Evaluation of stock structure for the Bering Sea/Aleutian Island Other Rockfish complex

Ingrid Spies and Paul Spencer

Introduction

In 2009 the Stock Structure Working Group (SSWG), consisting of members of the North Pacific Fisheries Management Council's (NPFMC) Scientific and Statistical Committee, Groundfish Plan Teams, geneticists, and assessment scientists, was formed to develop a set of guidelines to promote a rigorous and consistent procedure for making management decisions on stock structure for Alaska stocks. The committee produced a report, originally presented at the September 2009 meeting of the joint Groundfish Plan Team and updated for the September 2010 meeting (Spencer et al. 2010), which contains a template (Table 1) that identifies various scientific data from which we may infer stock structure. At the November 2013 meeting of the joint Groundfish Plan Team, the Team recommended application of the template to several stocks, including the Other Rockfish complex in the Bering Sea and Aleutian Islands (BSAI).

The Bering Sea/Aleutian Islands (BSAI) Other Rockfish complex includes all species of *Sebastes* and *Sebastolobus*, except Pacific ocean perch (POP, *Sebastes alutus*), northern rockfish (*Sebatses. polyspinis)* rougheye rockfish (*S. aleutianus*), blackspotted rockfish (*S. melanostictus*), and shortraker rockfish (*S. borealis*). The Other Rockfish complex is defined by what it excludes (i.e., POP, northern rockfish, rougheye rockfish, blackspotted rockfish, and shortraker rockfish) rather than by what it includes. The seven most abundant species in the complex are shortspine thornyhead; *Sebastolobus alascanus*, dusky rockfish; *Sebastes variabilis*, redbanded rockfish; *Sebastes babcocki*, redstriped rockfish; *Sebastes proriger*, yelloweye rockfish; *Sebastes ruberrimus*, harlequin rockfish; *Sebastes variegatus*, and sharpchin rockfish; *Sebastes zacentrus*. Dark rockfish are also relatively common but have been removed from the Other Rockfish complex and is now managed by the State of Alaska. The two most abundant species in the Other Rockfish complex are dusky rockfish and shortspine thornyheads (SST). This analysis is based on the most abundant species in the complex, because there is more data for those species.

The purpose of this document is to use the template produced by the SSWG to evaluate scientific information on stock structure. The SSWG template has a number of broad categories of information relevant to BSAI Other Rockfish, including area-specific exploitation rates, spatial concentration of fishery relative to abundance, generation time, life history differences, and potential for genetic differences and small dispersal distances. There are no genetic studies specifically on dusky rockfish, genetic structure can only be hypothesized based on the results of other studies.

Survey data is associated with high uncertainty, which can be ameliorated by smoothing the data with the random effects random walk model. Raw data with uncertainty estimates are presented in Tables 2 and 3. Smoothed data is presented, along with survey estimates, in Figures 1, 2, and 3. Exploitation rates in Table 4 and Figure 4 are based on smoothed data, while Figure 5 presents catch (Table 5) and survey biomass estimates.

Fishing mortality (area-specific exploitation rates), Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)

Area-specific exploitation rates are defined here as the yearly catch within a subarea divided by an estimate of the subarea biomass. Area-specific exploitation rates are generated to assess

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by the National Marine Fisheries Service and should not be construed to represent any agency determination or policy.

whether subarea harvest is disproportionate to biomass, which could result in reductions of subarea biomass for stocks with spatial structure.

Estimates of exploitation rates in the Aleutian Islands indicate that exploitation rates are higher than target values non-SST species, and below target values for SST. Exploitation rates are available for SST from 1994-2012, and are available for dusky beginning in 2004, and harlequin rockfish in 2003 (Table 4). Target fishing mortality rates, F_{ABC}, are 0.75*estimated natural mortality, which are 0.0225 for SST and 0.0675 for non-SST species in the Other Rockfish complex (Spies and Spencer 2013). Estimates of exploitation rates for SST have been below F_{ABC} since 1997 in the entire AI, and in the central (CAI) and western Aleutians (WAI) (Table 4; Figure 4). However, exploitation rates of SST have been higher than F_{ABC} in the Eastern AI (EAI) from 1997-2012, 0.03-0.5 (Figure 4). Exploitation rates have been above target levels for both harlequin and dusky rockfish throughout the entire AI. Harlequin rockfish appear to have been subject to exploitation rates as high as 4 for all years with data, 2003-2012 (Figure 4). Dusky rockfish have also been subject to high exploitation rates over the entire AI, from 2004-2012 (0.074-1.487; Table 4), as well in the WAI, CAI, and EAI separately (Figure 4).

Exploitation rates higher than 1 indicate more catch than biomass (Tables 4 and 5). For example, in 2010 and 2012 catch of harlequin rockfish exceeded survey biomass estimates (Figure 5). Similarly, in 2012 dusky rockfish catch was higher than the survey estimates of biomass (Figure 5). Assuming the catch estimates are reliable, survey biomass estimates are clearly underestimated in years in which they are less than the observed catch (Figure 5). This may occur from patchily-distributed rockfish populations and missing high density patches during the survey.

The CV of biomass estimates are lower for SST than for non-SST species in the Aleutian Islands, ranging from 0.12-0.19 for SST, 0.29-0.80 for dusky rockfish, 0.72-0.99 for redbanded rockfish, and 0.19-0.64 for harlequin rockfish (Table 2). In the eastern Bering Sea, CVs are similarly high for non-SST rockfish: 0.61-1 for dusky rockfish and 0.71-1 for redbanded rockfish, but as low as 0.09-0.12 for SST (Table 3). Despite high CVs, estimates of non-SST species are generally consistent. For example, dusky rockfish abundance fell within the range of 500-1,500 t from 1997-2012 in the Aleutian Islands, with the exception of a high biomass estimate in 2006 (Figure 6). When this data point was removed, the data appear to be consistent and to follow a clear (downward) trend (Figure 6b).
Catch of the Other Rockfish complex in the AI exceeded the ABC and TAC in 2012 and 2013, and an overage may occur in 2014, based on catches through September 2014 (Table 5).

Natural mortality

Natural mortality is considered here because it has been used as a proxy for F_{MSY} in species managed under a Tier 5 harvest control rule. It is not an element of the stock structure template. Shortspine thornyhead are considered to have low natural mortality (0.03) and non-SST species are assumed to have higher natural mortality (0.09) (Spies and Spencer 2013).

