current. Pacific Fishery Management Council, Portland, Oregon.

Field, J. C., E. J. Dick, D. Pearson, and A. D. MacCall. 2009. Status of bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2009. Pacific Fishery Management Council, Portland, OR.

Field, J. C., R. C. Francis, and K. Aydin. 2006. Top-down modeling and bottom-up dynamics: linking a fisheries-based ecosystem model with climate hypotheses in the Northern California Current. Progress in Oceanography 68:238-270.

Field, J. C. and X. He. 2009. Bocaccio rebuilding analysis for 2009. Pacific Fishery Management Council, Portland, OR.

Field, J. C. and D. Pearson. 2011. Status of the blackgill rockfish, *Sebastes melanostomus*, in the Conception and Monterey INPFC areas for 2011. Pacific Fishery Management Council, Portland, OR.

Ford, R. F. 1965. Distribution, population dynamics and behavior of a Bothid flatfish, *Citharichthys stigmaeus*. Ph.D. University of California San Diego.

Forrest, R. E., M. K. McAllister, M. W. Dorn, S. J. D. Martell, and R. D. Stanley. 2010. Hierarchical Bayesian estimation of recruitment parameters and reference points for Pacific rockfishes (*Sebastes* spp.) under alternative assumptions about the stock-recruit function. Can.J.Fish.Aquat.Sci. 67:1611-1634.

Forrester, C. R. 1969. Life history information on some groundfish species.

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

Francis, R. C. 1986. Two fisheries biology problems in West coast groundfish management. North American Journal of Fisheries Management 6:453-462.

Frey, H. W. 1971. California's living marine resources and their utilization. Calif. Dept. Fish Game.

Frisk, M. G., T. J. Miller, and M. J. Fogarty. 2002. The population dynamics of little skate *Leucoraja erinacea*, winter skate *Leucoraja ocellata*, and barndoor skate *Dipturus leavis*: predicting exploitation limits using matrix analysis. ICES J.of Mar.Sci. 59:576-586.

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

Garrison, K. J. and B. S. Miller. 1982. Review of the early life history of Puget Sound fishes. University of Washington Fish. Res. Inst., Seattle, Washington.

Genin, A. 2004. Bio-physical coupling in the formation of zooplankton and fish aggregations over abrupt topographies. Journal of Marine Systems 50:3-20.

Genin, A., L. Haury, and P. Greenblatt. 1988. Interactions of migrating zooplankton with shallow topography: predation by rockfishes and intensification of patchiness. Deep Sea Research 35:151-175.

Gertseva, V., J. M. Cope, and D. E. Pearson. 2009. Status of the U.S. splitnose rockfish (*Sebastes diploproa*) resource in 2009. Pacific Fishery Management Council, Portland, OR.

Gertseva, V. and I. G. Taylor. 2011. Status of the spiny dogfish shark resource off the continental U.S. Pacific Coast in 2011. Pacific Fishery Management Council, Portland, OR.

Gertseva, V. V. and M. J. Schirripa. 2008. Status of the Longnose Skate (*Raja rhina*) off the continental US Pacific Coast in 2007. Pacific Fishery Management Council, Portland, Oregon.

Gertseva, V. V. and J. T. Thorson. 2013. Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2013. Pacific Fishery Management Council, Portland, OR.

Gharrett, A. J., A. P. Matala, E. L. Peterson, A. K. Gray, and Z. Li. 2005. Two genetically distinct forms of rougheye rockfish are different species. Transactions of the American Fisheries Society 134:242-260.

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

Golden, J. T. and R. L. Demory. 1984. A progress report on the status of canary rockfish (Sebastes pinniger) in the INPFC Vancouver, Columbia and Eureka areas in 1984, Appendix 6. *in* Status of the Pacific coast groundfish fishery through 1990 and recommended acceptable biological catches for 1991: stock assessment and fishery evaluation. Pacific Fishery Management Council. Pacific Fishery Management Council, Portland, OR.

Golden, J. T. and C. Wood. 1990. Status of canary rockfish in the INPFC Vancouver, Columbia and Eureka areas and recommended ABC for 1991. Pages Appendix H *in*, Portland, Oregon.

Goode, G. B. 1884. The fishery and fisheries industries of the United States. Washington Government Printing Office.

Gotshall, D. W. 1969. Stomach contents of Pacific hake and arrowtooth flounder from northern California. Calif.Fish Game 55(1):75-82.

Gotshall, D. W. 1981. Pacific Coast Inshore Fishes. Sea Challengers and Western Marine Enterprises Publication, Los Osos California.

Gotshall, D. W., J. G. Smith, and A. Holbert. 1965. Food of the blue rockfish *Sebastes mystinus*. California Department of Fish and Game 51(3):147-162.

Gregory, P. A. and T. Jow. 1976. The validity of otoliths as indicators of age of petrale sole from California. California Department of Fish and Game 62(2):132-140.

Gunderson, D. R. 1971. Reproductive patterns of Pacific ocean perch (Sebastodes alutus) off Washington and British Columbia and their relation to bathymetric distribution and seasonal abundance. J.Fish.Res.Board Canada 28:417-425.

Gunderson, D. R. 1977. Population biology of Pacific ocean perch, Sebastes alutus , stocks in the Washington-Queen Charlotte Sound region, and their response to fishing. Fish.Bull. 75(2):369-403.

Gunderson, D. R. 1979. Results of cohort analysis for Pacific ocean perch stocks off British Columbia, Washington, and Oregon and an evaluation of alternative rebuilding strategies for these stocks. Unpublished report prepared for the Pacific Fishery Management Council, Portland OR.

Gunderson, D. R. 1981. An updated cohort analysis for Pacific ocean perch stocks off Washington and Oregon. Unpublished report prepared for the Pacific Fishery Management Council, Portland, OR.

Gunderson, D. R. 1984. The great widow rockfish hunt of 1980-82. North American Journal of Fisheries Management 4:465-468.

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

Hagerman, F. B. 1952. The biology of the Dover sole, Microstomus pacificus (Lockington). Calif.Dept.Fish and Game, Fish Bull. 85:48 p.

Haigh, R. and J. T. Schnute. 2003. The longspine thornyhead fishery along the west coast of Vancouver Island, British Columbia, Canada: portrait of a developing fishery. N.Amer.J.Fish.Mgmt. 23:120-140.

Hallacher, L. E. and D. A. Roberts. 1985. Differential utilization of space and food by the inshore rockfishes (*Scorpaenidae: Sebastes*) of Carmel Bay, California. Environ.Biol.Fish. 12:91-110.

Haltuch, M. 2011. 2011 petrale sole rebuilding analysis. NMFS, NWFSC, Seattle, WA, November 23, 2011.

Haltuch, M. and A. Hicks. 2009a. 2009 petrale sole rebuilding analysis. Pacific Fishery Management Council, Portland, OR.

Haltuch, M., A. Hicks, and K. See. 2011. Status of the U.S. petrale sole resource in 2010, Seattle, WA, November 23, 2011.

Haltuch, M. A. and A. Hicks. 2009b. Status of the U.S. petrale sole resource in 2008. Pacific Fishery Management Council, Portland, Oregon.

Haltuch, M. A., K. Ono, and J. Valero. 2013. Status of the U.S. petrale sole resource in 2012. Pacific Fishery Management Council, Portland, OR.

Hamel, O. 2011. Pacific Ocean Perch Rebuilding Analysis 2011. NMFS, NWFSC, Seattle, WA, December 13, 2011.

Hamel, O. and K. Ono. 2011. Stock Assessment of Pacific Ocean Perch in Waters off of the U.S. West Coast in 2011. NWFSC, Seattle, WA, September 20, 2011.

Hamel, O. S. 2006a. Rebuilding update for Pacific ocean perch. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2006b. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2005. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2006c. Status and Future Prospects for the Shortspine Thornyhead Resource in Waters off Washington, Oregon, and California as Assessed in 2005. *in* Volume 4: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2008a. Rebuilding update for darkblotched rockfish. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation.

Hamel, O. S. 2008b. Rebuilding update for Pacific ocean perch. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2008c. Status and future prospects for the darkblotched rockfish resource in waters off Washington, Oregon, and California as assessed in 2007. *in* Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation. Portland Fishery Management Council, Portland, OR.

Hamel, O. S. 2008d. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2007. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2009a. Rebuilding update for Pacific ocean perch in 2009. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S. 2009b. Status and Future Prospects for the Pacific Ocean Perch Resource in Waters off Washington and Oregon as Assessed in 2009. Pacific Fishery Management Council, Portland, Oregon.

Hamel, O. S., J. M. Cope, and S. Matson. 2013. Stock Assessment of Aurora Rockfish in 2013. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S., S. A. Sethi, and T. F. Wadsworth. 2009. Status and future prospects for Lingcod in waters off Washington, Oregon, and California as assessed in 2009. Pacific Fishery Management Council, Portland, OR.

Hamel, O. S., I. J. Stewart, and A. E. Punt. 2003. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Hamlett, W. C. and T. J. Koob. 1999. Female reproductive system. Pages 398-443 *in* W. C. Hamlett, editor. In Sharks, Skates and Rays. The Johns Hopkins University Press, Baltimire, MD.

