19. Assessment of the sculpin stock complex in the Bering Sea and Aleutian Islands

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Executive Summary

Summary of Changes in Assessment Inputs

1. Catch and retention data are updated with partial data for 2014.
2. Biomass estimates and length compositions from the 2013 and 2014 Bering Sea shelf survey and the 2014 Aleutian Islands survey have been added.

There are no changes to the assessment methodology.

Summary of Results

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)*	0.28	0.28	0.29	0.29
Tier	5	5	5	5
Biomass (t)	215,713	215,713	194,783	194,783
F_{OFL}	0.28	0.28	0.29	0.29
$maxF_{ABC}$	0.21	0.21	0.22	0.22
F_{ABC}	0.21	0.21	0.22	0.22
OFL (t)	56,424	56,424	56,487	56,487
maxABC (t)	42,318	42,318	42,852	42,852
ABC (t)	42,318	42,318	42,852	42,852
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing		n/a		n/a

** The sculpin complex mortality rate is a biomass-weighted average of the instantaneous natural mortality rates for the six most abundant sculpins in the BSAI: bigmouth (Hemitripterus bolini), great (Myoxocephalus polyacanthocephalus), plain (Myoxocephalus jaok), threaded (Gymnocanthus pistilliger), warty (Myoxocephalus verrucosus), and yellow Irish lord (Hemilepidotus jordani). The complex mortality rate may change as new survey data become available. See "results" section for more detail.*

Responses to SSC and Plan Team Comments on Assessments in General

There were no comments to be addressed.

Responses to SSC and Plan Team Comments Specific to this Assessment

There were no comments specific to the 2013 BSAI sculpin assessment.

Introduction

Forty-eight species of sculpins have been identified in the Bering Sea Aleutian Islands (BSAI) region (Families Cottidae, Hemitripteridae, Psychrolutidae, and Rhamphocottidae; Table 1). These species are managed as a complex, and biomass estimates are based on the six most abundant sculpins in the BSAI: bigmouth (*Hemitripterus bolini*), great (*Myoxocephalus polyacanthocephalus*), plain (*Myoxocephalus jaok*), threaded (*Gymnocanthus pistilliger*), warty (*Myoxocephalus verrucosus*), and yellow Irish lord (*Hemilepidotus jordani*). This non-target species complex is assessed biennially, to coincide with the frequency of trawl surveys in the Bering Sea and Aleutian Islands, with full assessments in even years. The 2013 executive summary can be found at http://www.afsc.noaa.gov/REFM/Docs/2013/BSAIsculpin.pdf. BSAI sculpins are managed as a Tier 5 stock, and a weighted average of species-specific natural mortality rates (*M*) is applied to the aggregate sculpin biomass to estimate standard reference points.

Sculpins belong to the superfamily **Cottoidea** in the order Scorpaeniformes, and are found in both freshwater and marine habitats. Sculpins are distributed throughout the BSAI and they occupy all benthic habitats and depths. They are relatively small, benthic-dwelling teleost fish with modified pectoral fins that allow them to grip the substrate, and they lack swim bladders. The six most common sculpin species in the BSAI appear to have a range of natural mortality, from 0.14-0.45 (TenBrink and Aydin 2009; Hutchinson and TenBrink 2011).

Little is known about stock structure of BSAI sculpin species, and little research on stock structure has been done for sculpins in general. However, other known aspects of their life history are relevant to this question. Most if not all sculpins lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschemeyer et al. 1983). Markevich (2000) observed the sea raven, *Hemitripterus villosus*, releasing eggs into crevices of boulders and stones in shallow waters in Peter the Great Bay, Sea of Japan. This type of reproductive strategy may make sculpin populations more sensitive to changes in benthic habitats than other groundfish species such as walleye pollock, which are broadcast spawners with pelagic eggs. In the western Pacific, great sculpins (*Myoxocephalus polyacanthocephalus*) are reported to have relatively late ages at maturity (5-8 years, Tokranov, 1985) despite being relatively short-lived (13-15 years). This suggests a limited reproductive portion of the lifespan relative to other groundfish species. Fecundity for the great sculpin in East Kamchatka waters ranged from 48,000 to 415,000 eggs (Tokranov 1985). Age and growth information is available for the great sculpin, yellow Irish lord, bigmouth, plain and warty sculpin based on samples collected from the 2005-2008 Eastern Bering Sea (EBS) shelf survey (TenBrink and Aydin 2009). Known life history characteristics for the most abundant sculpin species along the EBS shelf are presented in Table 2. Recent work has also provided information on diet and reproduction in large sculpins in the BSAI.

The diversity of sculpin species in the BSAI suggests that each sculpin population might react differently to natural or anthropogenic environmental changes. Within each sculpin species, observed spatial differences in fecundity, egg size, and other life history characteristics points to local population structure (Tokranov 1985). All of these characteristics indicate that sculpins as a group might be managed most efficiently within a spatial context rather than with a global annual aggregate BSAI total allowable catch (TAC). A recent study by TenBrink and Buckley (2012) found evidence for habitat partitioning among species *M. jaok, M. polyacanthocephalus*, and *M. scorpius*. They found that within species, larger individuals tend to be found in deeper water and diet composition differed among and within species.

Fishery

Historically, sculpins have been managed as part of the BSAI Other Species complex (sculpins, skates, sharks, and octopus). Specifications for this group were set by summing the individual ABCs and OFLs for each species group to create an aggregate OFL, ABC, and TAC. In 2010, the North Pacific Fishery Management Council passed amendment 87 to the GOA Fishery Management Plan, which separated the Other Species complex into its constituent species groups. Since that time, BSAI sculpins have been managed as an independent complex with its own harvest specifications. Sculpins are currently taken only as bycatch in fisheries directed at target species in the BSAI, and it is likely that future catch of sculpins will continue to be dependent on the distribution and limitations placed on target fisheries, rather than on any harvest level established for this category. Sculpin catch since 1998 is summarized in Table 3. There is no directed fishing for any sculpin species in the BSAI at this time.

Sculpins are caught by a wide variety of fisheries, but primarily trawl fisheries for Atka mackerel and the Pacific cod hook-and-line fishery in the Aleutian Islands and the Pacific cod hook-and-line fishery and yellowfin sole and pollock fisheries in the EBS (Table 4a). Total sculpin catch was calculated for each target fishery responsible for sculpin bycatch from 2003-2014 (Table 4b). In the Aleutian Islands sculpins are primarily caught in the Pacific cod and Atka mackerel fisheries. In the EBS, sculpins are primarily caught in the Pacific cod and yellowfin sole fisheries. Sculpins, in general, are not retained by fisheries in the BSAI region, and fishery observer data indicate that the retention rate has been 4-5% for the past three years (Table 3).

In 2002-2003, the observer program of the Alaska Fisheries Science Center (AFSC) initiated a species identification project which was prompted by the need to gather basic population data for groups in the Other Species complex. Beginning in January 2004, sculpin catch was identified to genus for the larger sculpin species: *Hemilepidotus, Myoxocephalus, and Hemitripterus.* In the BSAI region, *Hemitripterus* probably represents only one species, the bigmouth sculpin (Stevenson 2004). Another member of this genus, the sea raven, may occur in Alaskan waters but has never been identified in any of the BSAI shelf and slope trawl surveys conducted by AFSC. Therefore, it is reasonable to assume that all sculpins identified by observers as *Hemitripterus* sculpins were bigmouth sculpins. Beginning in 2008, most observers were required to identify to species all sculpins in the genera *Hemilepidotus, Myoxocephalus, and Hemitripterus.* According to observer catch totals, these genera form over 90% of all sculpin catch in the BSAI (Table 5). On longline vessels, bigmouth sculpin are identified to species, but not Irish lords and *Myoxocephalus.*

Data

Fishery:

Total sculpin catch is available from 1998-2014 (Table 3), but catches by genus are not available before 2004.

Removals from sources other than those that are included in the Alaska Region's official estimate of catch (e.g., removals due to scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs) are presented in Table 6.

Catch-at-length data is available for yellow Irish lord, and bigmouth, great, warty, and plain sculpin from the EBS shelf (Figure 1), spinyhead, darkfin, bigmouth, and blob sculpin in the EBS slope (Figure 2), and for yellow Irish lord, and bigmouth, and great sculpin from the Aleutian Islands (Figure 3).

Survey:

Research surveys provide biomass estimates for sculpin species in the BSAI (Figures 4, 5, and 6 and Tables 7, 8, 9, and 10). All three regions of the BSAI were sampled in 2004, 2010, and 2012. The EBS shelf survey is performed annually, the Aleutian survey was most recently performed in 2014, and the slope survey has not been run since 2012. Length measurements (fork length, FL) have been collected for a variety of sculpin species during AFSC trawl surveys. The five most abundant species from the EBS shelf survey have been measured annually since 2003: plain sculpin, warty sculpin, great sculpin and bigmouth sculpin, and yellow Irish lord since 2003 (Figures 1, 4). Size compositions of blob, bigmouth, spinyhead, and darkfin sculpin are measured on the slope survey, and are shown in Figure 2. Length frequency samples have been taken for great and bigmouth sculpin, and yellow Irish lord on the Aleutian Islands survey since 2002 (Figure 3).

Analytic Approach

There are no changes in the analytic approach since the last assessment. Sculpins in the BSAI are managed under Tier 5, where OFL = M * average survey biomass and ABC ≤ 0.75 * M * average survey biomass. Average biomass for the six most common species (threaded sculpin, yellow Irish lord, bigmouth sculpin, great sculpin, plain sculpin, warty sculpin, as well as "other" sculpin) was calculated as the average of the last 3 surveys (2004, 2010, and 2012 for the EBS slope and 2010, 2012, and 2014 for the EBS shelf and Aleutian Islands) in each area (Table 10). Average biomass for "other sculpins" is an average of the last 3 surveys for the rest of the species surveyed, including unidentified sculpins (Table 10). For this assessment, a weighted average of species-specific Ms is applied to the aggregate sculpin biomass, with the proportional 3-most-recent-survey average biomass of each of the most common species (threaded sculpin, yellow Irish lord, bigmouth sculpin, great sculpin, plain sculpin, warty sculpin) providing the weights.

Parameter Estimates

Natural mortality

In 2006, an analysis was undertaken to estimate natural mortality (M) for sculpin species found in the BSAI. Several methods were employed based on life history parameters including growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993, Jensen 1996), longevity (Hoenig 1983), and reproductive potential (Rikhter and Efanov 1976). Prior to 2007, little information was available for sculpin stocks in the BSAI FMP area, so M was estimated using reproductive potential methods applied to data for Russian sculpin species (Rikhter and Efanov 1976). From 2006 to 2008, the results of aging studies for EBS sculpin were used to produce M estimates specific to this area (Table 11). Estimates generated using different methods vary widely.

Results

Fishery catch of sculpins has been between 5,000 and 7,500 t since 1998. Comparison of the species composition of observed fishery catches to the species composition of the 3-survey average sculpin biomass estimates provides some information on the proportion of sculpin caught relative to their abundance. The proportion of sculpins in the catch varies between the Eastern Bering Sea and the Aleutian Islands (Table 5). Similar numbers of bigmouth sculpin are caught in each region, but approximately three times more yellow Irish lord and unidentified Hemilepidotus are caught in the Aleutian Islands. Plain sculpin and great sculpin are rarely caught in the Aleutians but each comprises approximately 30-40% of the catch in the EBS. Darkfin sculpin are not caught in the EBS but comprise approximately 25% of the Aleutian Island catches. These values generally follow the proportion caught in NMFS surveys, with a few exceptions. More darkfin sculpin are caught in the AI fishery than in the AI survey (31% fishery, 16% survey). In contrast, more great sculpin are caught in the AI survey than the AI

fishery (1% fishery, 7% survey). In the EBS, more bigmouth sculpin are caught in the survey than the fishery (8% fishery, 16% survey).

