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

Ingrid Spies, Kerim Aydin, Dan Nichol, Wayne Palsson, Jerry Hoff, and Todd T. TenBrink
Alaska Fisheries Science Center
National Marine Fisheries Service

Executive Summary

Summary of Changes in Assessment Inputs

Summary of Changes in the Input Data

1. Catch and retention data were updated with partial data for 2016 (as of October 11, 2016). This non-target species complex is assessed biennially, to coincide with the frequency of trawl surveys in the Bering Sea and Aleutian Islands (BSAI), with full assessments in even years. The 2015 executive summary can be found at http://www.afsc.noaa.gov/REFM/Stocks/assessments.htm.
2. Biomass estimates and length compositions from the 2015 and 2016 Bering Sea shelf survey, the 2016 slope survey, and the 2016 Aleutian Islands survey have been added.

Summary of Changes in Assessment Methodology

Assessment methodology for determining sculpin complex exploitable biomass in the BSAI has changed from an average of the last three survey years biomass estimate to a random effects to survey averaging approach. The OFL is the product of the random effects biomass and a biomass-weighted natural mortality *M* of the six most abundant BSAI sculpin species.

Summary of Results

The estimated 2017 total sculpin complex biomass in the Bering Sea and Aleutian Islands is 199,937 t. This represents an increase from the last full assessment in 2014. The recommended 2017 and 2018 ABC is 42,387 t based on an F_{ABC}=0.212 and the 2017 and 2018 overfishing level is 56,582 t based on an F_{OFL}=0.283.

Quantity	As estimated or *specified last* year for: 2016	2017	As estimated or *recommended this* year for: 2017	2018
M (natural mortality rate)*	0.29	0.29	0.283	0.283
Tier	5	5	5	5
Biomass (t)	180,570	180,570	199,937	199,937
F_{OFL}	0.29	0.29	0.283	0.283
$maxF_{ABC}$	0.22	0.22	0.212	0.212
F_{ABC}	0.22	0.22	0.212	0.212
OFL (t)	52,365	52,365	56,582	56,582
maxABC (t)	39,725	39,725	42,387	42,387
ABC (t)	39,725	39,725	42,387	42,387
Status	As determined *last* year for: 2014	2015	As determined *this* year for: 2015	2016
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/scorpius), 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

October 2016 SSC

The SSC reminds groundfish and crab stock assessment authors to follow their respective guidelines for SAFE preparation.

Authors' response: Noted.

October 2016 SSC

The SSC requests that stock assessment authors bookmark their assessment documents and commends those that have already adopted this practice.

Authors' response: Noted.

Responses to SSC and Plan Team Comments Specific to this Assessment

November 2014 Plan Team

The BSAI Plan Team recommended using the random effects model to estimate the sculpin biomass for future assessments. The SSC concurred (December 2014).

Authors' response: Assessment methodology has changed to using the random effects model for biomass estimates.

Introduction

Sculpins are found in both freshwater and marine habitats; they are distributed throughout the BSAI and occupy all benthic habitats and depths. Forty-seven species of sculpins have been identified in the Bering Sea Aleutian Islands (BSAI) region (Families Cottidae, Hemitripteridae, Psychrolutidae, and Rhamphocottidae; Table 1). However, these species are managed as a complex, and the complex natural mortality (*M*) estimate is based on the biomass of 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 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 (Figure 1) and most of the sculpin biomass is found on the EBS shelf, followed by the AI and EBS slope (Figure 2).

Sculpins belong to the superfamily Cottoidea in the order Scorpaeniformes. They are relatively small, benthic-dwelling teleost fish with modified pectoral fins that allow them to grip the substrate, and they lack swim bladders. Most 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. These types of reproductive strategies 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 2004-2010 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.

Little is known about stock structure of BSAI sculpin species, and little research on stock structure has been done for sculpins in general. The diversity of sculpin species in the BSAI suggests that different components of the sculpin complex would 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). In the BSAI, yellow Irish lord has been found to exhibit spatial differences in fecundity between the eastern Bering Sea and Aleutian Islands (TenBrink and Buckley 2013). Futhermore, 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 that diet composition differed among and within species. Therefore, the sculpin complex might be managed most efficiently within a spatial context rather than with a global annual aggregate BSAI total allowable catch (TAC).

Fishery

Prior to 2010, sculpins were 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 (Table 3). 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. Total sculpin catch is available from 1998-2016 (Table 4), but catches by genus were not available before 2004. 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 5). Total sculpin catch was calculated for each target fishery responsible for sculpin bycatch from 2004-2016 (Table 5). Sculpins, in general, are not retained by fisheries in the BSAI region, and fishery observer data indicate that the retention rate has been 5% or below for the past five years (Table 4).

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 6). On longline vessels, bigmouth sculpin are identified to species, but not Irish lords or sculpin of the genus Myoxocephalus.

Data

Fishery:

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 the Appendix. Fishery catch of sculpins has been between 4,400 and 7,700 t since 1998.

Survey:

The five most abundant species from the EBS shelf survey are measured annually: plain and great sculpin since 1998, warty and bigmouth sculpin since 2000, and yellow Irish lord since 2003 (Figure 3). Size compositions of blob, bigmouth, spinyhead, and darkfin sculpin are measured on the slope survey, and are shown in Figure 4. Length frequency samples have been taken for great and bigmouth sculpin, and yellow Irish lord on the Aleutian Islands survey since 2002 (Figure 5).

Research surveys provide biomass estimates for sculpin species in the BSAI (Figures 6, 7, 8 and Tables 6, 7, 8, 9, and 10). All three regions of the BSAI were sampled in 2004, 2010, 2012, and 2016. The EBS shelf survey is performed annually, and the Aleutian Island and slope surveys are typically biennial, although there was no slope survey in 2014. Length measurements (fork length, FL) have been collected for a variety of sculpin species during AFSC trawl surveys. A low coefficient of variation for most of the biomass estimates of the more abundant species reflects that the EBS shelf bottom trawl survey adequately estimates the biomass of these species (Tables 7, 8).

Other time series data used in the assessment:

Comparison of the species composition of observed fishery catches to random effect model estimates of sculpin biomass 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 6). Similar numbers of bigmouth sculpin are caught in each region, but approximately three times more yellow Irish lord are caught in the Aleutian Islands. Plain sculpin and great sculpin are rarely caught in the Aleutians but plain sculpin comprises approximately 20-40% of the catch in the EBS and warty sculpin comprise 2-4%. Darkfin sculpin are not caught in the EBS but comprise approximately 15-33% of the Aleutian Island catches. These values generally follow the proportion caught in NMFS surveys, with a few exceptions. In the EBS, more bigmouth sculpin are caught in the survey than the fishery (7-11% fishery, 17% survey). In the Aleutian survey, fewer bigmouth sculpin are caught than in the fishery (3% survey, 9-11% survey).

Biomass estimates for the 5 most abundant sculpin species in the Eastern Bering Sea shelf (yellow Irish lord, bigmouth sculpin, plain sculpin, great sculpin, and warty sculpin) seem to be relatively stable (Figure 6). Six trawl surveys conducted on the EBS slope (in 2002, 2004, 2008, 2010, 2012, and 2016) show that the slope contains a different sculpin community from the shelf and the AI, likely as a result of greater depths (Figure 1). In the AI, yellow Irish lord account for the highest proportion of sculpin biomass, followed by darkfin, great, and spectacled sculpin, whose abundances have fluctuated over the past 15 years (Tables 10, 11 and Figure 7). 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 and bigmouth sculpin since 1980 (Figure 7).

The length compositions by species have not changed throughout the years data has been collected, with few small sculpins caught by the survey (Figures 3, 4, 5). There appears to be considerable annual variability in the data, which may indicate incomplete sampling of sculpins on the slope (Table 9). The length composition data for blob, bigmouth, and spinyhead sculpins show two size modes, which are unrelated to gender but may indicate that two separate life stages inhabit the slope. The length frequency of great and bigmouth sculpin sampled in the Aleutian Islands does not yield a complete representation of the sculpin species population's size composition, whereas yellow Irish lords show a consistent size composition (Figure 5). Specimens smaller than 70 mm have not been collected for many sculpins, which may be due to size selectivity of the survey gear.

Analytic Approach

General Model Structure

A random effects model was used to estimate current biomass for the sculpin complex. In this model, process errors (step changes) from one year to the next are the random effects to be integrated over and the process error variance is the free parameter. The observations can be irregularly spaced; therefore this model can be applied to datasets with missing data. Large observation errors increase errors predicted by the model, which can be used to weight predicted estimates of biomass. The Survey Averaging Working Group document provides more information: (https://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2012/Sept/survey_average_wg.pdf).

Biomass estimates for the six most common species (threaded sculpin, yellow Irish lord, bigmouth sculpin, great sculpin, plain sculpin, warty sculpin, as well as "other" sculpin) were calculated using a random effects model, separately for each region (Aleutians, Bering Sea shelf, Bering Sea slope) and then combined. Biomass weighted natural mortality, complex *M*, was estimated by summing over the product of the proportional abundance of the six most common species with their respective estimates of natural mortality. The estimate of total sculpin biomass in the BSAI was the sum of the 2016 random effect model estimate of the six most abundant sculpins from the EBS shelf, EBS slope, and AI, and the 2016 random effect model estimate of all other sculpins over these three regions. Reference points were estimated using the complex estimate of *M* applied to the 2016 estimate of total sculpin biomass in the BSAI, which includes data for all species. The OFL is the product of the random effects biomass and the complex natural mortality rate *M*.

In 2016 there were no great sculpin caught on the EBS slope, but there were biomass estimates for this species for all previous surveys since 2002. Thus 2016 data was not used to estimate great sculpin on the EBS slope and did not contribute to the 2016 BSAI great sculpin biomass estimate. Similarly, plain, threaded, and warty sculpin were only observed occasionally in the Aleutian Islands and southern Bering Sea. These species were not included in individual random effect models in these regions because the random effect model cannot use zero as an input value (Figure 7).

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 12). Estimates generated using different methods vary widely. The six most common sculpin species in the BSAI appear to have a range of *M*, from 0.14-0.45, Table 12 (TenBrink and Aydin 2009; Hutchinson and TenBrink 2011). The estimates of *M* by species are shown in Table 12.

Results

Harvest specifications were based on the 2016 random effect model estimate of the 6 most common sculpin species in the BSAI and the 2016 random effect estimate of the other sculpin species. Figure 9 shows that random effect estimates of the sculpin complex in the EBS shelf, EBS slope, and AI have been fairly stable since the late 1980s on the EBS shelf, 2002 on the EBS slope, and 1980 in the Aleutian Islands. Similarly, random effect estimates of the six most common sculpin species show no significant changes in biomass between 2004-2016 (Table 13, Figure 10).

The following table shows how the BSAI sculpin complex *M* was calculated. The relative proportion of the 6 most common species out of the total, 188,033 t for each species was multiplied by the estimate of *M* for each species (Table 12) and summed for the estimate of *M* for the complex.

2017-2018 sculpin complex *M* harvest specification							
	2016 random effects model estimate						
species	EBS shelf	EBS slope	AI	**BSAI**	Relative proportion	*M*	weighted contribution to mort. est.
bigmouth	32,002	1,889	476	34,367	0.183	0.21	0.038
great	48,329	0	990	49,319	0.262	0.28	0.073
YIL	25,698	75	8,605	34,378	0.183	0.17	0.031
plain	57,753	0	0	57,753	0.307	0.40	0.123
threaded	148	0	0	148	0.001	0.45	0.000
warty	12,066	0	0	12,066	0.064	0.26	0.017
other	4,733	3,206	3,966	11,905		-	
total	180,729	5,170	14,037	**199,937**			Complex *M*: 0.283
Total (6 most common species only):				**188,033**			

Harvest recommendations

The 2017 ABC is 42,387 t, based on an F_{ABC} of 0.212 and a total biomass estimate of 199,937 t. The 2017 OFL is 56,582 t, based on F_{OFL} of 0.283.

weighted-average mortality rate	0.283
BSAI sculpin complex biomass estimate (t)	199,937
F_{OFL}	0.283
max F_{ABC}	0.212
rec. F_{ABC}	0.212
OFL (t)	56,582
max. ABC (t)	42,387
rec. ABC (t)	42,387

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 11). In the EBS the main predator of large sculpins (sculpins from the genera *Myoxocephalus*, *Hemitripterus* and *Hemilepidotus*) is Pacific cod (Figure 11). 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 5a). Other sculpins (those sculpins not in the above genera) in the EBS feed mainly on shrimp and benthic amphipods (Figure 12). 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 12). In the AI large sculpin have a different diet than in the EBS, consisting of crabs, Atka mackerel and miscellaneous shallow water fish (Figure 12). 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 12). Diet of other sculpins in the AI consists of infauna such as polychaetes and benthic crustaceans (Figure 13). 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 14).

Fishery Effects on the Ecosystem

Analysis of ecosystem considerations for those fisheries that affect the stocks within this complex 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.

