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

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

Executive Summary

Summary of Changes in Assessment Inputs

Changes in the input data:

1) Biomass estimates from the 2017 Gulf of Alaska (GOA) survey were added to the time series used in this assessment.
2) Complete catch is included for 2016 and 2015, as well as partial catch for 2017 (through October 25, 2017).

Changes in the assessment methodology:
The methodology has not changed since the last full assessment.

Summary of Results

The estimated 2018 total sculpin complex biomass in the GOA is 33,134 t. This represents a small decrease from the last full assessment in 2015. The recommended 2018 and 2019 ABC is 5,301 t based on an F_{ABC}=0.16 and the 2018 and 2019 overfishing level is 6,958 t based on an F_{OFL}=0.21.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2017	2018	2018	2019
M (natural mortality rate)[1]	0.21	0.21	0.21	0.21
Tier	5	5	5	5
Biomass (t)	34,943	34,943	33,134	33,134
F_{OFL}	0.21	0.21	0.21	0.21
$maxF_{ABC}$	0.16	0.16	0.16	0.16
F_{ABC}	0.16	0.16	0.16	0.16
OFL (t)	7,338	7,338	6,958	6,958
maxABC (t)	5,591	5,591	5,301	5,301
ABC (t)	5,591	5,591	5,301	5,301
	As determined *last* year for:		As determined *this* year for:	
Status	2015	2016	2016	2017
Overfishing	No	n/a	No	n/a

[1] *This is a sculpin complex average mortality rate, a biomass-weighted average of the 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).*

Area apportionment

GOA sculpins are managed with a single total allowable catch (TAC) for the entire Gulf of Alaska region; there is no area apportionment.

Responses to SSC and Plan Team Comments on Assessments in General

None.

Responses to SSC and Plan Team Comments Specific to this Assessment

November 2015 Plan Team

1. Calculate OFL/ABC for species as product of species-specific *M* and biomass.
   Author's response: This was done in the current assessment. It works out to be the same as the weighted *M* method, in the absence of rounding error. More rounding error occurs in calculating the weighted average *M* so species-specific *M* is preferable to reduce rounding error. In the following example, if X represents the biomass of species 1 and Y the biomass of species 2, and M_1 and M_2 are the natural mortalities of the two species, respectively, then multiplying species specific natural morality and summing the result provides:

   $$XM_1 = M_1X$$
   $$YM_2 = M_2Y$$
   $$OFL = XM_1 + YM_2.$$

   If a weighted average *M* is applied to both species and summed, the same result is achieved:

   $$OFL = X(\frac{x}{x+y})M_1 + Y(\frac{y}{x+y})M_2 = X + Y(\frac{XM_1 + YM_2}{X+Y}) = XM_1 + YM_2.$$

2. Apply average *M* to "other sculpins".
   Author's response: This was done in the current assessment.

3. Examine whether a combination of low fecundity and fishing mortality explain long term decline of bigmouth sculpin.
   Author's response:
   See Appendix.

December 2015 SSC

1. The SSC agrees with the PT recommendations for harvest specifications, specifically the use of the RE model biomass time series and the biomass-weighted natural mortality (M = 0.222). These result in the harvest specifications in the table below. We also agree with the PT in requesting possible explanations for the decline of bigmouth sculpin since the 1980s, including, but not limited, to low fecundity of bigmouth sculpin and fishing mortality. The SSC would also like to note the decline in survey biomass of the plain sculpin. We also suggest that investigations into the maximum age and natural mortality of the four primary sculpin species in this complex be added to research priorities.

   Author's response: Research priorities were added as suggested.

Introduction

Biomass calculations for the Gulf of Alaska sculpin complex are based on the most common large sculpin species in that region. These species are from the genera *Myoxocephalus, Hemitripterus,* and *Hemilepidotus,* and have been identified to the species level by observers from the North Pacific Groundfish Observer Program since 2008. Biomass for this assessment is based on survey estimates for the four most abundant sculpins in the GOA: bigmouth (*Hemitripterus bolini*), great (*Myoxocephalus polyacanthocephalus*), plain (*Myoxocephalus jaok*), and yellow Irish lord (*Hemilepidotus jordani*) applied to a random effects model.