The species composition of the sculpin complex as estimated by bottom trawl surveys of the EBS shelf, EBS slope, and AI demonstrates the diversity of this complex and the regional differences in its composition. The larger species dominate the EBS shelf, with great and plain sculpins being the most common, followed by bigmouth sculpins and yellow Irish lords (Table 7a, Figures 1 and 4). A low coefficient of variation for most of the biomass estimates of these more abundant species reflects that the EBS shelf bottom trawl survey adequately estimates the biomass of these species (Table 7). Biomass estimates for the 5 most abundant sculpin species in the Eastern Bering Sea shelf seem to be relatively stable (Figure 4). Five trawl surveys conducted on the EBS slope (in 2002, 2004, 2008, 2010, 2012, and 2014) show that the slope contains a different sculpin community from the shelf and the AI, likely as a result of greater depths (Figure 7). In the AI, yellow Irish lord account for the highest proportion of sculpin biomass, followed by spectacled sculpin. These are followed by darkfin sculpin, great sculpin, and bigmouth sculpin, which are similar in proportion (Table 9 and Figure 5). The spectacled and scissortail sculpins are not found on EBS surveys. The smaller sculpin species may be less vulnerable to capture by the gear used during the bottom trawl survey because they may pass through the net. Biomass trends of sculpin species in the AI seem to be stable except for an overall increase in yellow Irish lord biomass and a decrease in great sculpin since 1980 (Figure 5).

Total BSAI sculpin biomass estimates have been in the range of 200,000 t since 2004 to 2010 but increased in 2012 (2004: 239,174 t, 2010: 207,658 t, 2012: 215,713 t, and 2014: 194,783 t; Table 10). The single most recent estimate is the lowest since 2004, but does not necessarily indicate a trend, due to the uncertainty in the survey estimates. The relative proportions of sculpins in the Bering Sea shelf and slope and Aleutian Islands has remained stable between 2012-2014, consisting of 86%, 4%, and 10% respectively (Figure 8).

The length compositions by species are generally consistent, with few small sculpins caught by the survey. There appears to be considerable annual variability in the data, which may indicate incomplete sampling of sculpins on the slope (Figure 2). The length composition data for blob and bigmouth sculpins consistently show two size modes, which are unrelated to gender but may indicate that two separate life stages of bigmouth inhabit the slope.

For the great and bigmouth sculpin sampled in the Aleutians, thus the length frequency analysis does not yield a complete representation of the sculpin species population's size composition, whereas yellow Irish lords show a consistent size composition (Figure 3). Specimens smaller than 70 mm have not been collected for many sculpins, which may be due to size selectivity of the survey gear.

Harvest recommendations

2014 shelf average of threaded, YIL, bigmouth, warty, and other were all slightly lower. In the AI, YIL was up and great was down, as was other.

2015-2016 sculpin complex harvest specifications						
species	3-survey average biomass				*M*	weighted contribution to mort. est.
	EBS shelf	EBS slope	AI	**BSAI**		
threaded	2,350	0	2	**2,352**	0.45	0.01
YIL	17,630	54	14,443	**32,127**	0.17	0.03
bigmouth	26,711	2,908	614	**30,233**	0.21	0.04
great	44,873	134	1,267	**46,275**	0.28	0.07
plain	59,468	0	0	**59,468**	0.40	0.13
warty	6,870	0	0	**6,870**	0.26	0.01
other	5,884	5,659	5,916	**17,459**		
total	**163,785**	**8,755**	**22,242**	**194,783**		0.29

weighted-average mortality rate	0.29
F_{OFL}	0.29
max F_{ABC}	0.22
rec. F_{ABC}	0.22
OFL	56,487
max. ABC	42,852
rec. ABC	42,852

A random effect biomass estimate was calculated by combining all species for each region (AI, slope, shelf), and then combining regions: 180,570 t (95%CI: 158,772, 202,368). This estimate is lower than the 194,783 t estimated with the 3 survey average approach (Figure 9). The random effects model estimate is used to calculate ABC and OFL in Appendix 1.

Ecosystem Considerations

Ecosystem Effects on Stock

Aydin et al. (2007) have produced some diet analyses and consumption/predation tables based on ecosystem modeling and direct species data for the BSAI. Limited information indicates that in the EBS the larger sculpin species prey on shrimp and other benthic invertebrates, as well as some juvenile walleye pollock (Figure 10). In the EBS the main predator of large sculpins (sculpins from the genera *Myoxocephalus*, *Hemitripterus* and *Hemilepidotus*) is Pacific cod (Figure 10). Although the greatest mortality of large sculpins is unexplained in the ecosystem model, their fishing mortality is due to the flatfish trawl fishery and Pacific cod longline, trawl and pot fisheries (Table 4a). Other sculpins (those sculpins not in the above genera) in the EBS feed mainly on shrimp and benthic amphipods (Figure 11). Other sculpins are preyed upon by pinnipeds, Pacific cod and small demersal fish, but their main source

of mortality is from consumption by eelpouts, wintering seals and the Alaska skate (Figure 11). In the AI large sculpin have a different diet than in the EBS, consisting of crabs, Atka mackerel and miscellaneous shallow water fish (Figure 11). Large sculpins in the AI are preyed upon mainly by Pacific halibut, but the main source of their mortality is from the groundfish bottom trawl fishery (Figure 11). Diet of other sculpins in the AI consists of infauna such as polychaetes and benthic crustaceans (Figure 12). Pacific cod and walleye pollock are the main predators of other sculpins and are the main source of mortality of other sculpins in the AI (Figure 13).

Fishery Effects on the Ecosystem

Analysis of ecosystem considerations for those fisheries that affect the stocks within this complex (see Table 5) is given in the respective SAFE chapters for those fisheries The BSAI sculpin complex is not a targeted fishery; therefore reference to the effects of the fishery on the ecosystem will be described in those chapters of the fisheries that catch sculpins incidentally.

Ecosystem effects on *Sculpin complex*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys, changes mean wt-at-age	No effect	Probably no concern
a. Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	No effect	Probably no concern
Birds	Stable, some increasing some decreasing	No effect	Probably no concern
Fish (Pollock, Pacific cod, halibut)	Stable to increasing	Effects not known	Probably no concern
b. Changes in habitat quality			
Temperature regime	Butterfly sculpin biomass increases during years the cold pool extends throughout EBS shelf.	Warming of EBS shelf may shift population northward	Unknown
Winter-spring environmental conditions	None	Probably a number of factors	Unknown
Production	Fairly stable nutrient flow from upwelled BS Basin	Inter-annual variability low	No concern
***Targeted fisheries* effects on ecosystem (see relative chapters)**			

Data Gaps and Research Priorities

Sculpin life history has been studied more extensively in the western Bering Sea and associated waters than in the EBS or AI. Although we have recently acquired substantially more life history data for five species in the EBS concerning age and growth, diet, and some reproductive data, data gaps continue to persist for other species in the eastern Bering Sea and Aleutian Island regions. Age validation studies could be conducted to validate the newly acquired age data from the five species in the EBS. Genetic

analysis of species found in different regions would help determine if there are several stocks of sculpin species within the BSAI. Studies of habitat use and catchability studies of smaller sculpin species would be useful for determining why larger species make up most of the sculpin complex biomass. These data are necessary to improve management strategies and stock assessments for this non-target species group.

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Table 1. Members of the Sculpin complex observed during eastern Bering Sea and Aleutian Islands bottom trawl surveys. Updated 2004.

Family	Scientific name	Common name
Cottidae	*Archistes biseriatus*	Scaled sculpin
	Artediellus miacanthus	Bride sculpin
	Artediellus pacificus	Pacific hookhorn sculpin
	Bolinia euryptera	Broadfin sculpin
	Enophrys diceraus	Antlered sculpin
	Enophrys lucasi	Leister sculpin
	Gymnocanthus detrisus	Purplegray sculpin
	Gymnocanthus galeatus	Armorhead sculpin
	Gymnocanthus pistilliger	Threaded sculpin
	Gymnocanthus tricuspis	Arctic staghorn sculpin
	Hemilepidotus gilberti	Banded Irish lord
	Hemilepidotus hemilepidotus	Red Irish Lord
	Hemilepidotus jordani	Yellow Irish Lord
	Hemilepidotus papilio	Butterfly sculpin
	Hemilepidotus zapus	Longfin Irish lord
	Icelinus borealis	Northern sculpin
	Icelus canaliculatus	Blacknose sculpin
	Icelus euryops	Wide-eye sculpin
	Icelus spatula	Spatulate sculpin
	Icelus spiniger	Thorny sculpin
	Icelus uncinalis	Uncinate sculpin
	Jordania zonope	Longfin sculpin
	Leptocottus armatus	Pacific staghorn sculpin
	Myoxocephalus jaok	Plain sculpin
	Myoxocephalus polyacanthocephalus	Great sculpin
	Myoxocephalus quadricornis	Fourhorn sculpin
	Myoxocephalus verrucocus	Warty sculpin
	Radulinus asprellus	Slim sculpin
	Rastrinus scutiger	Roughskin sculpin
	Thyriscus anoplus	Sponge sculpin
	Triglops forficatus	Scissortail sculpin
	Triglops macellus	Roughspine sculpin
	Triglops metopias	Crescent-tail sculpin
	Triglops pingelii	Ribbed sculpin
	Triglops septicus	Spectacled sculpin
	Triglops xenostethus	Scalybreasted sculpin
	Zesticelus profundorum	Flabby sculpin
Hemitripteridae	*Blepsias bilobus*	Crested sculpin
	Hemitripterus bolini	Bigmouth sculpin
	Nautichthys oculofasciatus	Sailfin sculpin
	Nautichthys pribilovius	Eyeshade sculpin
Psychrolutidae	*Dasycottus setiger*	Spinyhead sculpin
	Eurymen gyrinus	Smoothcheek sculpin
	Malacoccottus zonurus	Darkfin sculpin
	Malacocottus kincaidi	Blackfin sculpin
	Psychrolutes paradoxus	Tadpole sculpin
	Psychrolutes phrictus	Blob sculpin
Rhamphocottidae	*Rhamphocottus richardsoni*	Grunt sculpin

Table 2. Life history information available for selected BSAI sculpin species. "O" refers to data from regions outside the EBS and AI (e.g. Kamchatka).

Species	Common Name	Maximum Length (cm)			Maximum Age		Fecundity (x1000)	Age at 50% Maturity
		O	AI	EBS	O	BSAI		
Myoxocephalus joak	Plain sculpin	75	NA	63	15	16	25.4 - 147	5 - 8
M. polyacanthocephalus	Great sculpin	82	76	82	13	17	48 - 415	6.9
M. verrucosus	Warty sculpin	78	NA	78		18	2.7	
Hemitripterus bolini	Bigmouth sculpin	83	83	78		23		
Hemilepidotus jordani	Yellow Irish lord	65	65	50	13	30	54 - 389	6-7
H. papilio	Butterfly sculpin	38		38				
Gymnocanthus pistilliger	Threaded sculpin	27		20	13	10	5 - 41	
G. galeatus	Armorhead sculpin	46		36	13		12 - 48	
Dasycottus setiger	Spinyhead sculpin	45		34	11			
Icelus spiniger	Thorny sculpin	17		17				
Triglops pingeli	Ribbed sculpin	20			6		1.8	
T. forficata	Scissortail sculpin	30		30	6		1.7	
T. scepticus	Spectacled sculpin	25	25	NA	8		3.1	
Malacoccottus zonurus	Darkfin sculpin		30	NA				

References: AFSC; Panchenko 2001; Panchenko 2002; Tokranov 1985; Andriyashev 1954; Tokranov 1988; Tokranov 1989; Tokranov 1995; Hoff 2000; Tokranov and Orlov 2001; TenBrink unpublished data.

Table 3. Total catch in metric tons (t) of sculpin complex compared to Other species catch (including squid), 1998-2009. Source: NMFS AKRO BLEND/Catch Accounting System, complete as of October 23, 2014.