Harry, G. Y. 1959. Time of spawning, length at maturity, and fecundity of the English, petrale, and Dover soles (*Parophrys vetulus*, *Eopsetta jordani*, and *Mircrostomus pacificus*, respectively). Fisheries Commission of Oregon, Research Briefs 7(1):5-13.

Hart, J. L. 1988. Pacific Fishes of Canada. Bull.Fish.Res.Bd.Canada 180:1-730.

Hawkins, S. L., J. Heifetz, C. M. Kondzela, J. E. Pohl, R. L. Wilmot, O. N. Katugin, and coauthors. 2005. Genetic variation of rougheye rockfish (*Sebastes aleutianus*) and shortraker rockfish (*S. borealis*) inferred from allozymes. Fishery Bulletin 103:524-535.

He, X., D. Pearson, E. J. Dick, J. Field, S. Ralston, and A. D. MacCall. 2006a. Status of the Widow Rockfish Resource in 2005. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

He, X., D. Pearson, E. J. Dick, J. C. Field, S. Ralston, and A. D. MacCall. 2008. Status of the widow rockfish resource in 2007: An Update. PFMC, Portland, Oregon.

He, X., D. E. Pearson, E. J. Dick, J. C. Field, S. Ralston, and A. D. MacCall. 2011. Status of the widow rockfish resources in 2011. Pacific Fishery Management Council, Portland, OR.

He, X., D. E. Pearson, J. C. Field, L. Lefebvre, and M. Key. 2013. Status of the Pacific sanddab resource in 2013. Pacific Fishery Management Council, Portland, OR.

He, X., A. Punt, A. D. MacCall, and S. Ralston. 2006b. Rebuilding Analysis for Widow Rockfish in 2005. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

He, X., S. V. Ralston, A. D. MacCall, D. E. Pearson, and E. J. Dick. 2003. Status of the widow rockfish resource in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Heifetz, J., J. N. Ianelli, D. M. Clausen, D. L. Courtney, and J. T. Fujioka. 2000. Slope rockfish. *in* Stock assessment fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2001. North Pacific Fishery Management Council, Anchorage.

Helly, J. J. and L. A. Levin. 2004. Global distribution of naturally occurring marine hypoxia on continental margins. Deep Sea Research 51:1159-1168.

Helser, T. 2006. Stock assessment of the blackgill rockfish (*Sebastes melanostomus*) population off the west coast of the United States in 2005. *in* Volume 5: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Hicks, A. C., M. A. Haltuch, and C. Wetzel. 2009. Status of greenstriped rockfish (*Sebastes elongatus*) along the outer coast of California, Oregon, and Washington Pacific Fishery Management Council, Portland, OR.

Hicks, A. C. and C. Wetzel. 2011. The Status of Dover Sole (*Microstomus pacificus*) along the U.S. West Coast in 2011. Pacific Fishery Management Council, Portland, OR.

Hicks, A. C., C. Wetzell, and J. Harms. 2013. The Status of Rougheye Rockfish (*Sebastes aleutianus*) and Blackspotted Rockfish (*S. melanostictus*) as a Complex Along the U.S. West Coast in 2013 Pacific Fishery Management Council, Portland, OR.

Hilborn, R., J. L. Valero, and M. Maunder. 2001. Status of the sablefish resource off the U.S. Pacific coast in 2001. *in* Appendix to the status of the Pacific Coast groundfish fishery through 2001 and acceptable biological catches for 2002 (Stock assessment and fishery evaluation). Pacific Fishery Management Council, Portland, OR.

Hill, K. T., E. Dorval, N. C. H. Lo, B. J. Macewicz, C. Show, and R. Felix-Uraga. 2008. Assessment of the Pacific sardine resource in 2007 for U.S. management in 2008. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-413.

Hobson, E. S. and J. R. Chess. 1988. Trophic relations of the blue rockfish, *Sebastes mystinus*, in a coastal upwelling system off northern California. Fishery Bulletin 86(4):715-743.

Hobson, E. S., J. R. Chess, and D. F. Howard. 1996. Zooplankters consumed by blue rockfish during brief access to a current off California's Sonoma coast. California Department of Fish and Game 82(2):87-92.

Hoenig, J. M. and S. H. Gruber. 1990. Life–history pattern in the elasmobranchs: implications for fisheries management. Pages 1-16 *in* H. L. J. Pratt, S. H. Gruber, and T. Taniuchi, editors. Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematic, and the Status of the Fisheries. Proceedings of the Second United States-Japan Workshop. NOAA Technical Report, Honolulu, HI.

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

Holden, M. J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Pages 117-137 *in* Sea Fisheries Research. John Wiley & Son, New York, NY.

Hosie, M. J. 1976. The arrowtooth flounder. Oregon Department of Fish and Wildlife.

Hulberg, L. W. and J. S. Oliver. 1979. Prey availability and the diets of two co-occurring flatfish. Pages 29-36 *in* S. J. Lipovsky and C. A. Simenstad, editors. Washington Sea Grant University of Washington, Seattle, 1979.

Hyde, J. R. and R. D. Vetter. 2007. The origin, evolution, and diversification of rockfishes of the genus *Sebastes* (Cuvier). Molecular Phylogenetics and Evolution 44:790-811.

Ianelli, J. N., R. Lauth, and L. D. Jacobson. 1994. Status of the thornyhead resource in 1994. *in* Status of the Pacific groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Portland, Oregon.

Ianelli, J. N., M. Wilkins, and S. Harley. 2000. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2000. *in* Appendix to Status of the Pacific coast groundfish fishery through 2000 and recommended Acceptable Biological Catches for 2001 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Ianelli, J. N. and M. Zimmerman. 1998. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1998. Pacific Fishery Management Council, Portland, OR.

Isaacs, J. D. and R. A. Schwartzlose. 1965. Migrant sound scatterers: interaction with the sea floor. Science 150:1810-1813.

Ito, D. H., D. K. Kimura, and M. E. Wilkins. 1986. Appendix 3: Current status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon. *in* Status of the Pacific coast groundfish fishery through 1986 and recommended acceptable biological catches for 1987. Pacific Fishery Management Council, Portland, OR.

Jacobson, L. D. 1990. Thornyheads stock assessment for 1990. Appendix D. *in* Status of the Pacific Coast Groundfish Fishery Through 1990 and Recommended Acceptable Biological Catches for 1991. Pacific Fishery Management Council, Portland, OR.

Jacobson, L. D. 1991. Thornyheads stock assessment for 1991. Appendix D. *in* Status of the Pacific Coast Groundfish Fishery Through 1991 and Recommended Acceptable Biological Catches for 1992. Pacific Fishery Management Council, Portland, OR.

Jacobson, L. D. and N. C. H. Lo. 1994. Spawning biomass of the northern anchovy in 1994, La Jolla, CA.

Jacobson, L. D. and R. D. Vetter. 1996. Bathymetric demography and niche separation of thornyhead rockfish: *Sebastolobus alascanus* and *Sebastablobus altivelis*. Can.J.Fish.Aquat.Sci. 53:600-609.

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

Jagielo, T. H., P. Adams, M. Peoples, S. Rosenfield, K. R. Silberberg, and T. E. Laidig. 1997. Assessment of lingcod in 1997. Pacific Fishery Management Council, Portland, OR.

Jagielo, T. H. and J. Hastie. 2001. Updated rebuilding analysis for lingcod. Unpublished report prepared for the Pacific Fishery Management Council, Portland, OR.

Jagielo, T. H. and F. Wallace. 2006. Assessment of Lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council in 2005 *in* Volume 5: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Jagielo, T. H., F. R. Wallace, and Y. W. Cheng. 2004. Assessment of lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2004 and recommended acceptable biological catches for 2005-2006 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Jagielo, T. H., D. Wilson-Vandenberg, J. Sneva, S. Rosenfield, and F. Wallace. 2000. Assessment of lingcod (Ophiodon elongatus) for the Pacific Fishery Management Council in 2000. *in* Appendix to Status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Jarvis, E. T., M. J. Allen, and R. W. Smith. 2004. Comparison of recreational fish catch trends to environment-species relationships and fishery-independent data in the Southern California Bight, 1980-2000. CalCOFI Reports 45:167-179.

Johnson, S. L., W. H. Barss, and R. L. Demory. 1982. Rockfish assessment studies on Heceta Bank, Oregon, 1980-81. Oregon Department of Fish and Wildlife Project Annual Report.

Jones, W. G. and G. Y. Harry, Jr. 1960. The Oregon trawl fishery for mink food 1948-1957. Fish Commission of Oregon Research Briefs 8:14-30.

Jorgensen, S. J., D. M. Kaplan, A. P. Klimley, S. G. Morgan, M. R. O'Farrell, and L. W. Botsford. 2006. Limited movement in blue rockfish *Sebastes mystinus*: internal structure of home range. Marine Ecological Progress Series 327:157-170.

Jow, T. 1969. Results of English sole tagging off California. Pac.Mar.Fish.Comm.Bull. 7:16-33.