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. A total of forty-six species of sculpins have been listed as occurring in the GOA (Table 19.1), and 39 of these have been identified on NMFS GOA research surveys. Sculpins are broadly distributed throughout the shelf and slope regions of the GOA, 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 (e.g. TenBrink and Aydin, 2009; TenBrink and Buckley, 2013). 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 relatively 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. 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 GOA showed fecundity averaged 2,283 eggs per female (Morgan Busby, AFSC, personal comm.). The diversity of sculpin species in the GOA 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 19.2. With the exception of data for bigmouth sculpins, all fecundity and maturity data in Table 19.2 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 total allowable catch (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 (Ormseth and Spencer, 2011; Patrick et al., 2010) The 2015 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 that time (Table 19.3). Sculpins are caught incidentally by a wide variety of fisheries and several gear types (Table 19.4a). Based on data from the NMFS Alaska Regional Office (AKRO) the main gear type catching sculpins is the non-pelagic trawl, followed by hook and line (Table 19.4a), and the main fisheries that catch sculpins are shallow water flatfish, Pacific cod, and IFQ halibut (Table 19.4b). 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 19.3 and 19.4b). 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 species for the larger sculpin genera: *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 plain, bigmouth, and yellow Irish lord caught by commercial fishing operations do not differ significantly from the biomass estimated from RACE surveys (Table 19.5 and Figure 19.1). However, the proportion of darkfin sculpin in the fishery appears much higher than in the survey. The estimates of sculpin complex biomass in the GOA has remained relatively stable since 1984, and CVs range from 0.08-0.28 (Table 19.6). Yellow Irish lord, bigmouth sculpin, great sculpin, and plain sculpin accounted for the majority of sculpin biomass in the GOA region, according to survey estimates from 1984-2017 (Table 19.7).

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. The GOA catch of sculpins in 2016 was 1,330 t, and the 2017 catch through October 25, 2017 was 1,226 t. Catches have ranged from 583-1,966 t since 2005 (Table 19.3). The 2017 GOA biomass estimate for sculpins is 33,134 t, a slight decrease from the 2015 estimate of 34,943 t. The complex weighted mortality remained at 0.21. Catch has remained below the OFL for GOA sculpins, and the stock complex is not currently subject to overfishing.

Survey

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 19.2 and Table 19.6). 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 19.7). Species-specific biomass estimates are available for these four species (Figure 19.3). Mean proportions in the survey indicate that yellow Irish lord is currently the most abundant (~59% of all sculpin biomass), followed by great sculpin at 23%, bigmouth sculpin at 14%, and plain sculpin at 4.4% (Figure 19.4). 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 19.4). The biomass of bigmouth sculpin declined from 1984-1995 and has remained at approximately 5,000 t since that time (Figure 19.4). The coefficients of variation (CVs) for the survey biomass estimates of the four most abundant sculpin species are at or below 0.40, suggesting that the GOA survey is doing an adequate job assessing the biomass of the more abundant species (Table 19.7).

Other time series data used in the assessment

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 19.5). These length compositions have remained fairly stable during this period and no strong trends are apparent. 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. Reference points and catch since 2011 are shown in Table 19.10.

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/PlanTeam/2012/Sept/surveyaveragewg.pdf).

Sculpins in the GOA are managed under Tier 5, where OFL = M * average survey biomass and ABC = 0.75 * M * average survey biomass. The proportion of bigmouth, great, plain and yellow Irish lord are determined by separate model runs for each species. The biomass of all other sculpins is also calculated using the random effects model. The total biomass estimate is a sum of the species-specific biomass from the random effect smoothing model for the four most common species and the other sculpins category (Figure 19.4 and Table 19.9). The proportions of bigmouth, great, plain and yellow Irish lord are used to determine the proportions for biomass-weighted natural mortality (Table 19.9).

Parameter Estimates

Harvest recommendations for GOA sculpins were made using the results of life history studies of sculpins in the eastern Bering Sea and Aleutian Islands. This is based on recommendations in 2009 by the BSAI Plan Team that M values based on age-based catch-curve analysis be used wherever possible (Table 19.8; Ormseth and TenBrink, 2009). Natural mortality estimates of sculpins in the BSAI are used to determine the biomass-weighted M used to calculate OFL and ABC in the GOA sculpin complex.

