Evaluation of stock structure for the Bering Sea/Aleutian Islands sculpin complex

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Executive Summary

This document presents several types of information about Bering Sea and Aleutian Island (BSAI) sculpins to evaluate the potential for stock structure in these species. This report follows the guidelines presented in the stock structure template prepared by the Stock Structure Working Group (Spencer et al. 2010). BSAI sculpin are managed within a BSAI sculpin complex which includes all 47 currently recognized species of sculpin in the BSAI (Table 1), and is managed under a Tier 5 harvest control rule. The Acceptable Biological Catch (ABC) and Overfishing Level (OFL) are calculated for the entire BSAI with no spatial allocations. OFL is calculated as the product of natural mortality, *M*, and the survey estimate of biomass for all sculpins in the BSAI, and ABC is 75% of the OFL. The sculpin complex mortality rate, *M*, 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*).

Biomass trends of the six most abundant sculpins have been mostly stable, although some decline is apparent in great and plain sculpin, based on the random effects model (Figure 1), and also notably in the butterfly sculpin. Aggregated catch of sculpin species in the Eastern Bering Sea (EBS) and the Aleutian Islands (AI) has also been stable since 2004 (Figure 2).

Differences in growth were observed among yellow Irish lord from the eastern Bering Sea (EBS) and the Aleutian Islands (AI), modeled by the von Bertalanffy growth curve. Growth and length differences have not been examined for other sculpin species in the BSAI but differences have been observed for great sculpin in Kamchatka (TenBrink and Aydin 2009).

In general sculpins are lightly exploited, and are taken only as bycatch directed at target species in the BSAI. Some regions of higher catch relative to estimated biomass has been observed; average bigmouth catch (2012, 2014, and 2016) in the central Aleutian Islands exceeded a spatial ABC but not OFL and average catch of yellow Irish lord over the years 2010, 2012, and 2014 has been higher than a species and area specific OFL.

No genetic analysis has been done on these species to examine stock structure, or on any closely related marine species of sculpin. However, 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.

Introduction

1. Distribution and species composition within the sculpin complex.

The majority (86%) of sculpin biomass is on the EBS shelf, followed by 4.8% in the EAI based on average survey biomass estimates over the years 2012, 2014, and 2016 (Table 2). The years 2012, 2014, and 2016 were chosen because they represent the three most recent Aleutian Islands surveys and some of the more common sculpins species were not identified to species prior to 2012. Approximately 3.5% of sculpin biomass is on the EBS slope, based on the most recent 3 EBS slope surveys in 2010, 2012, and 2016. The majority of bigmouth, plain, great, warty, and yellow Irish lord are found on the EBS shelf. Yellow Irish lord is the most prevalent sculpin in the Western, Central, and Eastern Aleutians, as well as the southern Bering Sea. Plain sculpin biomass dominates the EBS shelf at 35%, followed by great sculpin at 27%. Bigmouth sculpin is the most common sculpin on the EBS slope at 45%.

2. Application of stock structure template to the BSAI sculpin complex.

2.1 Harvest and trends

Harvest data and survey population trends are presented to address whether fishing mortality is high enough to result in spatially disproportionate harvesting and whether differences exist in population trends that may indicate demographic independence.

Fishing mortality (relative to target reference point)

The estimates of fishing mortality for the five-year period 2011-2015 indicates that the sculpin complex as a whole is lightly exploited relative to its ABC. The average catch divided by the estimate of biomass for the entire sculpin complex over the years 2011-2015 was 2.9% (Table 3). This represented 12.7% of the ABC from 2011-2015 (Spies et al. 2016). Data from 2016 was not presented because it was not available for all sculpin species of interest at the time the report was prepared.

Spatial concentration of harvest relative to abundance

Detailed estimates of catch from the observer database by species and area indicate that catch of most common species (bigmouth, great, plain, warty, threaded sculpin, and yellow Irish lord) are lower than the estimate of natural mortality (*M*) for those species, with two exceptions (Table 4a, 4b). Catch of yellow Irish lord on the EBS slope was high averaged over 2010, 2012, and 2016, 43% of the estimate of biomass averaged over the same years, which would exceed an area and species specific OFL.

Yellow Irish lord catch on the EBS slope was 3t, 12t, and 49t in 2010, 2012, and 2016, the years of the past 3 slope surveys respectively. Biomass estimates for the past 3 slope surveys have been 20, 28, and 104 t, respectively, resulting in catch/biomass estimates of 0.15, 0.43, and 0.47. Natural mortality for yellow Irish lord is 0.17, so catches exceeded the OFL in 2014 and 2016 (Table 4b).

In the central Aleutian Islands catch of bigmouth sculpin represented 19% of their estimated biomass on average in 2012, 2014, and 2016. However, *M* for bigmouth sculpin is 0.21 so catch was lower than OFL (but higher than ABC, Table 4b).

Population trends

Combined biomass estimates of the six most abundant sculpin species in the BSAI (yellow Irish lord, bigmouth, plain, great, warty, and threaded sculpin) have been stable since 2004, although some decline is apparent in plain and great sculpin, based on a random effects model applied to survey biomass (Figure 1). The six most common sculpin species on the EBS shelf have had a stable trend from 1982-2016 based on survey biomass estimates as well (Figure 3). However, butterfly sculpin has decreased significantly since the 1990's from approximately 50,000 t to an order of magnitude less (Figure 3). In the Aleutian Islands, great sculpin has declined from 5,000-7,000t in the 1990's to below 1,000 t currently (Figure 4). Bering sea slope thorny and spinyhead sculpin appear to have declined since the 1990's although biomass estimates were up for both species in 2016 (Figure 5).

2.2 Barriers and phenotypic characters

Generation time

Generation length (*L*), the average age of parents of a newborn cohort, is calculated as $L = \sum xB_x / N_1$, where *x* is age, B_x is the number of births by individuals of age *x*, $B_x = b_x N_x$, and N_X is the number of individuals of age *x* alive at any given time, and N_1 is the number of newborns (Waples et al. 2011). Demographic information on sculpins is not detailed enough to form concise calculations on the generation length of any species. However, a proxy for generation length can be age at 50% maturity because it provides an estimate of the age at spawning. Age at 50% maturity is available for plain sculpin from the Western Bering Sea, 5-8 years, great sculpin, 6.9 years (Eastern Bering Sea), and yellow Irish lord (Western Bering Sea), 6-7 years (Spies et al. 2016). Maximum age for the warty sculpin is 18, for bigmouth sculpin is 23, and threaded sculpin is 10 years (Table 5).