Kaplan, I. C. and T. E. Helser. 2008. Stock Assessment of the Arrowtooth flounder (Atheresthes stomias) Population off the West Coast of the United States in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Karnowski, M., V. Gertseva, and A. Stephens. 2012. Historical reconstruction of Oregon's commercial fisheries landings. Oregon Department of Fish and Wildlife.

Karpov, K. A., D. P. Albin, and W. H. Van Buskirk. 1995. The marine recreational fishery in northern and central California. Caliufornia Department of Fish and Game Bulletin 176:192 pgs.

Keeling, R. F., A. Körtzinger, and N. Gruber. 2010. Ocean deoxygenation in a warming world. Annual Reviews in Marine Science 2:199-229.

Kendall, A. W., Jr. and W. H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Pages 99-128 *in*. Alaska Sea Grant College Program, Anchorage, Alaska, 1986.

Kendall, A. W., Jr. and A. C. Matarese. 1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish, Anoplopoma fimbria , in relation to their potential use in management. Marine Fisheries Review 49:1-13.

Ketchen, K. S. 1956. Factors influencing the survival of the lemon sole (Parophrys vetulus) in Hecate Strait, British Columbia. Fish.Res.Bd.Canada 13:647-694.

Ketchen, K. S. 1986. The spiny dogfish (*Squalus acanthias*) in the northeast Pacific and a history of its utilization. Canadian Special Publication of Fisheries and Aquatic Sciences 88.

Ketchen, K. S. and C. R. Forrester. 1966. Population dynamics of the petrale sole, *Eopsetta jordani*, in waters off western Canada. Bull.Fish.Res.Bd.Canada 153:1-195.

Key, M., A. D. MacCall, T. Bishop, and B. Leos. 2006. Stock assessment of the gopher rockfish (*Sebastes carnatus*) *in* Volume 5: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Key, M., A. D. MacCall, D. B. Field, D. Aseltine-Neilson, and K. Lynn. 2008. The 2007 Assessment of Blue Rockfish (Sebastes mystinus) in California. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Mar.Ecol.Prog.Ser. 243:39-55.

King, J. R. and G. A. McFarlane. 2003. Marine fish life history strategies: applications to fishery management. Fisheries Management and Ecology 10:249-264.

Klingbeil, R. A. 1976. Southern range extensions of the blue rockfish, *Sebastes mystinus*; the flag rockfish, *S. rubrivinctus*; and the shortbelly rockfish, *S. jordani*. California Fish and Game 62:160.

Koslow, J. A., G. W. Boehlert, J. D. M. Gordon, R. L. Haedrick, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science 57:548-557.

Kramer, D. E. and V. M. O'Connell. 1995. Guide to Northeast Pacific rockfishes. Genera *Sebastes* and *Sebastolobus*. Alaska Sea Grant, Marine Advisory Bulletin 25.

Kravitz, M. J., W. G. Pearcy, and M. P. Guin. 1977. Food of five species of co-occurring flatfishes on Oregon's continental shelf. Fishery Bulletin 74(4):984-990.

Kronman, M. (S. B. M. H. Museum). 1999. Santa Barbara's hook-and-line fisheries, Santa Barbara, CA.

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

Lai, H. L., M. Haltuch, A. Punt, and J. M. Cope. 2006. Stock assessment of petrale sole: 2004. *in* Volume 2: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, Oregon.

Lai, H. L., J. V. Tagart, J. N. Ianelli, and F. R. Wallace. 2003. Status of the yellowtail rockfish resource in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Laidig, T. E., P. B. Adams, and W. M. Samiere (M. E. Wilkins and M. W. Saunders). 1997. Feeding habits of Sablefish, Anoplopoma fimbria, off the coast of Oregon and California. National Oceanic and Atmospheric Administration.

Laidig, T. E., D. L. Watters, and M. M. Yoklavich. 2009. Demersal fish and habitat associations from visual surveys on the central California shelf. Estuarine, Coastal, and Shelf Science 83:629-637.

Lamb, A. and P. Edgell. 1986. Coastal fishes of the Pacific northwest. Harbour Publishing Co. Ltd., Madeira Park, British Columbia.

LaRiviere, M. G., D. D. Jessup, and S. B. Mathews. 1980. Lingcod, Ophiodon elongatus , spawning and nesting in San Juan Channel, Washington. Calif.Dept.Fish and Game 67:231-239.

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

Larson, R. J. and D. Wilson-Vandenberg. 2001. Other nearshore rockfishes. Pages 185-188 *in* W. S. Leet, R. Klingbeil, and E. J. Larson, editors. California's Living Marine Resources: A status report, volume 1. California Department of Fish and Game.

Lauth, R. 1987. Spawning ecology and nesting behavior of the Cabezon, Scorpaenichthys mamoratus in Puget Sound, Washington. Master's Thesis. University of Washington.

Lauth, R. 2000. The 1999 Pacific west coast upper continental slope trawl survey of groundfish resources off Washington, Oregon, and California: estimates of distribution, abundance, and length composition. National Oceanic and Atmospheric Administration.

Lea, R. N., R. D. McAllister, and D. A. VanTresca. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. California Department of Fish and Game Fish Bulletin 177

Leaman, B. M. and R. J. Beamish. 1984. Ecological and management implications of longevity in some northeast Pacific groundfish. Bulletin of the International North Pacific Fisheries Commission 42:85-97.

Lee, Y. W. 2002. Oceanographic effect on the dynamics of food habits and growth conditions of some groundfish species of the Pacific Northwest. Ph.D Dissertation. Oregon State University.

Lenarz, W. H. 1993. An initial examination of the status of the darkblotched rockfish fishery off the coasts of California, Oregon, and Washington. *in* Appendix C in Appendices to the status of the Pacific Coast groundfish through 1993 and recommended acceptable biological catches for 1994.

Lenarz, W. H. and T. Wyllie Echeverria. 1991. Sexual dimorphism in *Sebastes*. Environmental Biology of Fishes 30:71-80.

Levin, P. S., E. E. Holmes, K. R. Piner, and C. J. Harvey. 2006. Shifts in a Pacific Ocean fish assemblage: The potential influence of exploitation. Conservation Biology 20:1181-1190.

Limbaugh, C. 1955. Fish life in the kelp beds and the effects of kelp harvesting. University of California, Institute of Marine Research 55-9:1-158.

Lorz, H. V., W. G. Pearcy, and M. Fraidenburg. 1983. Notes on the feeding habits of the yellowtail rockfish, Sebastes flavidus , off Washington and in Queen Charlotte Sound. Calif.Fish.Game 69:33-38.

Love, M. S. 1996. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, California.

Love, M. S. 2011. Certainly more than you want to know about the fishes of the Pacific Coast. A postmodern experience. Really Big Press, Santa Barbara, CA.

Love, M. S., B. Axell, P. Morris, R. Collins, and A. Brooks. 1987. Life history and fishery of the California scorpionfish, Scorpaena guttata , within the Southern California Bight. Fishery Bulletin 85:90-116.

Love, M. S., J. E. Caselle, and W. Van Buskirk. 1998. A severe decline in the commercial passenger fishing vessel rockfish (*Sebastes* spp.) catch in the southern California bight, 1980-1996. CalCOFI Reports 39:180-195.

Love, M. S. and A. W. Ebeling. 1978. Food and habitat of three switch-feeding fishes in the kelp forests off Santa Barbara, California. Fishery Bulletin 76(1):257-271.

Love, M. S., C. W. Mecklenburg, T. A. Mecklenburg, and L. K. Thorsteinson. 2005. Resource Inventory of Marine and Estuarine Fishes of the West Coast and Alaska: A Checklist of North Pacific and Arctic Ocean Species from Baja California to the Alaska-Yukon Border. US Department of the Interior, US Geological Survey. National Biological Information Infrastructure.

Love, M. S., P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: Sebastes) from the southern California bight.

Love, M. S. and M. Yoklavich. 2008. Habitat characteristics of juvenile cowcod, *Sebastes levis* (Scorpaenidae), in Southern California. Environmental Biology of Fishes (82):195-202.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, California.

Lowe, C. G., K. M. Anthony, E. T. Jarvis, L. F. Bellquist, and M. S. Love. 2009. Site fidelity and movement patterns of groundfish associated with offshore petroleum platforms in the Santa Barbara Channel. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:71-89.

Lowry, M. S. and J. V. Carretta. 1999. Market squid (*Loligo opalescens*) in the diet of Californa sea lions (*Zalophus californianus*) in southern California (1981-1995). CalCOFI Reports 40:196-207.

MacCall, A. D. 2002. Status of bocaccio off California in 2002. *in* Volume 1 Status of the Pacific Coast groundfish fishery through 2002 and recommended acceptable biological catches for 2003 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2003a. Bocaccio rebuilding analysis for 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2003b. Status of bocaccio off California in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2006a. Bocaccio Rebuilding Analysis for 2005. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2006b. Status of Bocaccio off California in 2005. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2008a. Bocaccio rebuilding analysis for 2007. Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2008b. Status of bocaccio off California in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

MacCall, A. D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. ICES J.of Mar.Sci. 66:2267-2271.