Results

Recent estimates of *M* are available for four of the sculpin species in the GOA sculpin complex (although estimates come from samples from the Bering Sea and Aleutian Islands): yellow Irish lord, great sculpin, bigmouth sculpin, and plain sculpin (Table 19.8), which comprise over 97% of the estimated GOA sculpin biomass in 2017 (Table 19.7). A biomass-weighted average *M* was calculated according to Table 19.9. Whether individual species *M*'s or a biomass weighted *M* are used to calculate ABC and OFL for the sculpin complex gives the same result. However, individual species *M*'s provides less rounding error because no further rounding is required except for the calculation of the contribution of the other species complex.

Biomass estimates for the 4 most common species and other sculpins using the random effects model are shown in Table 19.11.

Harvest recommendations

The 2018 ABC is 5,301 t, based on an F_{ABC} = 0.75*0.21=0.16, and a total biomass estimate of 33,134 t. The 2018 OFL is 6,958 t, based on F_{OFL}=0.21.

2018-2019 harvest recommendations for the GOA sculpin complex	
sculpin complex biomass	33,134
complex *M*	0.21
F_{OFL}	0.21
maximum permissible F_{ABC}	0.16
recommended F_{ABC}	0.16
OFL	6,958
maximum permissible ABC	5,301
recommended ABC	5,301

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 19.6). In the GOA the main predator of large sculpins are Pacific halibut, pinnipeds, small demersal fish and sablefish (Figure 19.6). Other sculpins in the GOA feed mainly on shrimp and benthic crustaceans (Figure 19.7). Other sculpins are mainly preyed upon by Pacific cod which is the main source of mortality (Figure 19.7). 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 19.4) 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.

Acknowledgments

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Tables

Table 19.1. Sculpin species observed in the Gulf of Alaska. 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). (Stevenson, 2015).

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
	Psychrolutes paradoxus	Tadpole sculpin
	Psychrolutes phrictus	Blob sculpin
Rhamphocottidae	*Rhamphocottus richardsoni*	Grunt sculpin

Table 19.2. 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 19.3. GOA total sculpin complex catch, retention rate, total Other Species catch (sculpin, sharks, skates, octopus and squid), and sculpin percentage of Other Species catch, 1997-2017. *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 Source:* NMFS AKRO BLEND/Catch Accounting System.

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	1,016	1%		
2016	1,330	3%		
2017	1,226*	1%		

+ Beginning in 2004, skates were removed from Other Species complex. Sculpin were split out from the Other Species complex in 2011.

* As of October 25, 2017.

Table 19.4a. Total catch (t) of all sculpins by target fishery in the Gulf of Alaska, 2013-2017 by gear type (NPT: non-pelagic trawl, PTR: pelagic trawl, HAL: hook and line, POT: pot). *Source: AKFIN database.* ** 2017 catch data are incomplete; retrieved October 25, 2017.*

	Gear Type				
Target fishery	**NPT**	**PTR**	**HAL**	**POT**	**Total**
arrowtooth flounder	377	0	0	0	377
Atka mackerel	3	0	0	0	3
deep flatfish	0	0	0	0	0
flathead sole	5	0	0	0	5
IFQ halibut	0	0	1,579	0	1,579
other target	1	0	0	0	1
Pacific cod	1,040	0	959	1,394	3,393
rex sole	19	0	0	0	19
rockfish	233	0	0	0	233
sablefish	2	0	78	0	80?
shallow flatfish	914	1	0	0	915
walleye pollock	118	5	0	0	123
Total	**2,712**	**6**	**2,616**	**1,394**	**6,728**

Table 19.4b. Total catch (t) of all sculpins by target fishery in the Gulf of Alaska, 2003-2017. *Source: AKFIN database. * 2017 catch data are incomplete; retrieved October 25, 2017.*

Gulf of Alaska									
Target fishery	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
arrowtooth flounder	16	7	19	36	38	16	16	27	69
Atka mackerel	0	0	0	0	0	0	0	0	0
deep flatfish	2	2	0	0	0	0	0	0	1
flathead sole	4	10	3	1	0	16	3	5	14
IFQ halibut	45	41	29	13	31	134	165	53	84
other target	6	0	0	0	0	0	11	0	12
Pacific cod	381	430	320	361	442	740	556	591	342
rex sole	27	19	11	7	8	4	31	11	3
rockfish	24	58	27	32	31	23	35	62	39
sablefish	1	2	16	4	7	2	20	1	3
shallow flatfish	113	129	200	125	376	959	515	155	143
walleye pollock	1	0	0	2	22	15	5	6	53
Total catch (mt)	**620**	**698**	**625**	**581**	**955**	**1,909**	**1,357**	**911**	**763**