Literature Cited

Alverson, D.L., and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36:133-143.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Technical Memorandum 178, 298pp.

Charnov, E.L. 1993. Life history invariants: Some explorations of symmetry in evolutionary ecology. Oxford University Press Inc., New York. 167p.

Eschmeyer, W.N., E.S. Herald, and H. Hammann, 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston: 336 pp.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Hoff, G.R. 2000. Biology and ecology of threaded sculpin, *Gymnocanthus pistilliger*, in the eastern Bering Sea. Fishery Bulletin 98:711-722.

Hutchinson, C. and TenBrink, T. 2011. Age determination of the Yellow Irish Lord: management implications as a results of new estimates of maximum age. North American Journal of Fisheries Management, 31(6) 1116-1122. DOI: 10.1080/02755947.2011.646453.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Ca. J. Fish. Aquat. Sci. 53: 820-822

Markevich, A. 2000. Spawning of the sea raven *Hemitripterus villosus* in Peter the Great Bay, Sea of Japan. Russian Journal of Marine Biology 26(4): 283-285.

Panchenko, V.V. 2001. Reproduction peculiarities of plain sculpin *Myoxocephalus jaok* in Peter the Great Bay, Sea of Japan. Russian Journal of Marine Biology 27(2): 111-112.

Panchenko, V.V. 2002. Age and growth of sculpins of the genus *Myoxocephalus* (Cottidae) in Peter the Great Bay (the Sea of Japan) Journal of Ichthyology 42(7): 516-522.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39(2):175-192.

Rikhter, V.A., and V.N. Efanov. 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc. 76/VI/8. Serial N. 3777. 13p.

Stevenson, D.E. 2004. Identification of skates, sculpins, and smelts by observers in North Pacific groundfish fisheries (2002-2003). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-142, 67p.

Stevenson, D. E. 2015. The Validity of Nominal Species of *Malacocottus* (Teleostei: Cottiformes: Psychrolutidae) Known from the Eastern North Pacific with a Key to the Species. Copeia: March 2015, Vol. 103, No. 1, pp. 22-33.

Stevenson, D.E. (2015): The Validity of Nominal Species of *Malacocottus* (Teleostei: Cottiformes: Psychrolutidae) Known from the Eastern North Pacific with a Key to the Species. *Copeia, 2015, 103 (1): 22-33.*

TenBrink, T. and Aydin K. 2009. Life history traits of sculpins in the eastern Bering Sea and Aleutian Islands. NPRB Project 628 Final Report. http://doc.nprb.org/web/06_prjs/628_Final_April2010.pdf

TenBrink, T., and Buckley, T. 2012. Resource partitioning among *Myoxocephalus* sculpins, and their predator-prey relationships with *Chionoecetes* crabs in the eastern Bering Sea. Marine Ecology Progress Series, 464: 221-235.

TenBrink, T., and Buckley, T. 2013. Life history aspects of the yellow Irish lord, *Hemilepidotus jordani*, in the eastern Bering Sea and Aleutian Islands. *Northwestern Naturalist* 94:126-136.

Tokranov, A.M. 1985. Reproduction of great sculpin, *Myoxocephalus polyacanthocephalus*

(Cottidae) in Kamchatka waters. J. Ichthyol. 24(4):119-127.
Tokranov, A.M. 1988. Reproduction of mass species of sculpins in coastal waters of Kamchatka. Biologiya Morya 4: 28-32.
Tokranov, A.M. 1989. Reproduction of sculpins in the genus *Gymnocanthus* (Cottidae) in the coastal waters of Kamchatka. Journal of Ichthyology 28(3): 124-128.
Tokranov, A.M. 1995. The size and sex structure of sculpins of the genus *Triglops* (Cottidae) in the coastal waters of Kamchatka. Journal of Ichthyology 35(4): 140-144.
Tokranov, A.M, and A.M. Orlov. 2001. Some biological features of Psychrolutidae in the Pacific waters off southeastern Kamchatka and the northern Kuril Islands: communication 2. Size-age and sex composition and feeding. Journal of Ichthyology 41(8): 575-583.

Table 1. Members of the sculpin complex observed during eastern Bering Sea and Aleutian Islands bottom trawl surveys. The species formerly recognized as blackfin sculpin (*Malacocottus kincaidi*) in Alaska is now considered darkfin sculpin (*Malacoccottus zonurus)*; blackfin sculpin is only found in the Salish Sea (Stevenson 2015).

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
	Malacocottus zonurus	Darkfin 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	
Malacocottus 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 and Buckley 2013.

Table 3. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the BSAI sculpin complex 2011 to 2016. **Estimated removals through November 3, 2016.*

Year	OFL (t)	ABC (t)	TAC (t)	Catch (t)
2011	58,300	43,700	5,200	5,373
2012	58,300	43,700	5,200	5,798
2013	56,400	42,300	5,600	5,828
2014	56,400	42,300	5,600	4,865
2015	52,365	39,725	4,700	4,980
2016*	52,365	39,725	4,500	4,410*

Table 4. Total catch in metric tons (t) of sculpin complex retained and discarded, 1998-2016. Source: NMFS AKRO BLEND/Catch Accounting System, complete as of November 3, 2016.

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	4,872	502	5,373	5%
2012	4,991	806	5,798	5%
2013	5,221	606	5,828	3%
2014	4,490	375	4,865	3%
2015	4,055	925	4,980	2%
2016	3,889	509	4,410	2%

Table 5a. Total catch in metric tons (t) of all sculpins by target fishery in the Aleutian Islands, 2004-2016. *Source:* NMFS AKRO Catch Accounting System, Nontarget Estimates. ** 2016 catch data are incomplete; retrieved October 4, 2016.*

	Aleutian Islands												
Target fishery	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016***
Alaska plaice	0	0	0	0	0	0	0	0	0	0	0	0	0
arrowtooth flounder	0	0	1	0	0	6	43	38	5	31	26	0	5
Atka mackerel	476	372	488	554	459	710	574	220	340	137	173	375	239
flathead sole	0	0	0	0	0	0	0	0	0	0	0	0	0
greenland turbot	0	0	0	1	2	1	0	0	0	0	0	0	0
halibut	5	1	4	0	5	0	0	6	0	8	52	102	20
Kamchatka flounder	0	0	0	0	0	0	0	20	22	34	5	5	4
other flatfish	0	0	0	0	0	0	0	0	0	0	0	0	0
other target	0	0	0	0	0	1	0	1	0	0	0	0	0
Pacific cod	360	213	374	406	400	492	722	105	377	304	98	362	93
bottom pollock	0	0	0	1	0	0	2	0	0	2	0	0	0
pelagic pollock	0	0	0	0	0	0	0	0	0	0	0	0	0
rock sole	0	0	0	0	0	0	0	0	0	0	0	0	0
rockfish	49	34	40	56	72	61	52	102	71	112	87	122	76
sablefish	0	0	1	2	1	4	2	1	2	1	0	0	0
yellowfin sole	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (t)	890	620	909	1,019	941	1,276	1,395	492	816	628	442	966	438

Table 5b continued. Total catch in metric tons (t) of all sculpins by target fishery in the eastern Bering Sea, 2004-2016. *Source:* NMFS AKRO Catch Accounting System, Nontarget Estimates* *2016 catch data are incomplete; retrieved October 4, 2016.*

	Eastern Bering Sea												
Target fishery	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016***
Alaska plaice	0	0	3	14	3	3	2	26	13	43	0	16	7
arrowtooth flounder	46	122	79	31	78	64	12	92	109	104	73	58	60
Atka mackerel	50	168	44	109	5	6	0	1	5	1	0	0	0
flathead sole	573	499	515	463	619	409	242	116	34	57	157	154	86
greenland turbot	5	1	1	1	1	1	1	1	1	0	3	0	21
halibut	1	0	1	0	4	0	0	3	0	23	37	60	79
Kamchatka flounder	0	0	0	0	0	0	0	29	1	0	14	27	16
other flatfish	55	59	10	26	1	1	2	0	1	1	0	1	18
other target	7	0	2	8	0	0	0	0	0	0	0	0	0
Pacific cod	3,157	2,533	2,277	2,333	1,663	1,255	1,123	1,794	2,003	1,511	2,098	2,044	1,807
bottom pollock	10	10	5	23	66	143	124	122	109	120	101	29	23
pelagic pollock	141	140	172	171	255	152	147	205	192	115	92	156	95
rock sole	268	463	675	760	1,090	1,292	918	897	948	1,264	787	438	610
rockfish	1	0	3	0	0	0	8	22	31	15	11	8	0
sablefish	1	0	0	0	1	1	1	0	0	1	0	0	0
yellowfin sole	941	1,147	1,124	2,432	2,896	2,562	1,631	1,807	1,936	1,927	1,264	1,087	835
Total (t)	5,255	5,142	4,911	6,372	6,681	5,889	4,211	5,117	5,383	5,181	4,636	4,077	3,658

Table 6. Composition of observed fishery catches, 2014-2016, 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 fishery observer data. *Source: NORPAC database.*

taxon	**EBS (shelf and slope)**				**AI**			
	fishery catch composition			proportion of average survey biomass	fishery catch composition			proportion of average survey biomass
	2014	2015	2016		2014	2015	2016	
Hemitripterus* spp.*								
H. bolini (bigmouth)	9%	11%	7%	17%	11%	9%	10%	3%
***Hemilepidotus* spp.**								
Hemilepidotus unidentified	12%	14%	13%	n/a	13%	33%	13%	n/a
H. hemilepidotus (RIL)	<1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%
H. jordani (YIL)	19%	15%	18%	13%	42%	43%	50%	64%
H. spinosus (BIL)	<1%	< 1%	< 1%	< 1%	<1%	< 1%	< 1%	< 1%
***Myoxocephalus* spp.**								
Myoxocephalus unidentified	2%	2%	4%	n/a	<1%	< 1%	< 1%	n/a
M. verrucosus (warty)	2%	4%	2%	6%	<1%	< 1%	< 1%	< 1%
M. jaok (plain)	23%	26%	20%	36%	<1%	< 1%	< 1%	< 1%
M. polyacanthocephalus (great)	31%	28%	35%	28%	1%	1%	2%	7%
Malacottus spp.								
M. zonurus (darkfin)	2%	1%	1%	<1%	33%	15%	25%	20%

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

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

Table 7. 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 1982-2016. 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
2015	28,835	0.48	29,542	0.13	36,000	0.12	60,641	0.30	10,436	0.26
2016	30,743	0.29	37,766	0.11	53,282	0.12	53,570	0.21	16,052	0.35

Table 8. Eastern Bering Sea (EBS) shelf sculpin complex biomass estimates (t) and 2016 coefficients of variation (CV) for all BSAI sculpin species observed, from EBS shelf surveys 1994-2016.

species	1994	1995	1996	1997	1998	1999	2000	2001
antlered sculpin	0	0	0	0	0	3	0	0
Arctic staghorn scul.	0	0	0	22	0	0	0	0
armorhead sculpin	5,313	605	523	1,252	917	254	347	289
butterfly sculpin	18,619	13,056	2,664	6,070	1,334	3,810	4,501	2,710
crested sculpin	0	0	0	0	0	4	4	2
darkfin sculpin	0	0	28	45	0	130	49	220
eyeshade sculpin	0	0	0	7	0	1	1	0
highbrow sculpin	0	0	0	0	0	0	0	0
hookhorn sculpin	7	3	0	0	12	2	3	4
purplegray sculpin	0	0	0	0	21	0	0	0
red Irish lord	0	0	0	0	0	42	0	0
ribbed sculpin	0	6	108	33	71	220	78	188
roughspine sculpin	0	11	0	6	50	12	35	8
sailfin sculpin	0	0	5	0	0	0	0	0
scissortail sculpin	0	14	10	0	3	3	1	9
spatulate sculpin	0	0	0	0	14	12	23	16
spectacled sculpin	0	0	9	652	168	200	491	174
spinyhead sculpin	1,384	1,245	684	874	958	1,462	1,816	1,681
thorny sculpin	397	71	191	931	1,351	1,037	992	858
bigmouth sculpin	28,426	29,492	31,254	29,722	36,276	24,681	26,200	25,760
great sculpin	98,267	88,609	86,850	80,124	65,299	47,979	62,919	40,938
plain sculpin	96,540	67,260	51,849	69,667	57,096	45,430	43,621	48,449
warty sculpin	0	0	0	3,915	8,879	10,644	11,744	15,727
yellow Irish lord	17,911	19,112	14,575	23,727	13,915	13,230	11,249	9,121
total	266,862	219,484	188,750	220,915	188,167	152,726	165,770	146,577

Table 8. continued.