MacCall, A. D. and X. He. 2002. Bocaccio rebuilding analysis for 2002. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2002 and recommended acceptable biological catches for 2003 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

MacCall, A. D., S. Ralston, D. Pearson, and E. Williams. 1999. Status of bocaccio off California in 1999 and outlook for the next millennium. *in* Appendix to Status of the Pacific Coast groundfish fishery through 1999 and recommended acceptable biological catches for 2000 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Mace, P. M., N. W. Bartoo, A. B. Hollowed, P. Kleiber, R. D. Methot, S. A. Murawski, and coauthors. 2001. Marine Fisheries Stock Assessment Improvement Plan. NOAA Technical Memorandum NMFS-F/SPO-56:69.

Mace, P. M. and I. J. Doonan. 1988. A generalized bioeconomic simulation model for fish population dynamics. New Zealand Fishery Assessment Research Document 88(4).

MacGregor, J. S. 1986. Relative abundance of four species of Sebastes off California and Baja California. Calif.Coop.Oceanic Fish.Invest.Rep. 27:121-135.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78(6):1069-1079.

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

Martin, L. and G. D. Zorzi. 1993. Status and review of the California skate fishery. Pages 39-52 *in* S. Branstetter, editor. Conservation biology of elasmobranchs, volume 115. NOAA Technical Report NMFS.

Mason, J. C., R. J. Beamish, and G. A. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) in waters off the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences 40:2621-2134.

Mason, J. E. 1998. Declining rockfish lengths in the Monterey Bay, California, recreational fishery, 1959-94. Marine Fisheries Review 60(3):15-28.

Mathews, S. B. and M. LaRiviere. 1987. Movement of tagged lingcod, Ophiodon elongatus , in the Pacific Northwest. Fish Bull. 85:153-159.

Matthews, K. R. 1986. Movement of two nearshore, territorial rockfishes previously reported as non-movers and implications to management. Calfornia Department of Fish and Game Bulletin 72(2):103-109.

Matthews, K. R. 1992. A telemetric study of the home ranges and homing routes of lingcod, Ophiodon elongatus , on shallow rocky reefs off Vancouver Island, British Columbia. Fish.Bull. 90:784-790.

Maunder, M., J. T. Barnes, D. Aseltine-Neilson, and A. D. MacCall. 2006. The Status of California Scorpionfish (Scorpaena guttata) off Southern California in 2004. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

MBC. 1987. Ecology of important fisheries species offshore California. Minerals Management Service, Pacific Outer Continental Shelf Region, Washington, D.C.

McClatchie, S., R. Goerick, R. Rich-Cosgrove, and R. Vetter. 2010. Oxygen in the Southern California Bight: multidecadal trends and implications for demersal fisheries. Geophysical Research Letters 37(19).

McEachran, J. D. 1990. Diversity of rays: why are there so many species? Chondros 5(2):1-6.

McFarlane, G. A. and R. Beamish. 1983a. Preliminary observations on the juvenile biology of sablefish (Anoplopoma fimbria) off the west coast of Canada. *in* Proceedings of the International Sablefish Symposium. Alaska Sea Grant Report 83-3.

McFarlane, G. A. and R. J. Beamish. 1983b. Biology of adult sablefish (*Anoplopoma fimbria*) in waters off western Canada. Alaska Sea Grant College Program, University of Alaska, Anchorage, 1983.

McFarlane, G. A. and J. R. King. 2003. Migration patterns of spiny dogfish (*Squalus acanthias*) in the North Pacific Ocean. Fishery Bulletin 101:358-367.

Merkel, T. J. 1957. Food habits of king salmon, *Oncorhynchus tshawytscha* (Walbaum), in the vicinity of San Francisco, California. California Department of Fish and Game 43:249-270.

Methot, R. D. 2000. Rebuilding analysis for canary rockfish. Unpublished report prepared for the Pacific Fishery Management Council, Portland, OR.

Methot, R. D. 2006. Updated Rebuilding Analysis for Canary Rockfish Based on Stock Assessment in 2005. *in* Volume 6: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Methot, R. D. and K. Piner. 2002a. Rebuilding analysis for yelloweye rockfish: update to incorporate results of coastwide assessment in 2002. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Methot, R. D. and K. Piner. 2002b. Status of the canary rockfish resource off California, Oregon and Washington in 2001. *in* Volume 1 Status of the Pacific Coast groundfish fishery through 2002 and recommended acceptable biological catches for 2003 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Methot, R. D. and J. Rogers. 2001. Rebuilding analysis for darkblotched rockfish. Unpublished report prepared for the Pacific Fishery Management Council, Portland, OR.

Methot, R. D. and I. J. Stewart. 2006. Status of the U.S. canary rockfish resource in 2005. *in* Volume 6: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Methot, R. D., F. Wallace, and K. Piner. 2003. Status of yelloweye rockfish off the U.S. West Coast in 2002. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Miller, A. K. and W. Sydeman. 2004. Rockfish response to low-frequency ocean climate change as revealed by the diet of a marine bird over multiple time scales. Marine Ecology Progress Series 281:207-216.

Miller, D. J. and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; a reef ecology study and giant kelp Macrocystis pyrifera, experiments in Monterey Bay, California. Calif.Dept.Fish and Game, Fish Bull. 158:131.

Miller, D. J. and D. Gotshall. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California: July 1, 1957-June 30, 1961. California Department of Fish and Game Fishery Bulletin 130:135 pgs.

Miller, D. J. and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif.Dept.Fish and Game, Fish.Bull. 157:249.

Mills, K. L., T. Laidig, S. Ralston, and W. J. Sydeman. 2007. Diets of top predators indicate pelagic juvenile rockfish (*Sebastes* spp.) abundance in the California Current System. Fisheries Oceanography 16(3):273-283.

Morejohn, G. V., J. T. Harvey, and L. T. Krasnow. 1978. The importance of *Loligo opalescens* in the food web of marine vertebrates in Monterey Bay, California. California Department of Fish and Game Bulletin 169:67-98.

Moser, H. G. 1974. Development and distribution of larvae and juveniles of Sebastolobus (Pisces: Family Scorpaenidae). Fishery Bulletin 72:865-884.

Moser, H. G. and E. H. Ahlstrom. 1978. Larvae and pelagic juveniles of blackgill rockfish, *Sebastes melanostomus*, taken in midwater trawls off Southern California and Baja California. Journal of the Fisheries Research Board of Canada 35:981-996.

Moser, H. G., R. L. Charter, W. Watson, D. A. Ambrose, J. Butler, S. R. Charter, and coauthors. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the Southern California Bight in relation to environmental conditions and fishery exploitation. CalCOFI Rep. 41:132-147.

Moser, H. G. e. 1996. The early stages of fishes in the California Current region. California Cooperative Oceanic Fisheries Investigations, Atlas No. 33. Allen Press, Inc., Lawrence, KS.

Moyle, P. B. and J. J. J. Cech. 1996. Fishes, An Introduction to Ichthyology, 3rd edition. Prentice-Hall, Upper Saddle River, NJ.

Mulligan, T. J. and B. M. Leaman. 1992. Length-at-age analysis: Can you get what you see? Can.J.Fish.Aquat.Sci. 49:632-643.

Myers, R. A., K. G. Bowen, and N. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences (56):2404-2419.

Nakano, H. and K. Nagasawa. 1996. Distribution of pelagic elasmobranchs caught by salmon research gillnets in the North Pacific. Fisheries Science 62:860-865.

Nichol, D. 1990. Life history examination of darkblotched rockfish (Sebastes crameri) off the Oregon coast. M.S. Thesis. Oregon State University.

Nichol, D. G. and E. K. Pikitch. 1994. Reproduction of darkblotched rockfish off the Oregon coast. Trans.Am.Fish.Soc. 123:469-481.

Nitsos, R. J. 1965. Species composition of rockfish (family *Scorpaenidae*) landed by California otter trawl vessels, 1962-1963. Pacific Marine Fisheries Commission, Portland, OR.

Nitsos, R. J. and P. H. Reed. 1965. The animal food fishery in California, 1961-1962. California Fish and Game 51(1):16-27.

NMFS, S. and S. OT (S. National Marine Fisheries). 1998. Status of the shortspine thornyhead resource off the U.S. Pacific coast in 1998. In: Appendix to Status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999. Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

NOAA (N. O. a. A. Administration). 1990. West coast of North America coastal and ocean zones strategic assessment: Data atlas. OMA/NOS, Ocean Assessments Division, Strategic Assessment Branch, NOAA.

Norton, E. C. and R. B. MacFarlane. 1995. Nutritional dynamics of reproduction in viviparous yellowtail rockfish, Sebastes flavidus Fish.Bull. 93:299-307.

O'Connell, C. P. 1953. The life history of the cabezon Scorpaenichthys marmoratus

O'Connell, V. M. and D. W. Carlile. 1993. Habitat-specific density of adult yelloweye rockfish Sebastes ruberrimus in the eastern Gulf of Alaska. Fish.Bull. 91:304-309.

