19. Assessment of the sculpin stock complex in the Gulf of Alaska

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Executive Summary

Summary of Changes in Assessment Inputs

Sculpin catch and retention data from the Gulf of Alaska (GOA) fisheries from 2003-2014 have been updated and partial 2015 data (as of October 23, 2015) has been added.

The methodology has changed based on recommendations presented at the September 2015 Plan Team meeting. The random effects smoothing model has been recommended as the methodology for determining the complex biomass. The proportion of each species, as determined by separate model runs for each species used to determine biomass in the species complex, was recommended to determine the proportions for biomass-weighted natural mortality, when different species in a complex are subject to different natural mortality. The total biomass estimate is a sum of the 2015 estimated species-specific biomass from the random effects smoothing model.

Summary of Results

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2015	2016	2016	2017
M (natural mortality rate)[1]	0.222	0.222	0.21	0.21
Tier	5	5	5	5
Biomass (t)	33,550	33,550	34,943	34,943
F_{OFL}	0.222	0.222	0.21	0.21
$maxF_{ABC}$	0.166	0.166	0.15	0.15
F_{ABC}	0.166	0.166	0.15	0.15
OFL (t)	7,448	7,448	7,183	7,183
maxABC (t)	5,569	5,569	5,387	5,387
ABC (t)	5,569	5,569	5,387	5,387
Status	As determined *last* year for:		As determined *this* year for:	
	2013	2014	2014	2015
Overfishing		n/a		n/a

[1] *This is a biomass-weighted average of the estimated instantaneous natural mortality rates for the four most abundant sculpins in the GOA: bigmouth (Hemitripterus bolini), great (Myoxocephalus polyacanthocephalus), plain (Myoxocephalus jaok), and yellow Irish lord (Hemilepidotus jordani).*

Responses to SSC and Plan Team Comments on Assessments in General

The methodology in this assessment follows the recommendations of the September 2015 Plan Team meeting. They recommended that the random effects survey smoothing model be used as a default for determining current survey biomass, and guidance was given for this assessment as follows:

Tier 5 complex with different *F* among species.
With no missing (strata) area/depths:

a. Run random effects model for overall complex biomass. Optionally, the species complex biomass variance could be recomputed as if it were one species (at the tow level) for computing the observation error (e.g., design-based variance).
b. Run random effects model with complex level area-specific biomass to get estimates of biomass by area (B_a).
c. Run random effects model with area-specific biomass for each species (i) or combination of species that have the same F_{ABC}/OFL (e.g. species with the same M) and compute the proportion of estimated species biomass by area ($p_{i,a}$).
d. For apportionment, to obtain area-specific ABC/OFL, use $F_{i,ABC/OFL} \cdot p_{i,a} \cdot B_a$,summed across species (i).

Responses to SSC and Plan Team Comments Specific to this Assessment

Same as general comments.

Introduction

In this assessment, we mainly focus on large sculpin species from the genera *Myoxocephalus*, *Hemitripterus*, and *Hemilepidotus* which observers from the North Pacific Groundfish Observer Program currently identify to genus in commercial catches. These species have been identified to the species level since 2008. Biomass for this assessment is based on survey estimates of biomass for the four most abundant sculpins in the GOA: bigmouth (*Hemitripterus bolini*), great (*Myoxocephalus polyacanthocephalus*), plain (*Myoxocephalus jaok*), and yellow Irish lord (*Hemilepidotus jordani*).

Sculpins are a group of benthic-dwelling predatory teleost fishes that include 48 species in waters off the coast of Alaska. The four most common species have been identified in the AFSC GOA surveys since 1984. Forty-six species of sculpins have been listed as occurring in the Gulf of Alaska (Table 1), and 39 of these have been identified on NMFS GOA research surveys. Sculpins are broadly distributed throughout the shelf and slope regions of the Gulf of Alaska occupying all benthic habitats and depths.

Recent studies on the reproductive biology of the five most abundant sculpin species in the Eastern Bering Sea Shelf area have provided new information on sculpin life history in Alaska. Prior to those studies much of the reproductive biology information comes from studies in the western North Pacific. Most, if not all sculpins lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschmeyer 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 pollock, which are broadcast spawners with pelagic eggs. In the western Pacific, great

sculpins *Myoxocephalus polyacanthocephalus* are reported to have late ages at maturity (5-8 years, Tokranov, 1985) despite being relatively short-lived. Great sculpin length and age at 50% maturity was estimated at 57.2 cm and 6.9 years from data collected in 2006 and 2007 along the eastern Bering Sea shelf (TenBrink and Aydin 2009). The maximum age for great sculpin from this study was 17 years, a little higher than Tokranov (1985). Fecundity for the great sculpin off East Kamchatka waters ranged from 48,000 to 415,000 eggs (Tokranov, 1985). In contrast, preliminary information on reproduction for bigmouth sculpin (*Hemitripterus bolini*) in the Gulf of Alaska shows fecundity averaged 2283 eggs per female (Morgan Busby, AFSC, personal comm.). The diversity of sculpin species in the Gulf of Alaska suggests that each sculpin population might respond differently to environmental changes (whether natural or fishing induced). Within each sculpin species, observed spatial differences in fecundity, egg size, and other life history characteristics suggest local population structure (Tokranov, 1985).

Information such as depth range, distribution, and maximum length has been collected for several years for many species during research surveys. There is no GOA-specific age-and-growth or maturity data for sculpins identified in this management region. Known life history characteristics for selected sculpin species in the GOA are presented in Table 2. With the exception of data for bigmouth sculpins, all fecundity and maturity data in Table 2 are from outside the GOA region.