species	2002	2003	2004	2005	2006	2007	2008	2009
antlered sculpin	0	0	0	0	1	0	0	0
Arctic staghorn scul.	0	0	0	0	7	0	0	0
armorhead sculpin	1,708	732	801	1,554	1,734	990	2,113	1,859
butterfly sculpin	2,921	1,068	1,069	1,319	2,766	1,956	541	794
crested sculpin	2	2	0	0	23	0	0	5
darkfin sculpin	529	11	124	36	69	46	1	3
eyeshade sculpin	2	0	0	0	0	1	0	0
highbrow sculpin	0	0	0	0	1	0	0	0
hookhorn sculpin	2	0	0	4	1	4	3	8
purplegray sculpin	0	0	0	14	4	0	6	29
red Irish lord	0	0	0	15	0	5	0	106
ribbed sculpin	156	140	558	261	385	309	368	581
roughspine sculpin	3	10	62	111	168	57	176	64
sailfin sculpin	0	0	0	0	0	0	0	0
scissortail sculpin	2	0	0	0	42	20	27	77
spatulate sculpin	19	4	13	23	47	52	23	60
spectacled sculpin	255	298	29	113	365	217	184	224
spinyhead sculpin	1,194	1,272	1,027	4,520	2,425	1,949	870	1,586
thorny sculpin	814	748	696	627	667	558	940	1,131
bigmouth sculpin	32,180	29,258	34,409	31,289	30,118	27,859	30,846	20,196
great sculpin	65,792	66,675	60,449	59,794	57,763	65,903	70,214	44,899
plain sculpin	52,525	73,448	69,363	76,426	66,851	77,922	56,914	47,322
warty sculpin	9,630	7,098	10,212	25,449	16,136	13,370	11,392	7,952
yellow Irish lord	9,415	14,386	33,637	27,441	31,720	23,622	32,389	23,056
total	178,709	196,304	213,744	230,977	213,679	218,966	209,182	151,116

Table 8. continued.

species	2010	2011	2012	2013	2014	2015	2016	*2016 CV*
antlered sculpin	0	1	9	0	0	0	0	-
Arctic staghorn scul.	0	0	0	0	0	0	0	-
armorhead sculpin	1,794	2,102	907	909	554	1,675	592	0.91
butterfly sculpin	939	1,948	2,426	568	477	1,512	1,544	0.32
crested sculpin	0	0	0	0	0	0	0	-
darkfin sculpin	22	17	142	40	25	0	53	0.88
eyeshade sculpin	0	0	0	0	2	0	0	-
highbrow sculpin	0	0	0	0	0	0	0	-
hookhorn sculpin	17	45	9	7	3	4	3	0.75
purplegray sculpin	14	17	21	144	61	71	48	0.65
red Irish lord	0	0	85	0	0	0	0	-
ribbed sculpin	477	84	292	86	85	141	43	0.41
roughspine sculpin	77	56	19	12	146	52	33	0.67
sailfin sculpin	1	0	0	0	0	0	0	-
scissortail sculpin	9	0	0	0	0	44	0	-
spatulate sculpin	60	118	49	92	40	19	378	0.24
spectacled sculpin	503	648	156	269	529	675	817	0.63
spinyhead sculpin	1,277	1,554	707	661	1,155	963	558	0.22
thorny sculpin	2,384	1,394	784	522	1,177	1,301	498	0.20
bigmouth sculpin	32,477	31,643	24,080	27,005	23,576	29,542	37,766	0.11
great sculpin	49,659	54,177	40,733	32,185	44,222	36,000	53,282	0.12
plain sculpin	55,200	59,306	53,271	47,273	69,999	60,641	53,570	0.21
warty sculpin	6,991	6,472	6,477	4,040	7,136	10,436	16,052	0.35
yellow Irish lord	21,518	20,212	22,155	7,990	9,218	28,835	30,743	0.29
total	175,080	180,758	157,312	123,019	158,963	172,319	196,077	

Table 9. Eastern Bering Sea (EBS) slope sculpin biomass estimates (t) from the 2002-2016 EBS slope surveys and the coefficient of variation (CV) for 2016.

common name	**2002**	**2004**	**2008**	**2010**	**2012**	**2016**	***2016 CV***
armorhead sculpin	1	0	0	0	0	0	-
bigmouth sculpin	1,920	1,286	3,053	3,191	4,138	1,769	0.17
blacknose sculpin	122	50	39	17	20	40	0.38
blob sculpin	1,449	1,431	1,110	3,325	1,030	1,773	0.15
butterfly sculpin	0	0	0	0	5	0	-
darkfin sculpin	1,525	1,804	1,073	1,082	1,498	790	0.22
flabby sculpin	0	0	0	0	0	1	0.38
great sculpin	44	5	9	88	290	0	-
roughskin sculpin	1	0	0	0	0	1	0.87
spatulate sculpin	0	0	0	0	0	0	-
spectacled sculpin	58	57	30	29	62	63	0.33
spinyhead sculpin	1,158	698	374	372	219	407	0.24
thorny sculpin	74	39	6	8	17	21	0.30
wide-eye sculpin	12	4	4	0	2	8	0.85
yellow Irish lord	0	113	6	20	28	104	0.97
total	6,364	5,487	5,704	8,132	7,309	4,977	-

Table 10. Aleutian Islands (AI) sculpin biomass estimates (t) from 1980-2016 AI trawl surveys and the coefficient of variation (CV) for 2016.

	biomass estimate (t)						
species	**1980**	**1983**	**1986**	**1991**	**1994**	**1997**	**2000**
antlered sculpin	0	5	180	17	0	0	0
armorhead sculpin	6	633	9	158	224	103	265
bigmouth sculpin	1,251	6,383	1,935	690	1,268	1,462	810
butterfly sculpin	0	0	0	55	0	0	0
crested sculpin	0	0	0	0	0	0	0
darkfin sculpin	2,492	3,447	4,189	2,447	3,494	3,068	2,366
great sculpin	6,729	11,238	5,802	2,899	1,998	1,958	1,053
Pacific staghorn scul.	0	0	8,253	24	1	0	0
plain sculpin	0	0	0	0	0	0	0
scissortail sculpin	56	14	56	323	298	213	63
sculpin unid.	148	106	72	3,488	192	73	46
spectacled sculpin	214	449	1,116	530	1,244	1,344	1,105
spinyhead sculpin	9	6	3	7	5	68	17
thorny sculpin	0	36	1	1	8	0	1
threaded sculpin	0	0	11	0	0	8	0
warty sculpin	0	0	318	0	12	0	0
yellow Irish lord	1,605	4,832	8,878	2,426	6,341	4,098	4,788
total	12,510	27,149	30,823	13,065	15,085	12,395	10,514

	biomass estimate (t)						
species	2000	2002	2004	2006	2010	2012	2014
antlered sculpin	0	20	17	8	0	0	0
armorhead sculpin	265	198	486	370	616	409	208
bigmouth sculpin	810	765	769	1,398	684	316	565
butterfly sculpin	0	0	0	0	0	0	0
crested sculpin	0	0	0	0	0	0	0
darkfin sculpin	2,366	3,648	4,078	4,022	5,008	4,349	2,906
great sculpin	1,053	1,484	964	1,687	896	1,903	710
Pacific staghorn scul.	0	0	9	0	0	0	0
plain sculpin	0	32	0	0	0	0	0
scissortail sculpin	63	442	2,072	133	155	79	121
sculpin unid.	46	130	198	177	120	105	88
spectacled sculpin	1,105	2,380	1,020	941	988	738	814
spinyhead sculpin	17	19	68	2	59	2	20
thorny sculpin	1	1	0	0	0	1	1
threaded sculpin	0	0	0	0	4	0	0
warty sculpin	0	0	0	0	0	0	0
yellow Irish lord	4,788	3,171	6,832	9,085	13,300	13,426	11,678
total	10,514	12,290	16,513	17,823	21,830	21,328	17,111

Table 10. continued.

species	2016	***2016 CV***
yellow Irish lord	3	1
darkfin	148	0.29
great	450	0.38
spectacled	0	-
bigmouth	0	-
armorhead	2,969	0.15
scissortail	1,000	0.41
unidentified sculpins	0	-
spinyhead	1	1.02
threaded	193	0.6
thorny	112	0.81
antlered	398	0.22
butterfly	4	0.62
crested	1	0.28
Pacific staghorn	0	1.11
plain	0	-
warty	8,279	0.16
total	13,558	

Table 11. Sculpin biomass estimates for the three most recent survey years when the Eastern Bering Sea (EBS) shelf and Aleutian Islands (AI) surveys occurred; 2012, 2014, 2016, and the three most recent survey years for the EBS slope, 2010, 2012, and 2016. Note: YIL = yellow Irish lord.

	EBS shelf			EBS slope			AI		
species	**2012**	**2014**	**2016**	**2010**	**2012**	**2016**	**2012**	**2014**	**2016**
antlered	9	-	-	-	-	-	-	-	3
Arctic staghorn	-	-	-	-	-	-	-	-	-
armorhead	907	569	592	-	-	-	416	210	148
bigmouth	24,080	23,576	37,766	3,191	4,245	1,769	339	709	450
blacknose	-	-	-	17	21	40	-	-	-
blob	-	-	-	3,325	1,030	1,773	-	-	-
butterfly	2,426	477	1,544	-	-	-	-	-	-
crescent-tail	-	-	-	-	-	-	-	-	-
crested	-	-	-	-	-	-	-	-	-
darkfin	142	25	53	1,082	1,530	790	4,514	3,231	2,969
flabby	-	-	-	0.39	0.21	1	-	-	-
great sculpin	40,733	44,222	53,282	88	309	-	1,930	805	1,000
Pacific hookhorn	9	3	3	-	-	-	-	-	-
Pacific staghorn	-	-	-	-	-	-	-	-	-
plain	53,271	69,999	53,570	-	-	-	-	-	1
purplegray	21	46	48	-	-	-	-	-	-
red Irish lord	85	-	-	-	-	-	-	-	-
ribbed	291	85	43	-	-	-	-	-	-
roughspine	19	146	33	-	-	-	-	-	-
roughskin				-	-	1	-	-	-
sailfin	-	-	-	-	-	-	-	-	-
scissortail	-	-	-	-	-	-	83	129	193
spatulate	49	39	378	-	-	-	-	-	-
spectacled	156	529	817	29	61.2	63	746	821	398
spinyhead	707	1,155	558	372	229	407	3	35	4
thorny	784	1,177	498	8	19	21	1	1	1
threaded	4,990	559	96	-	-	-	0	1	-
unidentfied	-	-	-	-	-	-	108	89	-
warty	6,477	7,136	16,052	-	-	-	-	-	-
wide-eye	-	-	-	0.14	2.35	8	-	-	-
YIL	22,154	9,218	30,743	20	29	104	14,166	13,916	8,279
total	**157,310**	**158,963**	**196,077**	**8,131**	**7,476**	**4,798**	**22,306**	**19,947**	**13,557**

Table 12. Natural mortality estimates from recent life history analyses of BSAI sculpins. All values are unpublished data from T. TenBrink (NOAA Fisheries, Alaska Fisheries Science Center). "SAFE *M*" indicates the value used in the computation of harvest recommendations for the BSAI sculpin assessments.

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

Table 13. Random effect model estimates of biomass for each of the six most abundant sculpin species, 2004-2016. The great sculpin estimate for the EBS slope was not included for 2016. Other sculpin included all sculpin except bigmouth, great, yellow Irish lord, threaded, and warty sculpin.

Year	Bigmouth sculpin	Great sculpin	Yellow Irish lord	Plain sculpin	Threaded sculpin	Warty sculpin	Other sculpin	Total
2004	32,690	61,989	29,481	70,276	1,148	10,119	15,579	221,282
2005	32,852	61,247	33,220	74,110	1,178	8,217	17,953	228,775
2006	32,757	60,740	35,471	69,099	1,326	10,380	18,024	227,798
2007	32,454	64,636	35,404	71,885	1,941	13,757	16,104	236,181
2008	32,463	63,255	36,778	58,540	2,411	14,441	15,426	223,315
2009	31,644	51,355	35,124	49,821	3,295	12,815	16,345	200,400
2010	32,783	50,587	34,038	54,491	2,139	10,789	17,347	202,174
2011	32,903	49,511	32,485	57,810	1,304	8,476	16,859	199,348
2012	31,947	43,373	31,003	54,405	1,568	7,272	14,375	183,942
2013	31,342	38,998	27,593	53,856	1,146	6,564	12,025	171,523
2014	31,112	41,784	28,874	65,987	3,581	6,029	11,993	189,359
2015	32,584	41,049	32,067	61,540	1,282	4,954	12,909	186,386
2016	34,367	49,320	34,379	57,753	148	12,066	11,905	199,937

Figures

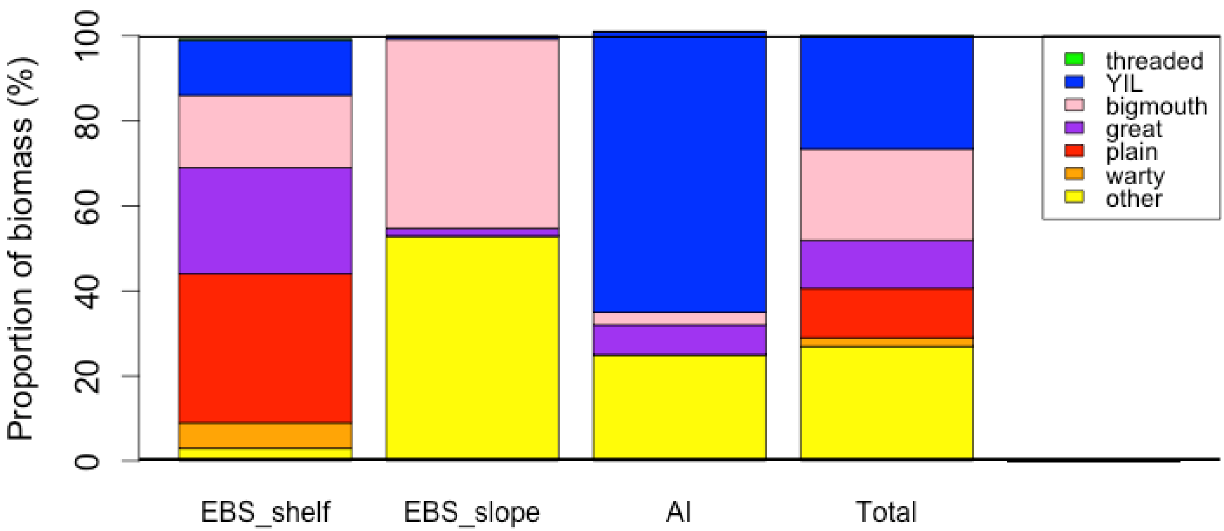

Figure 1. Species composition of the sculpin complex observed on the EBS shelf, EBS slope, and AI surveys, as well as the BSAI as a whole, based on the 3 most recent surveys in each region, 2016, 2015, and 2014 for the EBS shelf, 2012, 2014, and 2016 for the AI, and 2010, 2012 and 2016 for the EBS slope. "Other" sculpins contains a variety of species; see tables 7, 8, and 9 for more detail.