O'Connell, V. M. and F. C. Funk. 1986. Age and growth of yelloweye rockfish (Sebastes ruberrimus) landed in southeastern Alaska. Pages 171-185 *in*, volume 87-2. Alaska Sea Grant College Program, Anchorage, Alaska, 1986.

O'Farrell, M. R. and L. W. Botsford. 2005. Estimation of change in lifetime egg production from length frequency data. Canadian Journal of Fisheries and Aquatic Sciences 62:1626-1639.

O'Farrell, M. R. and L. W. Botsford. 2006. Estimating the status of nearshore rockfish (*Sebastes* spp.) populations with length frequency data. Ecological Applications 16(3):977-986.

Oda, K. T. 1992. Chilipepper. Pages 122 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's Living Marine Resources and Their Utilization. California Sea Grant Program, Davis, CA.

Orcutt, H. G. 1950. The life history of the starry flounder (Platichthys stellatus). Calif.Dept.Fish and Game, Fish.Bull. 78.

Orr, J. W., M. A. Brown, and D. C. Baker. 1998. Guide to Rockfishes (Scorpaenidae) of the Genera Sebastes, Sebastolobus, and Adelosebastes of the Northeast Pacific Ocean.

Orr, J. W. and S. Hawkins. 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanosticus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: *Scorpaeniformes*). Fishery Bulletin 106:111-134.

Orton, G. 1955. Early developmental stages of the California scorpionfish, Scorpaena guttata Copeia 1955:210-214.

Patrick, W. S., P. Spence, O. Osmeth, J. M. Cope, J. Field, D. Kobayashi, and coauthors. 2009. Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six U.S. fisheries. U.S. Dep. Commerce.

Pearcy, W. G. 1962. Egg masses and early developmental stages of the scorpaneid fish, Sebastolobus. J.Fish.Res.Bd.Canada 1169-1173.

Pearcy, W. G. 1978. Distribution and abundance of small flatfishes and other demersal fishes in a region of diverse sediments and bathymetry off Oregon. Fishery Bulletin 78:629-643.

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

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

Pearsall, I. A. and J. J. Fargo. 2007. Diet composition and habitat fidelity for groundfish in Hecate Strait, British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 2692:141.

Pearson, D. 1989. Survey of fishes and water properties of South San Francisco Bay, California, 1973-82. U.S. Dept. Comm.

Pearson, D. E., D. A. Douglas, and B. Barss. 1993. Biological observation from the Cobb Seamount rockfish fishery. Fishery Bulletin 91:573-576.

Pearson, D. E., J. E. Hightower, and J. T. H. Chan. 1991. Appendix D: Age, growth, year class strength, and potential yield for shortbelly rockfish. *in* Status of the Pacific coast groundfish fishery through 1989 and recommended acceptable biological catches for 1990. Pacific Fishery Management Council, Portland, OR.

Pearson, D. E. and S. L. Owen. 1992. English sole. Pages 99-100 *in* W. S. Leet, C. M. Dewees, and C. W. Haugen, editors. California's Living Marine Resources and Their Utilization. California Sea Grant Program, Davis, CA.

Pearson, K. E. and D. R. Gunderson. 2003. Reproductive biology and ecology of shortspine thornyhead rockfish, *Sebastolobus alascanus*, and longspine thornyhead rockfish, *S. altivelis*, from the northeastern Pacific Ocean. Environ.Biol.Fish. 67:117-136.

Pedersen, M. G. 1975. Movements and growth of petrale sole tagged off Washington and southwest Vancouver Island. J.Fish.Res.Bd.Canada 32:2169-2177.

Pederson, M. G. 1975. Movements and growth of petrale sole (*Eopsetta jordani*) tagged off Washington and southwest Vancouver Island. Fishery Research Board of Canada Progress Report 32(1):2169-2177.

Perez, M. A. and M. A. Bigg. 1986. Diet of northern fur seals, *Callorhinus ursinus*, off Western North America. Fishery Bulletin 84:957-970.

Perry, R. I., M. Stocker, and J. Fargo. 1994. Environmental effects on the distribution of groundfish in Hecate Strait, British Columbia. Can.J.Fish.Aquat.Sci. 51:1401-1409.

PFMC. 2004. Amendment 16-3 to the Pacific Groundfish Fishery Management Plan; rebuilding plans for bocaccio, cowcod, widow rockfish, and yelloweye rockfish. Draft Environmental Impact Statement. Pacific Fishery Management Council, Portland, OR.

PFMC. 2006. Final environmental impact statement for the proposed groundfish acceptable biological catch and optimum yield specifications and management measures: 2007-2008 Pacific coast groundfish fishery and Amendment 16-4: Rebuilding plans for seven depleted Pacific coast groundfish species. Pacific Fishery Management Council, Portland, OR.

PFMC and NMFS (Pacific Fishery Management Council and National Marine Fisheries Service). 2011. Proposed Harvest Specifications and Management Measures for the 2011-2012 Pacific Coast Groundfish Fishery and Amendment 16-5 to the Pacific Coast Groundfish Fishery Management Plan to Update Existing Rebuilding Plans and Adopt a Rebuilding Plan for Petrale Sole, Final Environmental Impact Statement. National Marine Fisheries Service, Northwest Region, Seattle, February 2011.

Phillips, J. B. 1939. The rockfish of the Monterey wholesale fish markets. California Fish and Game 25:214-225.

Phillips, J. B. 1957. A review of the rockfishes of California (Family Scorpaenidae). Calif.Dep.Fish and Game, Fish Bull. 104:158.

Phillips, J. B. 1964. Life history studies on ten species of rockfishes (genus Sebastodes). Calif.Dep.Fish and Game, Fish Bull. 126:70.

Phillips, J. B. and S. Inamura. 1954. The sablefish fishery of California. Pac.Mar.Fish.Comm.Bull. 3:5-38.

Piner, K. 2006. Cowcod Rebuilding Analysis 2005 Analysis of the Progress towards Rebuilding in the Southern California Bight. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Piner, K., E. J. Dick, and J. Field. 2006. 2005 Stock Status of Cowcod in the Southern California Bight and Future Prospects. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Piner, K. and R. Methot. 2001. Stock status of shortspine thornyhead off the Pacific west coast of the United States 2001. *in* Appendix to Status of the Pacific Coast Groundfish Fishery Through 2001 and Acceptable Biological Catches for 2002 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Piner, K., M. Schirripa, T. Builder, J. Rogers, and R. Methot. 2000. Bank rockfish (*Sebastes rufus*) stock assessment for Eureka, Monterey, and Conception INPFC Areas north of Pt. Conception, California. Pacific Fishery Mangement Council, Portland, OR.

Porter, P. 1964. Notes on fecundity, spawning, and early life history of petrale sole (*Eopsetta jordani*), with descriptions of flatfish larvae collected in the Pacific Ocean off Humboldt Bay, California. Humboldt State College, Arcata, CA.

Pratt, H. L. J. and J. G. Casey. 1990. Shark reproductive strategies as a limiting factor in directed fisheries, with a review of Holden's method of estimating growth parameters Pages 97-110 *in* H. L. J. Pratt, S. H. Gruber, and T. Taniuchi, editors. Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematic, and the Status of the Fisheries. Proceedings of the Second United States-Japan Workshop. NOAA Technical Report NMFS, Honolulu, HI.

Preti, A., S. E. Smith, and D. A. Ramon. 2004. Diet differences in the thresher shark (*Alopias vulpinus*) during transition from a warm-water regime to a cool-water regime off California-Oregon, 1988-2000. CalCOFI Reports 45:118-125.

SSC default rebuilding analysis (Version 2.8a, April 2005). 2005. University of Washington, Seattle.

Punt, A. E., O. S. Hamel, and I. J. Stewart. 2003. Rebuilding analysis for Pacific ocean perch for 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Punt, A. E. and J. N. Ianelli. 2001. Revised rebuilding analysis for Pacific ocean perch. Unpublished report to the Pacific Fishery Management Council, Portland, OR.

Punt, A. E. and A. D. MacCall. 2002. Revised rebuilding analysis for widow rockfish for 2002. Unpublished report to the Pacific Fishery management Council, Portland, OR.

Rackowski, J. P. and E. K. Pikitch. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest), Pacific and speckled sanddabs. Biological Report 82(11.107). Fish and Wildlife Service, U.S. Department of the Interior.

Ralston, S. 2006. An Assessment of Starry Flounder off California, Oregon, and Washington (2005). *in* Volume 2: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Ralston, S. and E. J. Dick. 2003. The status of black rockfish (Sebastes melanops) off Oregon and northern California in 2003. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Ralston, S. and J. N. Ianelli. 1998. When lengths are better than ages: The complex case of bocaccio. Pages 451-468 *in* F. Funk and T. J. Quinn Ii and J. Heifetz and J. Ianelli and J. E. Powers and J. F. Schweigert, and coeditors, editors. Fishery Stock Assessment Models. Univerisity of Alaska, Alaska Sea Grant College Program Report No. AK-SG-98-01, Fairbanks, Alaska.