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). Age at 50% maturity relative to maximum age does not appear to be as high for plain sculpin, great sculpin, or yellow Irish lord (Table 5, Table 6).

Physical limitations (clear physical inhibitors to movement)

Sculpins are found in both freshwater and marine habitats; they are distributed throughout the BSAI and 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. Most sculpins lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschemeyer et al. 1983). 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. 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. 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.

The physical environment of the Aleutian Islands has been described as having considerable ecological variability (Hunt and Stabeno 2005). Variation in ocean environment exists throughout the Aleutian Islands in the form of currents, passes, differences in water features, as well as in the species composition of coral, zooplankton, fish, and marine mammals. In addition, the Aleutian Islands and the Bering Sea are commonly accepted as different large marine ecosystems, and the Bering Sea slope is differentiated from the Bering Sea shelf by depth as well as species composition. Therefore, sculpins in the Bering Sea exist in a variety of ecosystems and may encounter barriers to movement. However, no clear barrier to movement has been defined for any sculpin species.

Growth differences

Length frequency differences were compared for yellow Irish lord in the Eastern Bering Sea and the Aleutian Islands (TenBrink and Buckley 2013) and no significant differences were observed (Figure 6). However, growth differences were observed when the von Bertalanffy growth model was fitted to length-at-age data for Bering Sea and Aleutian Islands yellow Irish lord (Figure 7).

The resulting von-Bertalanffy growth parameters are as follows (TenBrink and Buckley 2013):

Species	Area	Fish aged	t_{izero}	K	L_{inf}
Yellow Irish lord	AI	398	-0.808	0.147	45.8
Yellow Irish lord	EBS	386	0.056	0.299	43.0

Differences in growth have not been studied for any other sculpin species in the BSAI. However, Tokranov (1985, 1988) reported differences in growth of great sculpin between Kamchatka and Western Kamchatka (TenBrink and Aydin 2009).

2.3 Genetics

There have been no studies of genetic population structure involving any North Pacific sculpin species, or other marine sculpin species.

2.4 Interpretation of the information regarding stock structure

There is relatively little information regarding stock structure in sculpins. A study that examined growth found differences in yellow Irish lord among the EBS and AI (Tenbrink and Buckley 2013). Another study found differences among great sculpin in different regions of Kamchatka (Tokranov, 1985). 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.

In general sculpin are lightly exploited, and are caught only as bycatch, although there are exceptions by region and species. Butterfly sculpin has declined significantly in the Bering Sea. A precautionary approach would involve management of the sculpin complex within a spatial context rather than with a global annual aggregate BSAI total allowable catch (TAC).

3.0 Management implications

Implications for stock sustainability
There are no pressing needs for a change in the management of the sculpin complex. The butterfly sculpin stock on the EBS shelf is an arctic species, and the observed decline could be due to environmental factors as well as fishing, but whether a change in fishing would increase the stock size is not known. There has been a decline in bigmouth sculpin in the Aleutian Islands, which could be due to fishing. More research is needed on the reliability of early estimates of biomass in the 1980’s and 1990’s and how high catches have been in this region. Bering Sea slope yellow Irish lord appear to have been consistently highly exploited; however, survey biomass estimates have increased since 2008.

Risks/costs to the fishery and regulatory system
Although apportioning catch by region (e.g. WAI, CAI, EAI, EBS slope, EBS shelf) may represent a precautionary approach to management of BSAI sculpins, it may not change disproportionate harvest of CAI bigmouth sculpin or slope yellow Irish lord, and may impose an unreasonable level of complexity to management of this stock.

Acknowledgements

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References

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.

Hunt, Jr, G.L. and P.J.Stabeno. 2005. Oceanography and ecology of the Aleutian Archipelago: spatial and temporal variation. Fish. Oceanogr. 14 (Suppl. 1), 292–306.

Spencer, P., M. Canino, J. DiCosimo, M. Dorn, A.J. Gharrett, D. Hanselman, K. Palof, and M. Sigler. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan fishery groundfish management plans. Paper prepared for the September 2010 NPFMC Plan Team meeting.

Spies, I., Aydin, K., Nichol, D., Palsson, W., Hoff, J., and TenBrink, T. 2016. Assessment of the sculpin stock complex in the Bering Sea and Aleutian Islands. SAFE Chapter. NPFMC.

TenBrink, T., and Aydin, L. 2009. Life history traits of sculpins in the eastern Bering Sea and Aleutian Islands. NPRB Project 628 Final Report.

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

TenBrink, T.T. and Buckley, T.W., 2013. Life-history aspects of the yellow Irish lord (*Hemilepidotus jordani*) in the Eastern Bering Sea and Aleutian Islands. *Northwestern Naturalist*, *94*(2), pp.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.

Waples, R.S., Do, C. and Chopelet, J., 2011. Calculating Ne and Ne/N in age- structured populations: a hybrid Felsenstein- Hill approach. *Ecology*, *92*(7), pp.1513-1522.

Tables

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 (*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. Average survey biomass estimate in metric tons (t) for the Western, Central, and Eastern Aleutian Islands (WAI, CAI, and EAI respectively), the southern Bering Sea (SBS), and the eastern Bering Sea (EBS) shelf and the total over years 2012, 2014, and 2016. Bering Sea slope data is presented as the average over 2010, 2012, and 2016, the three most recent surveys.

	WAI	CAI	EAI	SBS	EBS shelf	EBS slope	TOTAL
bigmouth sculpin	138	72	234	56	28,474	3,033	32,007
great sculpin	274	320	610	130	46,079	126	47,539
plain sculpin	0	0	0	0	58,947	0	58,947
warty sculpin	0	0	0	0	9,888	0	9,888
threaded sculpin	0	0	0	0	1,882	0	1,882
yellow Irish lord	492	4,140	6,496	1,599	20,705	51	33,483
other	817	1,548	2,191	240	4,808	3,596	13,200
TOTAL	1,721	6,081	9,531	2,024	170,783	6,806	196,946

Table 3. Catch (t) of sculpin in the BSAI compared to ABCs and OFLs.