Target fishery	**2012**	**2013**	**2014**	**2015**	**2016**	**2017***
arrowtooth flounder	21	52	149	36	56	84
Atka mackerel	0	3	0	0	0	0
deep flatfish	0	0	0	0	0	0
flathead sole	5	3	0	1	1	0
IFQ halibut	0	934	164	175	180	125
other target	2	0	0	0	0	1
Pacific cod	449	478	541	629	858	887
rex sole	11	9	1	6	0	4
rockfish	55	70	33	44	43	43
sablefish	5	41	6	12	7	8
shallow flatfish	227	358	251	87	165	54
walleye pollock	20	17	39	27	20	20
Total catch (mt)	**795**	**1,965**	**1,184**	**1,017**	**1,330**	**1,226**

Table 19.5. Estimated species composition of GOA incidental sculpin catches for the past 5 GOA survey years, based on fishery observer data and RACE survey data. *Source: AKFIN database and RACEBASE survey database.*

Fishery					
	2009	**2011**	**2013**	**2015**	**2017**
Bigmouth	13.04%	13.99%	8.01%	8.38%	11.31%
Great	4.64%	2.14%	0.56%	1.16%	0.41%
YIL	40.34%	44.13%	31.72%	41.68%	45.03%
Plain	0.00%	0.00%	0.00%	0.00%	0.00%
Darkfin	24.60%	24.36%	22.24%	14.84%	17.10%
Warty	0.03%	0.00%	0.00%	0.00%	0.00%
Crested	0.00%	0.00%	0.00%	0.00%	0.00%
Other sculpin	17.35%	15.38%	37.46%	33.93%	26.14%

Survey					
	2009	**2011**	**2013**	**2015**	**2017**
Bigmouth	7.46%	11.04%	11.31%	10.29%	14.28%
Great	19.44%	25.77%	18.00%	19.63%	18.94%
YIL	59.67%	48.48%	56.84%	63.52%	55.86%
Plain	6.06%	9.71%	8.70%	1.09%	5.94%
Darkfin	1.45%	1.27%	0.74%	0.77%	0.79%
Warty	0.00%	0.00%	0.11%	0.00%	0.00%
Crested	0.00%	0.00%	0.00%	0.00%	0.00%
Other sculpin	5.91%	3.74%	4.31%	4.70%	4.18%

Table 19.6. Sculpin complex biomass estimates (t) based on NMFS bottom-trawl surveys, 1984-2017. This includes all sculpin species including unidentified sculpins. Note that the official biomass estimate for the GOA is presented in Table 19.9.

Year	**Total biomass (t)**	**CV**
1984	44,236	0.08
1987	31,811	0.11
1990	26,859	0.17
1993	25,414	0.12
1996	31,727	0.26
1999	30,879	0.11
2001	30,590	0.28
2003	26,562	0.09
2005	33,827	0.09
2007	32,750	0.11
2009	40,707	0.11
2011	31,720	0.09
2013	34,007	0.11
2015	45,222	0.16
2017	30,256	0.11

Table 19.7. GOA trawl survey biomass estimates (t) for individual sculpin species, 1996-2017, with 2017 CV. Common names of sculpins are listed with the following abbreviations: unidentified sculpin (unident.), yellow Irish lord (YIL). *Source: RACE GOA Oracle database.*

Species	**Biomass (t)**							
	1984	**1987**	**1990**	**1993**	**1996**	**1999**	**2001***	**2003**
unident.	3,283	483	1,302	213	414	96	172	48
threaded	-	-	-	1	3	-	21	-
armorhead	12	8	1	17	13	15	61	78
darkfin	1,324	877	594	948	477	371	335	607
butterfly	-	-	-	-	-	1	-	-
scissortail	8	32	103	51	60	47	62	94
spectacled	66	60	30	52	90	233	12	39
warty	-	-	9	-	-	-	339	-
Pacific staghorn	4	9	2	-	-	1	2	-
antlered	9	-	-	-	-	-	1	-
spinyhead	389	144	261	553	278	271	690	608
crested	-	-	3	1	-	-	6	-
thorny	-	-	3	1	1	-	1	-
YIL	14,439	13,592	11,701	11,661	17,804	20,255	20,945	12,064
bigmouth	15,871	10,196	8,600	5,612	4,246	3,983	3,471	5,767
great	8,833	6,007	3,815	5,846	7,326	3,913	3,540	6,037
plain	-	403	433	461	1,015	1,692	932	1,220
Total	**44,236**	**31,811**	**26,859**	**25,414**	**31,727**	**30,879**	**30,590**	**26,562**