Ralston, S., J. N. Ianelli, D. E. Pearson, M. E. Wilkins, R. A. Miller, and D. Thomas. 1996. Status of bocaccio in the Conception/Monterey/Eureka INPFC areas in 1996 and recommendations for management in 1997. *in* Appendix Vol. 1: Status of the Pacific Coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Ralston, S., D. Pearson, and J. Reynolds. 1998. Status of the chilipepper rockfish stock in 1998. *in* Status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biologic catches for 1999: stock assessment and fishery evaluation, appendix. Pacific Fishery Management Council, Portland, OR.

Ralston, S., D. E. Pearson, J. C. Field, and M. Key. 2010. Documentation of the California catch reconstruction project. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-461.

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

Reilly, P. 2001. Blue Rockfish. Pages 165-167 *in* W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson, editors. California's Living Marine Resources: A Status Report. The Resources Agency, California Department of Fish and Game.

Reilly, P. N., D. Wilson-Vandenberg, R. N. Lea, C. Wilson, and M. Sullivan. 1994. Recreational angler's guide to the common nearshore fishes of Northern and Central California.

Reilly, P. N., D. Wilson-Vandenberg, D. L. Watters, J. E. Hardwick, and D. Short. 1993. On board sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, May 1987 to December 1991. Marine Research Division Administrative Report:242 pgs.

Richardson, S. L. and W. A. Laroche. 1979. Development and occurrence of larvae and juveniles of the rockfishes Sebastes crameri , Sebastes pinniger , and Sebastes helvomaculatus (Family Scorpaenidae) off Oregon. Fish.Bull. 77:1-46.

Rickey, M. H. 1993. Status of the coastal arrowtooth flounder resource in 1993. *in* Appendices to the Status of the Pacific Coast Groundfish Fishery through 1993 and Recommended Acceptable Biological Catches for 1994: Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, OR.

Rickey, M. H. 1995. Maturity, spawning, and seasonal movements of arrowtooth flounder, Atheresthes stomias , off Washington. Fish.Bull. 93:127-138.

Robinson, H. J., G. M. Cailliet, and D. A. Ebert. 2007. Food habits of the longnose skate, *Raja rhina* (Jordan and Gilbert, 1880), in central California waters. Environmental Biology of Fishes 80:165-179.

Roedel, P. M. 1953. Common ocean fishes of the California coast. California Fish and Game Bulletin 91:184 pgs.

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

Rogers, J. B. 1994. Preliminary status of the splitnose rockfish stock in 1994. *in* Appendix H to the Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Portland, OR.

Rogers, J. B. 2003a. Darkblotched rockfish (Sebastes crameri) 2003 stock status and rebuilding update. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2003 and recommended acceptable biological catches for 2004 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Rogers, J. B. 2003b. Species allocation of *Sebastes* and *Sebastolobus* sp. caught by foreign countries from 1965 through 1976 off Washington, Oregon, and California, U.S.A. U.S. Department of Commerce.

Rogers, J. B. 2005a. Status of the darkblotched rockfish (*Sebastes crameri*) resource in 2005. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Rogers, J. B. 2005b. Update of darkbotched rockfish (*Sebastes crameri*) rebuilding analyses. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Rogers, J. B., T. L. Builder, P. R. Crone, J. Brodziak, R. D. Methot, R. J. Conser, and coauthors. 1998. Status of the shortspine thornyhead (Sebastolobus alascanus) resource in 1998. *in* Appendix to Status of the Pacific coast groundfish fishery through 1998 and recommended acceptable biological catches for 1999 (Stock assessment and fishery evaluation). Pacific Fishery Management Council, Portland, OR.

Rogers, J. B., L. D. Jacobson, R. Lauth, J. N. Ianelli, and M. Wilkins. 1997. Status of the thornyhead resource in 1997. *in* Appendix to Status of the Pacific coast groundfish fishery through 1997 and

recommended acceptable biological catches for 1998 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Rogers, J. B., R. D. Methot, T. L. Builder, K. Piner, and M. Wilkins. 2000. Status of the darkblotched rockfish (Sebastes crameri) resource in 2000. *in* Appendix to Status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Rogers, J. B. and E. K. Pikitch. 1992. Numerical definition of groundfish assemblages caught off the coasts of Oregon and Washington using commercial fishing strategies. Canadian Journal of Fisheries and Aquatic Sciences 49:2648-2656.

Rogers, J. B., M. Wilkins, D. Kamakawa, F. Wallace, T. Builder, M. Zimmerman, and coauthors. 1996. Status of the remaining rockfish in the Sebastes complex in 1996 and recommendations for management in 1997. *in* Appendix to Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Rosenthal, R. J., L. Haldorson, L. J. Field, V. Moran-O'Connell, M. G. LaRiviere, J. Underwood, and coauthors. 1982. Inshore and shallow offshore bottomfish resources in the southeastern Gulf of Alaska (1981-1982). Alaska Dept. Fish and Game, Juneau, Alaska.

Sakuma, K. M. and S. Ralston. 1995. Distribution patterns of late larval groundfish off central California in relation to hydrographic features during 1992 and 1993. Calif.Coop.Oceanic Fish.Invest.Rep. 36:179-192.

Sampson, D. and Y. W. Lee. 1999. An Assessment of the Stocks of Petrale Sole off Washington, Oregon and Northern California in 1998. *in* Status of the Pacific Coast groundfish fishery through 1998 and recommended biological catches for 1994: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Sampson, D. B. 1996. Appendix C: Stock status of canary rockfish off Oregon and Washington in 1996. *in* C. Pacific Fishery Management, editor. Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Sampson, D. B. 2002. Analysis of data from the at-sea data collection project. Coastal Oregon Marine Experiement Station, Oregon State University.

Sampson, D. B. 2005. The status of Dover sole off the U.S. west coast in 2005. Pacific Fishery Management Council, Portland, OR, In press.

Sampson, D. B. 2008. The Status of Black Rockfish off Oregon and California in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Sampson, D. B. and E. M. Stewart. 1993. An assessment of the English sole stock off Oregon and Washington. *in* Appendix H-1 to status of the Pacific coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994 (SAFE Report). Pacific Fishery Management Council, Portland, OR.

Sampson, D. B. and E. M. Stewart. 1994. Appendix G: Status of the canary rockfish resource off Oregon and Washington in 1994. *in* Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Sampson, D. B. and C. Wood. 2001. Stock status of Dover sole off the west coast in 2000. *in* Appendix to the Status of the Pacific Coast Groundfish Fishery Through 2001 and Acceptable Biological Catches for 2002 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Sarmiento, J. L., T. M. Hughes, R. J. Stouffer, and S. Manabe. 1998. Simulated response of the ocean carbon cycle to anthropogenic climate warming. Nature 393:245-249.

Saunders, M. W. and G. A. McFarlane. 1993. Age and length at maturity of the female spiny dogfish, *Squalus acanthias*, in the Strait of Georgia, British Columbia, Canada. Environ.Biol.Fish. 38:49-57.

Schirripa, M. and J. J. Colbert. 2006. Status of the sablefish resource off the continental U.S. Pacific coasts in 2005. *in* Volume 4: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Schirripa, M. J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. *in* Volume 1: Status of the Pacific Coast groundfish fishery through 2002 and recommended acceptable biological catches for 2003 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Schirripa, M. J. 2008. Status of the sablefish resource off the continental U.S. Pacific coast in 2007. Status of the Pacific Coast groundfish fishery through 2007.Stock assessment and fishery evaluation.Stock assessments and rebuilding analyses.

Schirripa, M. J. and R. Methot. 2001. Status of the sablefish resource off the U.S. Pacific coast in 2001. *in* Appendix to the Status of the Pacific Coast Groundfish Fishery Through 2001 and Acceptable Biological Catches for 2002 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Seibel, B. A. 2011. Critical oxygen levels and metabolic suppression in oceanic oxygen minimum zones. The Journal of Experimental Biology 214:326-336.

Sette, O. E. and R. H. Fielder. 1928. Fishery industries of the United States, 1927. *in* Report of the United States Commissioner of Fisheries for the Fiscal Year 1928. U.S. Department of Commerce.

Shaffer, J. A., D. C. Doty, R. M. Buckley, and J. E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish Sebastes diploproa Mar.Ecol.Prog.Ser. 123:13-21.

Shaw, F. R. and D. R. Gunderson. 2006. Life history traits of the greenstriped rockfish, *Sebastes elongatus*. California Fish and Game 92:1-23.

Shaw, W. N. and T. J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- lingcod. Army Corps of Engineers TR EL-82-4.

Siebenaller, J. F. 1978. Genetic variability in deep-sea fishes of the genus sebastolobus. Pages 95-122 *in* B. Battaglia and J. Beardmore, editors. Marine Organisms, New York, NY.

Siebenaller, J. F. and G. N. Somero. 1982. The Maintenance of Different Enzyme Activity Levels in Congeneric Fishes Living at Different Depths. Physiological Zoology 55:171-179.

Simenstad, C. A., B. S. Miller, C. F. Nybalde, K. Thornburgh, and L. J. Bledsoe. 1979. Food web relationships of northern Puget Sound and the Strait of Juan de Fuca. US Interagency (NOAA, EPA) Energy/Environ. Res. Dev. Prog. Rep., Washington , D.C.