The Gulf of Alaska (GOA) sculpin complex has been managed as an independent complex with its own harvest specifications since 2010, when 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. Historically, sculpins were managed as part of the GOA Other Species complex, which also included sharks, skates, octopus and squid, and a single TAC was specified for the entire Other Species complex. Sculpins are currently a non-target species complex in the GOA, so sculpin catch depends solely on the TAC and spatial temporal limitations placed on target fisheries. Vulnerability analyses indicate that the individual species in the sculpin complex have a wide range of vulnerabilities to overfishing (largely as a result of differences in life history and thus productivity), which may suggest that two or more separate sculpin complexes could be considered. This non-target species complex is on a biennial assessment schedule to coincide with the frequency of trawl surveys in the Gulf of Alaska. The 2014 full assessment can be found at http://www.afsc.noaa.gov/REFM/Stocks/assessments.htm. Biomass and reference points are presented based on standard methods using data from the NMFS GOA trawl survey.

Fishery

There are no directed fisheries for sculpin species in the GOA at this time. Retained catch of sculpin species in the GOA has decreased recently from a mean of 15% from 2005-2012 to less than 2% on average since then (Table 3). Sculpins are caught incidentally by a wide variety of fisheries and several gear types (Table 4a). Based on data from the NMFS Alaska Regional Office (AKRO) the main gear type catching sculpins is the non-pelagic trawl (Table 4a), and the main fisheries that catch sculpins are flatfish, Pacific cod, and IFQ halibut (Table 4b). The majority of retained sculpins were taken on trawl catcher vessels targeting shallow water flatfish. With recent decreased demand for these flatfish and higher TACs for pollock and Pacific cod, the retained portion of sculpins in the catch has decreased (Tables 3 and 4b). It is unclear which sculpin species were commonly taken in GOA groundfish fisheries prior to 2004, because observers did not regularly identify animals in these groups to species.

In 2002-2003, the observer program of AFSC initiated a species identification project to address the need to gather basic population data for groups in the Other Species complex. Beginning in January 2008, sculpin catch was identified to genus for the larger sculpin species: *Hemilepidotus, Myoxocephalus, and Hemitripterus.* Several species of *Hemilepidotus* and *Myoxocephalus* have been identified from surveys. In Alaskan waters, *Hemitripterus* probably represents only one species, the bigmouth sculpin (Stevenson 2004). Another member of this genus, the sea raven (*H. villosus*), has never been identified in any of the GOA trawl surveys conducted by AFSC. Therefore, it is reasonable to assume that all sculpins identified by observers as *Hemitripterus* sculpins were bigmouth sculpins. The observed proportions of the four most abundant species (plain, bigmouth, and great sculpin, as well as yellow Irish lord) caught by commercial fishing operations do not differ significantly from the biomass estimated from RACE surveys (Table 5). The estimates of sculpin complex biomass in the GOA has remained relatively stable since 1984, and CVs range from 0.08-0.28 (Table 6). According to total catch figures for 1996-2015, the aforementioned large sculpin genera contributed the vast majority of all sculpin catch in the GOA region (Table 7).

The GOA catch of sculpins in 2014 was 1,187 t, and the 2015 catch through October 23, 2015 was 856 t. Catches have ranged from 583-1,966 t since 2005 (Table 3). The 2015 GOA biomass estimate for sculpins is 34,943 t, a slight increase from the 2013 estimate of 33,550 t. The complex weighted mortality decreased slightly from 0.222 to 0.21. This resulted in a small decrease in the 2015 recommended ABC and OFL. Catch has remained below the OFL for GOA sculpins, and the stock complex is not currently subject to overfishing.

Year	Biomass	OFL	ABC	TAC	Catch
2014	33,550	7,448	5,569	5,569	1,187
2015	34,943	7,448	5,569	5,569	856[1]
2016	34,943	7,183	5,387		
2017	34,943	7,183	5,387		

Data

Aggregate sculpin biomass estimates are derived from the GOA bottom trawl surveys. In the GOA, these aggregate data show no clear temporal trend, and should not be used as an indicator of population status for a complex with so much species diversity (Figure 1 and Table 6). Species-specific biomass estimates were available for only selected sculpin species for the period 1984-2015 due to difficulties with species identification and survey priorities. Approximately 97% of the sculpin biomass is comprised of the larger sculpin species in the GOA: great, plain, bigmouth sculpin, and yellow Irish lord (Table 7). Species-specific biomass estimates are available for these four species (Figure 2). Mean proportions in the survey indicate that yellow Irish lord is currently the most abundant (~62% of the sculpin biomass), followed by great sculpin at 23%, bigmouth sculpin at 13%, and plain sculpin at 2% (Figure 3). These proportions have changed since the 1984 GOA survey, in which the biomass of bigmouth sculpin was higher than that of yellow Irish lord (Figure 3). The biomass of bigmouth sculpin declined from 1984-1995 and as remained at approximately 5,000 t since that time (Figure 3). The coefficients of variation (CVs) for the survey biomass estimates of 7 out of 10 sculpin species are at or below 0.35, suggesting that the GOA survey is doing an adequate job assessing the biomass of the more abundant species (Table 7).

Length measurements (fork length, FL in mm) have been collected for a variety of sculpin species during AFSC surveys of Alaska. The four most abundant species from the GOA survey have been measured on every biennial survey since 2003: yellow Irish lord, plain sculpin,

great sculpin and bigmouth sculpin (Figure 4). These length compositions have remained fairly stable during this period. The surveys tend to catch bigmouth sculpins on the larger end of the length range, similar to the length observations of bigmouth from the eastern Bering Sea (EBS) shelf survey. Little information is known about bigmouth sculpin life history; this may suggest that the younger or smaller bigmouth sculpins occur in areas not sampled well by the surveys.