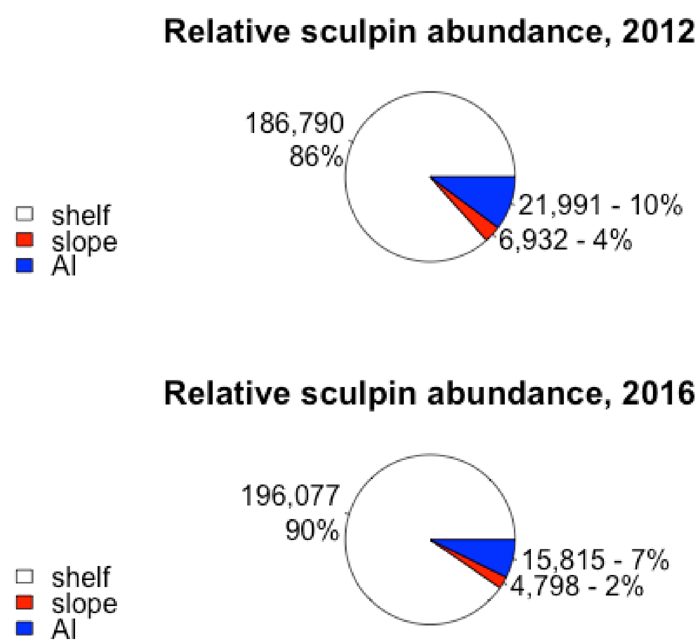

Figure 2. Relative abundance of sculpins from the three surveys for 2012 and 2016, the two most recent years with Eastern Bering Sea slope, Aleutian Islands and Eastern Bering Sea shelf surveys. Data shown in plot are biomass (t).

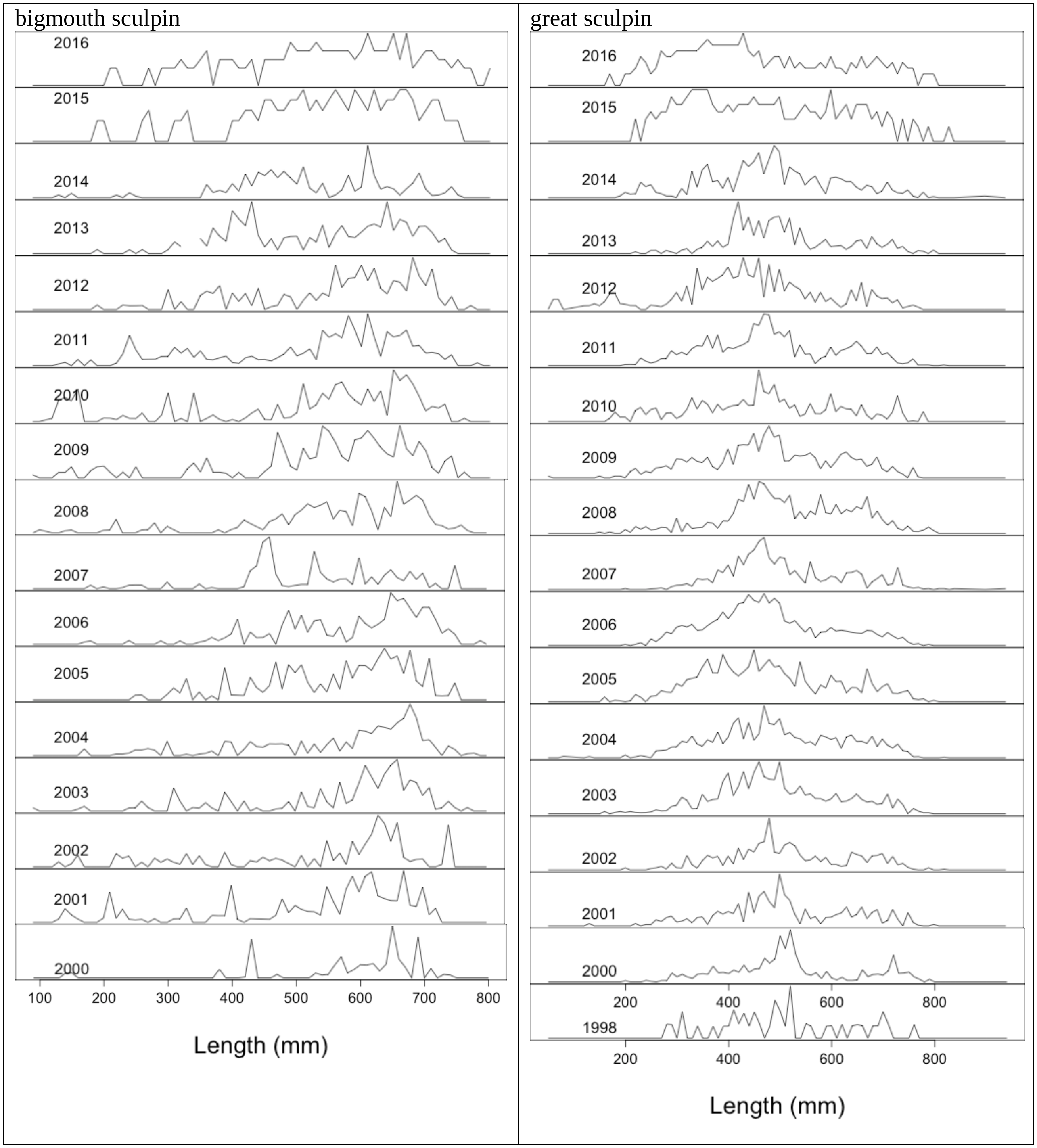

Figure 3. Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, through 2016. Year range is determined by available data.

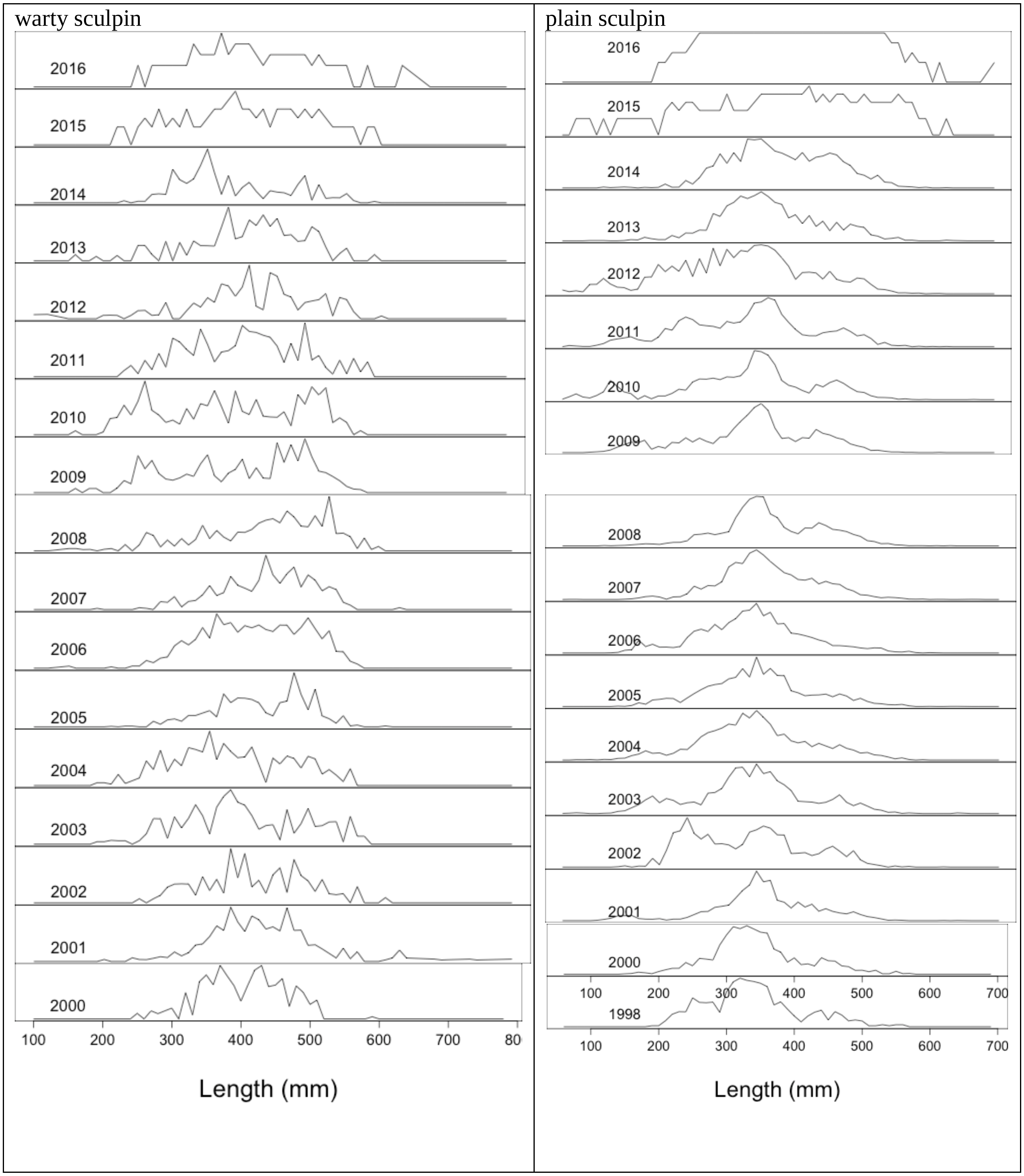

Figure 3 (continued). Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, through 2016. Length scale differs among species.

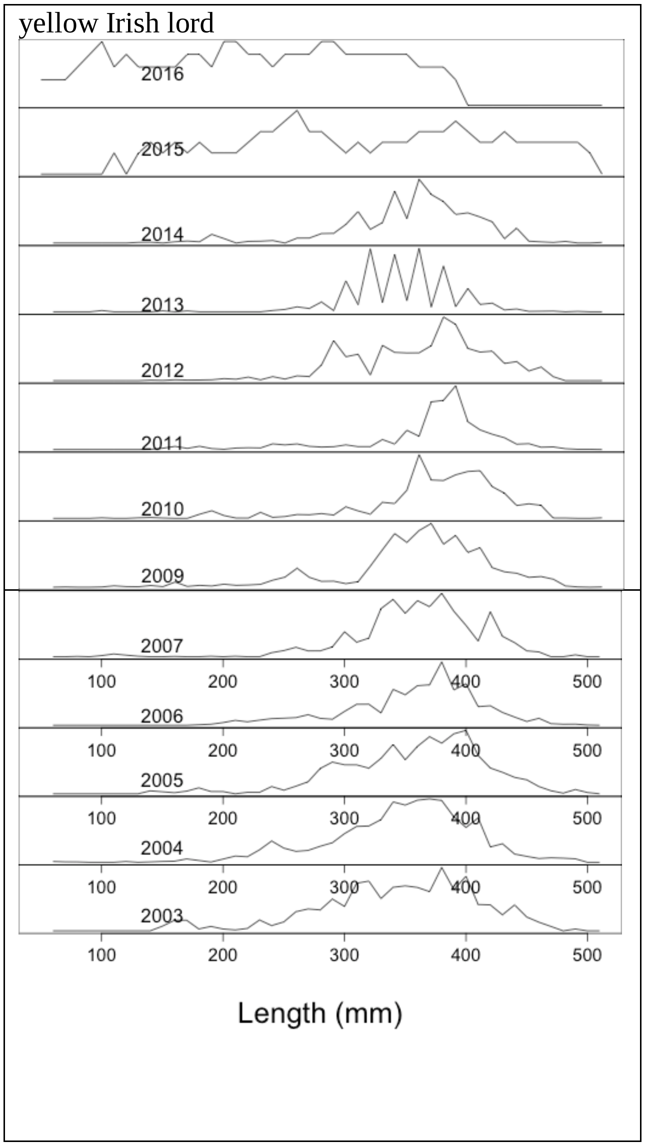

Figure 3 (continued). Length frequencies (fork length, FL in mm) of yellow Irish lord, bigmouth, great, warty, and plain sculpin from EBS shelf survey data, through 2016. Length scale differs among species, and is based on the lengths observed for each species.