Year	EBS sculpin catch	AI sculpin catch	BSAI sculpin catch	% of sculpins retained
1998	5,204	1,081	6,285	
1999	4,503	967	5,470	
2000	5,673	1,413	7,086	
2001	6,067	1,603	7,670	
2002	6,043	1,133	7,176	
2003	5,184	599	5,614	1%
2004	5,242	894	6,020	1%
2005	5,114	621	5,642	2%
2006	4,907	911	5,733	3%
2007	6,505	1,016	7,702	5%
2008	6,682	935	7,368	6%
2009	5,915	1,263	7,039	9%
2010	4,227	1,397	5,624	4%
2011	5,146	488	5,634	5%
2012	5,420	819	6,239	5%
2013	5,194	632	5,827	4%
2014	4,204	420	4,624	5%

Table 4a. Total catch in metric tons (t) of all sculpins by target fishery in the eastern Bering Sea and Aleutian Islands, 2003-2014 by gear type (NPT: non-pelagic trawl, PTR: pelagic trawl, TRW: trawl, HAL: hook and line, POT: pot). *Source: NMFS AK regional office catch accounting system. * 2014 catch data are incomplete; retrieved October 8, 2014.*

Aleutian Islands	**Gear Type**					
Target fishery	**NPT**	**PTR**	**TRW**	**HAL**	**POT**	**Total**
arrowtooth flounder	779	0	0	121	0	900
Atka mackerel	7692	0	0	0	0	7692
flathead sole	1	0	0	0	0	1
Greenland turbot	57	0	0	208	0	265
IFQ halibut	0	0	0	1758	0	1758
Kamchatka flounder	441	0	0	0	0	441
other species	0	0	0	174	0	174
Pacific cod	1913	0	0	7216	322	9451
pollock	0	0	0	0	0	0
rock sole	1892	0	0	16	0	1908
rockfish	0	0	0	816	8	824
sablefish	13	2	0	0	0	15
Total	12,788	2	0	10,309	330	23,429

Eastern Bering Sea	**Gear Type**					
Target fishery	**NPT**	**PTR**	**TRW**	**HAL**	**POT**	**Total**
Alaska plaice	192	0	0	0	0	192
arrowtooth flounder	2,628	0	4	37	0	2,669
Atka mackerel	359	0	0	0	0	359
flathead sole	10,505	9	36	0	0	10,550
Greenland turbot	45	0	0	2,065	0	2,110
IFQ halibut	0	0	0	1,836	0	1,836
other flatfish	455	0	3	0	0	458
other species	326	0	0	207	253	786
Pacific cod	17,948	2	0	192,666	4,850	215,466
pollock	566	34,416	0	9	0	34,991
rock sole	18,575	11	0	0	0	18,586
rockfish	287	0	0	28	0	315
sablefish	7	0	0	159	20	186
yellowfin sole	40,281	7	0	0	0	40,288
Total	92,174	34,445	43	197,007	5,123	328,792

Table 4b. Total catch in metric tons (t) of all sculpins by target fishery in the eastern Bering Sea and Aleutian Islands, 2003-2014. *Source: NMFS AK regional office catch accounting system. * 2014 catch data are incomplete; retrieved October 8, 2014.*

	Eastern Bering Sea											
Target fishery	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Alaska plaice	0	0	0	4	11	3	4	7	62	19	82	0
arrowtooth flounder	138	128	262	256	105	399	278	103	214	345	245	181
Atka mackerel	25	65	69	35	119	13	15	0	1	7	2	0
flathead sole	1058	1805	1376	1405	1257	1286	772	544	230	108	264	443
Greenland turbot	221	146	158	106	84	66	191	315	364	327	50	39
IFQ halibut	38	28	25	29	9	820	2	11	6	13	262	559
other flatfish	89	124	98	18	95	4	16	4	3	5	2	1
other target	232	290	33	38	64	57	7	7	2	0	0	21
Pacific cod	17849	21551	22144	17396	15451	15595	13298	11876	18901	15626	22018	19089
pollock	2089	2159	2201	3397	2883	4676	4467	2478	3018	2745	2168	2626
rock sole	988	800	912	1595	1772	1663	2230	2137	1621	1595	1793	1461
rockfish	12	10	5	5	4	2	7	40	73	13	62	9
sablefish	9	5	5	15	21	18	26	4	11	1	23	10
yellowfin sole	2916	1562	2106	2260	3880	4199	4376	3540	3933	3257	4618	2749
Total catch (mt)	25,664	28,673	29,394	26,559	25,755	28,801	25,689	21,066	28,439	24,061	31,589	27,188

Table 4b continued. Total catch in metric tons (t) of all sculpins by target fishery in the eastern Bering Sea and Aleutian Islands, 2003-2014.
*Source: NMFS AK regional office catch accounting system. * 2014 catch data are incomplete; retrieved October 8, 2014.*

	Aleutian Islands											
Target fishery	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
arrowtooth flounder	0	0	0	110	8	27	90	236	106	39	142	147
Atka mackerel	383	596	517	631	687	643	900	837	494	867	497	639
flathead sole	0	0	0	0	1	0	0	0	0	0	0	0
Greenland turbot	22	4	15	19	92	11	43	45	8	0	1	0
IFQ halibut	254	267	106	61	9	562	24	29	9	27	139	323
Kamchatka flounder	0	0	0	0	0	0	0	0	111	182	97	51
other target	11	6	3	89	13	6	27	0	18	0	0	0
Pacific cod	478	862	635	857	1077	995	1250	1607	280	733	545	136
pollock	0	0	1	0	1	1	0	3	0	0	10	0
rock sole	0	0	0	0	0	0	0	0	0	0	0	0
rockfish	122	70	67	80	149	161	169	84	201	150	364	295
sablefish	75	11	26	111	45	27	82	75	95	46	91	65
Total catch (mt)	1345	1816	1370	1958	2082	2433	2585	2916	1211	1451	1,885	1,656

Table 5. Composition of observed fishery catches, 2012-2014, and species composition of the 3-survey average biomass estimate of sculpin complex biomass, by species and/or genus. Fishery catch proportions are based on on fishery observer data. *Source: NORPAC database.* Most sculpins are not identified to species; therefore percentages represent relative proportions of those identified to species here.

taxon	EBS (shelf and slope)				AI			
	fishery catch composition			proportion of average survey biomass	fishery catch composition			proportion of average survey biomass
	2012	2013	2014		2012	2013	2014	
Hemitripterus* spp.*				**16%**				**1%**
H. bolini (bigmouth)	8%	8%	8%	16%	8%	8%	9%	1%
***Hemilepidotus* spp.**				**13%**				**50%**
Hemilepidotus unidentified	4%	8%	11%	n/a	27%	35%	15%	n/a
H. hemilepidotus (RIL)	<1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%
H. jordani (YIL)	11%	9%	22%	13%	38%	33%	40%	50%
H. spinosus (BIL)	<1%	< 1%	< 1%	< 1%	<1%	< 1%	< 1%	< 1%
***Myoxocephalus* spp.**				**60%**				**7%**
Myoxocephalus unidentified	2%	2%	2%	n/a	1%	< 1%	< 1%	n/a
M. verrucosus (warty)	1%	1%	2%	4%	<1%	< 1%	< 1%	< 1%
M. jaok (plain)	32%	36%	23%	31%	<1%	< 1%	< 1%	< 1%
M. polyacanthocephalus (great)	41%	39%	30%	24%	2%	1%	1%	7%
Malacottus spp.								
M. zonurus (darkfin)	1%	2%	1%	1%	24%	23%	35%	16%

** *Hemitripterus* spp. is likely all *H. bolini.*

§ Miscellaneous sculpins comprises unidentified sculpins as well as a number of minor sculpin species.

Table 6. Total removals from sources other than those that are included in the Alaska Region's official estimate of catch (e.g., removals due to scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs) for BSAI sculpins through November 9, 2014, and for arrowtooth only from 2008 onwards. Source: AKR.V_NONCOMMERCIAL_FISHERY_CATCH table.

Year	Non-commercial catch (t)
1990	0.1
1991	0.1
1992	0
1993	0
1994	0
1995	0
1996	1.2
1997	0
1998	1.4
1999	1.1
2000	2.1
2001	1.1
2002	2.3
2003	1.8
2004	3.1
2005	2.4
2006	2.2
2007	2
2008	2
2009	1.6
2010	27.6
2011	26.8
2012	19.1
2013	16.6
2014	8.9

Table 7a. Eastern Bering Sea (EBS) shelf sculpin complex biomass estimates (t) and coefficients of variation (CV) for the five most abundant BSAI sculpin species, from EBS shelf surveys 1982-2014. YIL = yellow Irish lord. Asterisks represent cases in which sculpin were not identified to species.

	YIL		**bigmouth**		**great**		**plain**		**warty**	
	biomass	CV	biomass	CV	biomass	CV	biomass	CV	biomass	CV
1982	52,700	0.33	22,841	0.22	6,026	0.29	58,297	0.19	*	
1983	46,475	0.40	19,945	0.21	37,989	0.27	86,344	0.16	2,008	0.63
1984	31,569	0.32	27,644	0.21	19,204	0.33	57,482	0.12	54,900	0.33
1985	13,116	0.24	14,219	0.22	30,234	0.19	37,122	0.10	1,985	0.78
1986	25,810	0.31	11,234	0.23	56,836	0.11	48,549	0.09	293	0.50
1987	41,574	0.48	22,996	0.18	50,845	0.13	55,852	0.11	3,938	0.24
1988	24,867	0.33	22,038	0.25	47,806	0.13	53,772	0.13	3,794	0.32
1989	22,047	0.39	16,636	0.22	37,244	0.16	57,857	0.15	*	
1990	10,212	0.18	16,123	0.24	37,573	0.26	36,991	0.26	*	
1991	10,258	0.17	20,483	0.23	67,848	0.23	113,180	0.08	3,306	0.45
1992	17,091	0.20	18,300	0.21	95,097	0.15	74,712	0.13	*	
1993	22,031	0.46	19,630	0.18	67,549	0.12	87,653	0.13	49	1.00
1994	17,911	0.28	28,426	0.22	99,271	0.10	44,319	0.15	*	
1995	19,112	0.28	29,492	0.18	88,622	0.18	67,240	0.13	*	
1996	14,573	0.19	31,250	0.22	90,999	0.13	54,096	0.10	*	
1997	23,727	0.28	29,722	0.17	85,371	0.24	73,287	0.08	3,915	0.48
1998	13,913	0.31	36,276	0.24	65,840	0.22	57,306	0.09	8,968	0.33
1999	13,229	0.20	24,681	0.18	50,039	0.14	47,324	0.12	11,090	0.19
2000	11,249	0.22	26,200	0.19	62,963	0.40	43,618	0.08	11,744	0.18
2001	9,121	0.35	25,760	0.16	41,071	0.28	48,449	0.10	15,726	0.15
2002	9,415	0.35	32,180	0.34	65,888	0.19	52,525	0.17	9,630	0.20
2003	14,205	0.25	29,161	0.14	67,357	0.19	80,187	0.09	7,098	0.17
2004	33,637	0.33	34,409	0.14	61,176	0.11	69,363	0.10	10,212	0.18
2005	27,444	0.26	31,289	0.13	60,100	0.09	76,426	0.10	25,500	0.51
2006	31,720	0.44	30,118	0.13	57,804	0.10	66,851	0.10	16,136	0.25
2007	23,765	0.34	27,859	0.18	66,000	0.11	77,922	0.11	13,370	0.27
2008	32,389	0.35	30,846	0.14	70,223	0.13	56,914	0.15	11,392	0.27
2009	23,056	0.43	20,196	0.16	44,901	0.12	47,322	0.09	7,952	0.26
2010	21,518	0.45	32,477	0.13	49,665	0.14	55,132	0.12	6,991	0.27
2011	20,212	0.59	31,643	0.11	54,177	0.17	59,306	0.09	6,472	0.27
2012	22,154	0.54	24,080	0.14	40,733	0.14	53,271	0.12	6,477	0.24
2013	7,990	0.42	27,005	0.12	32,185	0.16	47,273	0.15	4,040	0.18
2014	9,218	0.69	23,576	0.13	44,222	0.16	69,999	0.09	7,136	0.21

Table 7b. Eastern Bering Sea (EBS) shelf sculpin complex biomass estimates (t) and 2014 coefficients of variation (CV) for the less abundant BSAI sculpin species, from EBS shelf surveys 1994-2014.