Analytic Approach

Model Structure

Sculpins in the GOA are managed under Tier 5, where OFL = *M* * average survey biomass and ABC = 0.75 * *M* * average survey biomass. Average biomass was calculated as the average of the last 4 GOA trawl survey estimates, and the proportion of each species is based on the average proportion from the last 4 surveys (Figure 3 and Table 9).

The methodology has changed based on recommendations presented at the September 2015 Plan Team meeting. The random effects smoothing model has been recommended as the methodology for determining the complex biomass. The proportion of each species, as determined by separate model runs for each species used to determine biomass in the species complex, is used to determine the proportions for biomass-weighted natural mortality, when different species in a complex are subject to different natural mortality. The total biomass estimate is a sum of the 2015 estimated species-specific biomass from the random effect smoothing model.

Parameter Estimates

In the past, harvest recommendations for GOA sculpins were made using an estimate of natural mortality (*M*) based on data from the western Bering Sea (Rikhter and Efanov, 1976). In 2008, life history studies of sculpins in the eastern Bering Sea and Aleutian Islands were completed and the results of those studies are now used to make harvest recommendations for sculpins in the BSAI (Table 8; Ormseth and TenBrink 2009. In 2009, the BSAI Plan Team recommended that *M* values based on age-based catch-curve analysis be used wherever possible. In addition, separate ABC and OFL calculations were made for each species for which recent estimates of *M* were available, and the individual values were aggregated to create sculpin complex harvest recommendations. In effect, this means that for the BSAI, a weighted average of species-specific *M*'s is applied to the aggregate sculpin biomass, with the proportional average biomass of each species providing the weights.

Results

Harvest recommendations

Recent estimates of *M* are available for four of the sculpin species in the GOA sculpin complex: yellow Irish lord, great sculpin, bigmouth sculpin, and plain sculpin (Table 8). Together, these 4 species comprise 97% of the estimated GOA sculpin biomass in 2015 (Table 7). A biomass-weighted average *M* was calculated according Table 9.

The weighted average M of 0.205 (rounded to 0.21) was used to make the following harvest recommendations. The recommended F_{ABC} was calculated as 0.75*0.205=0.15.

2016-2017 harvest recommendations for the GOA sculpin complex	
sculpin complex biomass	34,943
complex *M*	0.21
F_{OFL}	0.21
maximum permissible F_{ABC}	0.15
recommended F_{ABC}	0.15
OFL	7,183
maximum permissible ABC	5,387
recommended ABC	5,387

Ecosystem Considerations

Ecosystem Effects on the Stock

Little is known about sculpin food habits in the GOA, especially during fall and winter months. Limited information indicates that in the GOA, the larger sculpin species prey on shrimp and other benthic invertebrates, as well as some juvenile walleye pollock (Figure 5). In the GOA the main predator of large sculpins are Pacific halibut, pinnipeds, small demersal fish and sablefish (Figure 5). Other sculpins in the GOA feed mainly on shrimp and benthic crustaceans (Figure 6). Other sculpins are mainly preyed upon by Pacific cod which is the main source of mortality (Figure 6). The source of above information is from Aydin et al. (2007).

Fishery Effects on the Ecosystem

The analyses of ecosystem considerations for those fisheries that affect the species within this complex (see Table 4) are given in the respective target fisheries SAFE chapters. The GOA 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 target 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 affect	Probably no concern
a. Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	No affect	Probably no concern
Birds	Stable, some increasing some decreasing	No affect	Probably no concern
Fish (Pollock, Pacific cod, halibut)	Stable to increasing	Affects not known	Probably no concern
b. Changes in habitat quality			
Temperature regime	None	Affects not known	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

Data gaps exist in sculpin species life history characteristics, spatial distribution and abundance in Alaskan waters, especially in the GOA. Most importantly no data on maximum age or natural mortality exists for the four main sculpin species in the GOA. Therefore, collections for age data on yellow Irish lord, great sculpin, bigmouth sculpin and plain sculpin are needed from this region. Collecting seasonal food habits data (with additional summer collections) would help to clarify the role of both large and small sculpin species within the GOA ecosystem. These data are necessary to improve management strategies for non-target species.

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Tables

Table 1. Sculpin species observed in the Gulf of Alaska.

Family	Scientific name	Common name
Cottidae	*Artediellus pacificus*	Pacific hookear sculpin
	Artedius lateralis	Smoothhead sculpin
	Bolinia euryptera	Broadfin sculpin
	Enophyrs bison	Buffalo sculpin
	Enophrys diceraus	Antlered sculpin
	Gymnocanthus galeatus	Armorhead sculpin
	Gymnocanthus pistilliger	Threaded sculpin
	Hemilepidotus hemilepidotus	Red Irish Lord
	Hemilepidotus jordani	Yellow Irish Lord
	Hemilepidotus papilio	Butterfly sculpin
	Hemilepidotus spinosus	Brown Irish lord
	Hemilepidotus zapus	Longfin Irish lord
	Icelinus borealis	Northern sculpin
	Icelinus burchami	Dusky sculpin
	Icelinus filamentosus	Threadfin sculpin
	Icelinus tenuis	Spotfin sculpin
	Icelus spatula	Spatulate sculpin
	Icelus spiniger	Thorny sculpin
	Icelus uncinalis	Uncinate sculpin
	Jordania zonope	Longfin sculpin
	Leptocottus armatus	Pacific staghorn sculpin
	Microcottus sellaris	Brightbelly sculpin
	Myoxocephalus jaok	Plain sculpin
	Myoxocephalus polyacanthocephalus	Great sculpin
	Myoxocephalus verrucocus	Warty sculpin
	Paricelinus hopliticus	Thornback sculpin
	Radulinus asprellus	Slim sculpin
	Rastrinus scutiger	Roughskin sculpin
	Thecopterus aleuticus	Whitetail 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
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 GOA sculpin species. "O" designates data was obtained from individuals of that species outside the GOA region.