Smith, B. D., G. A. McFarlane, and A. J. Cass. 1990. Movements and mortality of tagged male and female lingcod in the Strait of Georgia, British Columbia. Trans.Am.Fish.Soc. 119:813-824.

Smith, K. L. and N. O. Brown. 1983. Oxygen consumption of pelagic juveniles and demersal adults of the deep-sea fish Sebastolobus altivelis, measured by depth. Mar.Biol. 76:325-332.

Smith, S. E., D. W. Au, and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research 49:663-678.

Sopher, T. R. 1974. A trawl survey of the fishes of Arcata Bay, California. Humbolt State University.

Stanley, R. D., B. M. Leaman, L. Haldorson, and V. M. O'Connell. 1994. Movements of tagged adult yellowtail rockfish, *Sebastes flavidus*, off the West Coast of North America. Fish.Bull. 92:655-663.

Starr, P. J. and J. Fargo. 2004. Petrale sole stock assessment for 2003 and recommendations for management in 2004. CSAS Res. Doc. 2004/036:92.

Starr, P. J. and R. Haigh. 2000. Assessment of the Canadian longspine thornyhead (*Sebastolobus altivelis*) for 2000. Canadian Stock Assessment Secretariat, Nanaimo, British Columbia.

Starr, R. M., J. H. Heine, J. M. Felton, and G. M. Cailiet. 2002. Movements of bocaccio (*Sebastes paucispinis*) and greenspotted (*Sebastes chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. Fishery Bulletin 100:324-337.

Stein, D. and T. J. Hassler. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest): Brown rockfish, copper rockfish, black rockfish. U.S. Fish and Wildlife Service.

Stein, D. L., B. N. Tissot, M. A. Hixon, and W. Barss. 1992. Fish-habitat associations on a deep reef at the edge of the Oregon continental shelf. Fish.Bull. 90:540-551.

Steiner, R. 1978. Food habits and species composition of neritic reef fishes off Depoe Bay, Oregon. M.S. Thesis. Oregon State University.

Stephens, A. 2011. 2011 rebuilding analysis for darkblotched rockfish. Pacific Fishery Management Council, Portland, OR, November, 2011.

Stephens, A., O. Hamel, I. Taylor, and C. Wetzel. 2011. Status and future prospects for the darkblotched rockfish resource in waters off Washington, Oregon, and California in 2011. Pacific Fishery Management Council, Portland, OR, November, 2011.

Stephens, A. and I. G. Taylor. 2013. Stock assessment and status of longspine thornyhead (*Sebastolobus altivelis*) off California, Oregon and Washington in 2013. Pacific Fishery Management Council, Portland, OR.

Stepien, C. A. 1995. Population genetic divergence and geographic patterns from DNA sequences: examples from marine and freshwater fishes. Pages 263-287 *in* Evolution and the Aquatic Ecosystem Defining Unique Units in Population Conservation, volume 17. American Fisheries Society.

Stepien, C. A., A. K. Dillon, and A. K. Patterson. 2000. Population genetics, phylogeography, and systematics of the thornyhead rockfishes (*Sebastolobus*) along the deep continental slopes of the North Pacific Ocean. Can.J.Fish.Aquat.Sci. 57:1701-1717.

Stewart, I. J. 2006. Status of the U.S. English sole resource in 2005. *in* Volume 2: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Stewart, I. J. 2008a. Rebuilding analysis for canary rockfish based on the 2007 stock assessment. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation.

Stewart, I. J. 2008b. Status of the U.S. canary rockfish resource in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Stewart, I. J. 2008c. Updated U.S. English sole stock assessment: Status of the resource in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Stewart, I. J. 2009a. Rebuilding analysis for canary rockfish based on the 2009 updated stock assessment. Pacific Fishery Management Council, Portland, OR.

Stewart, I. J. 2009b. Rebuilding analysis for yelloweye rockfish based on the 2009 stock assessment. Pacific Fishery Management Council, Portland, OR.

Stewart, I. J. 2009c. Status of the U.S. canary rockfish resource in 2009 (Update of 2007 assessment model). Pacific Fishery Management Council, Portland, OR.

Stewart, I. J., J. T. Thorson, and C. Wetzel. 2011. Status of the U.S. sablefish resource in 2011. Pacific Fishery Management Council, Portland, OR.

Stewart, I. J., J. R. Wallace, and C. McGilliard. 2009. Status of the U.S. yelloweye rockfish resource in 2009. Pacific Fishery Management Council, Portland, OR.

Stroud, R. K., G. H. Fiscus, and H. Kajimura. 1981. Food of the Pacific white-sided dolphin, *Lagenorhychus obligquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington. Fishery Bulletin 78(4):951-959.

Sydeman, W., M. M. Hester, J. A. Thayer, F. Gress, P. Martin, and J. Buffa. 2001. Climate change,reproductive performance and diet composition of marine birds in the Southern California Current System,1969 - 1997. Progress in Oceanography 49:309-329.

Tagart, J. V. 1988. Appendix D: Status of the yellowtail rockfish stocks in the International North Pacific Fishery Commission Vancouver and Columbia areas. *in* Status of the Pacific coast groundfish fishery through 1988 and recommended acceptable biological catches for 1989. Pacific Fishery Management Council, Portland, OR.

Tagart, J. V. 1991. Population dynamics of yellowtail rockfish (*Sebastes flavidus*) stocks in the northern California to Vancouver Island region. Ph.D. Dissertation. University of Washington.

Tagart, J. V. 1993. Status of the yellowtail rockfish resource in 1993. *in* Stock assessment and fishery evaluation: Appendices to the status of the Pacific Coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994. Pacific Fishery Management Council, Portland, Oregon.

Tagart, J. V., J. T. Golden, D. K. Kimura, and R. L. Demory. 1980. Evaluation of alternative trip limits for Pacific ocean perch. Unpublished report prepared for the Pacific Fishery Management Council, Portland, OR.

Tagart, J. V., J. N. Ianelli, A. Hoffman, and F. R. Wallace. 1997. Status of the yellowtail rockfish resource in 1997. *in* Stock assessment and fishery evaluation: Status of the Pacific Coast groundfish fishery through 1997 and recommended acceptable biological catches for 1998. Pacific Fishery Management Council, Portland, Oregon.

Tagart, J. V. and F. R. Wallace. 1996. Status of the yellowtail rockfish resource in 1996. *in* Stock assessment and fishery evaluation: Appendix volume 2 to the status of the Pacific Coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997. Pacific Fishyery Management Council, Portland, Oregon.

Tagart, J. V., F. R. Wallace, and J. N. Ianelli. 2000. Status of the yellowtail rockfish resource in 2000. *in* Appendix to Status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Tanasichuk, R. W., D. M. Ware, W. Shaw, and G. A. McFarlane. 1991. Variations in diet, daily ration, and feeding periodicity of pacific hake (*Merluccius productus*) and spiny dogfish (*Squalus acanthias*) off the Lower West Coast of Vancouver Island. Can.J.Fish.Aquat.Sci. 48(11):2118-2128.

Taylor, C. A., W. Watson, T. Chereskin, J. Hyde, and R. Vetter. 2004. Retention of larval rockfishes, *Sebastes* near natal habitat in the Southern California Bight, as indicated by molecular identification methods. CalCOFI Rep. 45:152-166.

Taylor, I. G. 2008. Modeling spiny dogfish population dynamics in the Northeast Pacific. University of Washington, Seattle, WA.

Taylor, I. G. 2011. Rebuilding analysis for yelloweye rockfish based on the 2011 update stock assessment. NMFS, Seattle, WA, October 13, 2011.

Taylor, I. G. and A. Stephens. 2013. Stock Assessment of Shortpine Thornyhead in 2013. Pacific Fishery Management Council, Portland, OR.

Taylor, I. G. and C. Wetzel. 2011. Status of the U.S. yelloweye rockfish resource in 2011 (Update of 2009 assessment model). National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle.

Thomas, D. H. and A. D. MacCall. 2001. Bocaccio. Pages 162-164 *in* W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson, editors. California's Living Marine Resources: A Status Report. Calif. Dept. Fish and Game.

Thompson, J. E. 2006. Age, growth and maturity of the longnose skate (*Raja rhina*) for the US west coast and sensitivity to fishing impacts. Oregon State University, Corvallis, OR.

Thompson, J. E. and R. W. Hannah. 2010. Using cross-dating techniques to validate ages of aurora rockfish (*Sebastes aurora*): estimates of age, growth and female maturity. Environmental Biology of Fishes 88:377-388.

Tribuzio, C. 2009. Life history, ecology and population demographics of spiny dogfish in the Gulf of Alaska. University of Alaska, Fairbanks, AK.

Tribuzio, C. A., V. F. Gallucci, and G. G. Bargmann. 2009. Reproductive biology and management implications for spiny dogfish in Puget Sound, Washington. *in* V. F. Gallucci, G. A. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

Tribuzio, C. A., G. H. Kruse, and J. T. Fujioka. 2010. Age and growth of spiny dogfish (*Squalus acanthias*) in the Gulf of Alaska: analysis of alternative growth models. Fishery Bulletin 108(2):119-135.