Population trends (Different areas show different trend directions)

Dusky rockfish in the AI do not exhibit a temporal trend in biomass when all data points are included (Figure 6a). However, when the anomalously large year (2006) is excluded, the data indicate a downward trend (Figure 6b). The biomass estimate from 2012 is the lowest on record (Table 2). This is consistent with high exploitation rate estimates. Dusky rockfish biomass

estimates in the WAI is larger than an order of magnitude than biomass estimates in the EAI (Figure 2).

Uncertainty of redbanded and harlequin rockfish biomass is high relative to biomass (Table 2). Whether trends exist in the abundance of these species is unclear from the data.

Generation time (e.g. >10 years) [adapted from Lundsford et al. 2009]

Rockfish are typically long-lived and slow growing. The maximum age of dusky rockfish (*Sebastes variabilis*) formerly known as light dusky (Orr and Blackburn 2004) in the GOA is 59 years from the survey and 76 years from the fishery (Lundsford et al. 2009). Estimates of natural mortality range from 0.06 to 0.09. The generation time for dusky rockfish has been estimated at 23 years following the methods described in Restrepo et al. 1998 and using the estimates available from the dusky age-structured model (Lunsford et al. 2009). Two studies have estimated the age at 50% maturity of dusky rockfish in the GOA and range from 9.2 years to 11.3 years. These values indicate dusky rockfish have a shorter generation time than other rockfish, likely due to the higher natural mortality and earlier maturity.

Generation time may be as long as 100 years in SST, but maturity ogives have not been estimated for this species (Stepien et al. 2000).

Age/size structure (significantly different size/age compositions)

Length frequencies for dusky rockfish are shown in Figures 7, 8, and 9. Figure 7 provides data from 1997 through 2012. Figures 8 and 9 show length frequency data from 2012 and a previous year (2006 in Figure 8 and 1997 in Figure 9) to highlight differences between the most recent year and past years. There appears to be a higher proportion of younger length classes in 2012 proportional to earlier years. This is highlighted in Figures 8 and 9.

Isolation-by-distance (significant regression)

There is no genetic data for dusky, harlequin, or redbanded rockfish. Isolation by distance population structure has been identified in rockfish species such as copper, brown, and grass rockfishes along the United States west coast (*Sebastes caurinus*, *S. rastrelliger*, and *S. auriculatus*; Buonaccorsi et al. 2002, 2004, 2005), Pacific ocean perch off Alaska (*Sebastes aleutus*; Palof et al. 2011), and northern rockfish in the Bering Sea and Aleutian Islands (BSAI) region of Alaska (*Sebastes polyspinis*; Gharrett et al. 2012). Given the similarity in life history among rockfish species, it may be hypothesized that such genetic population structure could exist in the species that comprise the Other Rockfish complex Genetic data suggests that the genus *Sebastolobus*, which includes all thornyhead rockfish, are subject to genetic population structure (Stepien et al. 2000).

Dispersal distance (<<management area)

Dispersal distances are not available for the species in the Other Rockfish complex. For rockfish stock in which dispersal estimates are available, the estimates are relatively low (e.g. 100-200 km for northern rockfish (Gharrett et al. 2012) and 10 km in grass rockfish (Buonaccorsi 2004). Low dispersal distances can be inferred in other rockfish species based on similarity in life history traits.

Conclusions

The two main findings are that: 1) the Aleutian Island ABCs and TACs are often exceeded (Table 2); and 2) Aleutian Islands exploitation rates are higher than target values (F_{ABC}) for non-SST species.

The abundance of shortspine thornyhead is significantly higher than any of the other species in the Other Rockfish complex. It is between 10-50 times more abundant than the second most abundant species in the complex, dusky rockfish (Table 2). TAC and ABC for the AI and the EBS are based on the sum of the SST and non-SST ABCs for their respective regions. This allows SST to be fished at lower exploitation rates, and the non-SST component of the complex to be fished harder, while maintaining catches near ABC limits.

Estimates of SST biomass appear reliable and have low CVs; however, the biomass estimates of the non-SST species are more uncertain. There are several years in which catch of harlequin and dusky rockfish in the Aleutian Islands is higher than the upper bound for the biomass estimate (Figure 5). Some of the non-SST species can be considered rare species in the BSAI, for which our trawl survey may not be have the most suitable design for producing reliable biomass estimates (Figure 5). Despite the higher levels of uncertainty associated with non-SST species, estimates of the most common species, dusky rockfish, are consistent over time and show distinctive trends, with the exception of the high biomass estimate in 2006 (Figure 2 and Figure 6).

Generation time is high in rockfish, approximately 23 years in dusky rockfish and possibly as long as 100 years in SST (Stepien et al. 2000). The time for populations to reach equilibrium following a change in fishing pressure is approximately their generation time. Therefore, declines in population size and changes in age and length frequency could take as long as several decades. Recovery following declines due to high fishing pressure requires periods of time similar to the generation length.

The National Marine Fisheries Service National Standards Guidelines (50 C.F.R. 600.310 et seq.) states that a "'Stock complex' means a group of stocks that are sufficiently similar in geographic distribution, life history, and vulnerabilities to the fishery such that the impact of management actions on the stocks is similar." The life-history of the species are not similar; natural mortality in SST is estimated to be one-third that of non-SST species in the Other Rockfish complex. Additionally, some of the non-SST species in the Other Rockfish complex appear to be exploited in much higher proportions than intended. However, many of these species have high coefficients of variation for the survey biomass (particularly for the subarea biomass estimates), which hinder estimates of reliable exploitation rates. Of the non-SST species, the lowest CVs are observed for dusky rockfish in the AI area (< 0.42 in 5 of the 7 years since 1997), but even here the catch estimates exceed the smoothed estimates of biomass obtained with random effects model in recent years. This result is biologically implausible, and reflects uncertainty in the biomass estimates, or possibly errors in the catch data, but the latter may be less likely.

A Tier 6 approach may be the most appropriate for the non-SST species, given the uncertainty in biomass estimates. For the non-SST species, there will be uncertainty in the estimates of the exploitation rate whether or not they are grouped in a complex with SST. However, partitioning these species into their own complex may allow better monitoring of the catch and biomass data, and better meet the intended management specified by the NPFMC Tier system for stocks with unreliable biomass estimates.