Species	common name	maximum length (cm)		maximum age		fecundity (x1000)	age at 50% maturity
		O	GOA	O	GOA		
Myoxocephalus joak	plain	75	59	16		25.4 - 147	5 - 8
M. polyacanthocephalus	great	82	72	17		48 - 415	6.9
M. verrucosus	warty	78		18		2.7	
Hemitripterus bolini	bigmouth	83	86	23		2.3	
Hemilepidotus jordani	yellow Irish lord	65	50	30		54-389	6 - 7
H. papilio	butterfly	38					
G. pistilliger	threaded	27		13		5 - 41	
G. galeatus	armorhead	46	28	13		12 - 48	
Dasycottus setiger	spinyhead	45	22	11			
Icelus spiniger	thorny	17					
Triglops pingeli	ribbed	20		6		1.8	
T. forficate	scissortail	30	28	6		1.7	
T. scepticus	spectacled	25		8		3.1	

References: AFSC; Panchenko 2002; Tokranov 1985; Andriyashev 1954; Tokranov 1988; Tokranov 1995; Tokranov and Orlov 2001; Busby, AFSC, personal comm. TenBrink and Buckley 2012.

Table 3. GOA total sculpin complex catch, retention rate, total Other Species catch (sculpin, sharks, skates, octopus and squid), and sculpin percentage of Other Species catch, 1997-2015. *Source: Other species total catch: AKRO Catch Accounting System, retention rate: estimated from fishery observer data obtained from the AFSC Fishery Monitoring and Analysis program, Sculpin complex total catch: AKFIN data base.*

Year	Sculpin complex total catch	retention rate	Other species total catch	Percent of Other Species catch
1997	898		4,823	19%
1998	526		7,422	7%
1999	544		3,788	14%
2000	940		5,455	17%
2001	587		3,383	17%
2002	919		8,162	11%
2003	629	7%	6,266	10%
2004+	701	9%	1,705	41%
2005	626	16%	2,513	25%
2006	583	16%	3,881	15%
2007	960	19%	3,035	32%
2008	1,925	14%	2,967	65%
2009	1,374	18%	3,188	43%
2010	911	12%	1,866	49%
2011	763	10%	1,678	45%
2012	795	13%		
2013	1,966	1%		
2014	1,187	3%		
2015*	856	1%		

+ Beginning in 2004, skates were removed from Other Species complex.

* As of October 23, 2015.

Table 4a. Total catch (t) of all sculpins by target fishery in the Gulf of Alaska, 2011-2015 by gear type (NPT: non-pelagic trawl, PTR: pelagic trawl, HAL: hook and line, POT: pot). *Source: AKFIN database. * 2015 catch data are incomplete; retrieved October 23, 2015.*

Aleutian Islands	**Gear Type**				
Target fishery	**NPT**	**PTR**	**HAL**	**POT**	**Total**
arrowtooth flounder	307	0	0	0	307
Atka mackerel	3	0	0	0	3
deep flatfish	1	0	0	0	1
flathead sole	22	0	0	0	22
IFQ halibut	0	0	1343	0	1343
other target	14	0	0	0	14
Pacific cod	503	0	842	989	2334
rex sole	28	0	0	0	28
rockfish	240	0	0	0	240
sablefish	2	0	63	0	65
shallow flatfish	1053	0	0	0	1053
walleye pollock	135	21	0	0	156
Total	**2308**	**21**	**2248**	**989**	**5566**

Table 4b. Total catch (t) of all sculpins by target fishery in the Gulf of Alaska, 2003-2015. *Source: AKFIN database. * 2015 catch data are incomplete; retrieved October 23, 2015.*

	Gulf of Alaska												
Target fishery	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015 ***
arrowtooth flounder	16	7	19	36	38	16	16	27	69	21	52	148	16
Atka mackerel	0	0	0	0	0	0	0	0	0	0	3	0	0
deep flatfish	2	2	0	0	0	0	0	0	1	0	0	0	0
flathead sole	4	10	3	1	0	16	3	5	14	5	3	0	1
IFQ halibut	45	41	29	13	31	134	165	53	84	0	934	162	162
other target	6	0	0	0	0	0	11	0	12	2	0	0	0
Pacific cod	381	430	320	361	442	740	556	591	342	449	478	541	523
rex sole	27	19	11	7	8	4	31	11	3	11	9	1	4
rockfish	24	58	27	32	31	23	35	62	39	55	70	33	43
sablefish	1	2	16	4	7	2	20	1	3	5	41	6	10
shallow flatfish	113	129	200	125	376	959	515	155	143	227	358	252	74
walleye pollock	1	0	0	2	22	15	5	6	53	20	17	43	22
Total catch (mt)	**620**	**698**	**625**	**581**	**955**	**1909**	**1357**	**911**	**763**	**795**	**1965**	**1186**	**855**

Table 5. Estimated species composition of GOA incidental sculpin catches, 2011, 2013, 2015, based on fishery observer data and RACE survey data. *Source: AKFIN database and RACEBASE survey database.*