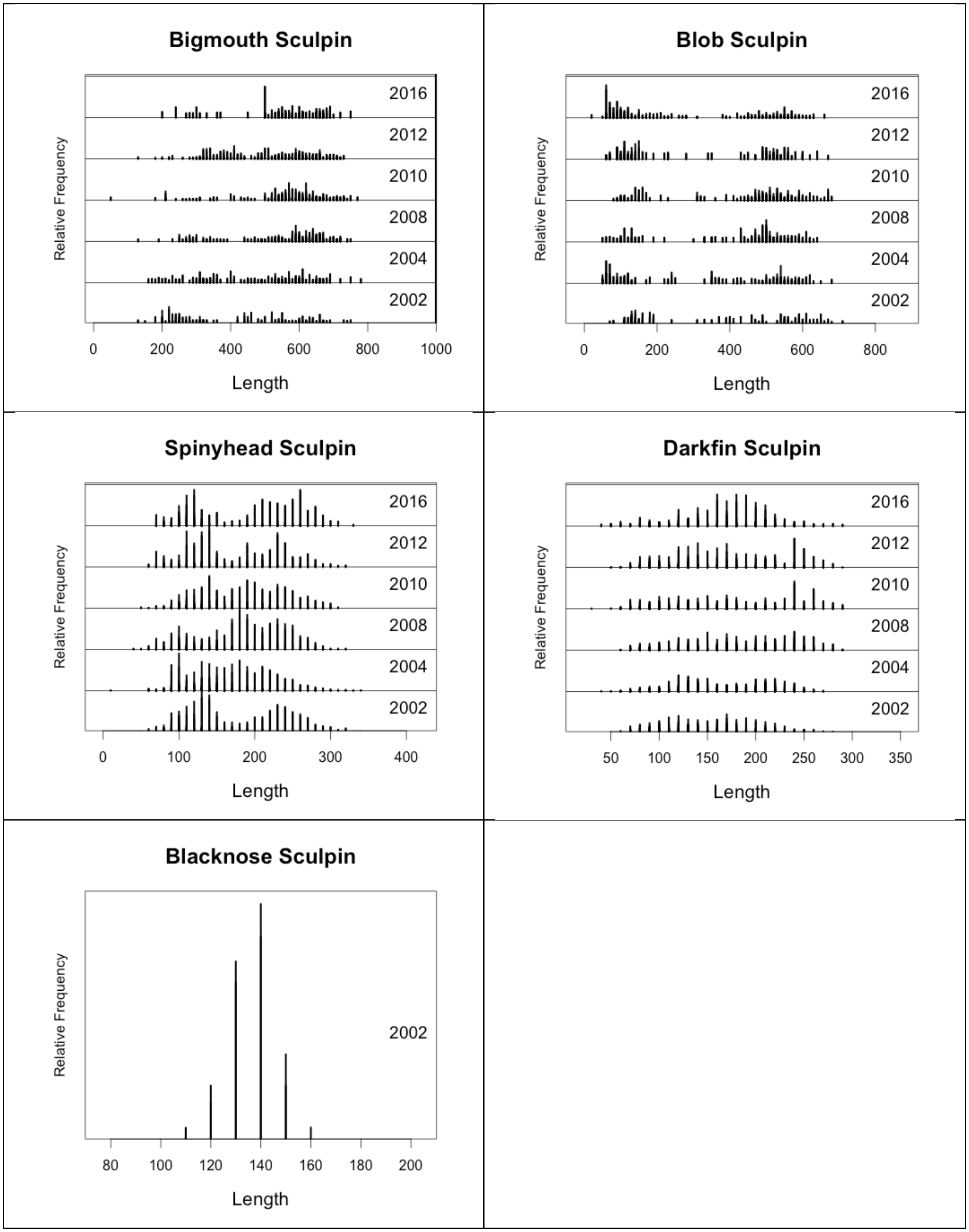

Figure 4. Length frequencies (fork length, FL in mm) from EBS slope survey data for the five most abundant EBS slope sculpin species: spinyhead, darkfin, bigmouth, blacknose, and blob sculpin. Data is from 2002-2016, except for blacknose sculpin because length data for was only available in 2002.

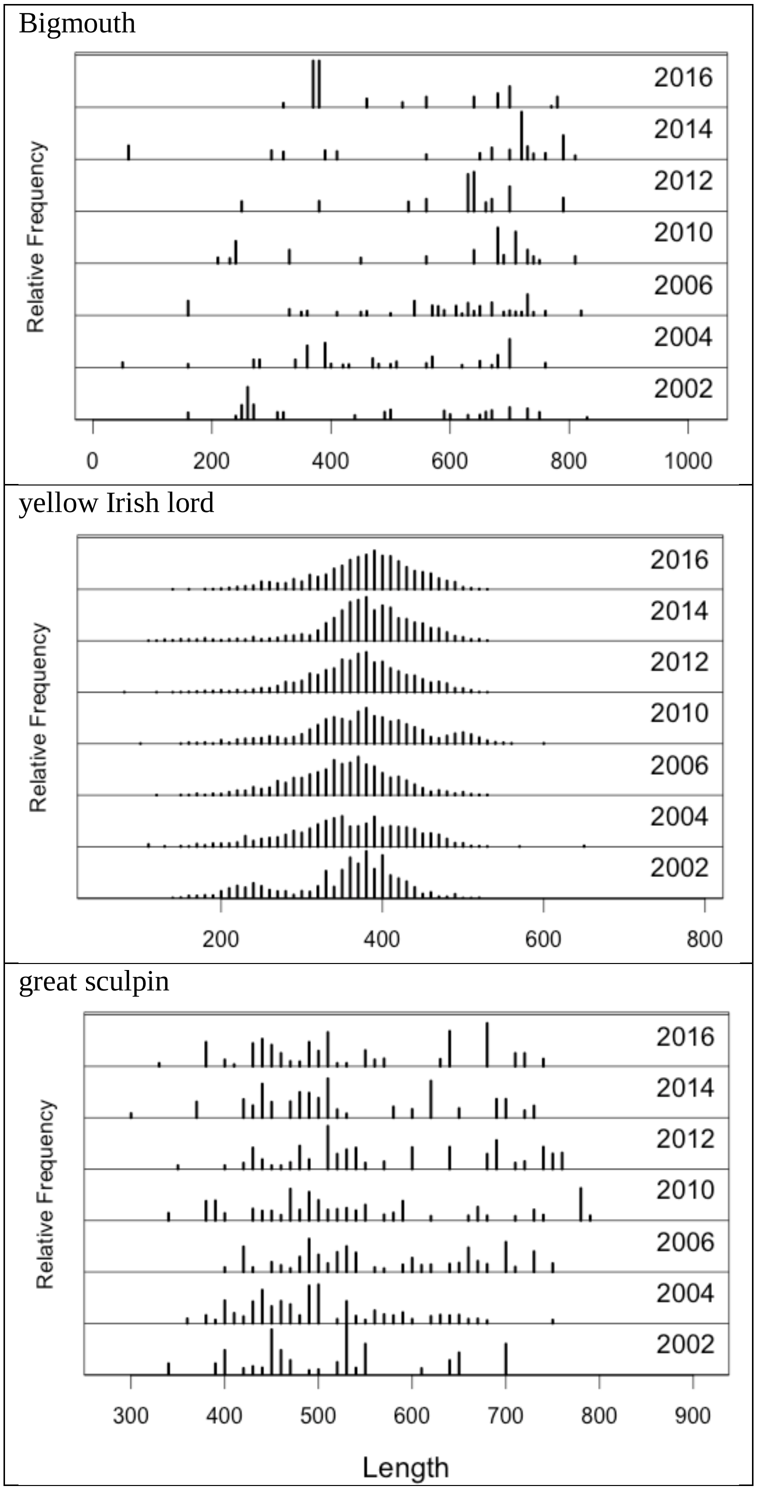

Figure 5. Survey length composition for the 3 most abundant sculpin species in the AI, 2002-2016 bigmouth (upper panel, yellow Irish lord (middle panel), and great sculpin (lower panel).

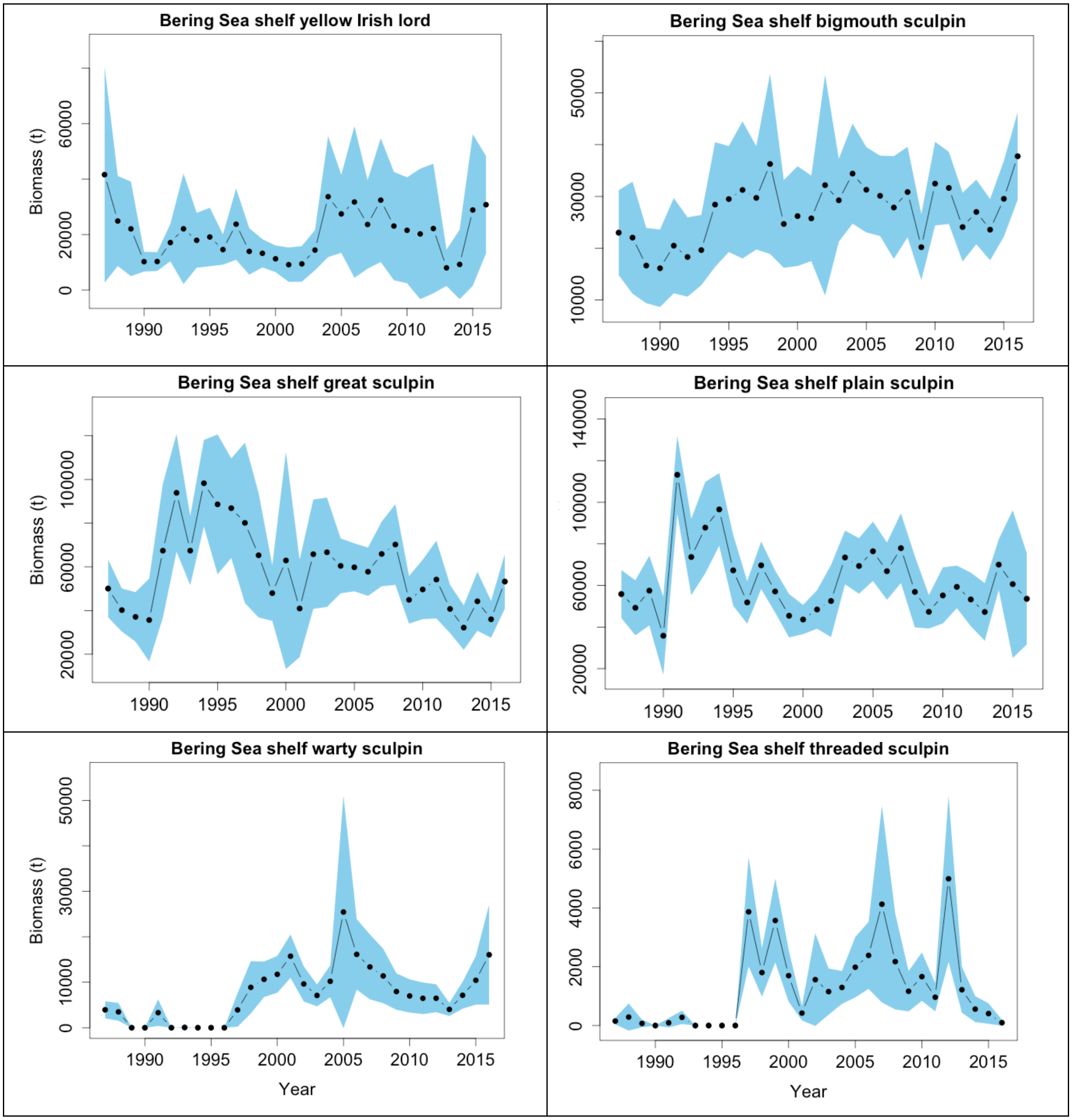

Figure 6. EBS shelf survey biomass estimates for the six most abundant sculpin species, from annual EBS shelf bottom trawl surveys, 1982-2016. Shaded portion represents 95% confidence intervals for survey estimates of biomass.