Tier 6 assessments typically require reliable catch history from 1978-1995. The mean catch from this period is used as the OFL, and the ABC is 0.75*OFL. The mean catch from 1978-1995 was 66.3 t in the Eastern Bering Sea and 118.0 t in the Aleutian Islands. Catches have been increasing in recent years in the Aleutian Islands (Figure 10). The mean catch of non-SST Other Rockfish between 2001-2011 was 299 t, higher than a Tier 6 OFL of 118 t (Figure 10). Mean catch from 2001-2011 in the Eastern Bering Sea was 34.7 t, lower than the proposed Tier 6 OFL of 66.3 t (Figure 10).

References

Buonaccorsi, V.P., Kimbrell, C.A., Lynn, E.A. and Vetter, R.D. 2002. Population structure of copper rockfish (*Sebastes caurinus*) reflects postglacial colonization and contemporary patterns of larval dispersal Canadian Journal of Fisheries and Aquatic Sciences 59: 1374-1384.

HARVEST AND TRENDS

Buonaccorsi, V.P., Westerman, M., Stannard, J., Kimbrell, C., Lynn, E., and Vetter, R.D. 2004. Molecular genetic structure suggests limited larval dispersal in grass rockfish, *Sebastes rastrelliger*. Marine Biology 145: 779-788.

Buonaccorsi, V.P., Kimbrell, C.A., Lynn, E.A., and Vetter, R.D. 2005. Limited realized dispersal and introgressive hybridization influence genetic structure and conservation strategies for brown rockfish, *Sebastes auriculatus*. Conservation Genetics 6: 697-713.

Canino, M.F., Spies, I.B., Cunningham, K., Hauser, L. and Grant, W. S. 2010. Multiple ice-age refugia in Pacific cod, *Gadus macrocephalus*. Molecular Ecology 19: 4339-4351.

Canino, M.F., O'Reilly, P. Hauser, L., and Bentzen, P. 2005. Genetic differentiation in walleye Pollock (*Theragra chalcogramma*) in response to selection at the pantophysin (*Pan I*) locus. Canadian Journal of Fisheries and Aquatic Sciences **62**: 2519-2529 doi: 10.1139/F05-155.

Gharrett, A.J., Riley, R.J., and Spencer, P.D. 2012. Genetic analysis reveals restricted dispersal of Northern rockfish along the continental margin of the Bering Sea and Aleutian Islands. Transactions of the American Fisheries Society **141**(2): 370-382.

Lunsford, C.R., S.K. Shotwell, and D.H. Hanselman. 2009. Gulf of Alaska pelagic shelf rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, p. 925-992, Appendix A. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Orr, J.W. and S. Hawkins 2008. Species of the rougheye rockfish complex: resurrection of *Sebastes melanostictus* (Matsubara, 1934) and a redescription of *Sebastes aleutianus* (Jordan and Evermann, 1898) (Teleostei: Scorpaeniformes). Fish Bull. 106:111-134.

Restrepo, V. R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing national standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31.

Spencer, P., Canino, M., DiCosimo, J,. Dorn, M., Gharrett, A.J. Hanselman, D., Palof, K., and Sigler, M. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans. North Pacific Fishery Management Council.

Spies, I., and Spencer, P. 2013. Assessment of the Other Rockfish stock complex in the Bering Sea/Aleutian Islands. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage AK 99501.

Stepien, C., Dillon, A., and Patterson, A. 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.

Table 1. Framework of types of information to consider when defining spatial management units (from Spencer et al. 2010).

Factor and criterion	Justification
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	If this value is low, then conservation concern is low
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem.
Population trends (Different areas show different trend directions)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased.
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change.
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Temporally stable differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change.
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal
Genetics	
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation.

Table 2. Biomass estimates and CV for SST, dusky rockfish, redbanded rockfish, and harlequin rockfish from the Western, Central, and Eastern Aleutian Islands (WAI, CAI, and EAI), and the Southern Bering Sea (SBS). Note: the total is the sum of the Aleutian and Southern Bering Sea biomass estimates.

	WAI		CAI		EAI		SBS		Total	
	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
SST										
1991	5,131	0.28	908	0.34	115	0.49	187	0.58	6,341	0.23
1994	4,503	0.20	1,554	0.27	187	0.46	1,071	0.52	7,315	0.16
1997	6,725	0.24	2,011	0.16	159	0.45	1,545	0.69	10,440	0.18
2000	6,312	0.26	3,815	0.27	522	0.49	1,051	0.48	11,700	0.17
2002	8,247	0.33	5,454	0.20	543	0.51	1,012	0.41	15,256	0.19
2004	12,002	0.26	4,354	0.23	979	0.45	945	0.56	18,280	0.18
2006	11,116	0.17	5,987	0.16	774	0.60	968	0.55	18,844	0.12
2010	12,103	0.23	5,108	0.13	865	0.44	1,052	0.73	19,127	0.16
2012	9,419	0.20	3,519	0.23	1,505	0.51	452	0.77	14,895	0.15
Dusky Rockfish										
1997	54.4	0.95	77.5	0.50	442	0.98	138.3	0.46	712.2	0.62
2000	164.8	0.43	579.4	0.56	485.3	0.54	55.4	0.36	1284.9	0.33
2002	47.8	0.65	334.1	0.46	149	0.43	96.9	0.36	627.8	0.28
2004	248.1	0.86	389.2	0.62	92.7	0.39	1358.6	0.91	2088.6	0.61
2006	33.2	0.63	5568.8	0.95	343.2	0.46	730.9	0.96	6676.1	0.80
2010	6.8	0.99	331.7	0.53	221.6	0.34	120	0.44	680.1	0.29
2012	3.8	1.00	114.6	0.46	118.1	0.46	134.6	0.57	371.1	0.29
Redbanded Rockfish										
1991	0	--	0	--	0	--	1	0.98	1	0.98
1994	0	--	0	--	0	--	0	--	0	--
1997	1	0.96	1	0.97	0	--	0	--	2	0.68
2000	0	--	0	--	0	--	0	--	0	--
2002	1	1.07	0	--	1	1.05	0	--	1	0.75
2004	1	1.02	4	1.01	0	--	0	--	5	0.83
2006	1	1.05	0	--	5	0.99	0	--	5	0.87
2010	0	--	3	0.99	0	--	0	--	3	0.99
2012	1	0.98	2	1.03	0	--	0	--	3	0.72
Harlequin Rockfish										
1991	7	0.86	13	0.35	2	0.53	0	0.66	22	0.64
1994	1	0.36	12	0.27	5	0.41	2	0.78	20	0.21
1997	10	0.46	53	0.40	5	0.41	0	0.97	68	0.26
2000	3	0.92	15	0.17	8	0.40	0	0.73	25	0.44
2002	0	0.55	13	0.24	9	0.26	2	0.65	24	0.19
2004	404	0.71	90	0.17	2	0.46	4,167	0.60	4,663	0.37
2006	3	0.28	23	0.13	15	0.71	7	0.52	48	0.23
2010	3	0.47	8	0.31	10	0.40	0	1.00	22	0.23
2012	11	0.48	0	0.43	0	0.44	0	0.71	11	0.26