	Proportion of catch (fishery)			Biomass proportion (survey)		
	2011	**2013**	**2015**	**2011**	**2013**	**2015**
Bigmouth sculpin	0.07	0.11	0.09	0.12	0.12	0.11
Great sculpin	0.22	0.18	0.24	0.27	0.19	0.21
Plain sculpin	0.01	0.00	0.03	0.10	0.09	0.01
Yellow Irish lord	0.69	0.69	0.63	0.51	0.60	0.67

Table 6. Sculpin complex biomass estimates (t) based on NMFS bottom-trawl surveys, 1984-2015.

year	biomass (t)	CV
1984	40,954	0.08
1987	31,328	0.11
1990	25,556	0.18
1993	25,371	0.12
1996	31,313	0.26
1999	30,783	0.11
2001	30,418	0.28
2003	26,514	0.09
2005	33,519	0.09
2007	32,468	0.11
2009	40,559	0.11
2011	31,668	0.09
2013	33,962	0.11
2015	45,012	0.16

Table 7. GOA trawl survey biomass estimates (t) for individual sculpin species, 1996-2011, with 2011 CV. *Source: AKFIN database.*

species	biomass (t)							
	1996	**1999**	**2001***	**2003**	**2005**	**2007**	**2009**	**2011**
crested	-	-	6	-	-	-	-	-
spinyhead	278	271	690	608	463	422	410	410
antlered	-	-	1	-	-	-	-	-
armorhead	13	15	60	78	28	58	216	17
threaded yellow	3	-	21	<1	2	-	2	-
Irish lord	17,804	20,255	20,945	12,064	15,952	15,720	25,219	15,771
butterfly	<1	1	-	-	-	-	-	-
bigmouth	4,246	3,983	3,471	5,767	5,543	3,126	3,154	3,154
thorny	1	-	1	<1	<1	<1	<1	<1
Pacific staghorn	-	1	2	-	14	-	8	7
darkfin	477	371	335	607	944	790	614	412
plain	1,015	1,692	932	1,220	3,912	4,456	2,562	3,160
great	7,326	3,913	3,540	6,037	6,574	7,734	8,215	8,354
warty	-	-	339	-	-	33	-	-
scissortail	60	47	62	94	23	30	111	21
spectacled	90	233	12	40	105	96	68	104
total	**31,313**	**30,782**	**30,417**	**26,515**	**33,560**	**32,468**	**40,559**	**31,668**

species	biomass (t)		CV
	2013	**2015**	**2015**
crested	-	-	-
spinyhead	447	595	0.14
antlered	-	-	-
armorhead	67	90	0.27
threaded yellow	-	14	0.70
Irish lord	19,841	29,519	0.23
butterfly	-	-	-
bigmouth	3,947	4,778	0.18
thorny	1	-	-
Pacific staghorn	-	3	0.92
darkfin	258	358	0.24
plain	3,036	506	0.36
great	6,282	9,012	0.16
warty	39	-	-
scissortail	35	45	0.39
spectacled	9	92	0.55
total	**33,962**	**45,012**	**0.16**

* The 2001 trawl survey did not cover the eastern GOA, so those numbers are not directly comparable.

Table 8. List of available natural mortality information for sculpins. Values are from Ormseth and TenBrink 2009.

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	0.15	0.47	0.51	0.17	
	AI	M	0.21	0.23	0.27	0.17	
	AI	F	0.16	0.27	0.31	0.17	
great sculpin	EBS	M	0.28	0.39	0.43	0.25	0.28
	EBS	F	0.25	0.27	0.3	0.31	
bigmouth sculpin	EBS	both	0.21	0.21	0.24	n/a	0.21
plain sculpin	EBS	M	0.28	0.38	0.42	0.39	0.4
	EBS	F	0.26	0.27	0.55	0.41	

Table 9. Estimated biomass for the four most abundant sculpin species in the GOA (yellow Irish lord, great, bigmouth, and plain sculpins), the proportion of total biomass, and the weighted contribution to *M*.

species	estimated biomass	proportion of total biomass	*M*	weighted contribution to *M*	weighted average *M*
yellow Irish lord	21,614	0.62	0.17	0.11	
great	8,113	0.23	0.28	0.07	
bigmouth	4,469	0.13	0.21	0.03	
plain	747	0.02	0.40	0.01	
	34,943				0.21