Year	OFL (t)	ABC (t)	TAC (t)	Catch (t)	% ABC caught
2011	58,300	43,700	5,200	5,373	12.3
2012	58,300	43,700	5,200	5,798	13.3
2013	56,400	42,300	5,600	5,828	13.8
2014	56,400	42,300	5,600	4,865	11.5
2015	52,365	39,725	4,700	4,980	12.5
2016	52,365	39,725	4,500	4,946	12.5
				Average	12.7%

Table 4a. Catch from observer database averaged over 2012, 2014, and 2016, except for the EBS slope which was averaged over 2010, 2012, and 2016 because the past three surveys were conducted in those years.

	WAI	CAI	EAI	SBS	EBS shelf	EBS slope	TOTAL
bigmouth sculpin	6	14	34	3	284	37	382
great sculpin	1	1	6	0	1,336	3	1,347
plain sculpin	0	0	0	0	902	0	902
warty sculpin	0	0	0	0	81	0	81
threaded sculpin	0	0	0	0	0	0	0
yellow Irish lord	5	79	114	1	507	22	734
TOTAL	12	94	154	4	3,110	72	3,446

Table 4b. The proportion of the mean catch out of the mean estimate of survey biomass from 2012, 2014, and 2016 from the observer database by species and area.

	M	WAI	CAI	EAI	SBS	EBS shelf	EBS slope	TOTAL
bigmouth sculpin	0.21	0.04	0.19	0.15	0.05	0.01	0.01	0.01
great sculpin	0.28	0.00	0.00	0.01	0.00	0.03	0.02	0.03
plain sculpin	0.40	0.00	0.00	0.00	0.00	0.02	0.00	0.02
warty sculpin	0.26	0.00	0.00	0.00	0.00	0.01	0.00	0.01
threaded sculpin	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
yellow Irish lord	0.17	0.01	0.02	0.02	0.00	0.02	0.43	0.02
TOTAL		0.01	0.02	0.02	0.00	0.02	0.01	0.02

Table 5. 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 and Buckley 2013.

Table 6. Summary of available data on stock identification for the BSAI sculpin complex. Framework of types of information to consider when defining spatial management units (from Spencer et al. 2010).

HARVEST AND TRENDS	
Factor and criterion	Justification
Fishing mortality (5-year average percent of F_{abc} or F_{ofl})	If this value is low, then conservation concern is low Average catch/RE estimate of biomass 2011-2015=2.9%. Average percentage of ABC caught 2011-2015 was 12.7%.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	If fishing is focused on very small areas due to patchiness or convenience, localized depletion could be a problem. Catch relative to survey estimates of biomass of bigmouth sculpin was relatively high on average over 2012, 2014 and 2016 in the central Aleutian Islands (0.19), which would have exceeded spatially allocated ABC but not the OFL for this species in the CAI. Average catch relative to biomass of yellow Irish lord averaged over 2010, 2012, and 2016 was 0.43 on the EBS slope. No other species or areas showed evidence of relatively high catches.
Population trends (Different areas show different trend directions)	Differing population trends reflect demographic independence that could be caused by different productivities, adaptive selection, differing fishing pressure, or better recruitment conditions. The six most common sculpin species on the EBS shelf have had a stable trend from 1982-2016 based on survey biomass estimates as well (Figure 3). However, butterfly sculpin has decreased significantly since the 1990's from approximately 5,000 t to zero in most years (Figure 3). In the Aleutian Islands, great sculpin has declined from 5,000-7,000t in the 1990's to below 1,000 t currently (Figure 4). Bering sea slope thorny and spinyhead sculpin appear to have declined since the 1990's although biomass estimates were up for both species in 2016 (Figure 5).
Barriers and phenotypic characters	
Generation time (e.g., >10 years)	If generation time is long, the population recovery from overharvest will be increased. The age at 50% maturity for female great sculpin was 6.9 years. The 50% maturity for plain sculpin was 5-8 years and 6-7 years for yellow Irish Lord, from Western Bering Sea samples (Spies et al. 2016).
Physical limitations (Clear physical inhibitors to movement)	Sessile organism; physical barriers to dispersal such as strong oceanographic currents or fjord stocks Sculpins occupy benthic habitats and depths but are not sessile. It is not known whether they are migratory or sedentary. No physical limitations to their movement are known.
Growth differences (Significantly different LAA, WAA, or LW parameters)	Temporally stable differences in growth could be a result of either short term genetic selection from fishing, local environmental influences, or longer-term adaptive genetic change. The growth rate of Yellow Irish Lords in the Aleutian Islands was slower than those in the eastern Bering Sea. (TenBrink and Buckley 2013).
Age/size-structure (Significantly different size/age compositions)	Differing recruitment by area could manifest in different age/size compositions. This could be caused by different spawning times, local conditions, or a phenotypic response to genetic adaptation.

	No significant difference in sizes of Yellow Irish Lords in the Aleutians and eastern Bering Sea (TenBrink and Buckley 2013).
Spawning time differences (Significantly different mean time of spawning)	Differences in spawning time could be a result of local environmental conditions, but indicate isolated spawning stocks. Bering Sea Yellow Irish Lords were spawning or near spawning in June and July, and spent individuals were observed in September. In the Aleutian Islandsspawning was slightly later, with advanced vitellogenesis in June-August and spent individuals in October (TenBrink and Buckley 2013).
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	Temporally stable differences in maturity-at-age could be a result of fishing mortality, environmental conditions, or adaptive genetic change. The age at 50% maturity for female great sculpin was 6.9 years. The 50% maturity for plain sculpin was 5-8 years and 6-7 years for yellow Irish Lord, from Western Bering Sea samples (Spies et al. 2016).
Morphometrics (Field identifiable characters)	Identifiable physical attributes may indicate underlying genotypic variation or adaptive selection. Mixed stocks w/ different reproductive timing would need to be field identified to quantify abundance and catch No data.
Meristics (Minimally overlapping differences in counts)	Differences in counts such as gillrakers suggest different environments during early life stages. No data.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Primary indicator of limited dispersal or homing No data.
Mark-recapture data (Tagging data may show limited movement)	If tag returns indicate large movements and spawning of fish among spawning grounds, this would suggest panmixia No data.
Natural tags (Acquired tags may show movement smaller than management areas)	Otolith microchemistry and parasites can indicate natal origins, showing amount of dispersal No data.
Genetics	
Isolation by distance (Significant regression)	Indicator of limited dispersal within a continuous population No data.
Dispersal distance (<<Management areas)	Genetic data can be used to corroborate or refute movement from tagging data. If conflicting, resolution between sources is needed. No data.
Pairwise genetic differences (Significant differences between geographically distinct collections)	Indicates reproductive isolation. No data.