species	1994	1995	1996	1997	1998	1999	2000	2001	2002
Pacific hookhorn	7	3	0	0	12	2	3	4	2
crested	0	0	0	0	0	4	4	2	2
spinyhead	1,384	1,245	684	874	958	1,462	1,816	1,681	1,194
purplegray	0	0	0	0	21	0	0	0	0
armorhead	5,313	605	523	1,252	916	254	347	289	1,708
threaded	0	0	0	3,867	1,801	3,572	1,697	423	1,560
red Irish lord	0	0	0	0	0	42	0	0	3
butterfly	18,619	13,056	2,664	6,070	1,334	3,810	4,501	2,710	2,921
spatulate	0	0	0	0	14	12	23	16	19
thorny	397	71	191	931	1,351	1,036	992	858	814
darkfin	0	0	16	45	0	130	49	220	529
sailfin	0	0	5	0	0	0	0	0	0
scissortail	0	14	10	0	3	3	1	9	2
roughspine	0	11	0	6	50	12	35	7	3
crescent-tail	0	0	0	0	0	0	0	0	0
ribbed	0	6	108	33	71	220	78	188	156
spectacled	0	0	9	652	168	200	491	174	255
total	25,720	15,011	4,210	13,730	6,699	10,759	10,037	6,581	9,168

species	2003	2004	2005	2006	2007	2008	2009	2010	2011
Pacific hookhorn	0	0	4	1	4	3	8	17	45
crested	2	0	0	23	0	0	5	0	0
spinyhead	1,272	1,027	4,520	2,479	1,949	870	1,586	1,277	1,554
purplegray	0	0	14	4	0	6	29	14	17
armorhead	729	801	1,554	1,734	990	2,113	1,859	1,794	2,102
threaded	1,154	1,295	1,983	2,385	4,126	2,174	1,166	1,663	962
red Irish lord	0	73	15	0	5	0	106	0	0
butterfly	1,067	1,069	1,319	2,766	1,956	541	794	939	1,948
spatulate	4	13	23	47	52	23	60	60	118
thorny	748	696	627	667	558	940	1,159	2,384	1,394
darkfin	11	124	36	69	46	1	3	22	17
sailfin	0	0	0	0	0	0	0	1	0
scissortail	0	0	0	42	20	27	77	9	0
roughspine	10	62	111	168	57	176	64	77	56
crescent-tail	0	0	0	1	0	0	0	0	0
ribbed	140	558	261	400	309	368	581	477	84
spectacled	298	29	113	365	217	184	224	503	648
total	5,435	5,747	10,580	11,151	10,289	7,426	7,721	9,237	8,945

Table 7b. continued.

species	2012	2013	2014	*2014 CV*
Pacific hookhorn	9	7	3	*0.50*
crested	0	0	0	-
spinyhead	707	661	1,155	*0.24*
purplegray	21	144	46	*0.61*
armorhead	907	909	569	*0.81*
threaded	4,990	1,217	559	*0.40*
red Irish lord	85	0	0	-
butterfly	2,426	568	477	*0.29*
spatulate	49	92	39	*0.35*
thorny	784	522	1,177	*0.16*
darkfin	142	40	25	*0.70*
sailfin	0	0	0	-
scissortail	0	0	0	-
roughspine	19	12	146	*0.80*
crescent-tail	0	0	0	-
ribbed	292	86	85	*0.31*
spectacled	156	269	529	*0.56*
total	10,587	4,527	4,812	

Table 8. Eastern Bering Sea (EBS) slope sculpin biomass estimates (t) from the 2002-2012 EBS slope surveys and the coefficient of variation (CV) for 2012.

common name	**2002**	**2004**	**2008**	**2010**	**2012**	***2012 CV***
armorhead	1	0	0	0	0	
bigmouth	1,920	1,286	3,053	3,191	4,245	*0.17*
blacknose	122	50	39	17	21	*0.39*
blob	1,471	1,431	1,110	3,325	1,030	*0.21*
darkfin	1,525	1,804	1,073	1,082	1,530	*0.44*
flabby	0	0	0	0	0	
great	44	5	9	88	309	*0.47*
roughskin	1	0	0	0	0	
spatulate	0	0	0	0	0	
spectacled	58	57	30	29	61	*0.71*
spinyhead	1,158	698	374	372	229	*0.23*
thorny	74	39	6	8	18	*0.34*
wide-eye	12	4	4	0	2	*0.85*
yellow Irish lord	0	113	6	20	29	*0.59*
total	**6,409**	**5,497**	**5,705**	**8,136**	**7,479**	

Table 9. Aleutian Islands (AI) sculpin biomass estimates (t) from 1980-2014 AI trawl surveys and the coefficient of variation (CV) for 2014.

	biomass estimate (t)						
species	**1980**	**1983**	**1986**	**1991**	**1994**	**1997**	**2000**
yellow Irish lord	2,462	5,049	10,065	3,813	7,227	4,667	6,711
darkfin	2,535	3,442	4,245	2,874	3,795	3,442	2,533
great	8,749	11,973	6,325	4,117	2,329	2,138	1,168
spectacled	214	454	1,137	523	1,245	1,344	1,122
bigmouth	1,430	8,644	2,557	1,137	1,830	1,617	1,005
armorhead	8	641	32	168	257	105	288
scissortail	61	14	58	317	298	219	67
unidentified sculpins	436	114	74	3,531	193	75	49
spinyhead	9	7	6	8	7	71	19
threaded	0	0	11	0	0	8	0
thorny	0	36	1	1	8	0	1
antlered	0	5	180	16	0	0	0
butterfly	0	0	1	58	0	0	0
crested	0	0	0	0	0	0	0
Pacific staghorn	0	0	8,253	24	2	0	0
plain	0	0	0	0	0	0	0
warty	0	0	318	3	12	0	0
total	**15,905**	**30,377**	**33,261**	**16,589**	**17,202**	**13,687**	**12,963**

	biomass estimate (t)						
species	**2002**	**2004**	**2006**	**2010**	**2012**	**2014**	***2014 CV***
yellow Irish lord	4,240	8,357	10,797	15,247	14,166	13,916	*0.16*
darkfin	3,971	4,521	4,520	5,431	4,514	3,231	*0.15*
great	1,494	1,519	2,121	1,067	1,930	805	*0.32*
spectacled	2,393	1,040	993	956	746	821	*0.28*
bigmouth	1,191	790	1,647	794	339	709	*0.35*
armorhead	208	506	424	637	416	210	*0.30*
scissortail	442	2,073	136	155	83	129	*0.30*
unidentified sculpins	138	100	181	124	108	89	*0.23*
spinyhead	23	72	12	59	3	35	*0.44*
threaded	0	0	0	4	0	1	*0.94*
thorny	2	0	0	0	1	1	*0.78*
antlered	20	17	8	0	0	0	-
butterfly	0	0	0	0	0	0	-
crested	0	0	0	0	0	0	-
Pacific staghorn	0	9	0	0	0	0	-
plain	32	0	0	0	0	0	-
warty	0	0	0	0	0	0	-
total	**14,155**	**19,003**	**20,838**	**24,473**	**22,306**	**19,947**	

Table 10. Sculpin biomass estimates for the three most recent survey years; 2004, 2010, and 2012 for the EBS slope and 2010, 2012, and 2014 for the EBS shelf and the Aleutian Islands (AI). YIL = yellow Irish lord. Biomass estimates are based on these values, the mean of the most recent three surveys.

	EBS shelf			EBS slope			AI		
species	**2010**	**2012**	**2014**	**2004**	**2010**	**2012**	**2010**	**2012**	**2014**
antlered	-	9	-	-	-	-	0	0	0
armorhead	1,956	907	569	-	-	-	637	416	210
bigmouth	32,477	24,080	23,576	1,289	3,191	4,245	794	339	709
blacknose	-	-	-		17	21	-	-	-
blob	-	-	-		3,325	1,030	-	-	-
butterfly	965	2,426	477	-	-	-	-	-	-
crescent-tail	-	-	-	-	-	-	-	-	-
crested	-	-	-	-	-	-	-	-	-
darkfin	22	142	25	1,798	1,082	1,530	5,431	4,514	3,231
flabby	-	-	-	-	0.39	0.21	-	-	-
great sculpin	49,665	40,733	44,222	5	88	309	1,067	1,930	805
Pacific hookhorn	17	9	3	-	-	-	-	-	-
Pacific staghorn	-	-	-	-	-	-	0	0	0
plain	55,135	53,271	69,999	-	-	-	-	-	-
purplegray	14	21	46	-	-	-	-	-	-
red Irish lord	0	85	0	-	-	-	-	-	-
ribbed	474	291	85	-	-	-	-	-	-
roughspine	77	19	146	-	-	-	-	-	-
sailfin	1	0	0	-	-	-	-	-	-
scissortail	9	0	0	-	-	-	155	83	129
spatulate	60	49	39	-	-	-	-	-	-
spectacled	503	156	529	57	29	61.2	956	746	821
spinyhead	1,277	707	1,155	701	372	229	59	3	35
thorny	2,385	784	1,177	39	8	19	0.10	1	1
threaded	1,501	4,990	559	-	-	-	4	0	1
unidentfied	-	-	-	1,486	-	-	124	108	89
warty	6,998	6,477	7,136	-	-	-	-	-	-
wide-eye	-	-	-	-	0.14	2.35	-	-	-
YIL	21,518	22,154	9,218	113	20	29	15,247	14,166	13,916
total	**175,054**	**157,310**	**158,963**	**5,488**	**8,131**	**7,476**	**24,473**	**22,306**	**19,947**

Table 11. Natural mortality estimates from recent life history analyses of BSAI sculpins. All values are unpublished data from T. Tenbrink. "SAFE *M*" indicates the value used in the computation of harvest recommendations for the 2010 assessment.

species	area	sex	Hoenig	Jensen	Charnov	catch curve	SAFE *M*
yellow Irish lord	EBS	*M*	0.17	0.41	0.45	0.17	0.17
	EBS	*F*	0.14	0.47	0.51	0.17	
	AI	*M*	0.15	0.23	0.27	0.17	
	AI	*F*	0.15	0.27	0.31	0.17	
threaded sculpin	EBS	*M*	0.42	0.6	0.65	n/a	0.45
	EBS	*F*	0.47	0.36	0.4	n/a	
great sculpin	EBS	*M*	0.28	0.39	0.43	0.25	0.28
	EBS	*F*	0.25	0.27	0.3	0.31	
plain sculpin	EBS	*M*	0.28	0.38	0.42	0.39	0.40
	EBS	*F*	0.26	0.27	0.55	0.41	
warty sculpin	EBS	*M*	0.28	0.58	0.63	n/a	0.26
	EBS	*F*	0.23	0.41	0.47	n/a	
bigmouth sculpin	EBS	*both*	0.20 M 0.18 F	0.21	0.24	n/a	0.21

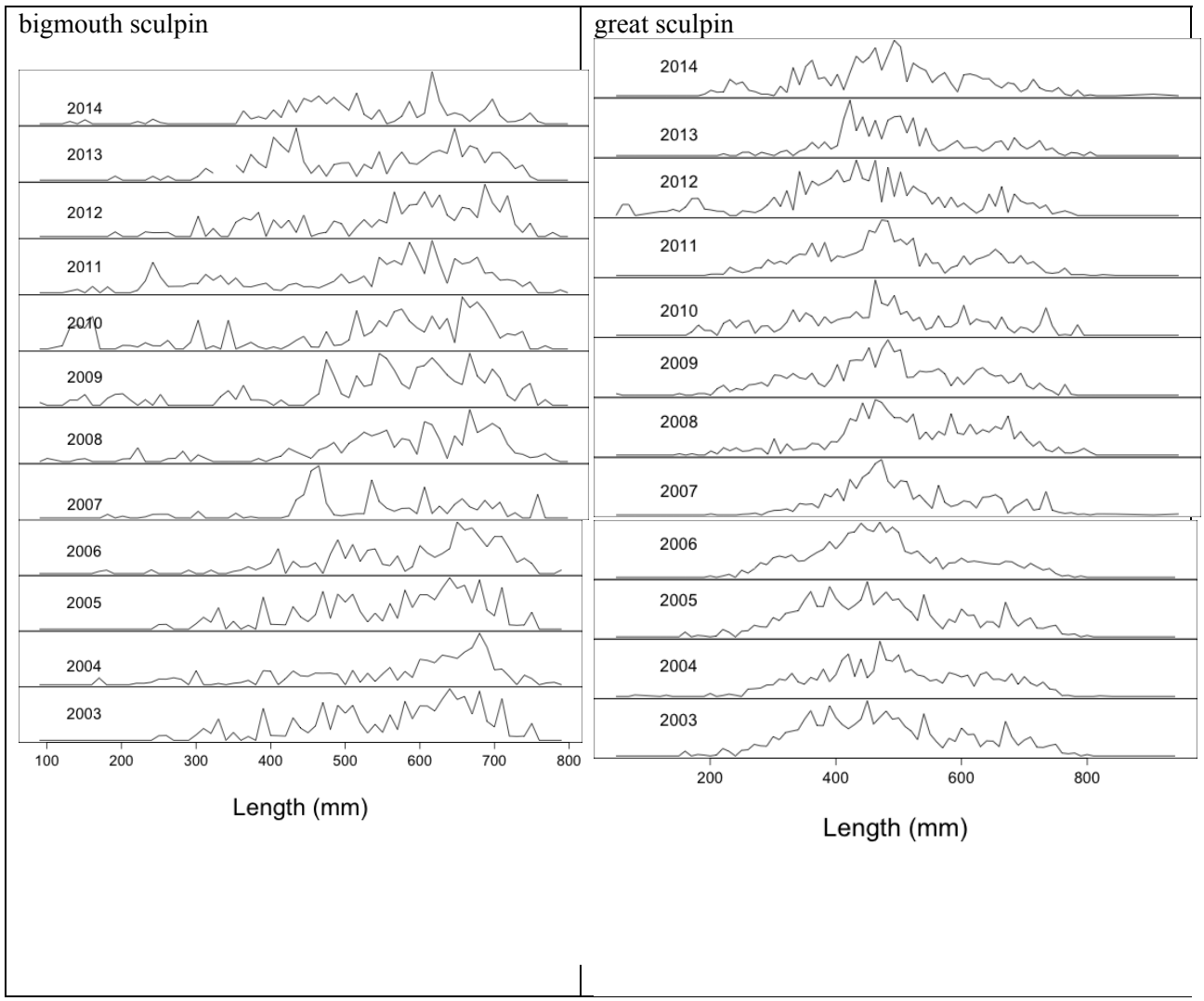

Figure 1. Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2001-2012 (2003-2012 for Yellow Irish Lord). Length scale differs among plots.