Table 3. Biomass estimates and CV for SST, dusky, and redbanded rockfish from the Eastern Bering Sea.

	Biomass	CV
SST		
2002	16,950	0.12
2004	18,793	0.09
2008	26,055	0.12
2010	29,334	0.12
2012	29,565	0.11
Dusky Rockfish		
2002	25	0.57
2004	13	0.57
2008	10	1.00
2010	117	0.87
2012	40	0.61
Redbanded Rockfish		
2002	0	--
2004	1	1.00
2008	7	0.71
2010	1	1.00
2012	4	1.00

Table 4. Exploitation rates from the Aleutian Islands for shortspine thornyhead (SST), dusky, and harlequin rockfish. Exploitation rates are based on catch divided by random effects estimates of biomass. Target fishing mortality rates (F_{ABC}) are 0.0675 for non-SST species, and 0.0225 for SST (Spies and Spencer 2013).

Year	SST	harlequin	dusky
1994	0.021		
1995	0.011		
1996	0.006		
1997	0.006		
1998	0.006		
1999	0.005		
2000	0.006		
2001	0.008		
2002	0.012		
2003	0.012	0.553	
2004	0.006	0.340	0.173
2005	0.007	0.194	0.110
2006	0.009	0.502	0.074
2007	0.008	0.980	0.157
2008	0.007	1.039	0.177
2009	0.008	0.850	0.196
2010	0.010	1.962	0.420
2011	0.010	3.511	0.981
2012	0.011	3.798	1.487

Table 5. Catch (t) of dusky rockfish in the Eastern Bering Sea (EBS), Western Aleutians (WA), Central Aleutians (CA), and Eastern Aleutians (EA), based on the National Marine Fisheries Service (NMFS) surveys. Source: NMFS AKRO BLEND/Catch Accounting System.

Area	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean
EBS	161	170	208	276	195	152	257	424	457	359	291	268
WA	16	14	9	14	13	11	19	3	2	2	1	9
CA	81	53	50	46	57	36	40	33	30	41	23	45
EA	33	66	102	171	111	94	166	345	398	289	236	183
All AI	130	133	161	231	181	141	225	381	430	332	260	237

Table 6. Catch, TAC, ABC, and OFL for the Other rockfish complex, updated September 2014.

[1]Updated version 2014 September 4.

	BSAI	AI	EBS	Total
OFL (2012)	1,700			1,700
ABC (2012)		570	710	1,280
TAC (2012)		570	500	1,070
Catch (2012)		736	210	947
OFL (2013)	1,540			1,540
ABC (2013)		473	686	1,159
TAC (2013)		473	400	873
Catch (2013)[1]		640	191	832
OFL (2014)	1,550			1,550
ABC (2014)		473	690	1,163
Catch (2014)		411	261	673[1]
TAC (2014)				
OFL (2015)	1,550			1,550
ABC (2015)		473	690	1,163
TAC (2015)				