Figures

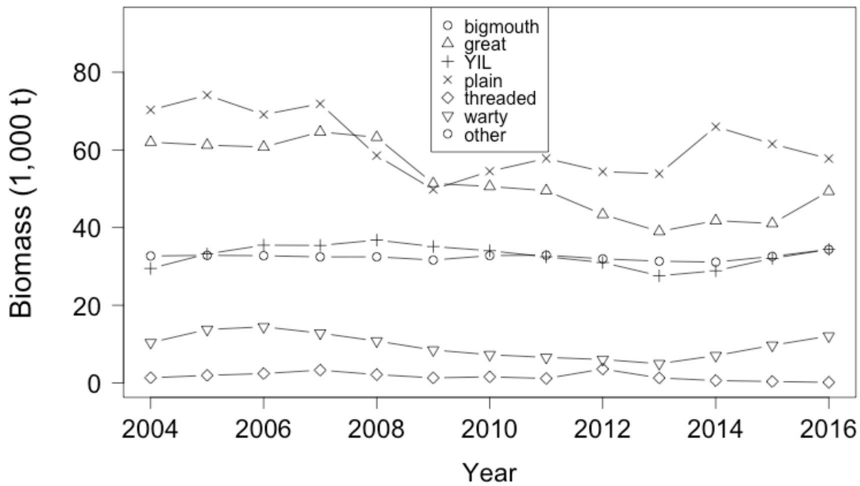

Figure 1. Random effect estimates of biomass (1,000 t) for the six most common sculpin species in the BSAI.

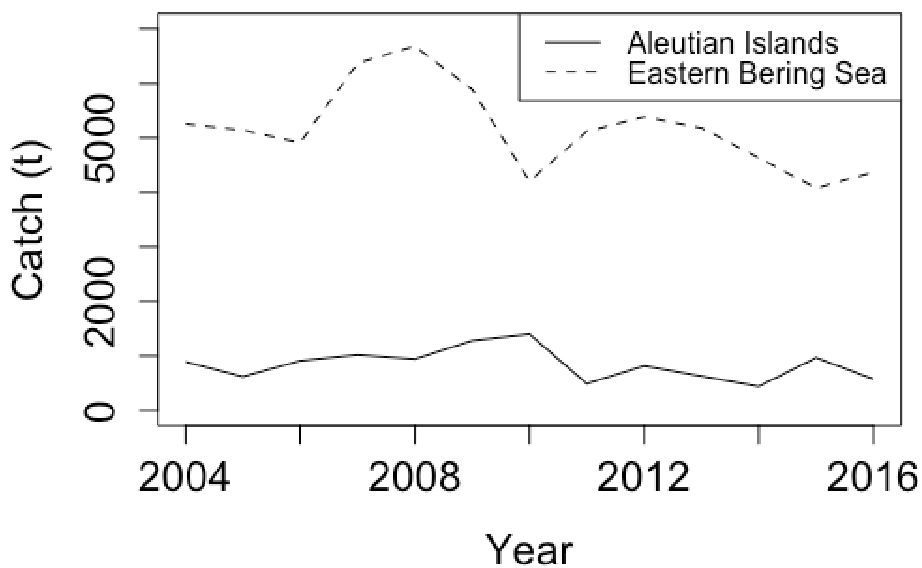

Figure 2. Catch estimates of all sculpins in the Aleutian Islands (solid line) and the Eastern Bering Sea from 2004-2016. Source: NMFS AKRO BLEND/Catch Accounting System.