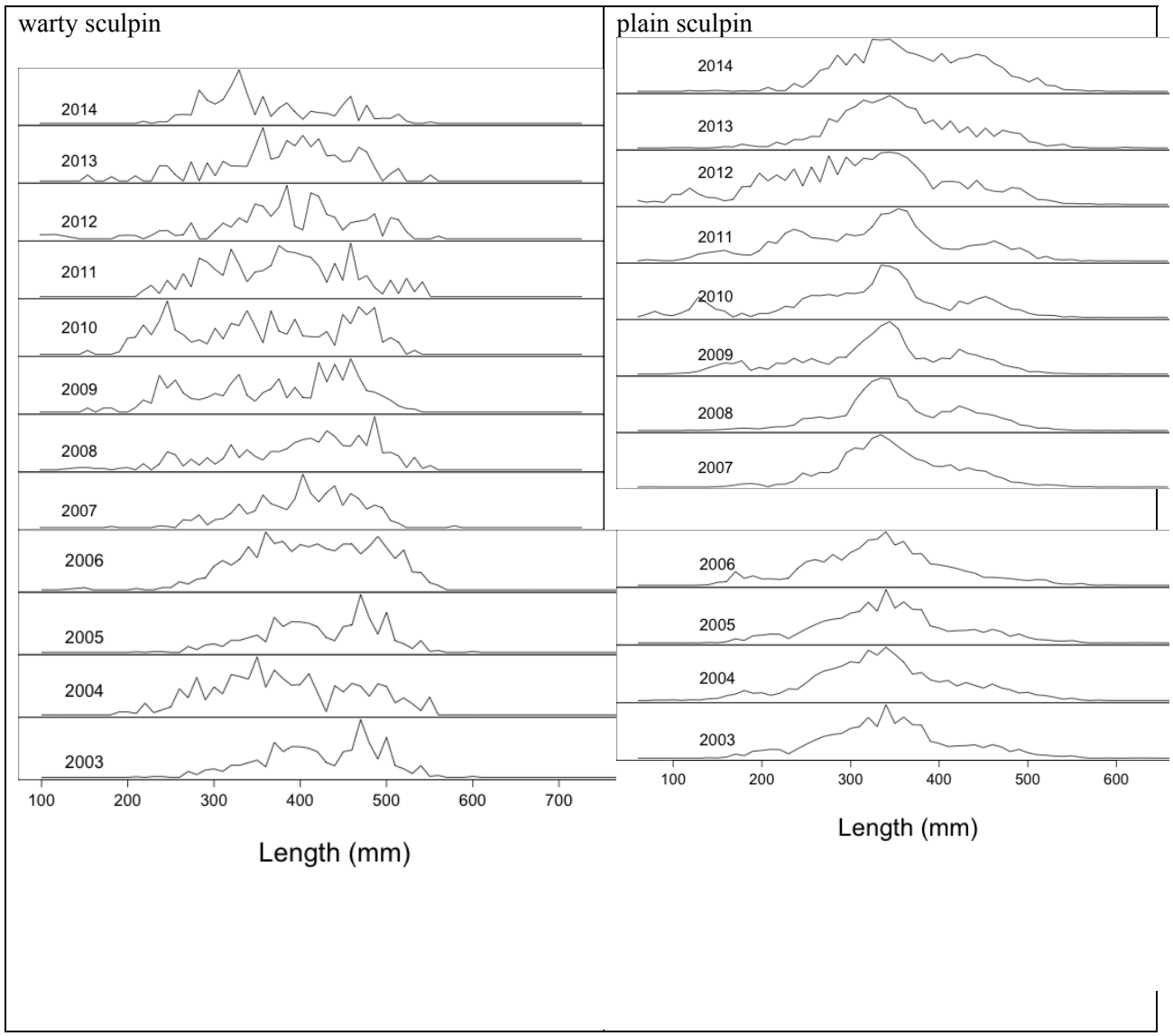

Figure 1 (continued). Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2001-2012 (2003-2012 for Yellow Irish Lord). Length scale differs among plots.

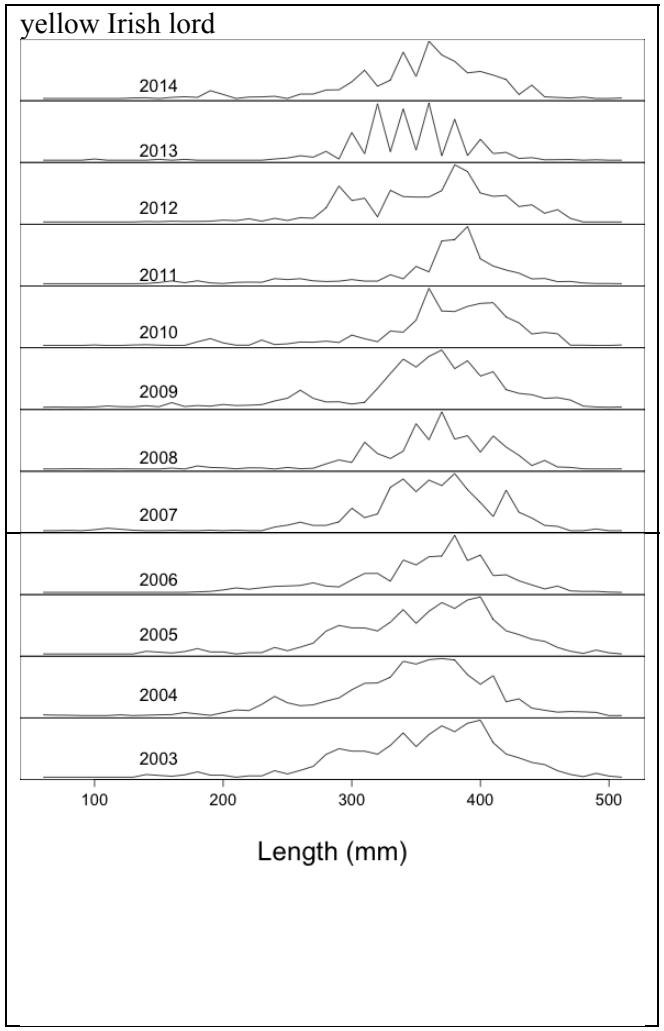

Figure 1 (continued). Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2001-2012 (2003-2012 for Yellow Irish Lord). Length scale differs among plots.

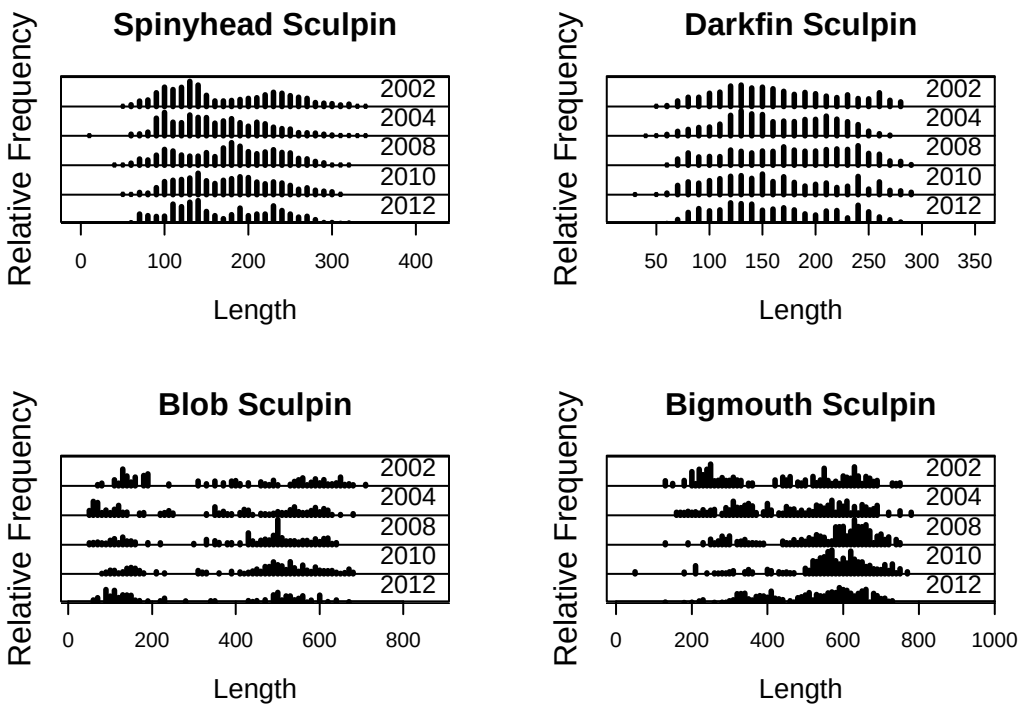

Figure 2. Length frequencies (fork length, FL in mm) from EBS slope survey data for the four most abundant sculpin species in these surveys.

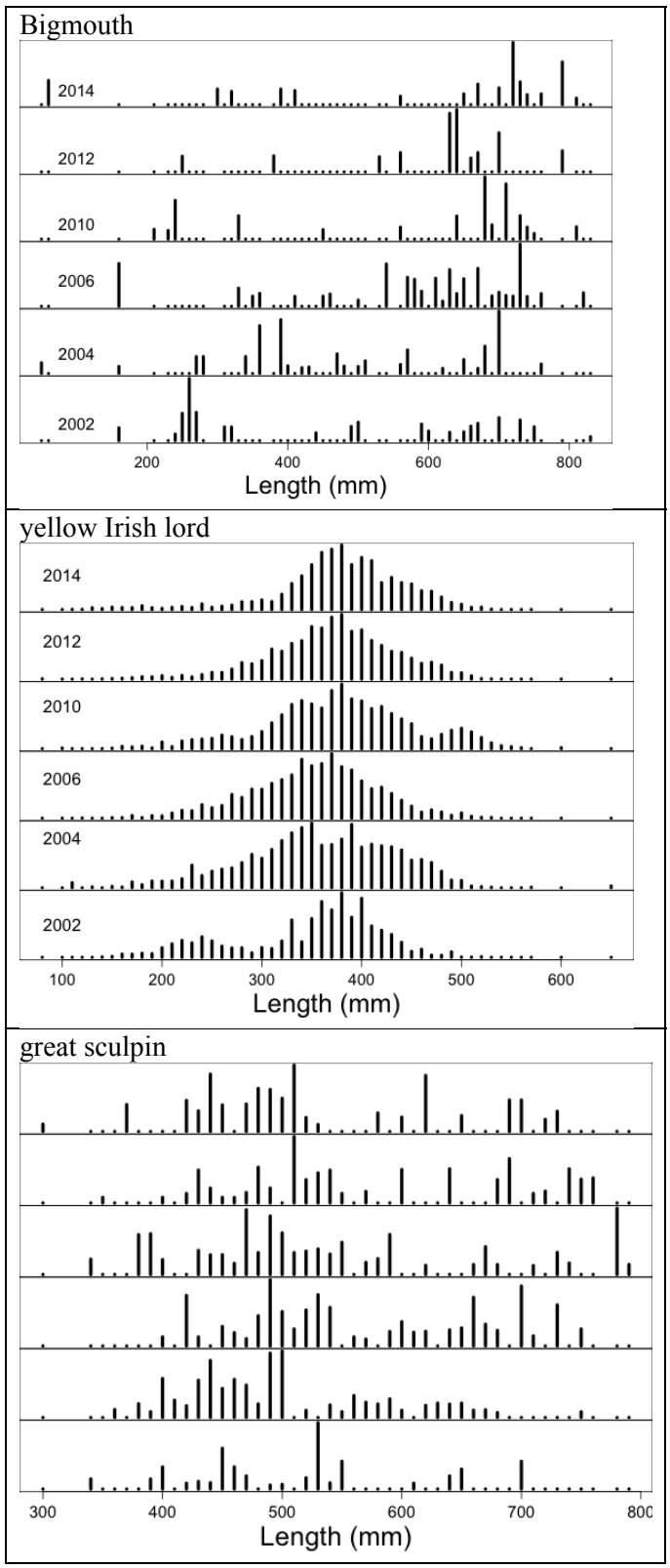

Figure 3. Survey length composition for the 3 most abundant sculpin species in the AI, 2004-2014 bigmouth (upper panel, yellow Irish lord (middle panel), and great sculpin (lower panel).