Figures

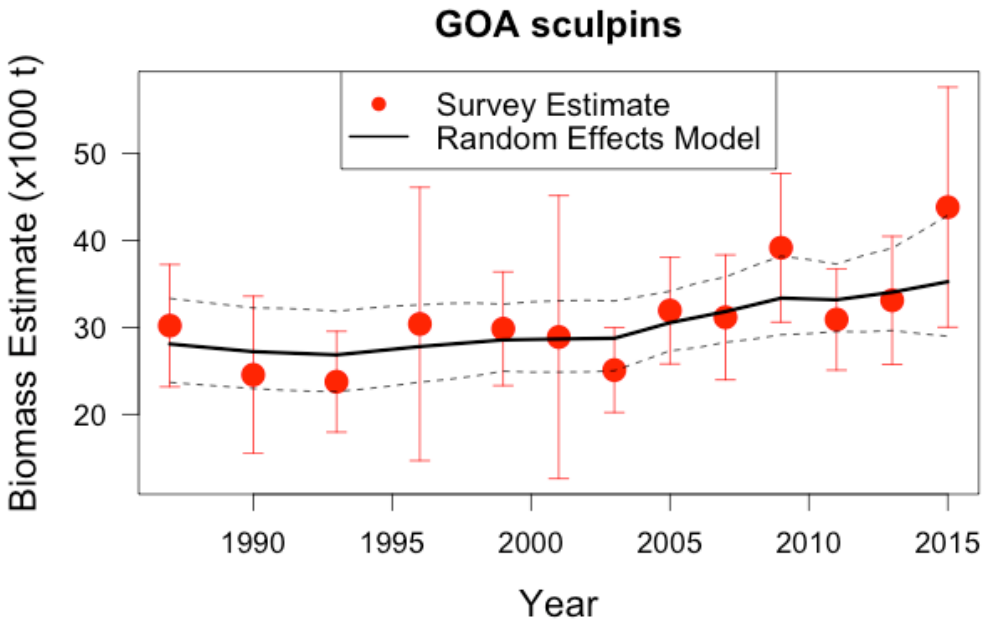


Figure 1. GOA sculpin complex biomass estimate (x1,000 t), derived from the sum of the biomass estimates for bigmouth, plain, great sculpin, and yellow Irish lord (solid black line). The 95% confidence intervals are shown as dotted lines, and the red circles and error bars indicate survey estimates and respective survey 95% confidence intervals.

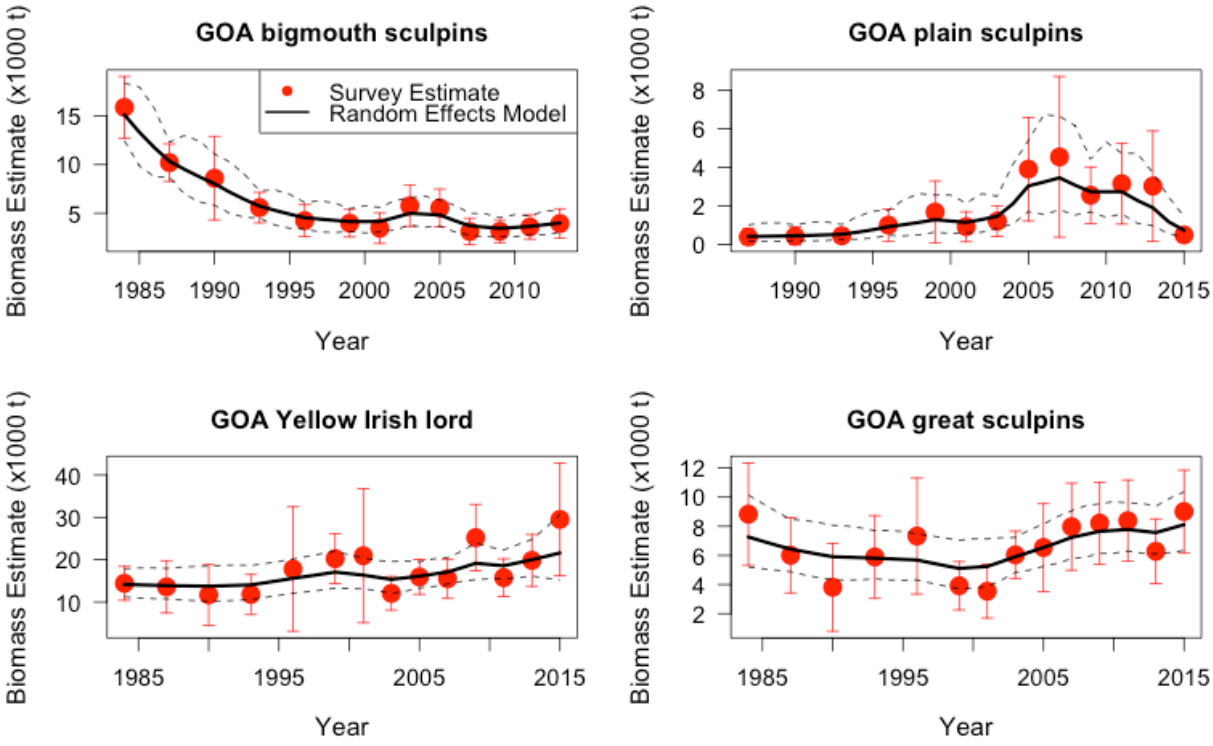


Figure 2. GOA sculpin biomass estimates (x1,000 t) for the four most abundant sculpin species, bigmouth, plain, great sculpin, and yellow Irish lord (solid black lines). The 95% confidence

intervals are shown as dotted lines, and the red circles and error bars indicate survey estimates and respective survey 95% confidence intervals.