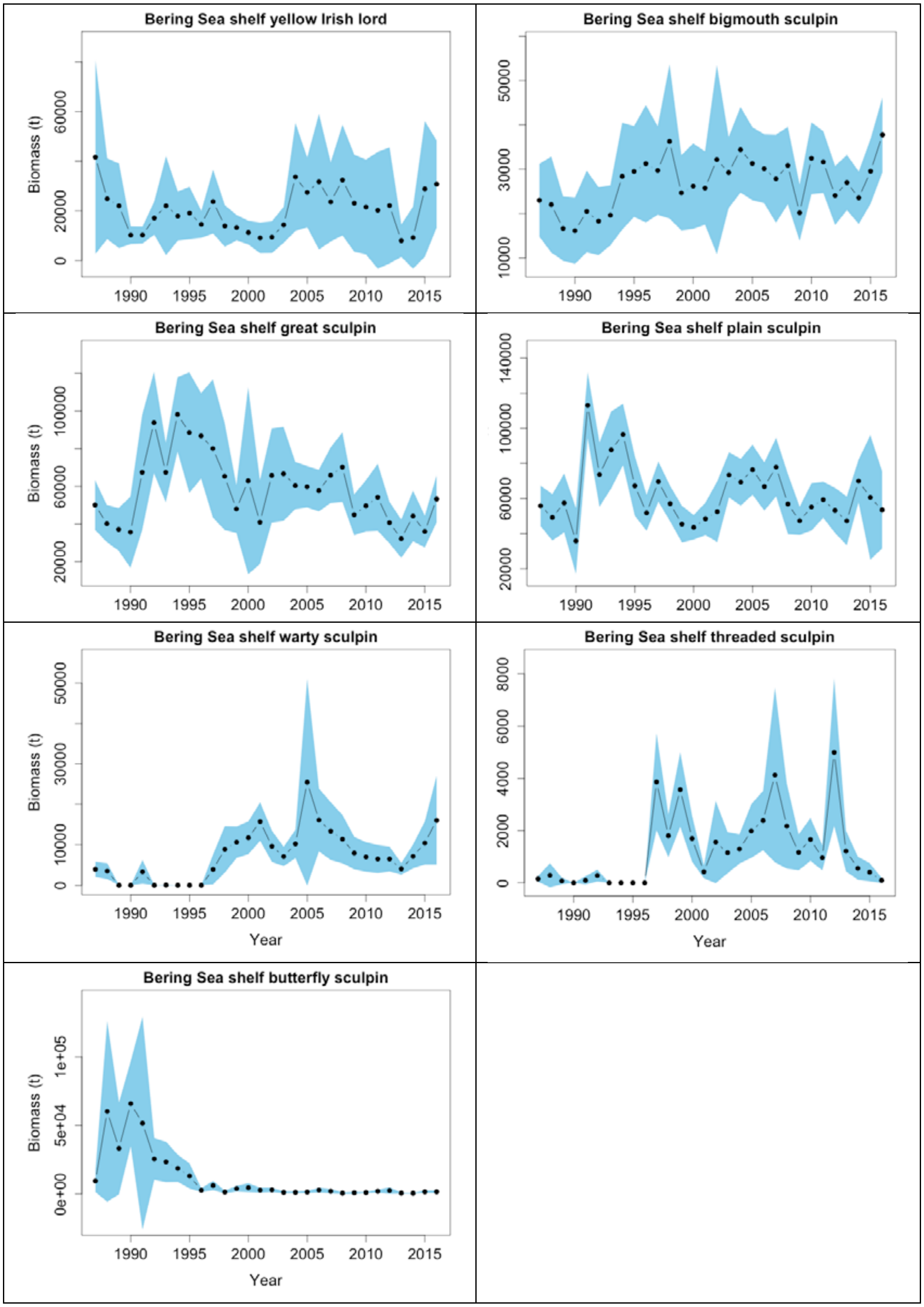

Figure 3. EBS shelf survey biomass estimates for the six most abundant sculpin species and butterfly sculpin, from annual EBS shelf bottom trawl surveys, 1982-2016. Shaded portion represents 95% confidence intervals for survey estimates of biomass.

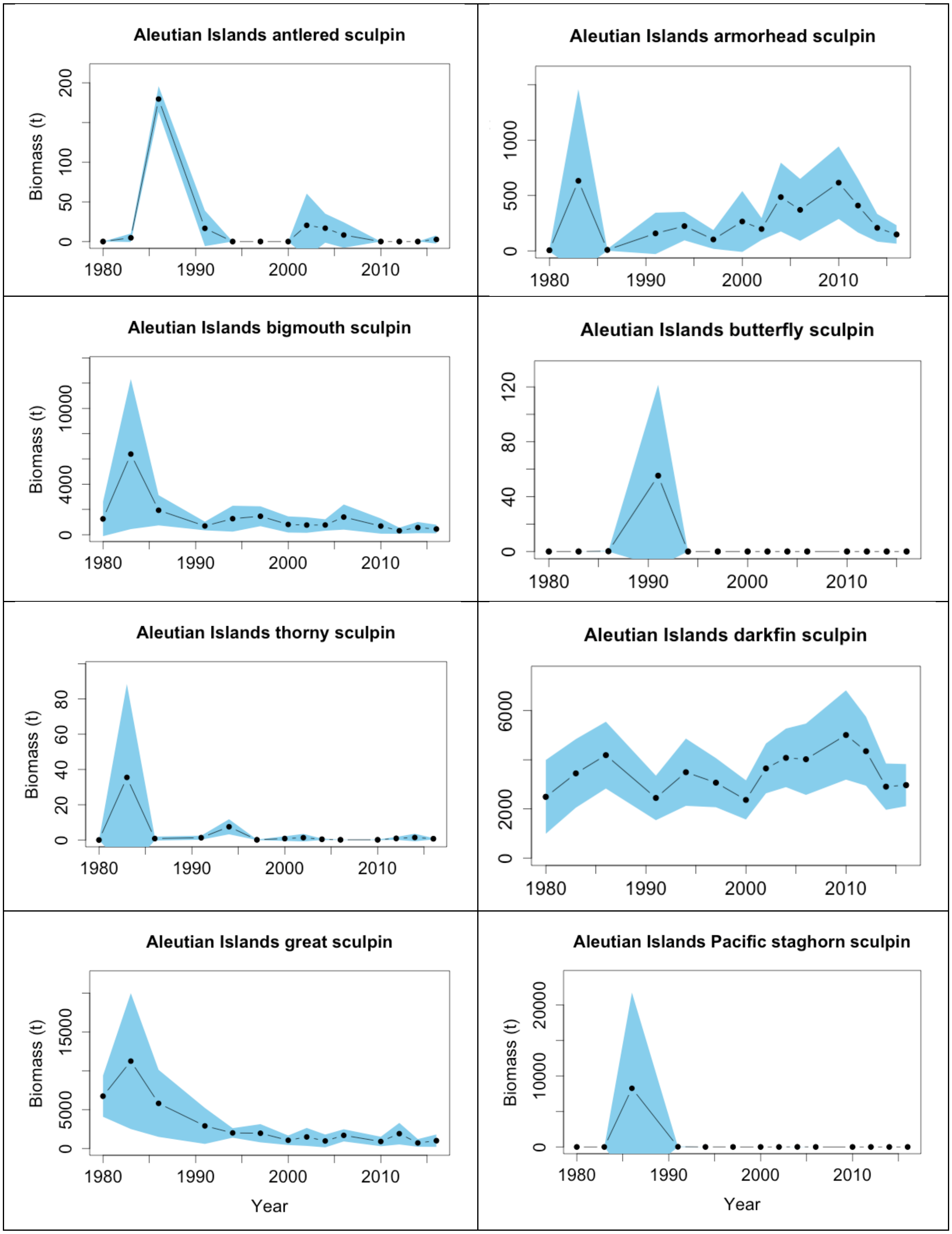

Figure 4. Aleutian Islands (AI) survey biomass estimates for all species observed, from AI trawl surveys 1980-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