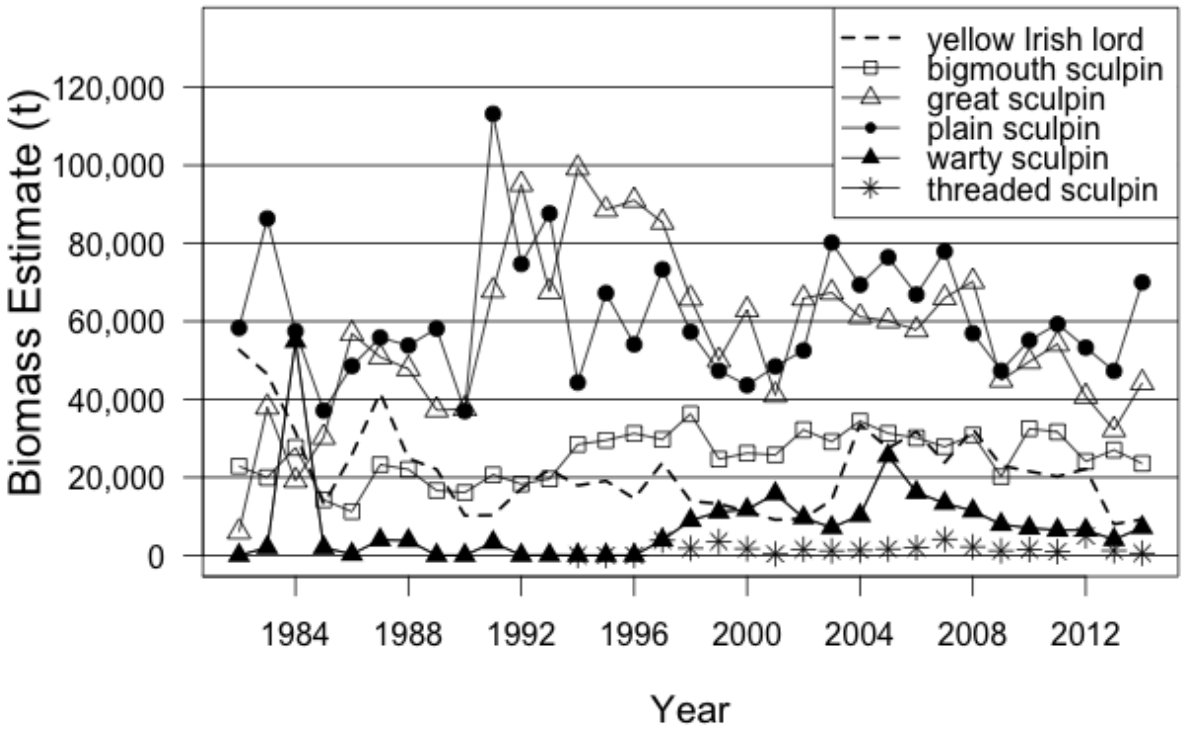

Figure 4. EBS shelf survey biomass estimates for the six most abundant sculpin species, from annual EBS shelf bottom trawl surveys for selected sculpin species, 1982-2014.

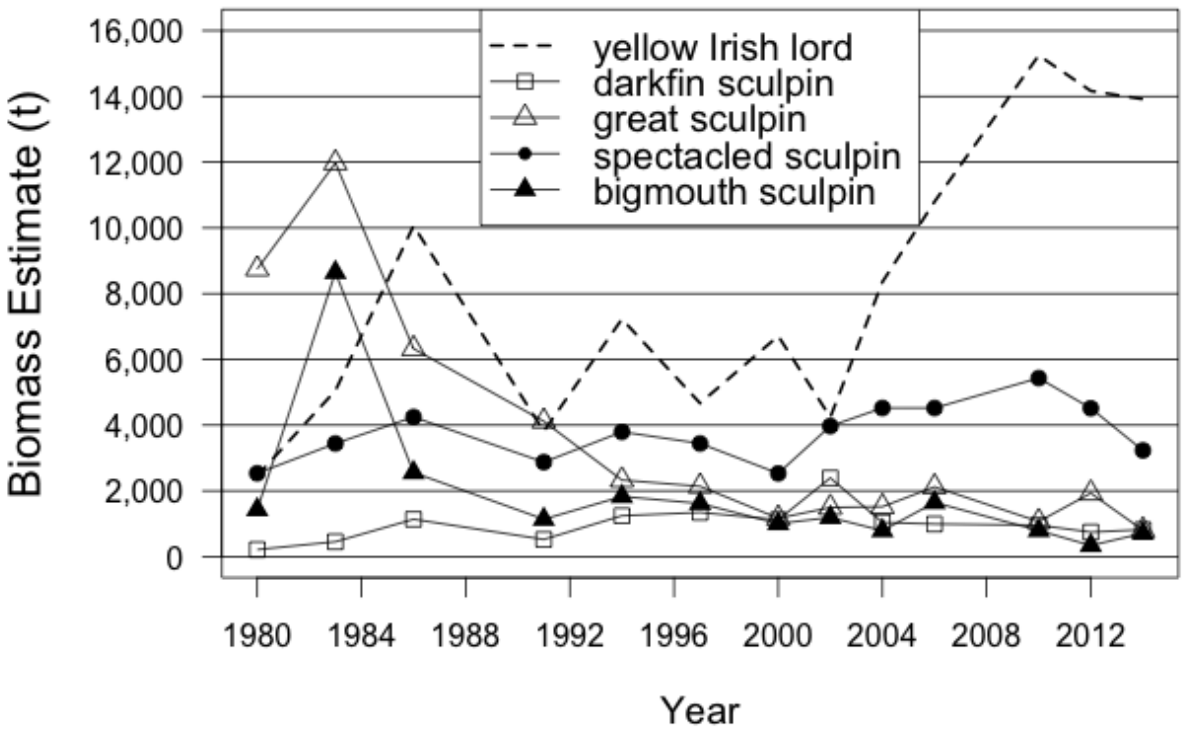

Figure 5. Aleutian Islands (AI) survey biomass estimates for the five most abundant sculpin species, from AI trawl surveys 1980-2014.

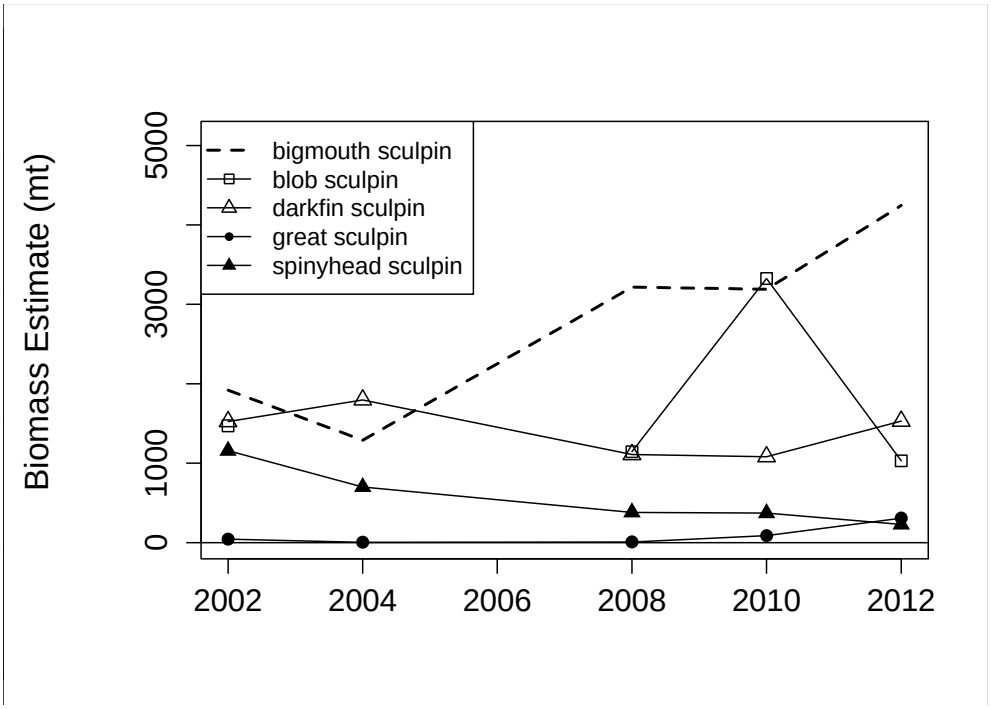

Figure 6. Bering sea slope survey biomass estimates for the five most abundant sculpin species, from slope trawl surveys 2002-2012.

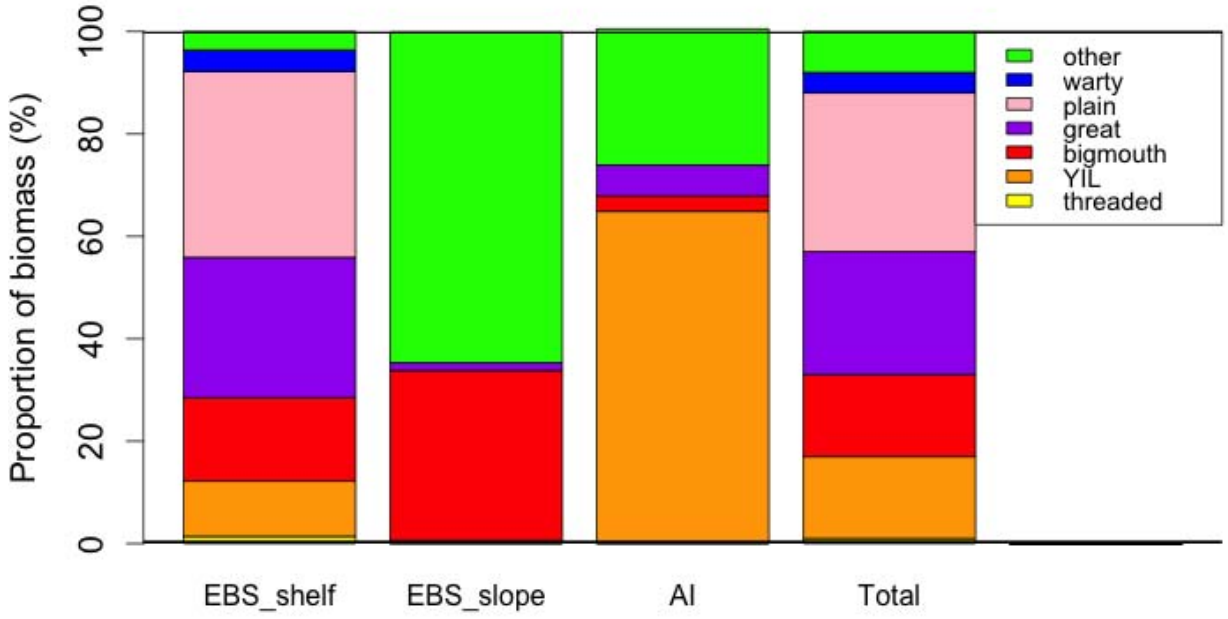

Figure 7. Species composition of the sculpin complex in the three subregions of the BSAI, as well as the BSAI as a whole, for the entire time series based on the 3 most recent surveys in each region. "Other" sculpins contains a variety of species; see tables 6, 7, and 8 for more detail.