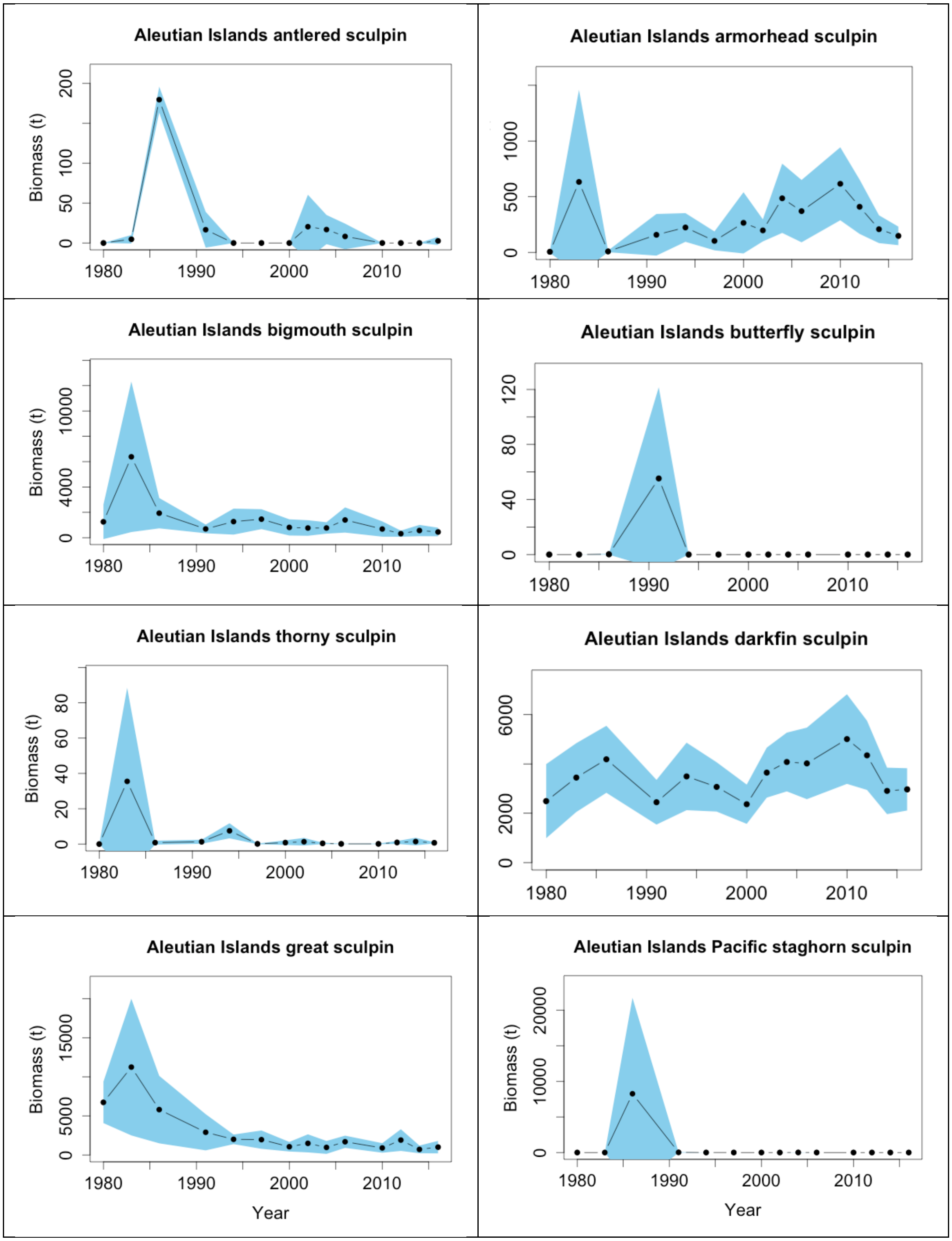

Figure 7. Aleutian Islands (AI) survey biomass estimates for all species observed, from AI trawl surveys 1980-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

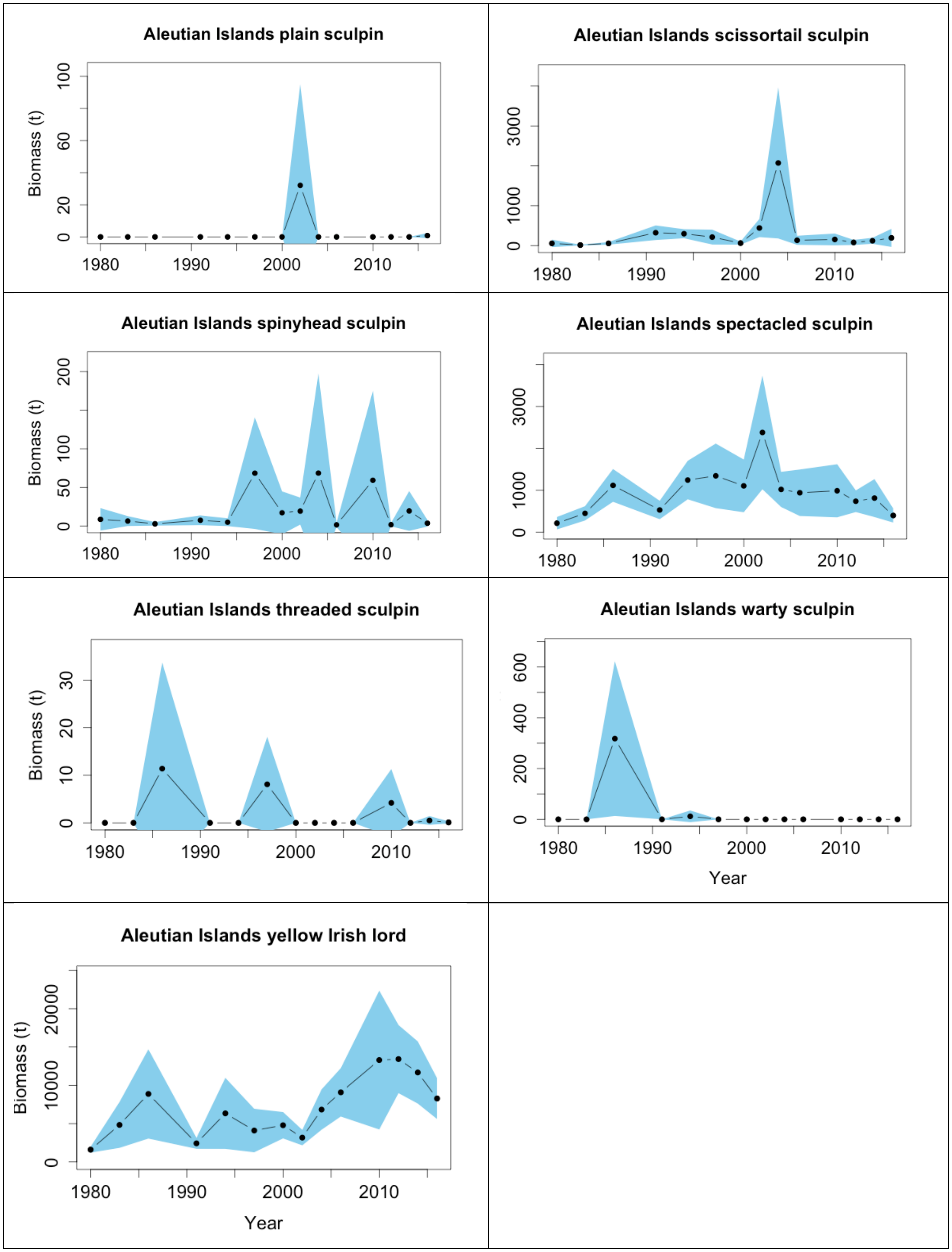

Figure 7 continued. Aleutian Islands (AI) survey biomass estimates for all species observed, from AI trawl surveys 1980-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

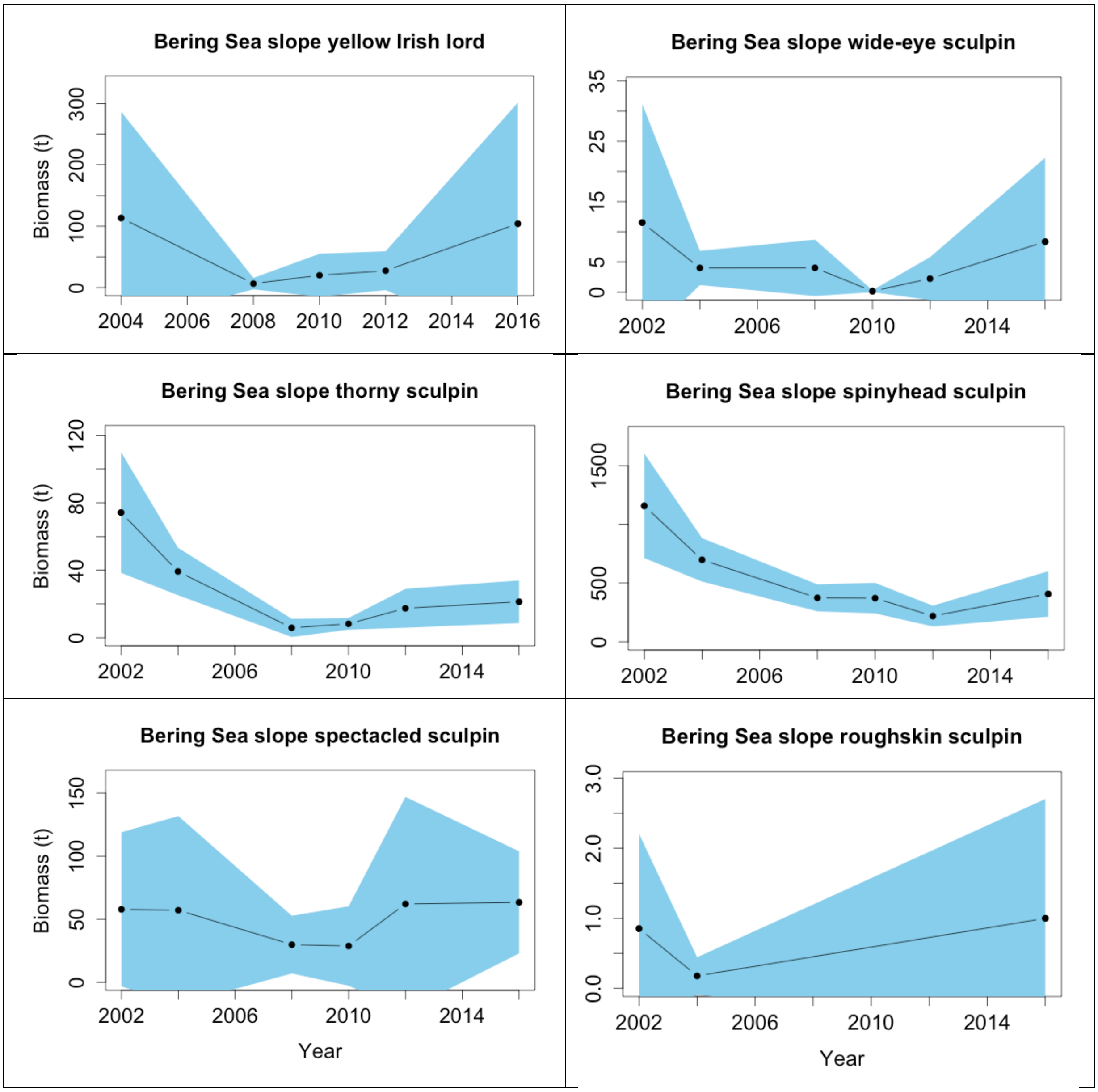

Figure 8. Bering sea slope survey biomass estimates for all sculpin species observed on slope trawl surveys 2002-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