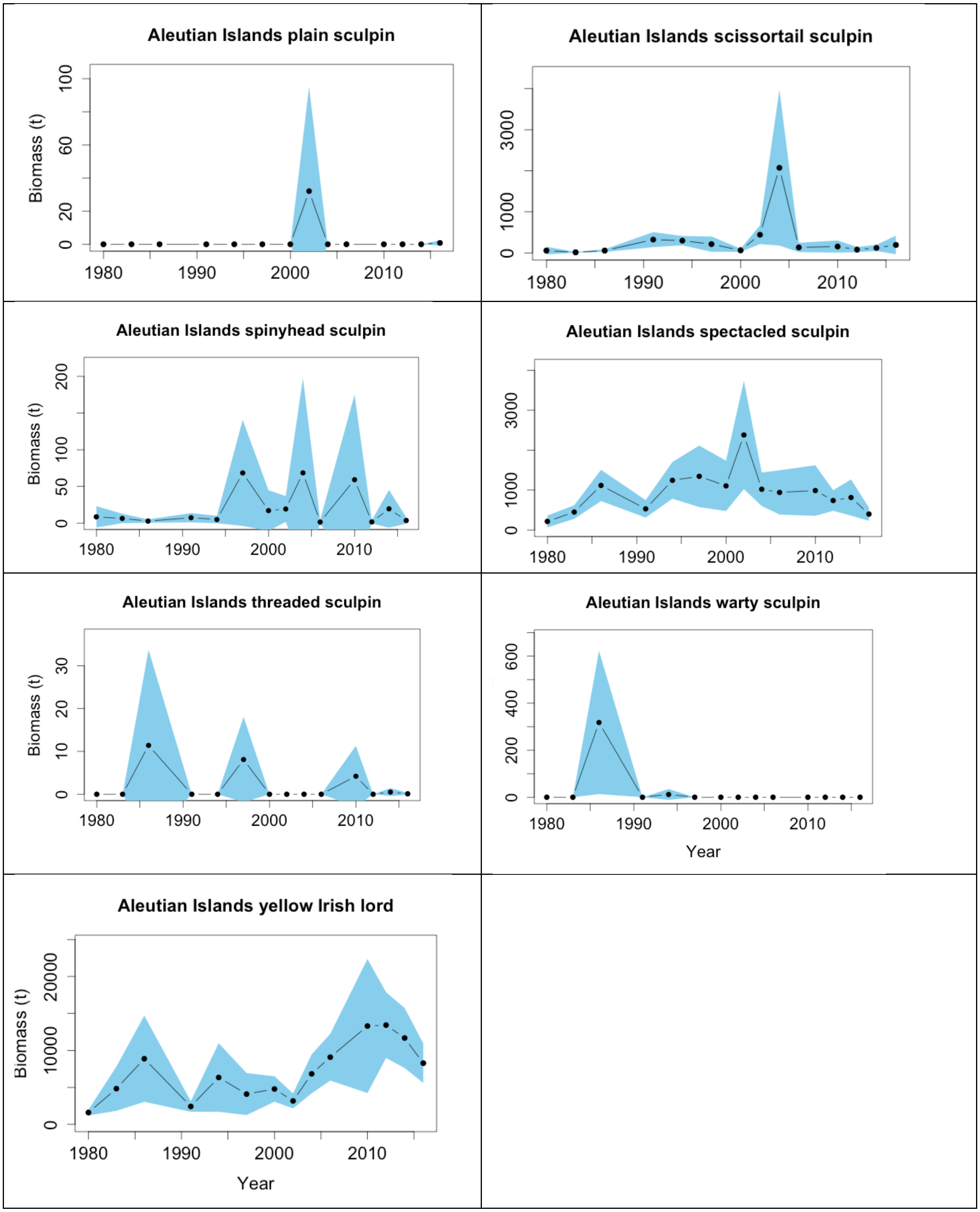

Figure 4 continued. Aleutian Islands (AI) survey biomass estimates for all species observed, from AI trawl surveys 1980-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