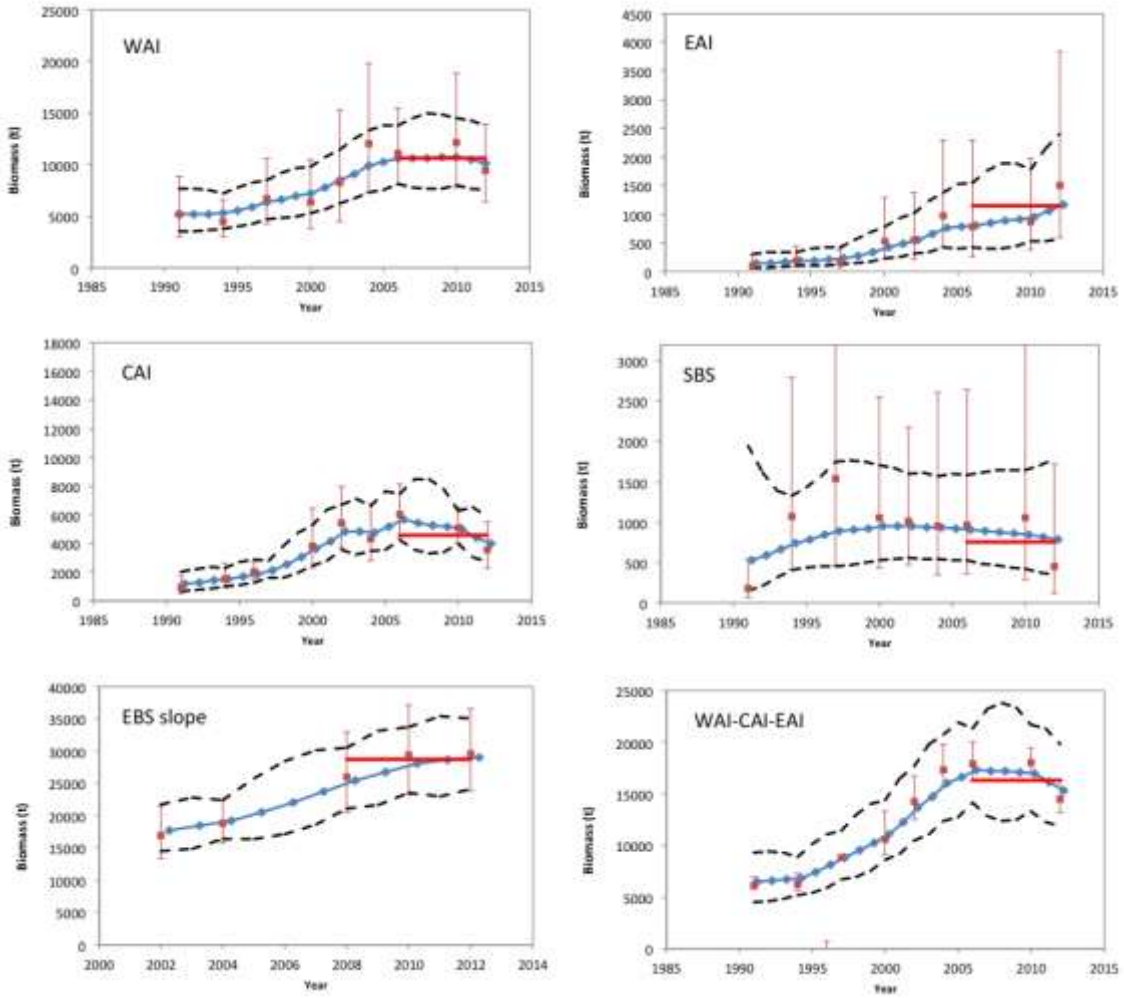


Figure 1. Shortspine thornyhead survey data (red, with 95% confidence intervals) and the random effects model fit to survey data (blue with black 95% confidence intervals) for the Western Aleutian Islands (WAI), Central Aleutian Islands (EAI), Eastern Aleutian Islands (EAI), Southern Bering Sea (SBS), Eastern Bering Sea (EBS) slope, and the Aleutian Islands combined (WAI-CAI-EAI).

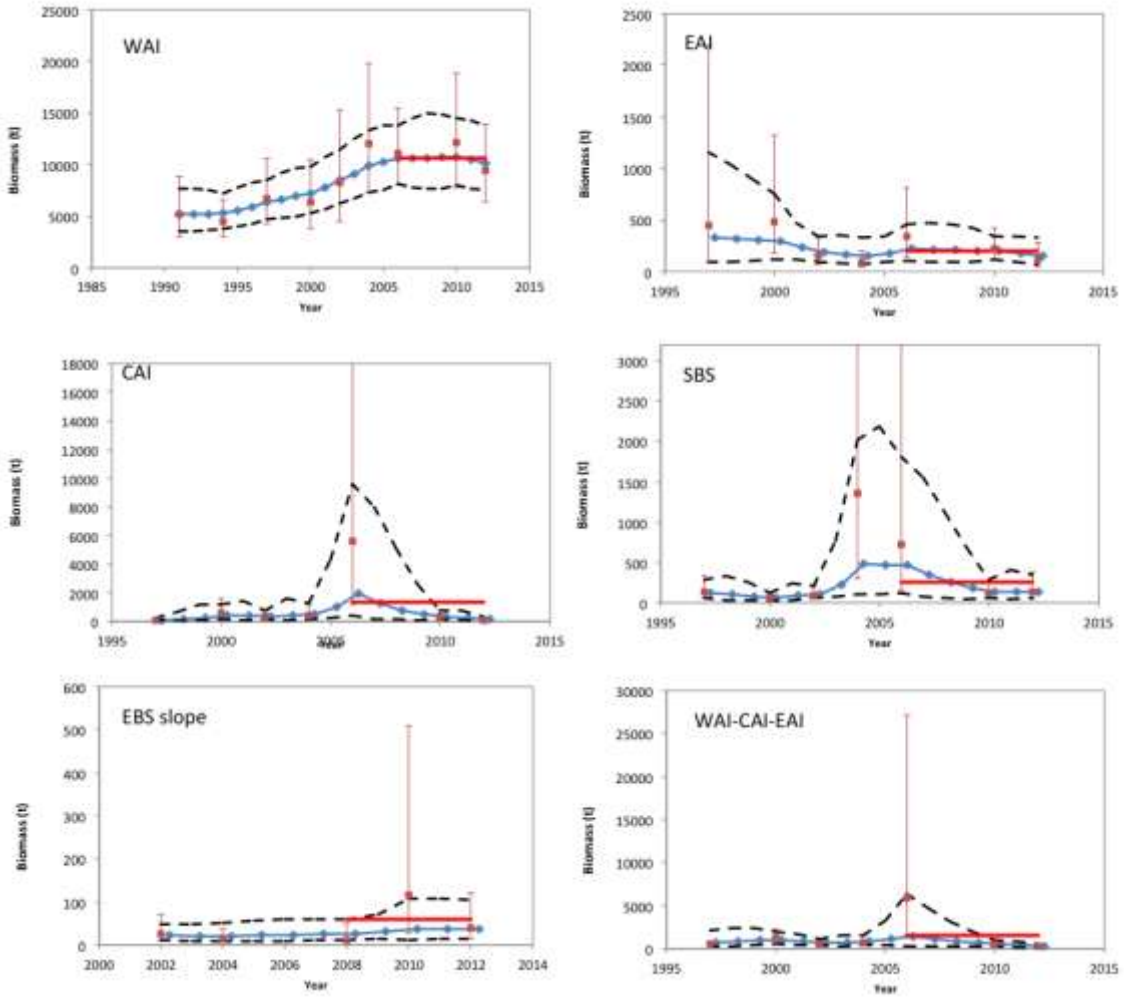


Figure 2. Dusky rockfish survey data (red, with 95% confidence intervals) and the random effects model fit to survey data (blue with black 95% confidence intervals) for the Western Aleutian Islands (WAI), Central Aleutian Islands (EAI), Eastern Aleutian Islands (EAI), Southern Bering Sea (SBS), Eastern Bering Sea (EBS) slope, and the Aleutian Islands combined (WAI-CAI-EAI).