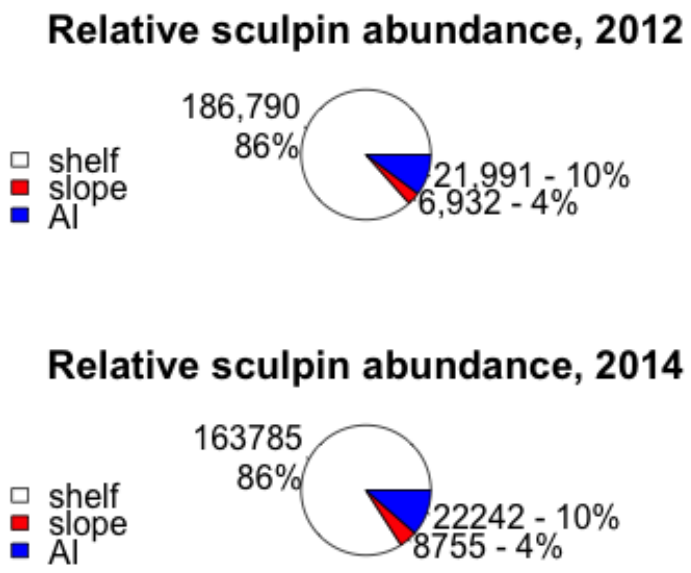

Figure 8. Relative abundance of sculpins in three subregions of the BSAI for 2012 and 2014. Data shown in plot are biomass (t).

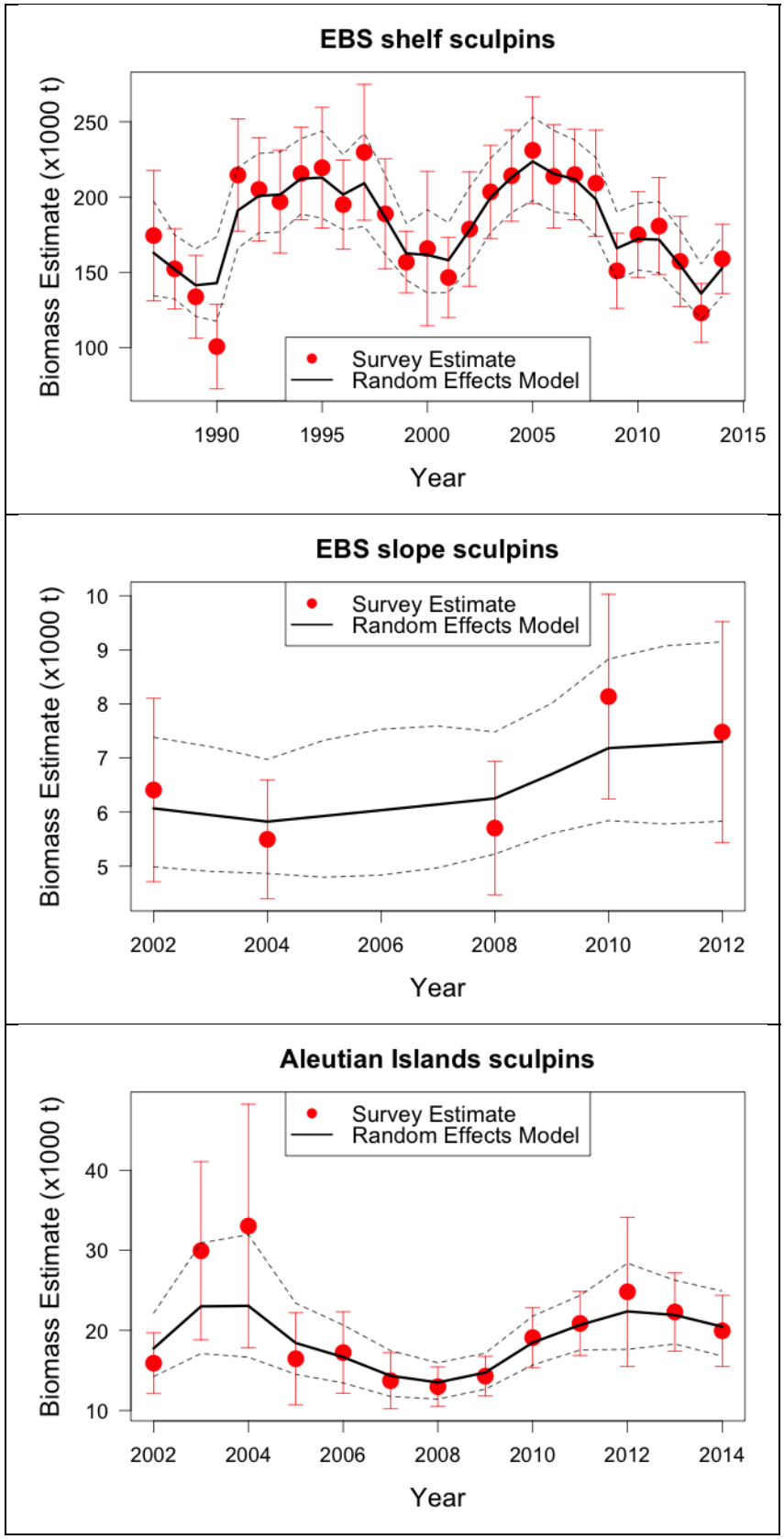

Figure 9. Random effects model estimates of biomass for all shelf sculpins (top), slope (middle), and Aleutians (bottom).

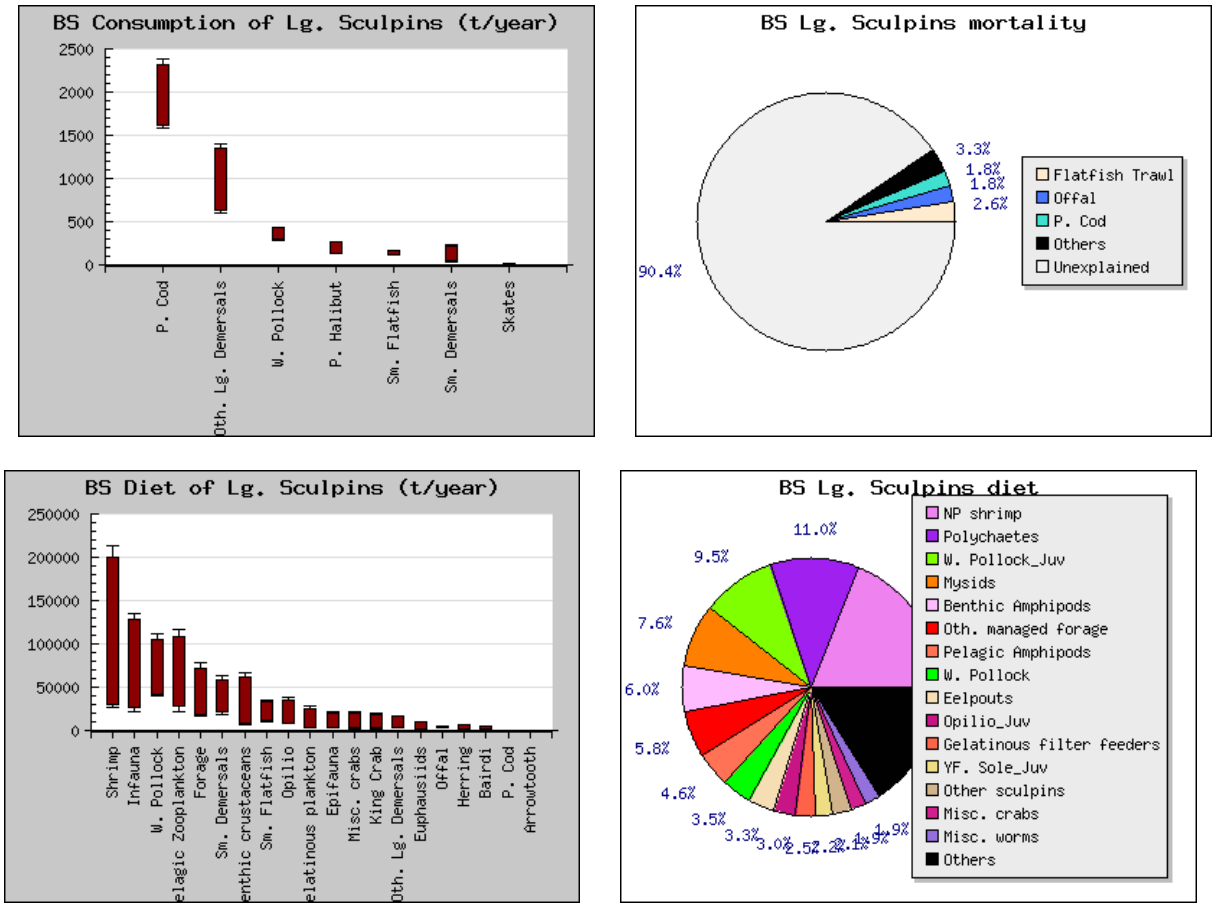

Figure 10. Figures showing Consumption, mortality, and diet of large sculpins from the eastern Bering Sea. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

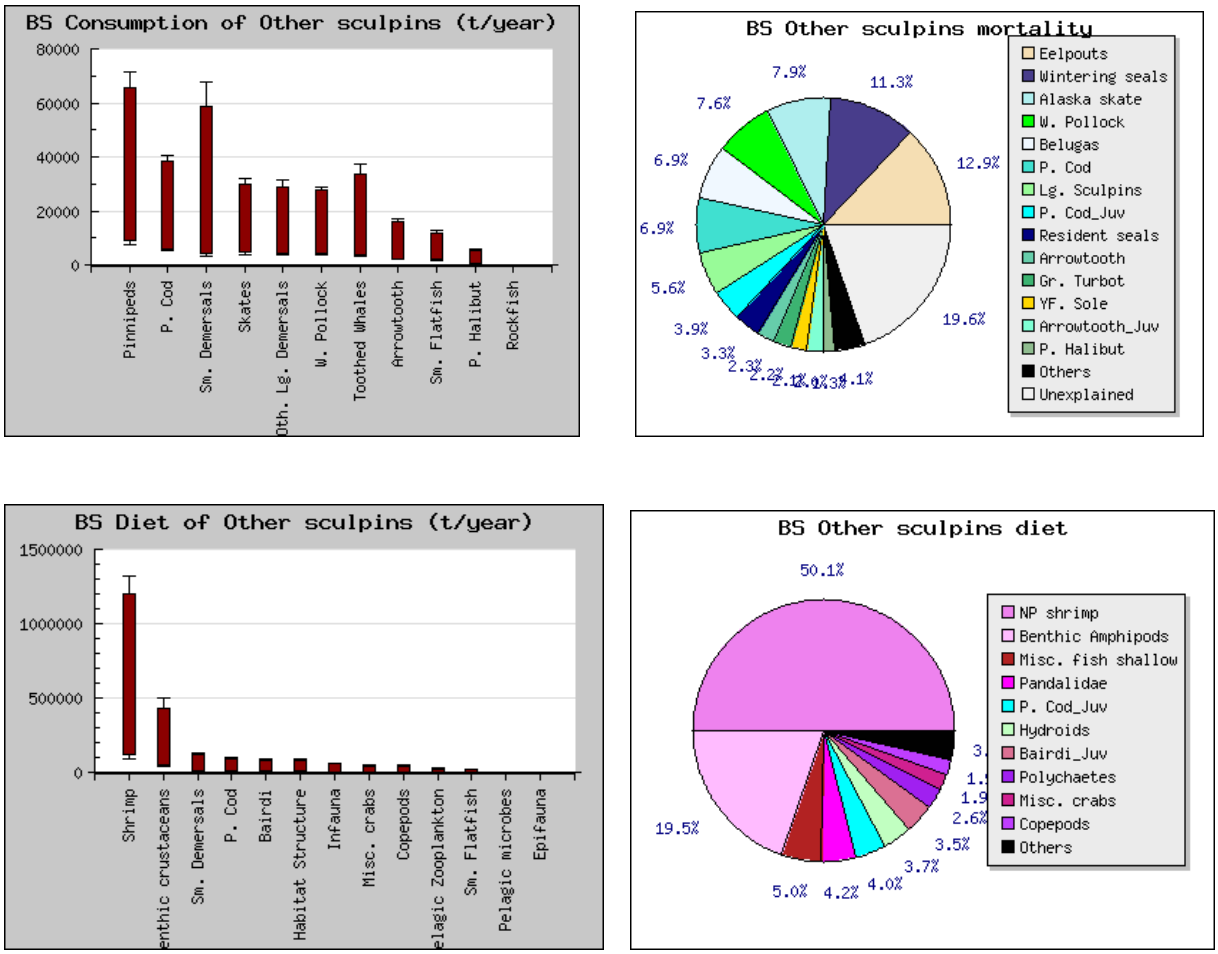

Figure 11. Figures showing Consumption, mortality, and diet of other sculpins from the eastern Bering Sea. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