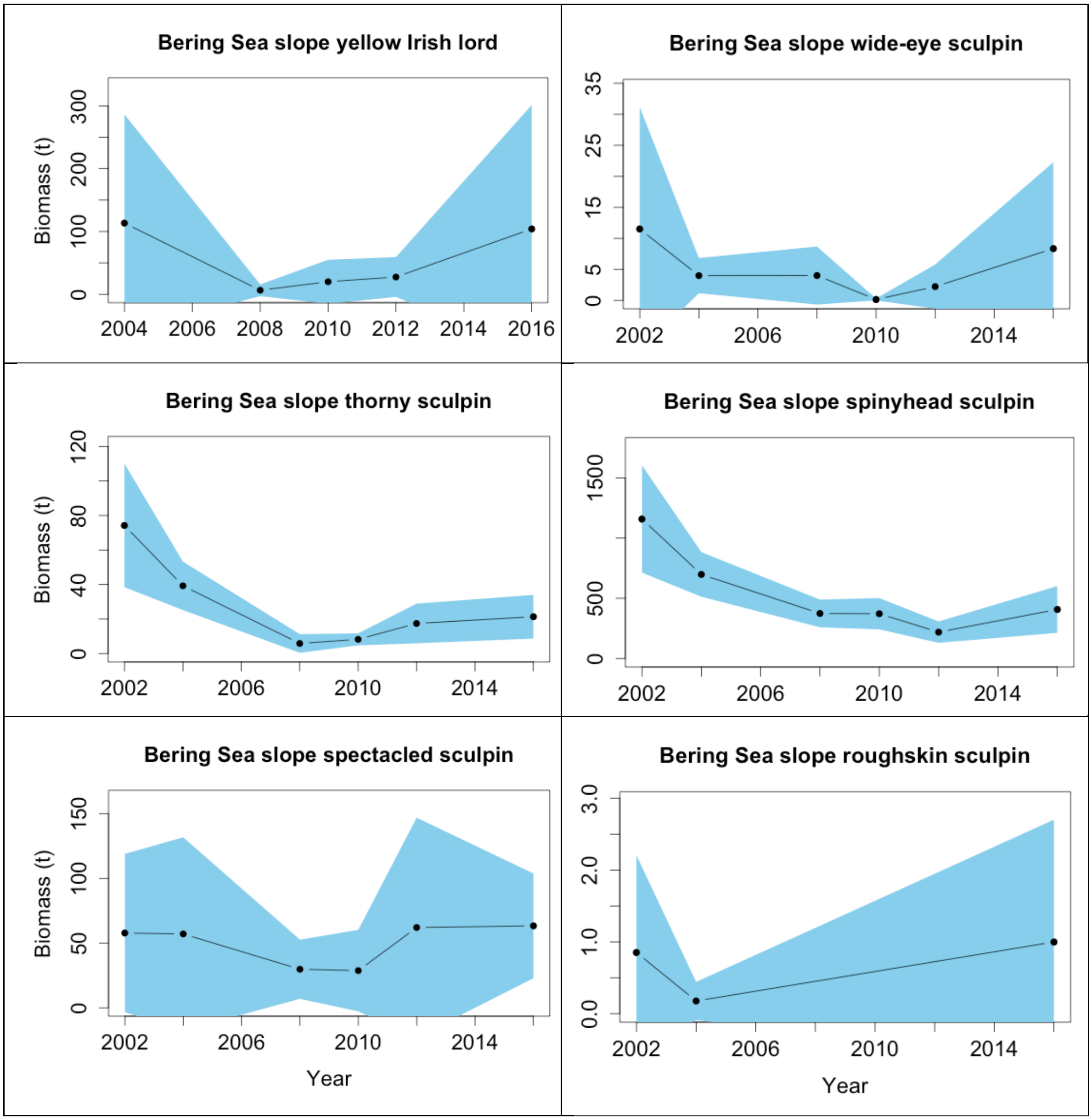

Figure 5. Bering sea slope survey biomass estimates for all sculpin species observed on slope trawl surveys 2002-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

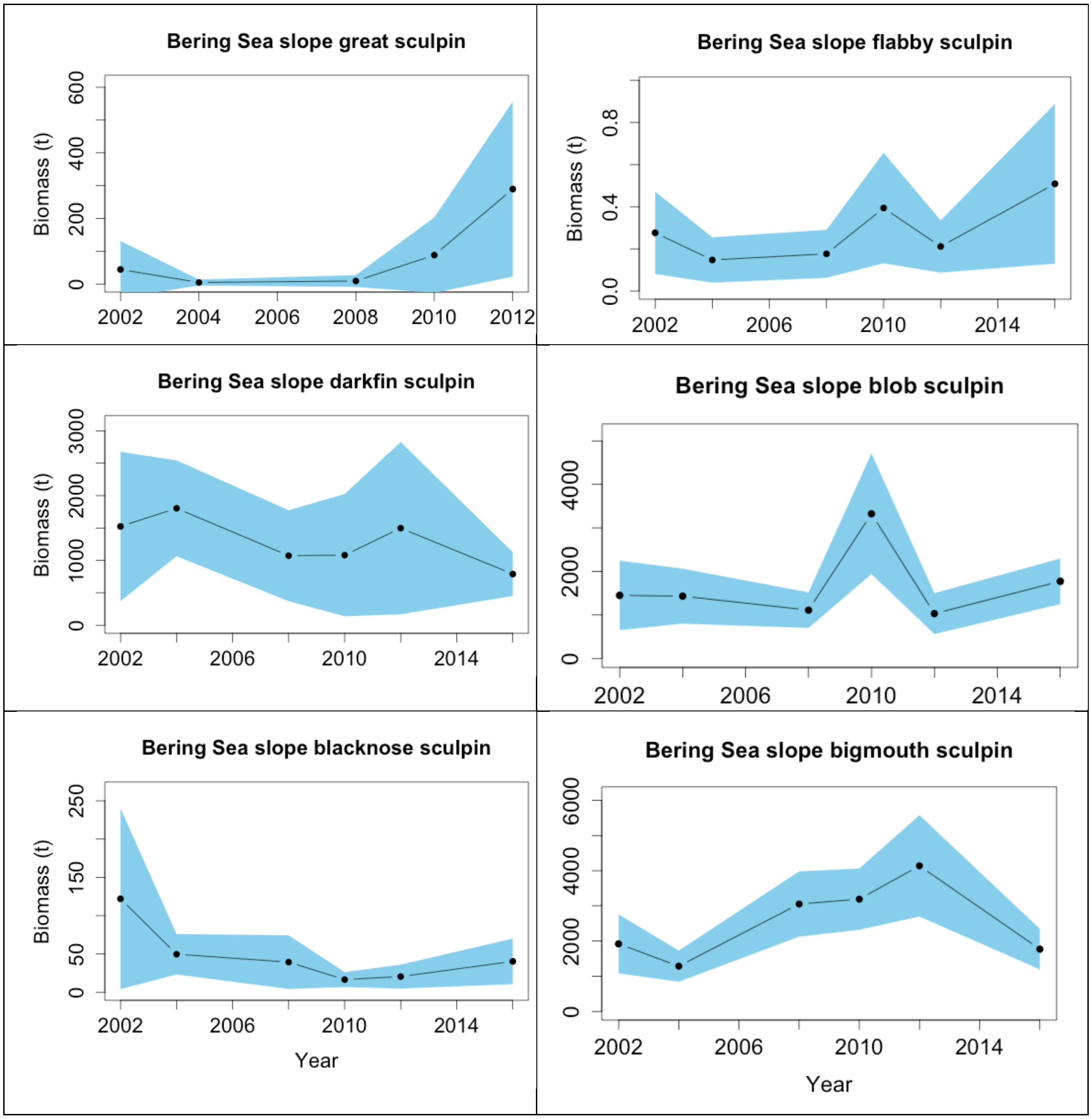

Figure 5 continued. Bering sea slope survey biomass estimates for all sculpin species observed on slope trawl surveys 2002-2016. The shaded portion represents 95% confidence intervals for survey estimates of biomass.