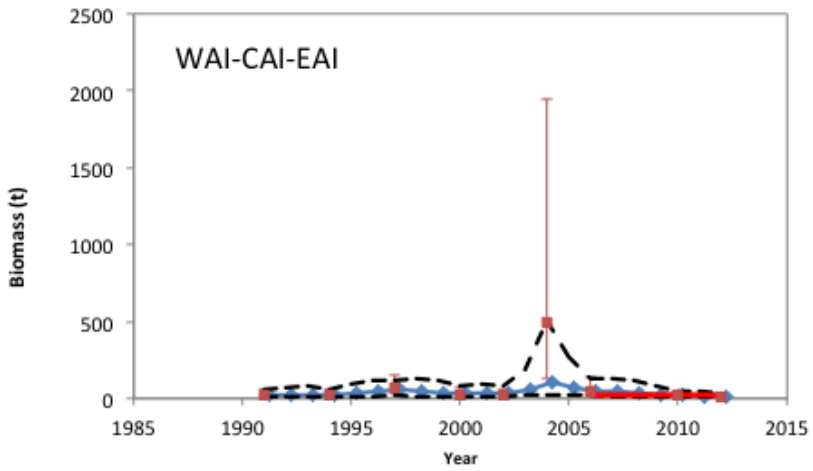


Figure 3. Harlequin rockfish survey data (red, with 95% confidence intervals) and the random effects model fit to survey data (blue with black 95% confidence intervals) for the Western Aleutian Islands (WAI), Central Aleutian Islands (EAI), and Eastern Aleutian Islands (EAI) combined.

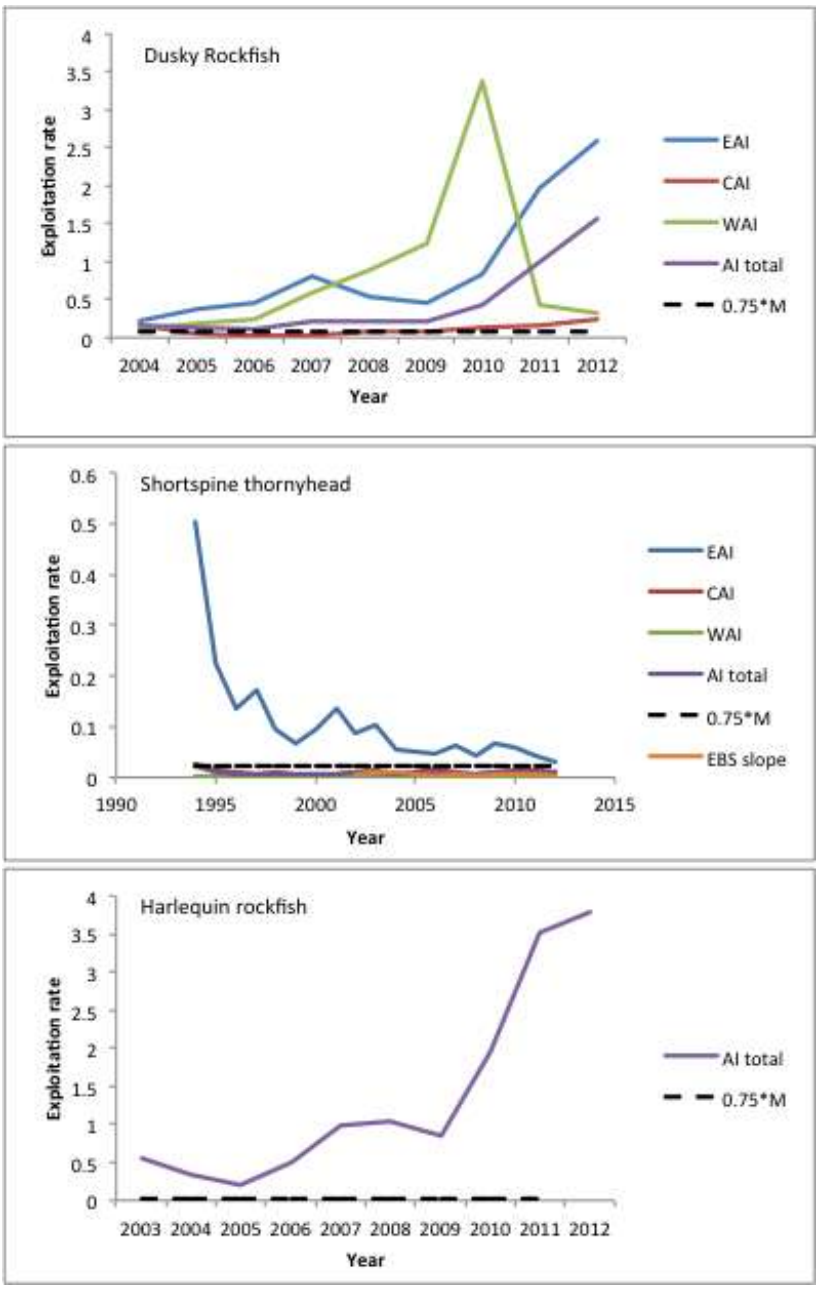


Figure 4. Exploitation rates for dusky rockfish in the western, central, and eastern Aleutian Islands (WAI, CAI, and EAI; 2004-2012), shortspine thornyhead from the three Aleutian Islands regions (1990-2012), and harlequin rockfish from the AI combined (2003-2012).