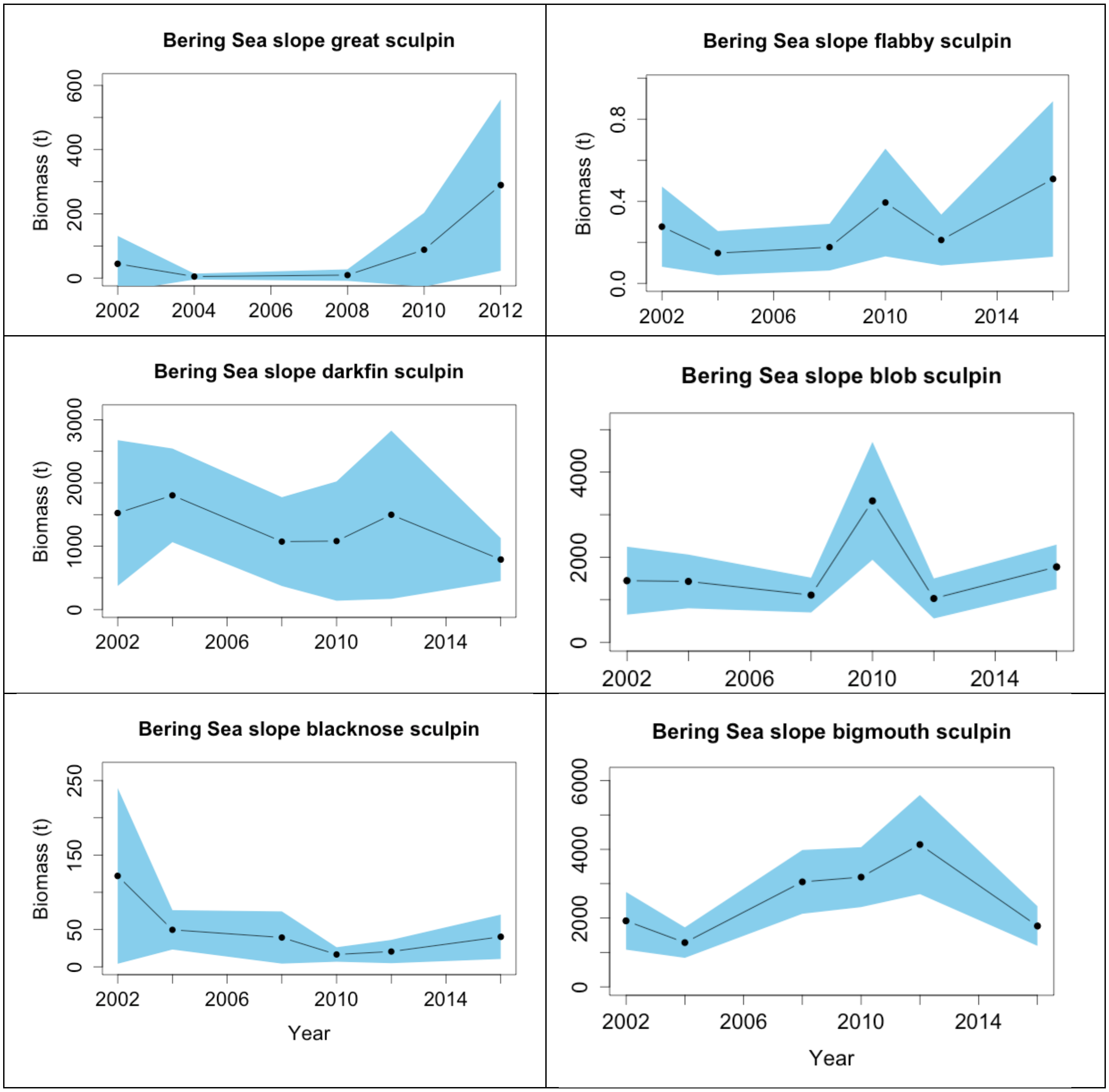

Figure 8 continued. Bering sea slope survey biomass estimates for all sculpin species observed on slope trawl surveys 2002-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

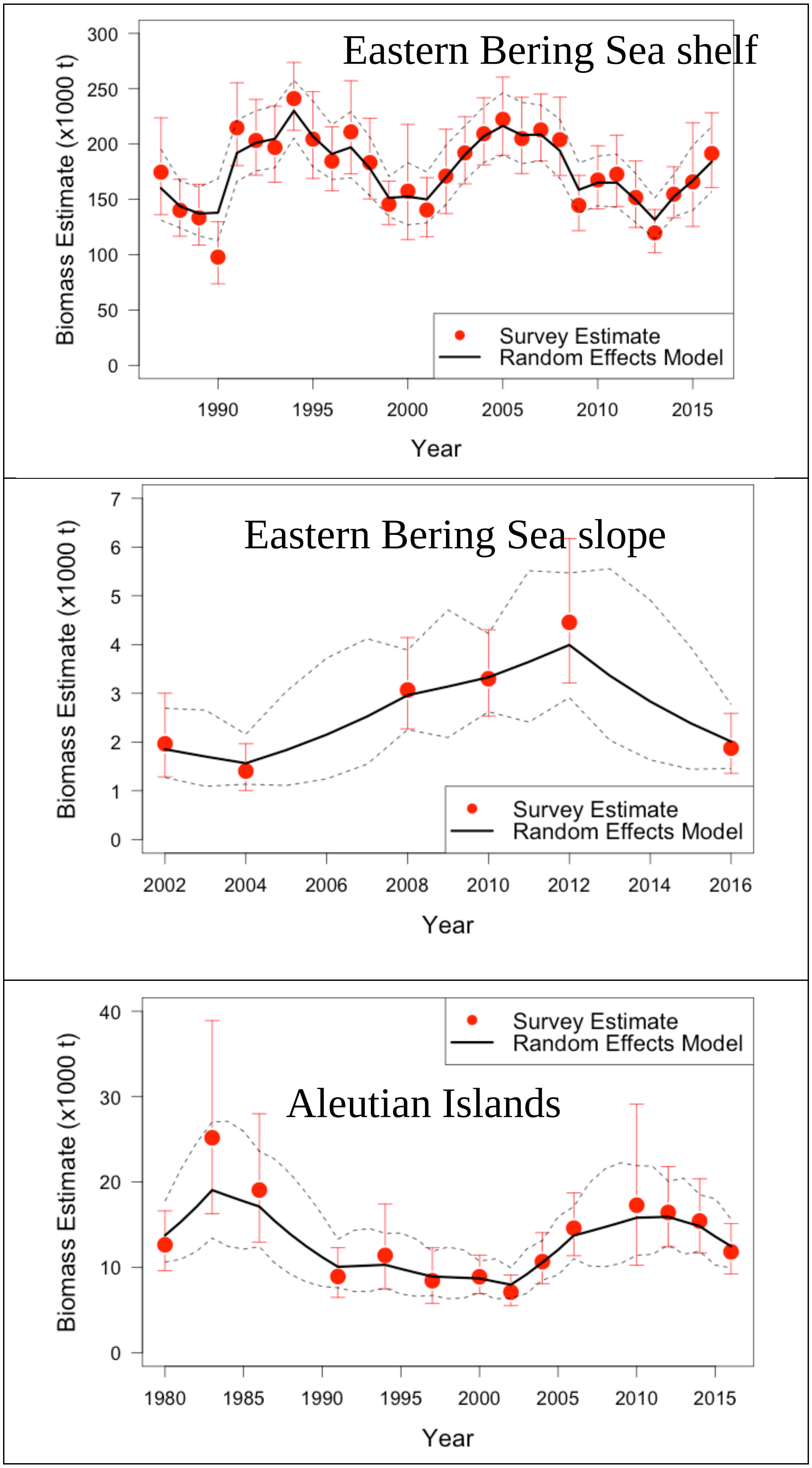

Figure 9. Random effects model estimates of biomass by region for the six most common shelf sculpins (top), slope (middle), and Aleutians (bottom). Error bars represent 95% confidence intervals for survey estimates of biomass, and dotted lines represent 95% confidence intervals from the random effects model.

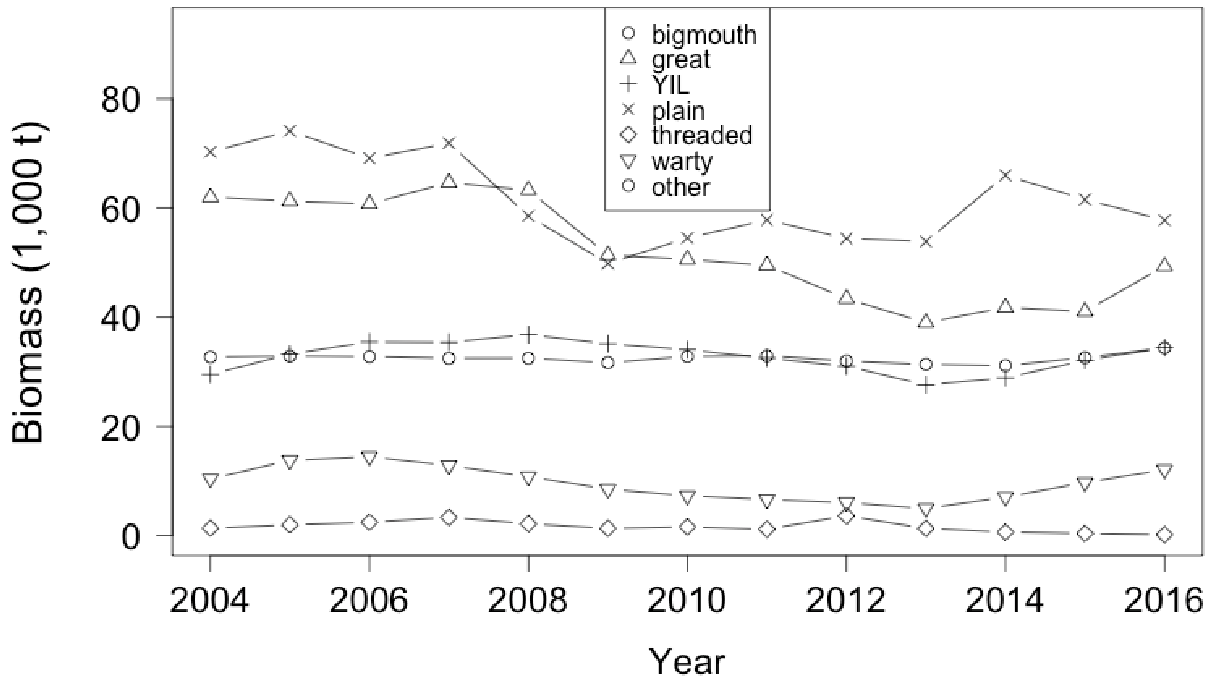

Figure 10. Random effect estimates of the six most common sculpin species in the BSAI, in 1,000 t.

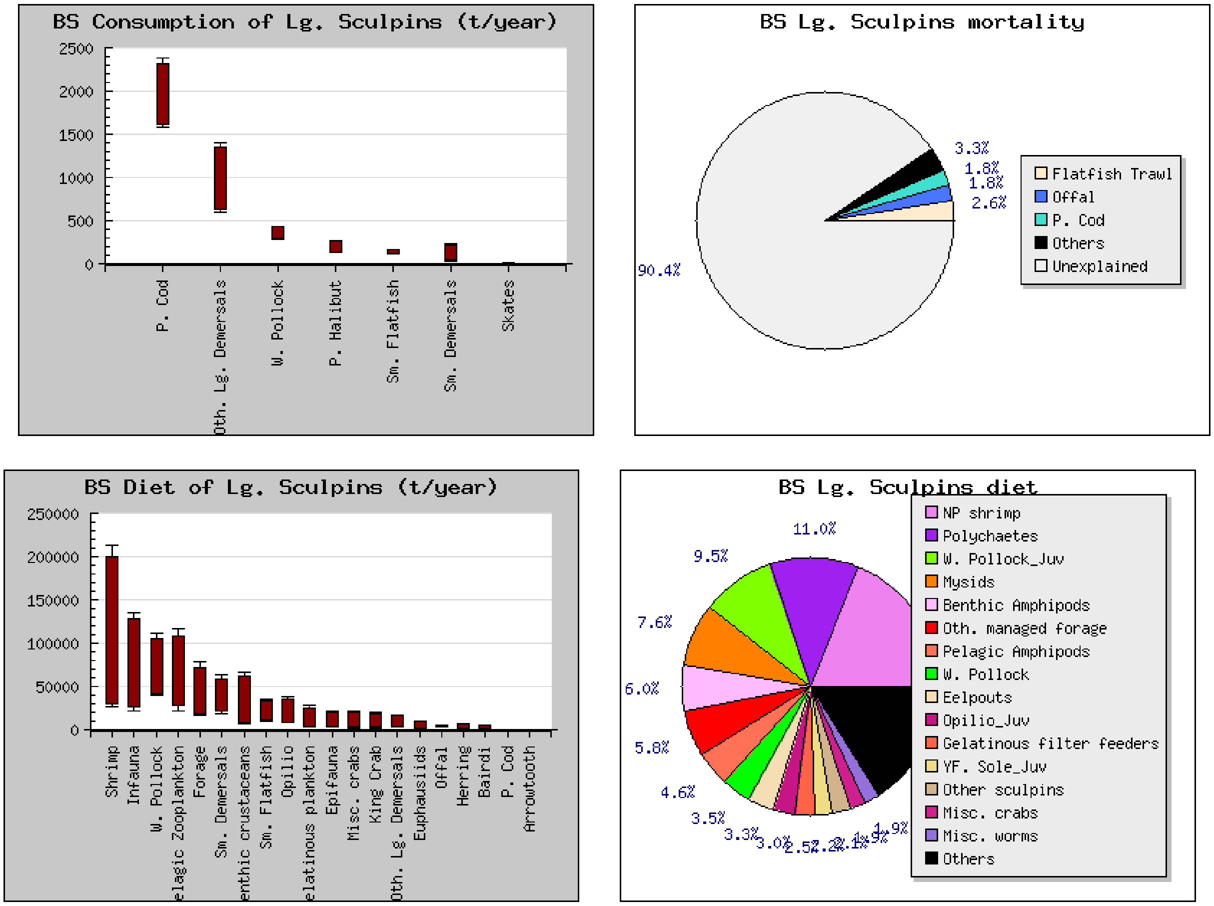

Figure 11. Figures showing Consumption, mortality, and diet of large sculpins (bigmouth sculpin, brown Irish lord, great sculpin, Hemilepidotus unid., Myoxocephalus unid., plain sculpin, red Irish lord, warty sculpin, and yellow Irish lord) from the eastern Bering Sea. Source: REEM ecosystem website. *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.