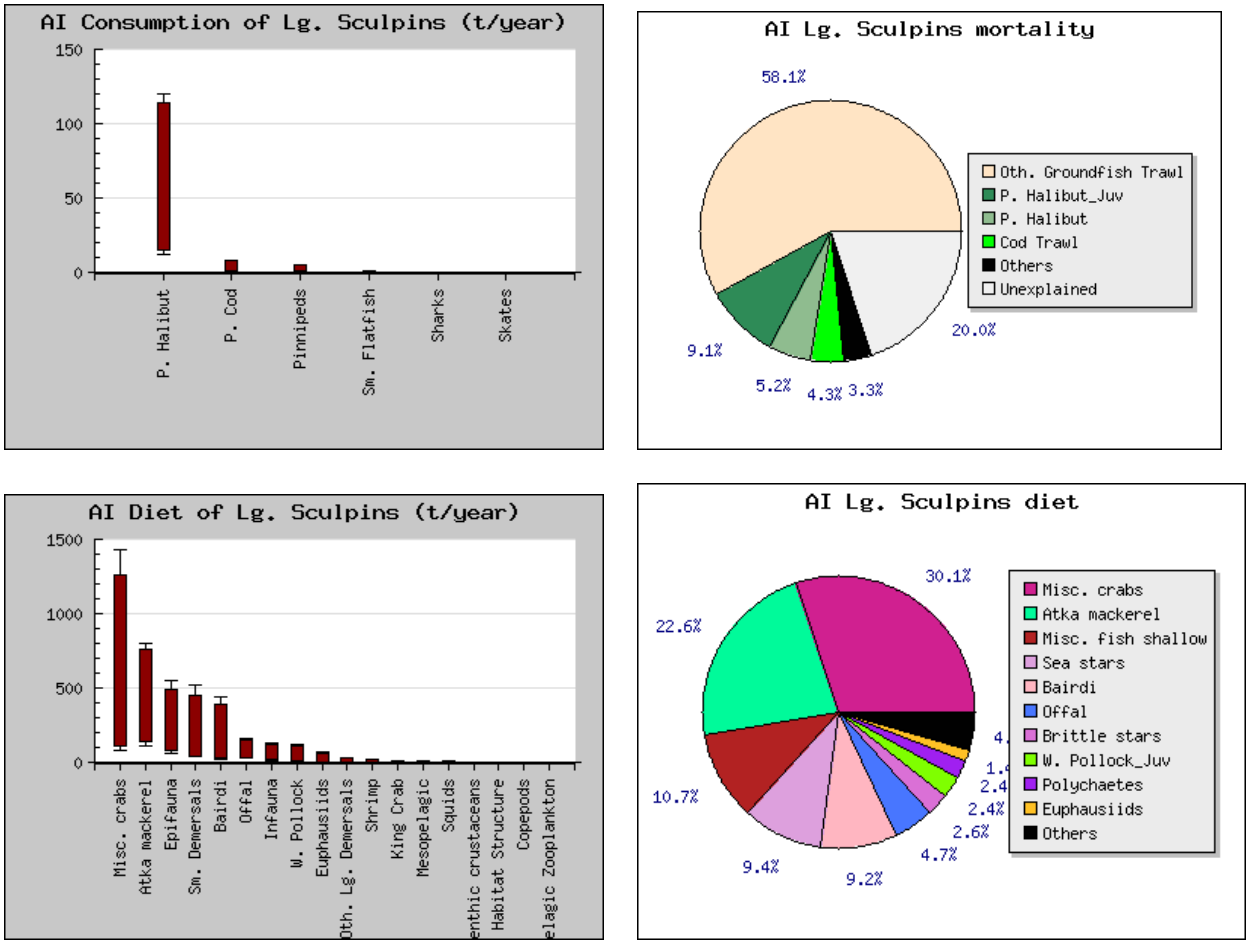

Figure 12. Figures showing Consumption, mortality, and diet of large sculpins from the Aleutian Islands. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

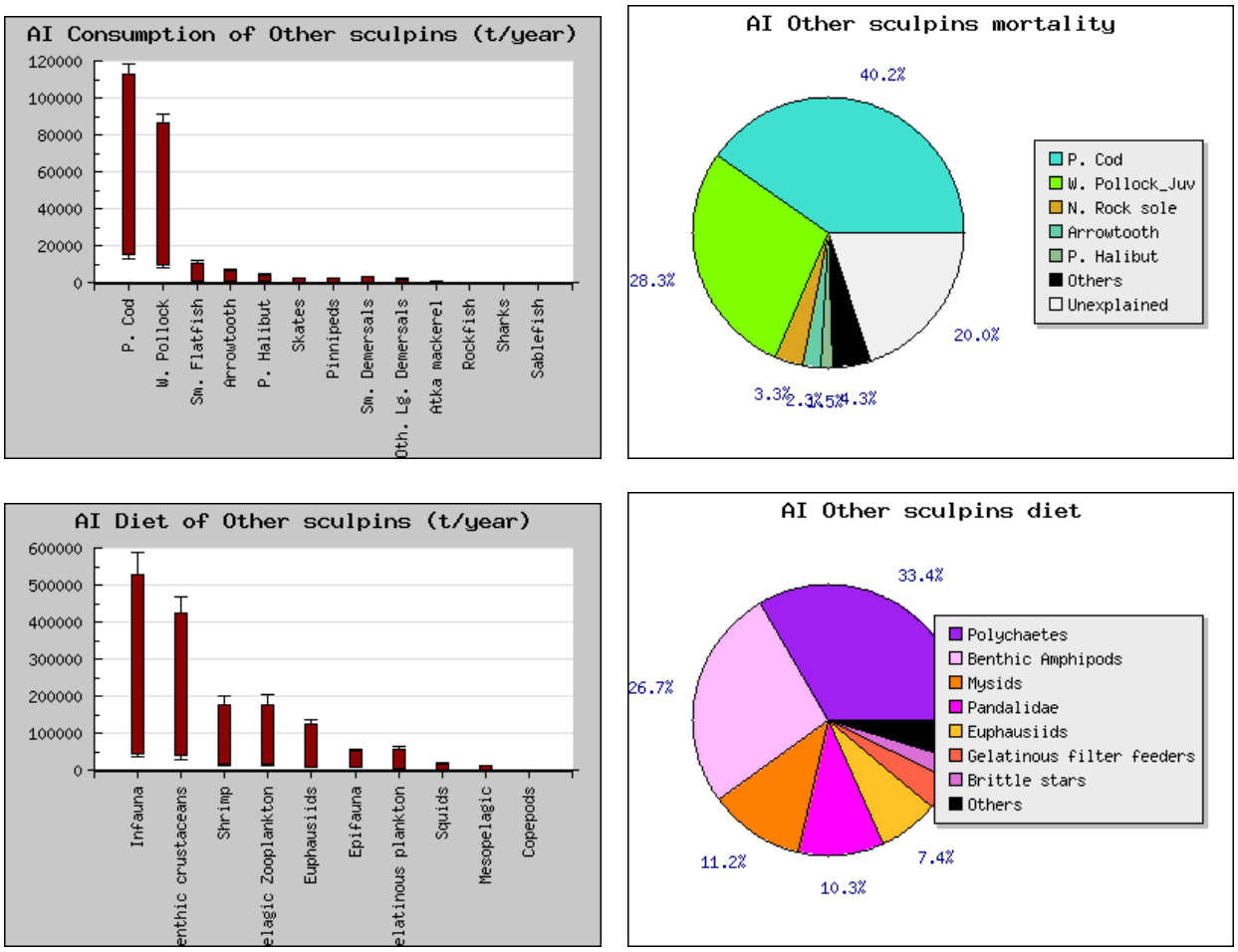

Figure 13. Figures showing Consumption, mortality, and diet of other sculpins from the Aleutian Islands. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

Appendix 1. Assessment of the sculpin stock complex in the Bering Sea and Aleutian Islands, using alternative methodology

Introduction

Here we explore alternative methodology for calculating the estimate of BSAI sculpin biomass. In the past, and in the main assessment presented here, a strict average of three most recent surveys for each region (Aleutian Islands, Bering Sea shelf, and Bering Sea slope) has been used. This appendix calculates the BSAI estimate of biomass using the random effects model. The model was applied separately to survey biomass estimates from the Aleutian Islands, Bering Sea shelf, and Bering Sea slope surveys (Figure 9). The 2014 random effects model estimate of sculpin biomass in the BSAI is the sum of the random effects biomass estimate for the Bering Sea slope, Shelf, and Aleutian Islands. The variance is summed to obtain 95% confidence intervals. The resulting estimate of biomass is 180,570 t (158,772, 202,368; Table A1). The biomass weighted M is 0.29, the same value obtained using the 3 year average of each of the six most common sculpin species (Table A2).

The random effects estimate of BSAI sculpin biomass is lower than the 3 survey average, 180,570 t vs. 194,783 t. The ABC with the random effects method is also lower, 39,725 t, compared to 42,852 t, and the OFL is lower as well, 52,365 t compared to 56,487 t.

Summary of Results

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2014	2015	2015	2016
M (natural mortality rate)*	0.28	0.28	0.29	0.29
Tier	5	5	5	5
Biomass (t)	215,713	215,713	180,570	180,570
F_{OFL}	0.28	0.28	0.29	0.29
$maxF_{ABC}$	0.21	0.21	0.22	0.22
F_{ABC}	0.21	0.21	0.22	0.22
OFL (t)	56,424	56,424	52,365	52,365
maxABC (t)	42,318	42,318	39,725	39,725
ABC (t)	42,318	42,318	39,725	39,725
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014

Table A1. Random effects model estimates of all sculpin species from the Bering Sea shelf, slope, and Aleutian Islands. The total includes 95% confidence intervals in parentheses.

	Shelf	Slope	Aleutian Islands	Total (95% confidence intervals)
1987	162,897			
1988	152,030			
1989	141,416			
1990	142,858			
1991	191,032			
1992	200,837			
1993	201,563			
1994	212,245			
1995	212,881			
1996	201,678			
1997	209,148			
1998	186,396			
1999	162,545			
2000	161,606			
2001	158,034			
2002	178,080	6,069	17,751	201,900 (173,213, 230,587)
2003	199,695	5,946	23,001	228,642 (201,365, 255, 918)
2004	213,058	5,825	23,065	241,948 (214,265, 269,636)
2005	223,669	5,929	18,427	248,025 (218,221, 277,829)
2006	215,516	6,035	16,667	238,218 (209,168, 267,267)
2007	211,804	6,143	14,330	232,277 (205,989, 258,565)
2008	198,538	6,252	13,497	218,288 (190,478, 246,098)
2009	166,016	6,701	14,735	187,452 (163,267, 211,637)
2010	172,174	7,182	18,475	197,832 (174,078, 221,585)
2011	171,693	7,243	20,681	199,616 (174,032, 225,201)
2012	154,809	7,304	22,374	184,487 (160,512, 208,462)
2013	135,917	7,304	21,922	165,143 (144,966, 185,319)

Table A2. Weighted contribution to M estimate, based on random effect model estimates of each of the six most common sculpin species in the BSAI in each of the three regions.

2015-2016 sculpin complex harvest specifications						
	3-survey average biomass					
species	EBS shelf	EBS slope	AI	**BSAI**	*M*	weighted contribution to mort. est.
threaded	690	0	0	**690**	0.45	0.00
YIL	9,409	27	13,947	**23,383**	0.17	0.02
bigmouth	24,080	4,007	621	**28,708**	0.21	0.04
great	49,628	277	1,790	**51,695**	0.28	0.09
plain	55,132	0	0	**55,132**	0.40	0.13
warty	6,879	0	0	**6,879**	0.26	0.01
total	**145,818**	**4,311**	**16,358**	**166,487**		0.29