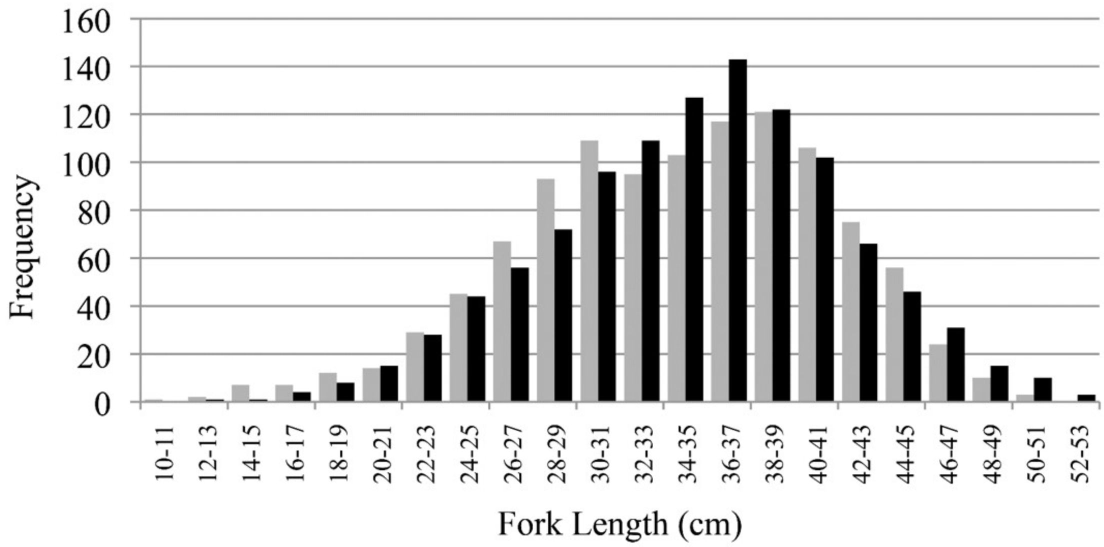

Figure 6. Length frequency distributions for Yellow Irish Lords (*Hemilepidotus jordani*) in the eastern Bering Sea (gray) and Aleutian Islands (black). (No significant differences observed).

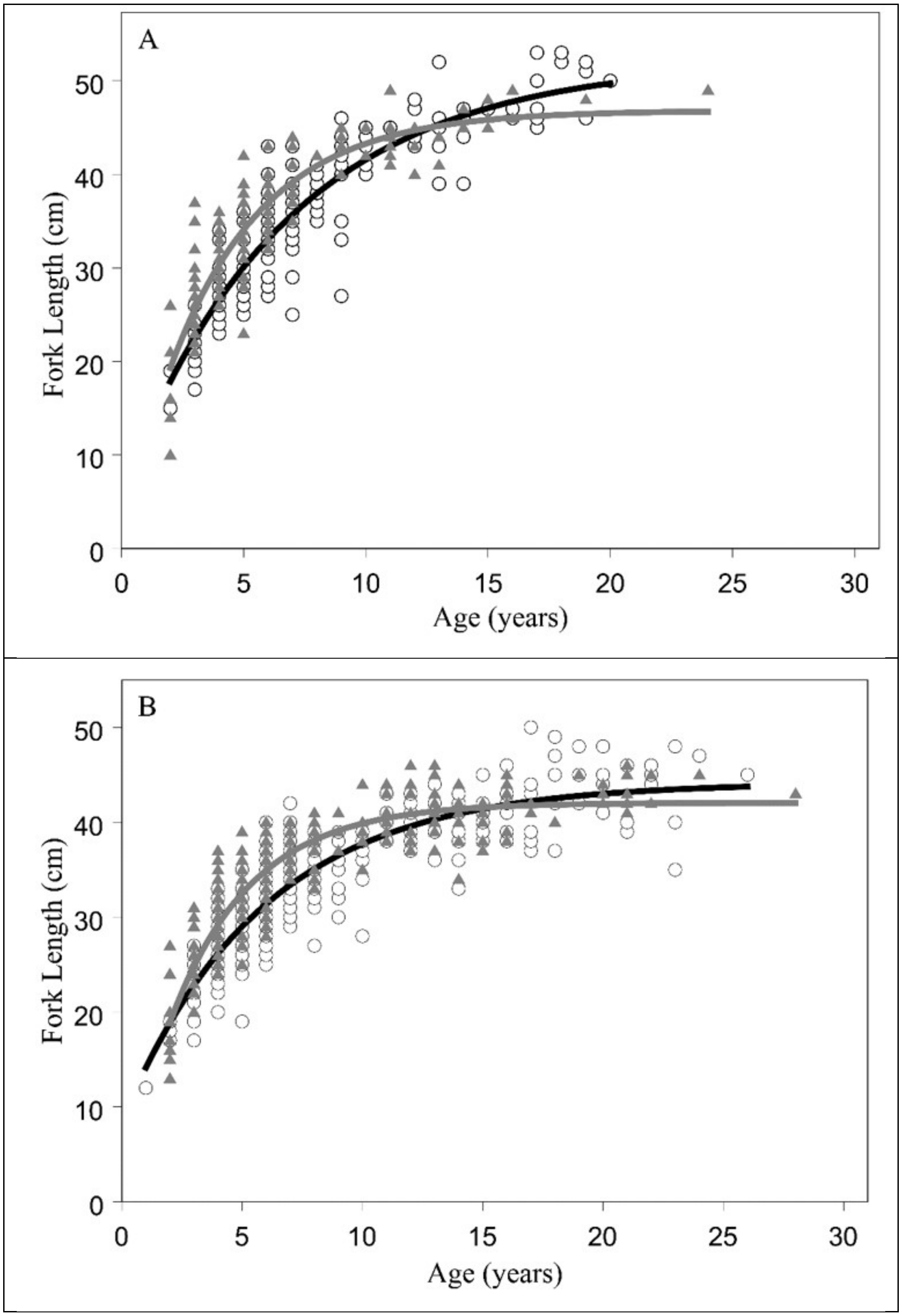

Figure 7. The von Bertalanffy growth models fitted to length-at-age data for (A) male and (B) female Yellow Irish Lords (*Hemilepidotus jordani*) in the eastern Bering Sea (triangles, gray lines) and the Aleutian Islands (circles, black lines).