Trumble, S. J. 1995. Abundance, movements, dive behavior, food habits, and mother – pup interactions of harbor seals (*Phoca vitulina richardsi*) near Monterey Bay, California. M.S. California State University Fresno.

Tsou, T. and F. R. Wallace. 2006. Updated Rebuilding Analysis for Yelloweye Rockfish Based on Stock Assessment in 2006. *in* Volume 6: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Turnock, B. J., T. K. Wilderbuer, and E. S. Brown (T. Gulf of Alaska Groundfish Plan). 2005. Arrowtooth Flounder. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage, AK 99510.

Turnock, J., M. Wilkins, M. Saelens, and C. Wood. 1993. Status of West Coast petrale sole in 1993. *in* Appendix G. In: Status of the Pacific Coast groundfish fishery through 1993 and recommended biological catches for 1994: stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Vega, N. M., V. F. Gallucci, L. Hauser, and J. Franks. 2009. Differences in growth in the spiny dogfish over a latitudinal gradient in the Northeast Pacific. *in* V. F. Gallucci, G. A. McFarlane, and G. G. Bargmann, editors. Biology and Management of Dogfish Sharks. American Fisheries Society.

Vetter, R. D. and E. A. Lynn. 1997. Bathymetric demography, enzyme activity patterns, and bioenergetics of deep-living scorpaenid fishes: paradigms revisited. Mar. Ecol. Prog. Ser. 155:173-188.

Wakefield, W. W. 1990. Patterns in the distribution of demersal fishes on the upper continental slope off central California with studies on the role of ontogenetic vertical migration in particle flux. University of California, San Diego, CA.

Wakefield, W. W. and K. L. J. Smith. 1990. Ontogenetic vertical migration in Sebastolobus altivelis as a mechanism for transport of particulate organic matter at continental slope depths. Limnology and Oceanography 35:1314-1328.

Walker, P. A. and R. G. Hislop. 1998. Sensitive skates or resilient rays? Spatial and temporal shifts in ray species composition in the central and north-western North Sea between 1930 and the present day. ICES J.of Mar.Sci. 55:392-402.

Wallace, F. R. 2002. Status of the yelloweye rockfish resource in 2001 for northern California and Oregon waters. *in* Appendix to the Status of the Pacific Coast Groundfish Fishery Through 2001 and Acceptable Biological Catches for 2002 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Wallace, F. R., Y. W. Cheng, and T. S. Tsou. 2008. Status of the black rockfish resource north of Cape Falcon, Oregon to the U.S.-Canadian border in 2006. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Wallace, F. R., A. Hoffman, and J. A. Tagart. 1999. Status of the black rockfish resource in 1999. *in* Appendix to the Status of the Pacific Coast Groundfish Fishery Through 1999 and Recommended Acceptable Biological Catches for 2000. Pacific Fishery Management Council, Portland, OR.

Wallace, F. R. and J. V. Tagart. 1994. Status of coastal black rockfish stocks in Washington and northern Oregon in 1994. *in* Appendix F: Status of the Pacific Coast Groundfish Fishery Through 1994 and Recommended Acceptable Biological Catches for 1995. Pacific Fisheries Management Council, Portland, Oregon.

Wallace, F. R., T. Tsou, T. Jagielo, and Y. W. Cheng. 2006. Status of yelloweye rockfish (Sebastes ruberrimus) off the U.S. West Coast in 2006. *in* Volume 6: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, OR.

Wallace, J. and H. L. Lai. 2006. Status of the yellowtail rockfish in 2004. *in* Volume 3: Status of the Pacific Coast groundfish fishery through 2005, Stock assessment and fishery evaluation: Stock assessments and rebuilding analyses. Pacific Fishery Management Council, Portland, Oregon.

Wallace, J. R. 2008a. Update to the status of yelloweye rockfish (Sebastes ruberrimus) off the U.S. West Coast in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation Stock Assessments and Rebuilding Analyses.

Wallace, J. R. 2008b. Updated Rebuilding Analysis for Yelloweye Rockfish Based on the Stock Assessment Update in 2007. Status of the Pacific Coast groundfish fishery through 2007, Stock assessment and fishery evaluation.

Wallace, J. R. 2009. 2009 darkblotched rockfish rebuilding analysis. Pacific Fishery Management Council, Portland, OR.

Wallace, J. R. 2011. Rebuilding analysis for canary rockfish based on the 2011 updated stock assessment. Pacific Fishery Management Council, Portland, OR.

Wallace, J. R. and J. M. Cope. 2011. Status update of the U.S. canary rockfish resource in 2011. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle.

Wallace, J. R. and O. S. Hamel. 2009. Status and Future Prospects for the Darkblotched Rockfish Resource in Waters off Washington, Oregon, and California as Updated in 2009. Pacific Fishery Management Council, Portland, OR.

Waples, R. S., A. E. Punt, and J. M. Cope. 2008. Integrating genetic data in marine resource management: how can we do it better? Fish and Fisheries 9:423-449.

Weinberg, K. L. 1994. Rockfish assemblages of the middle shelf and upper slope off Oregon and Washington. Fish.Bull. 92:620-632.

Weinberg, K. L., M. E. Wilkins, and T. A. Dark. 1984. The 1983 Pacific West Coast bottom trawl survey of groundfish resources: estimates of distribution, abundance, age and length composition. U.S. Dept. of Commerce.

Weise, M. J. and J. T. Harvey. 2005. Impact of the California sea lion (*Zalophus californianus*) on salmon fisheries in Monterey Bay, California. Fishery Bulletin 103:685-696.

Westrheim, S. J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (*Scorpaenidae*) species in the northeast Pacific Ocean. J.Fish.Res.Board Canada 32:2399-2411.

Westrheim, S. J. and A. R. Morgan. 1963. Results from tagging a spawning stock of Dover sole, Microstomus pacificus Pac.Mar.Fish.Comm.Bull. 6:13-21.

Whitney, F. A., H. J. Freeland, and M. Robert. 2007. Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific. Progress in Oceanography 75:179-199.

Wilkins, M. E. 1986. Development and evaluation of methodologies for assessing and monitoring the abundance of widow rockfish, Sebastes entomelas Fish.Bull. 84:287-310.

Williams, E. H., A. D. MacCall, S. Ralston, and D. E. Pearson. 2000. Status of the widow rockfish resource in Y2K. *in* Appendix to Status of the Pacific coast groundfish fishery through 2000 and recommended acceptable biological catches for 2001 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Williams, E. H. and S. Ralston. 2002. Distribution and co-occurrence of rockfishes (family: *Sebastidae*) over trawlable shelf and slope habitats of California and southern Oregon. Fisheries Bulletin 100:836-855.

Williams, E. H., S. Ralston, A. D. MacCall, D. Woodbury, and D. E. Pearson. 1999. Stock assessment of the canary rockfish resource in the waters off southern Oregon and California in 1999. *in* Status of the Pacific coast groundfish fishery through 1999 and recommended acceptable biological

catches for 2000 (Stock Assessment and Fishery Evaluation). Pacific Fishery Management Council, Portland, OR.

Wilson-Vandenberg, D., P. N. Reilly, and C. E. Wilson. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, January through December 1994. Marine Research Division Administrative Report:96 pgs.

Wood, C. C., K. S. Ketchen, and R. J. Beamish. 1979. Population dynamics of the spiny dogfish (*Squalus acanthias*) in British Columbia waters. Journal of the Fisheries Research Board of Canada 36:647-656.

Wyllie Echeverria, T. 1987. Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. Fish.Bull. 85:229-240.

Yang, M. S. 1995. Food habits and diet overlap of arrowtooth flounder (Atheresthes stomias) and Pacific halibut (Hippoglossus stenolepis) in the Gulf of Alaska. Pages 205-223 *in*. Alaska Sea Grant College Program, University of Alaska, Anchorage, Alaska, 1995.

Yang, M. S. and P. A. Livingston. 1985. Food habits and diet overlap of two congeneric species, Atheresthes stomias and A. evermanni , in the eastern Bering Sea. Fish.Bull. 84:615-623.

Yoklavich, M. M., H. G. Greene, G. M. Cailliet, D. E. Sullivan, R. N. Lea, and M. S. Love. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin 98:625-641.

Yoklavich, M. M., M. S. Love, and K. A. Forney. 2007. A fishery independent assessment of cowcod (Sebastes levis) in southern California's Cowcod Conservation Areas using direct observations from an occupied submersible. Canadian Journal of Fisheries and Aquatic Sciences 64(12):1795-1804.

Zhou, S., S. Yin, J. T. Thorson, A. D. M. Smith, and M. Fuller. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Can.J.Fish.Aquat.Sci. 69:1292-1301.

Zimmerman, M. and P. Goddard. 1996. Biology and distribution of arrowtooth flounder, *Atheresthes stomias* , and Kamchatka flounders (*A. evermanni*) in Alaskan waters. Fish Bull.