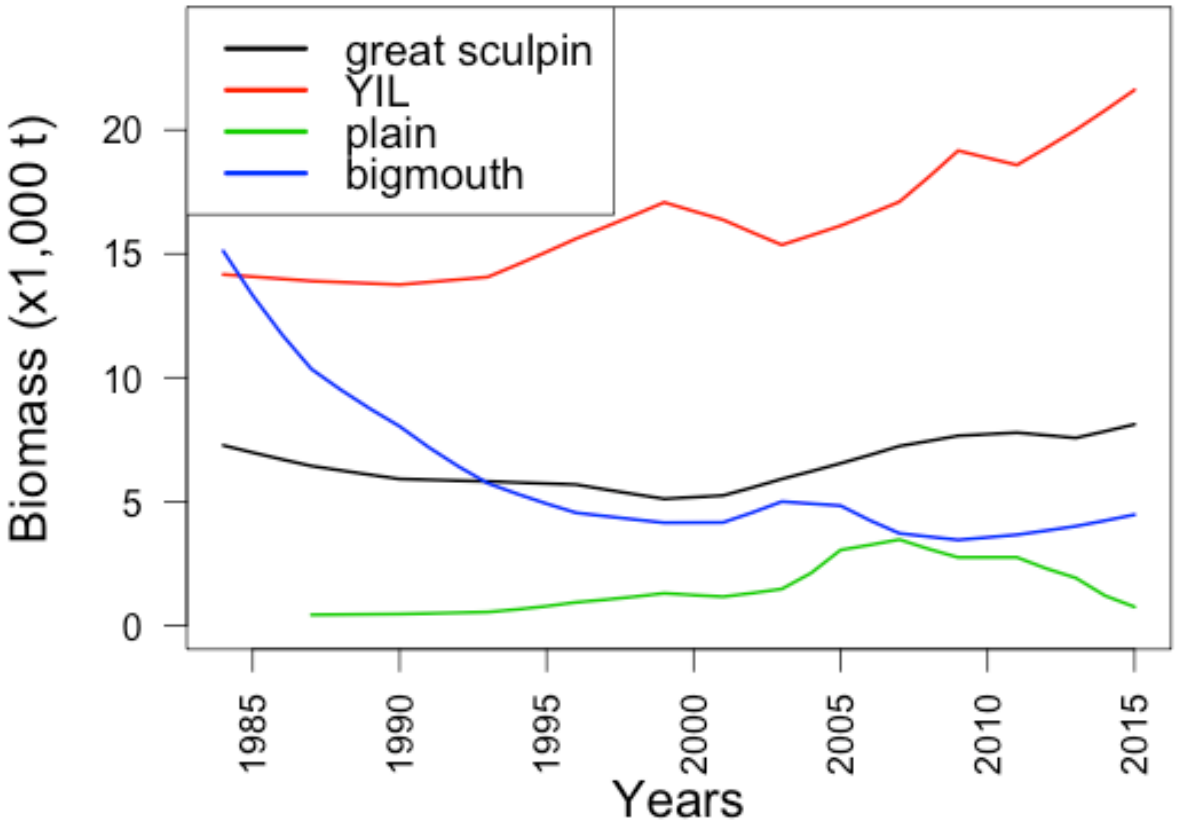


Figure 3. Biomass (x1,000 t) of the four most abundant sculpin species in the GOA, great sculpin, yellow Irish lord (YIL), plain sculpin, and bigmouth sculpin from 1984-2015.

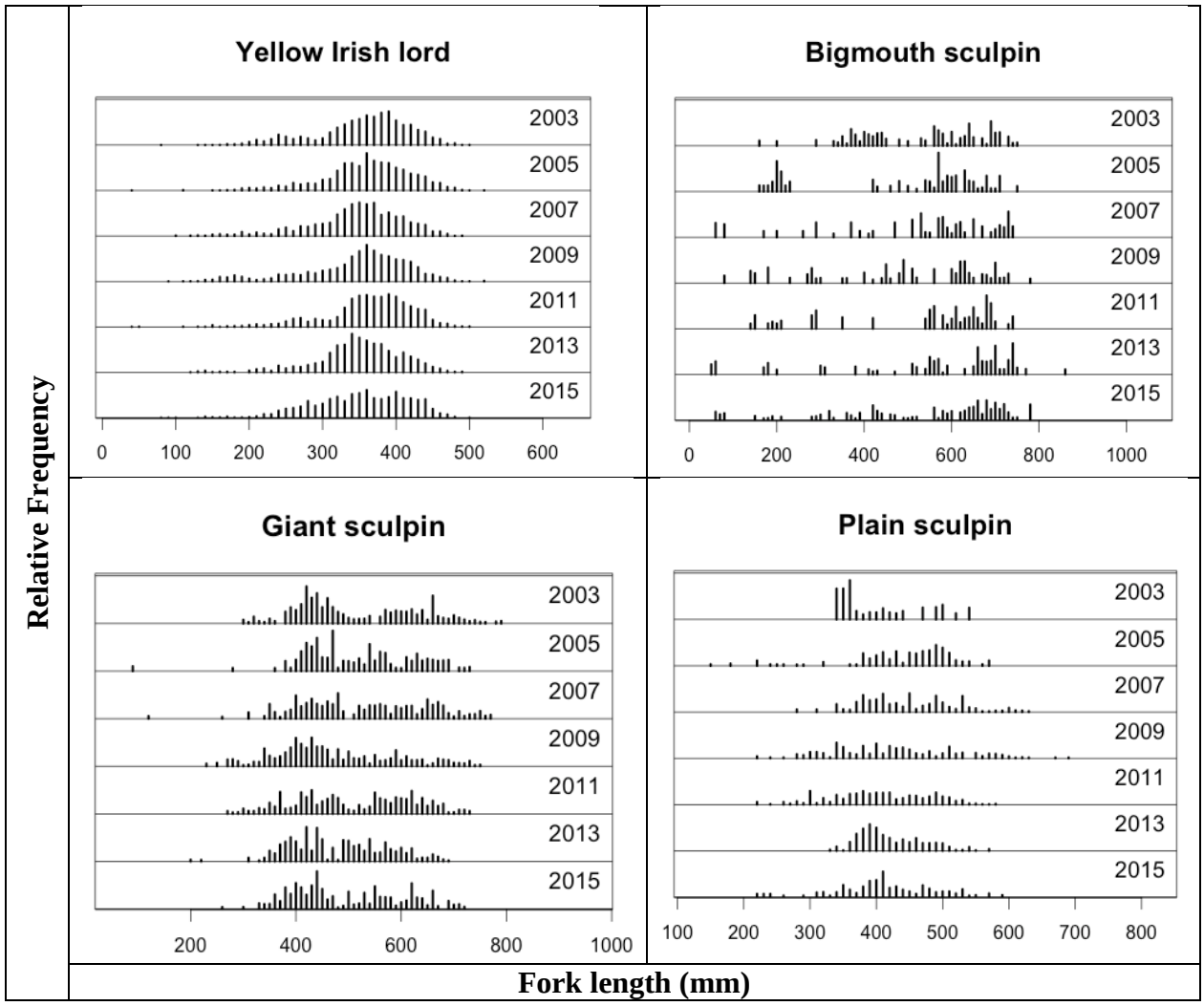
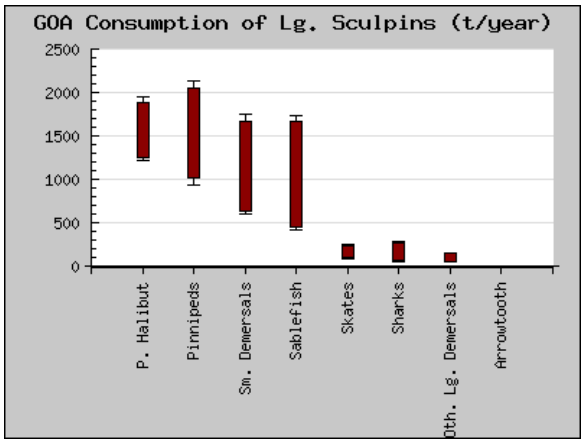
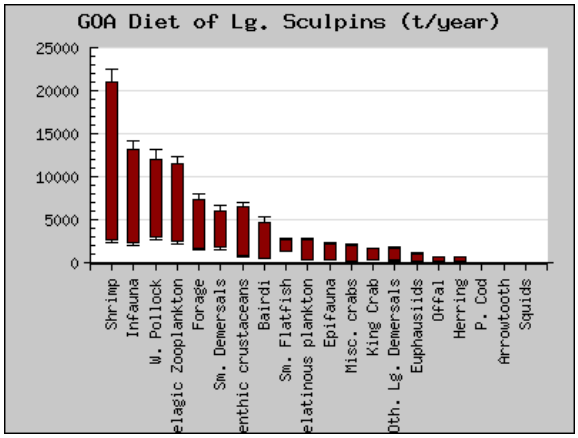