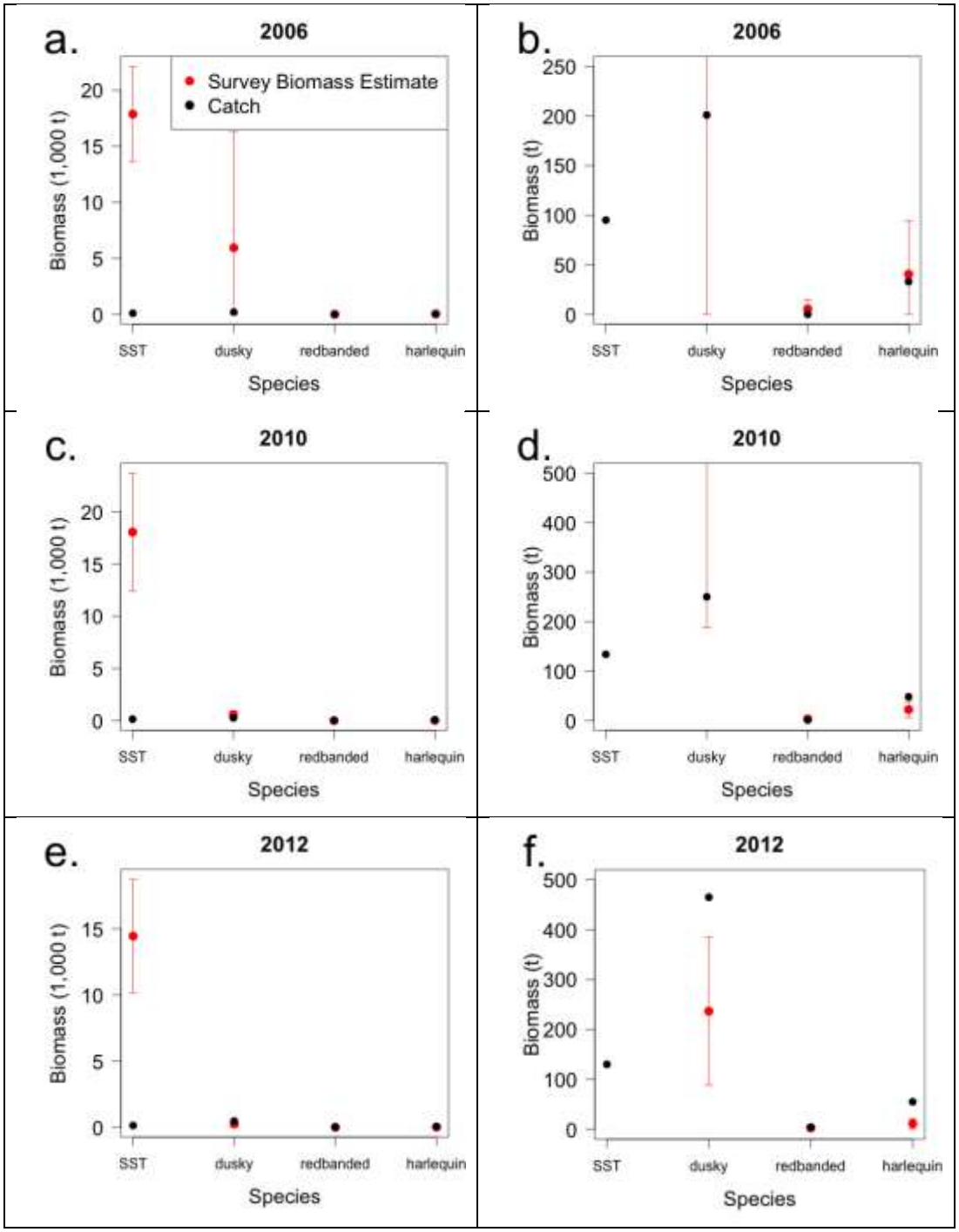
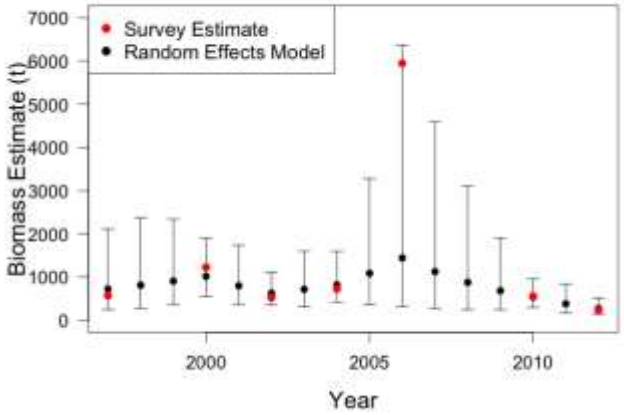


Figure 5. Biomass estimates of shortspine thornyhead (SST), dusky, redbanded, and harlequin rockfish from the Aleutian Islands survey in 2006, 2010, and 2012. Panels in the first column (panels a, c, e) show all data points, and y-axis values are reduced in the second column (panels b, d, f) to show detail of non-SST species. The legend in panel a. applies to all panels.

a. Dusky rockfish in the Aleutian Islands



b. Same data with 2006 data point removed

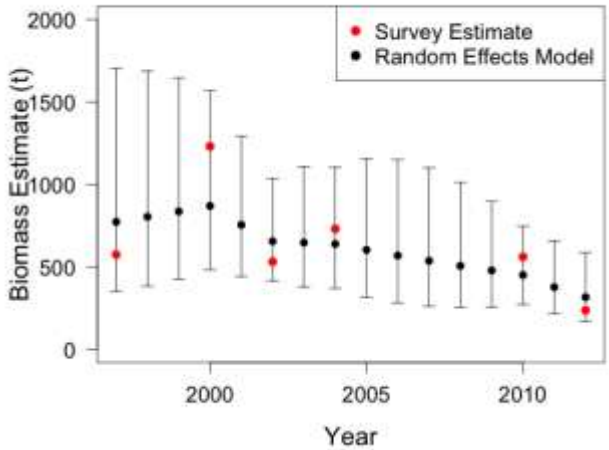


Figure 6. Dusky rockfish biomass estimates based on National Marine Fisheries Service (NMFS) surveys and output of random effects model smoothing. Panel a shows the random effects model output based on the entire Aleutian Island survey data since 1997, and panel b. shows the random effects model output with the 2006 data point removed.