	2005	**2007**	**2009**	**2011**	**2013**	**2015**	**2017**	**2017 CV**
unident.	320	167	147	60	44	71	97	0.61
threaded	2	-	2	-	-	14	-	0.73
armorhead	28	54	197	17	67	91	61	0.40
darkfin	931	790	614	412	258	358	247	0.18
butterfly	-	-	-	-	-	-	-	-
scissortail	23	31	111	21	35	45	4	1.00
spectacled	105	97	68	104	9	92	13	0.60
warty	-	33	-	-	39	-	-	-
Pacific staghorn	14	-	8	7	-	3	38	0.60
antlered	-	-	-	-	-	-	-	-
spinyhead	463	424	410	195	447	597	308	0.23
crested	-	-	-	-	-	-	-	-
thorny	-	-	-	-	1	-	5	0.86
YIL	15,943	15,508	25,219	15,771	19,841	29,532	17,333	0.16
bigmouth	5,543	3,128	3,154	3,591	3,947	4,783	4,430	0.17
great	6,542	7,970	8,215	8,384	6,282	9,128	5,877	0.27
plain	3,913	4,548	2,562	3,160	3,036	508	1,844	0.40
Total	**33,827**	**32,750**	**40,707**	**31,720**	**34,007**	**45,222**	**30,256**	

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

Table 19.8. List of available natural mortality information for sculpins (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 19.9. 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*. Estimated biomass for other sculpins is also included, which does not contribute to the weighted average *M*. Weighted average *M* is rounded from 0.211 to 0.21 for calculation of reference points.

species	estimated biomass	proportion of total biomass	*M*	weighted contribution to *M*	weighted average *M*
yellow Irish lord	19,060	0.590	0.17	0.100	
great	7,379	0.228	0.28	0.064	
bigmouth	4,438	0.137	0.21	0.029	
plain	1,423	0.044	0.40	0.018	
other	834	-	-	-	
	33,134				0.211

Table 19.10. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the BSAI sculpin complex 2011 to present. **Estimated removals through October 25, 2017.*

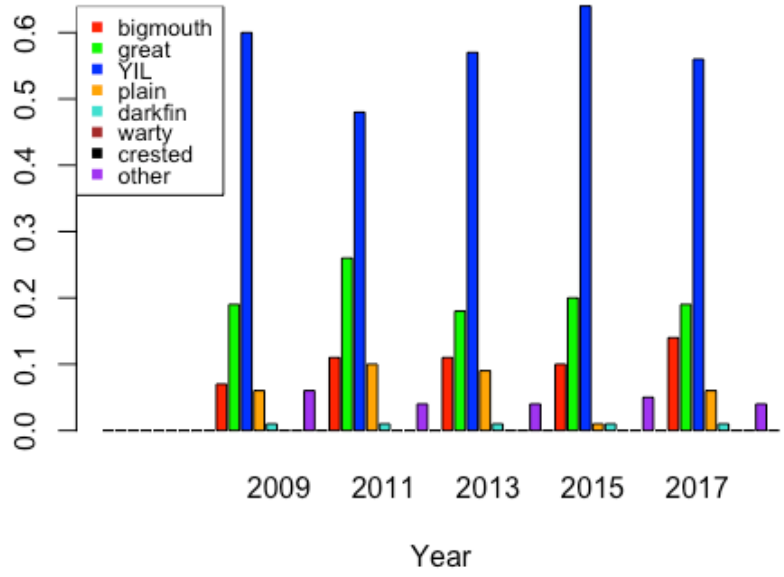
Year	OFL (t)	ABC (t)	TAC (t)	Catch (t)
2011	7,328	5,496	5,496	763
2012	7,641	5,731	5,731	795
2013	7,641	5,731	5,731	1,966
2014	7,448	5,569	5,569	1,187
2015	7,448	5,569	5,569	1,016
2016	7,338	5,591	5,591	1,330
2017*	7,338	5,591	5,591	1,226*
2018	6,958	5,301		
2019	6,958	5,301		

Table 19.11. Random effect model estimates of biomass for each of the four most abundant sculpin species, 1984-2017. Other sculpin includes all sculpin except bigmouth, great, yellow Irish lord (YIL), and plain. Total was computed using data for all sculpins in a single random effects model run, with total variance for all four species as well as other sculpins, and is not expected to equal the sum of the results for the four species and other sculpins presented here.