Figure 4. Length composition (fork length, FL in mm) from survey data for the 4 most abundant sculpin species in the GOA, 2003-2015.





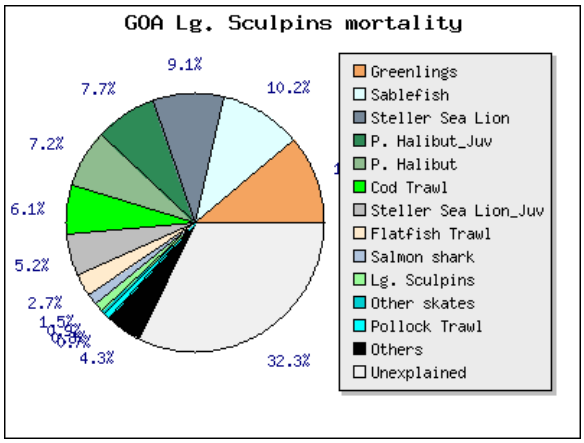
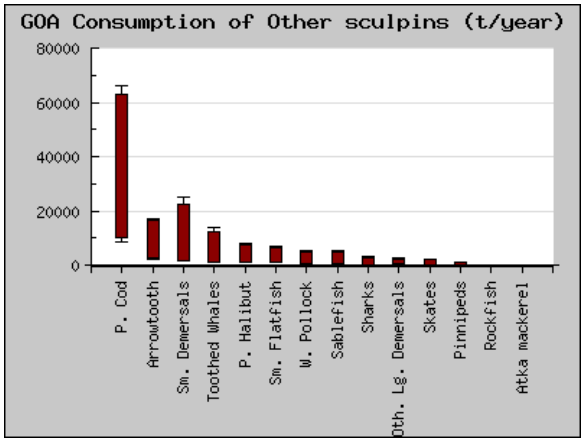
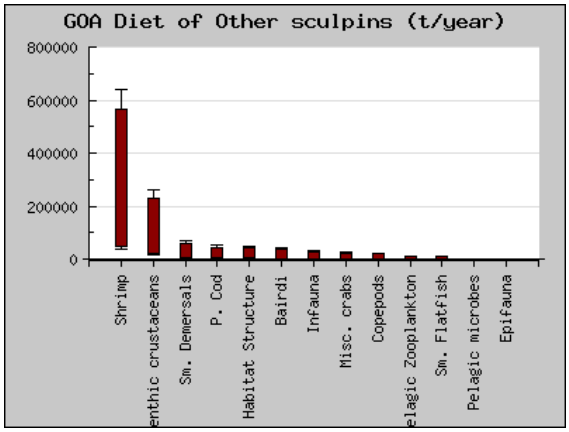


Figure 5. Diet, consumption and mortality information for large sculpins in the GOA.





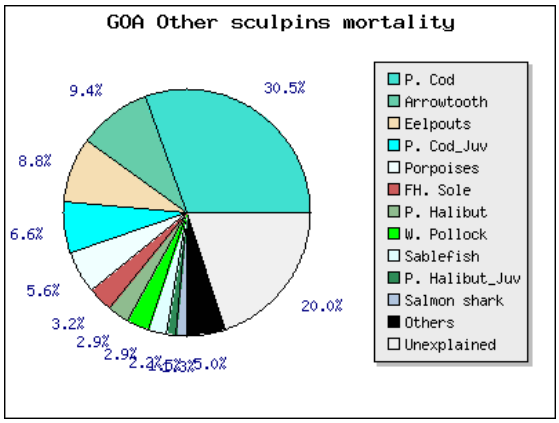


Figure 6. Diet, consumption and mortality information for other sculpins in the GOA.

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