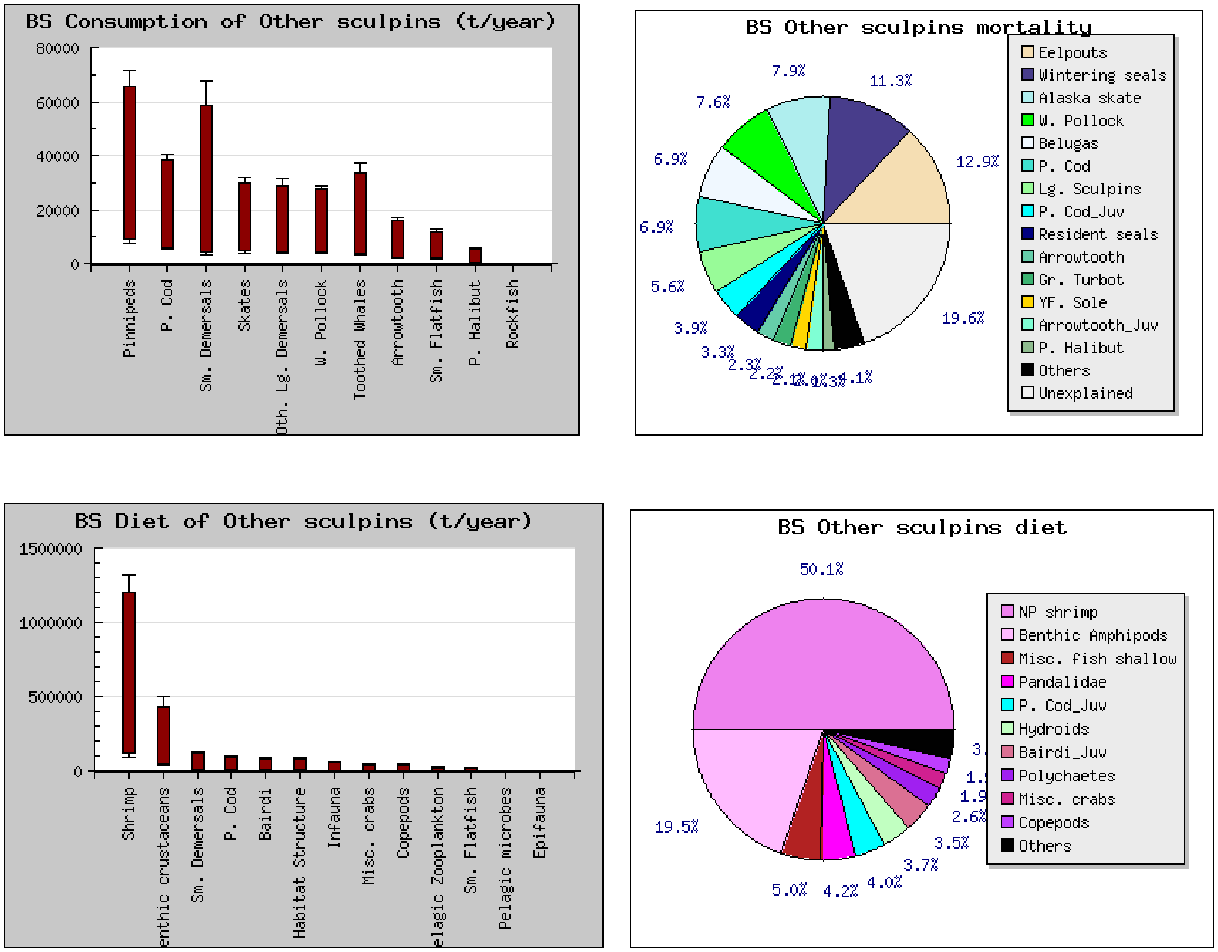

Figure 12. Figures showing Consumption, mortality, and diet of other sculpins (all sculpins not included in large sculpins – Figure 11) from the eastern Bering Sea. Source: REEM ecosystem website. *Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

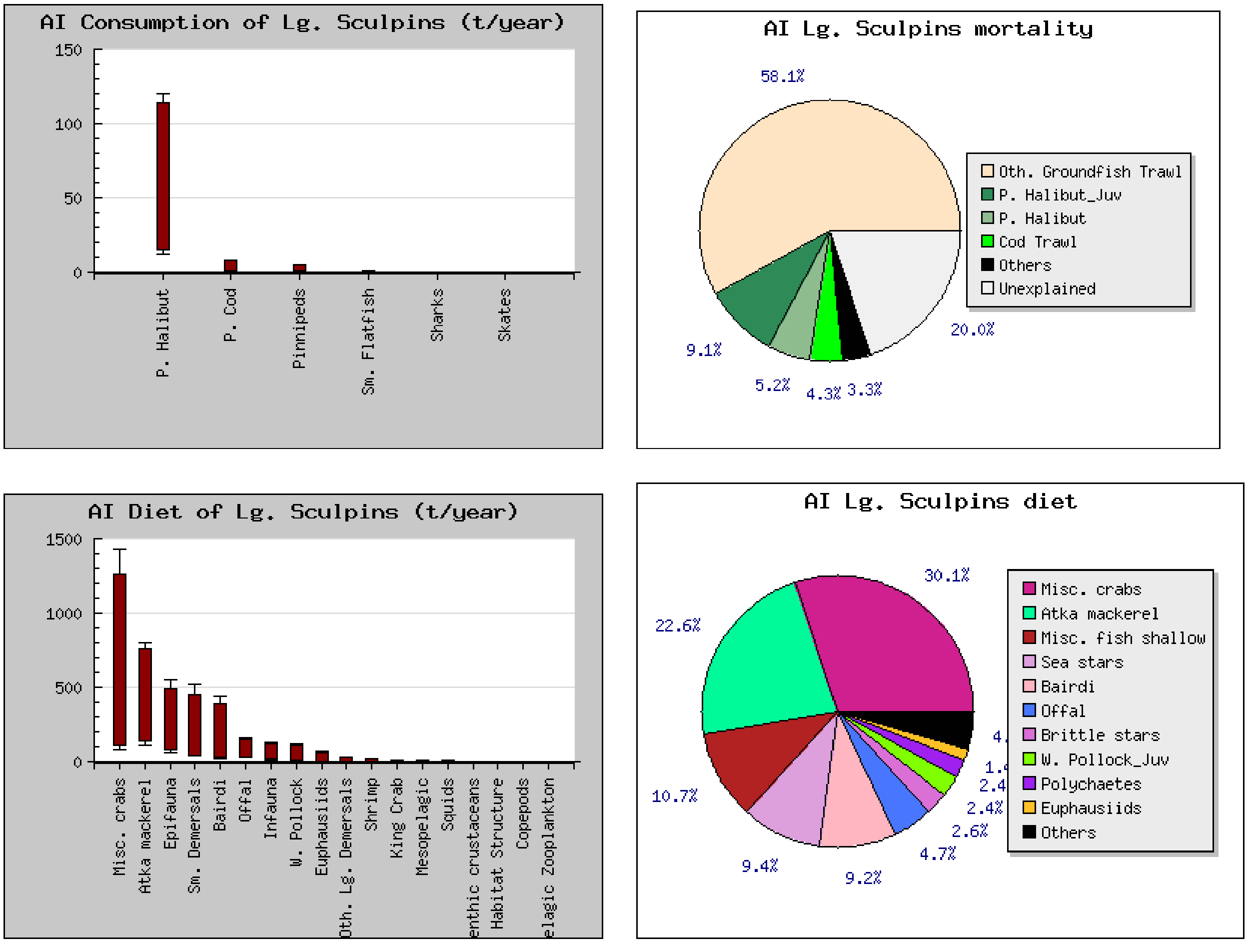

Figure 13. Figures showing Consumption, mortality, and diet of large sculpins (bigmouth sculpin, brown Irish lord, great sculpin, Hemilepidotus unid., Myoxocephalus unid., plain sculpin, red Irish lord, warty sculpin, and yellow Irish lord) from the Aleutian Islands. Source: REEM ecosystem website. *Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

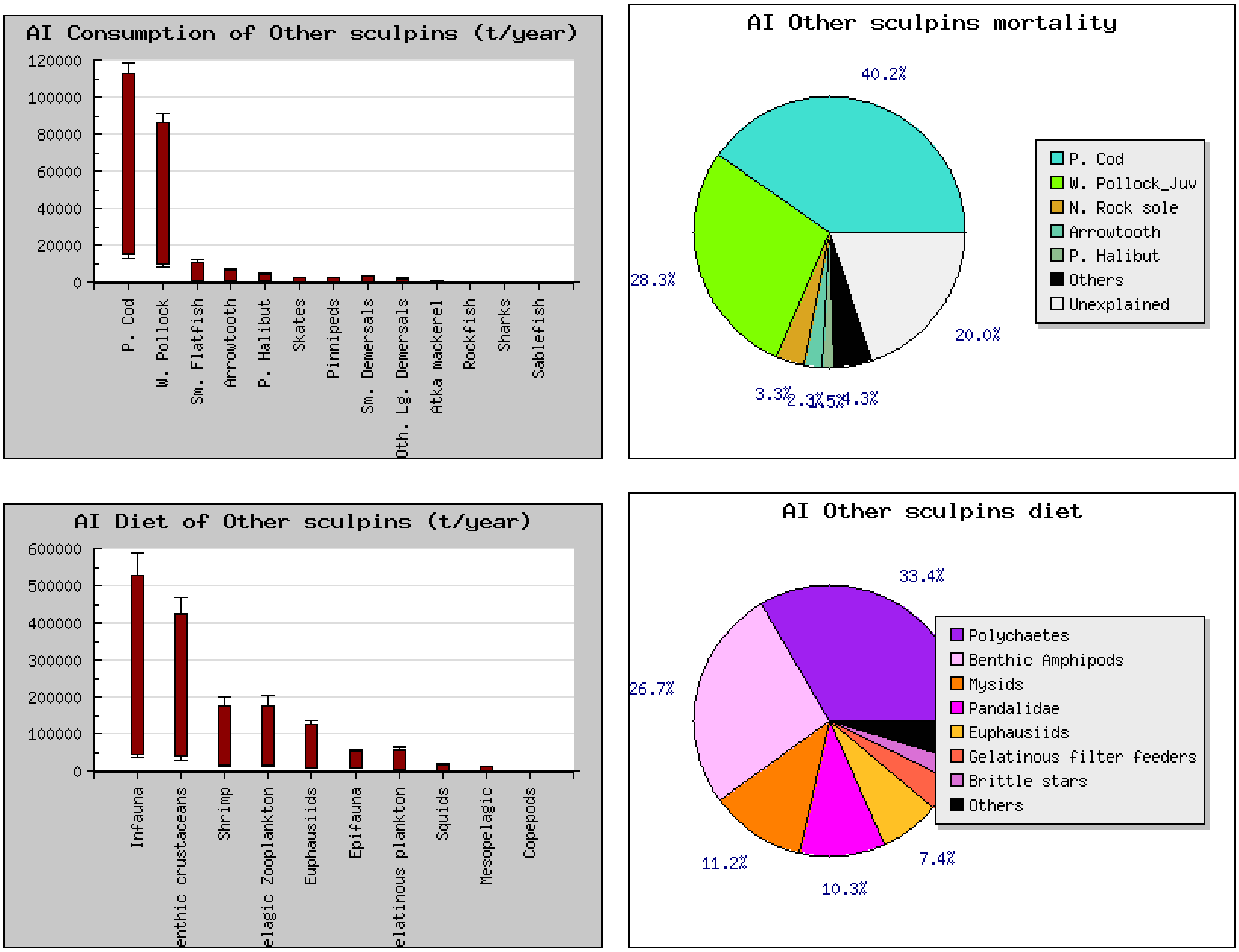

Figure 14. Figures showing Consumption, mortality, and diet of other sculpins (sculpins not in the large sculpin category, Figure 11) from the Aleutian Islands. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

Appendix A. Supplemental Catch Data

Table A1. 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 4, 2016. Source prior to 2010: NMFS-AFSC survey databases. Source 2010 onwards: AKR.V_NONCOMMERCIAL_FISHERY_CATCH table.

Non-commercial catch (t)			
Year	**NMFS**	**ADFG**	**IPHC**
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	18.9	0.3	5.0
2011	16.8	0.6	4.0
2012	13.3	0.0	1.8
2013	4.7	0.0	4.8
2014	10.4	0.0	4.7
2015	6.7	0.0	5.8

(This page intentionally left blank)