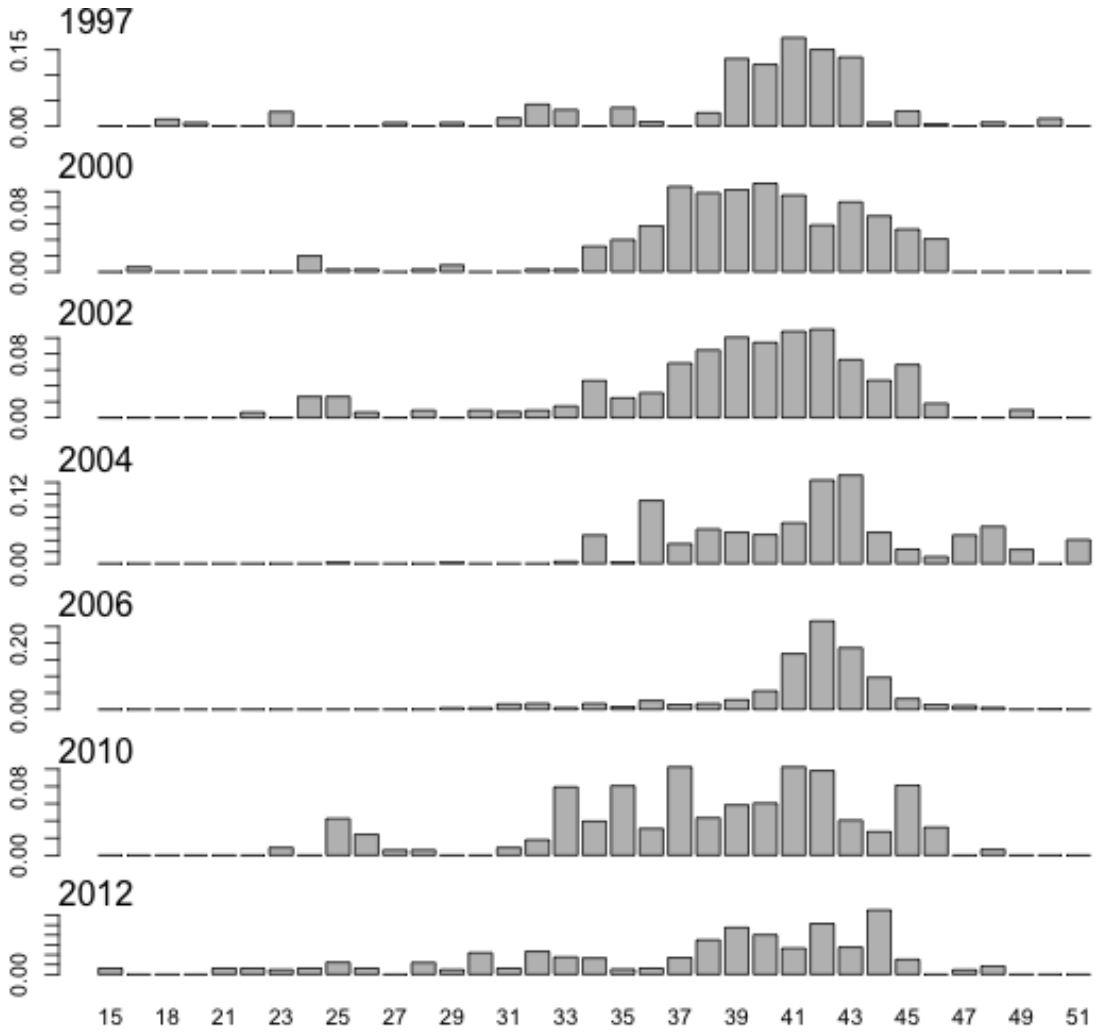


Figure 7. Dusky rockfish lengths (cm) from 1997-2012.

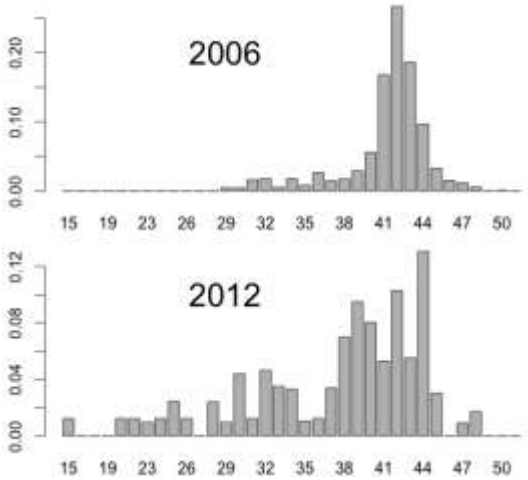


Figure 8. Dusky rockfish lengths (cm) from 2006 and 2012.

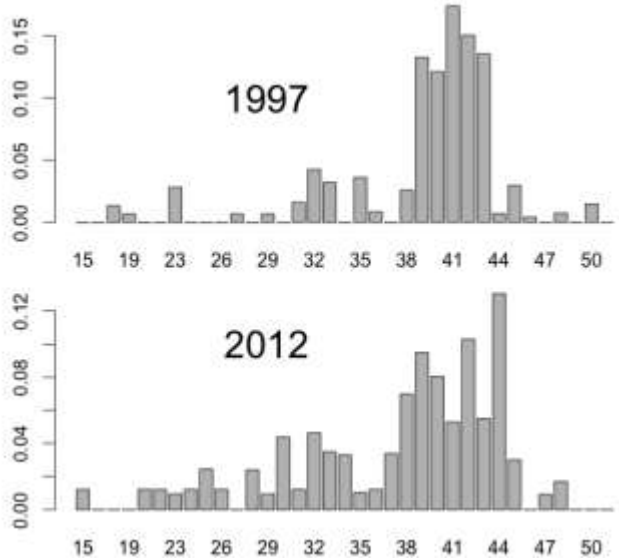


Figure 9. Dusky rockfish lengths from1997 and 2002.

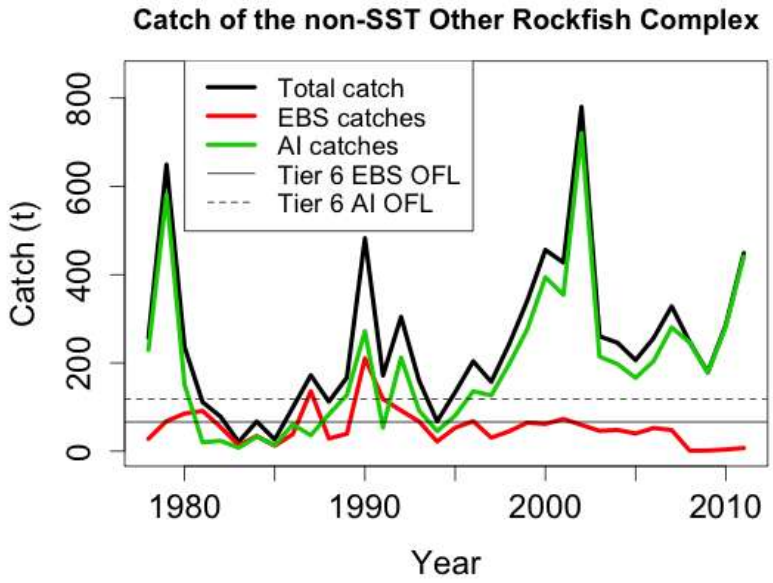


Figure 10. Catches of non-SST rockfish in the Other Rockfish complex from1977-2011. Proposed Tier 6 overfishing limits (OFLs) are shown as horizontal lines, dotted for the AI and solid for the EBS.