Year	Bigmouth sculpin	Great sculpin	Plain sculpin	YIL	Other sculpins	Total
1984	15,056	7,208	428	14,280	3,962	41,501
1985	13,288	6,939	440	14,257	3,166	38,689
1986	11,728	6,679	451	14,233	2,530	36,068
1987	10,351	6,429	464	14,209	2,022	33,624
1988	9,513	6,256	489	14,221	2,058	32,222
1989	8,742	6,088	516	14,233	2,094	30,879
1990	8,033	5,924	544	14,245	2,131	29,591
1991	7,194	5,886	649	14,345	2,017	28,940
1992	6,442	5,848	775	14,445	1,908	28,304
1993	5,768	5,811	926	14,546	1,805	27,681
1994	5,338	5,769	1,032	14,878	1,660	28,170
1995	4,939	5,727	1,150	15,217	1,526	28,667
1996	4,571	5,686	1,281	15,564	1,403	29,173
1997	4,430	5,504	1,225	15,883	1,337	29,440
1998	4,293	5,328	1,171	16,208	1,274	29,711
1999	4,161	5,157	1,320	16,539	1,214	29,984
2000	4,166	5,223	1,487	16,414	1,350	29,778
2001	4,172	5,290	2,108	16,291	1,502	29,574
2002	4,554	5,598	2,990	16,086	1,505	29,286
2003	4,970	5,924	3,190	15,883	1,507	29,001
2004	4,888	6,219	3,404	16,150	1,636	30,607
2005	4,807	6,528	3,058	16,421	1,776	32,301
2006	4,237	6,851	2,748	16,783	1,688	32,969
2007	3,734	7,190	2,747	17,153	1,604	33,651
2008	3,599	7,384	2,746	17,765	1,537	34,825
2009	3,468	7,583	2,341	18,400	1,472	36,039
2010	3,565	7,632	1,996	18,343	1,184	34,865
2011	3,666	7,680	1,344	18,286	952	33,729
2012	3,831	7,550	905	18,627	952	34,112
2013	4,003	7,421	1,135	18,975	953	34,500
2014	4,221	7,589	1,424	19,225	1,057	35,155
2015	4,450	7,760	428	19,477	1,172	35,823
2016	4,444	7,567	440	19,267	989	34,340
2017	4,438	7,379	451	19,060	834	32,918

Figures

a. Fishery



b. Survey

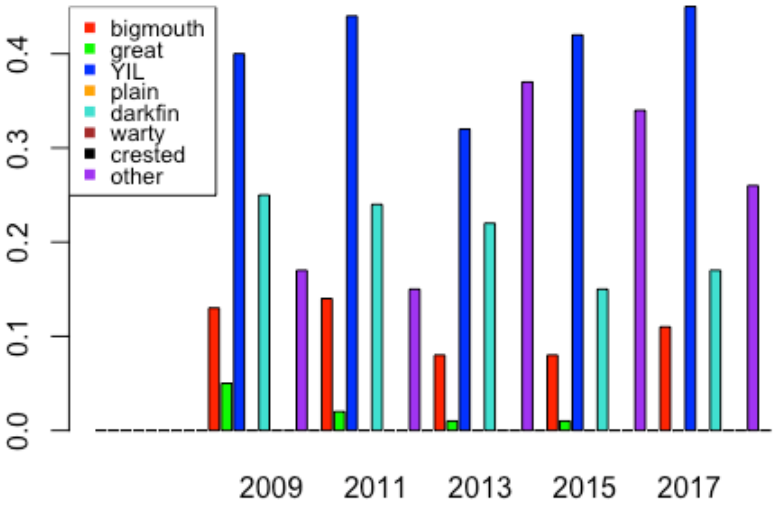


Figure 19.1. The proportion of bigmouth, great, yellow Irish lord (YIL), plain, darkfin, warty, crested, and other sculpin caught in the fishery vs. the NMFS GOA survey.

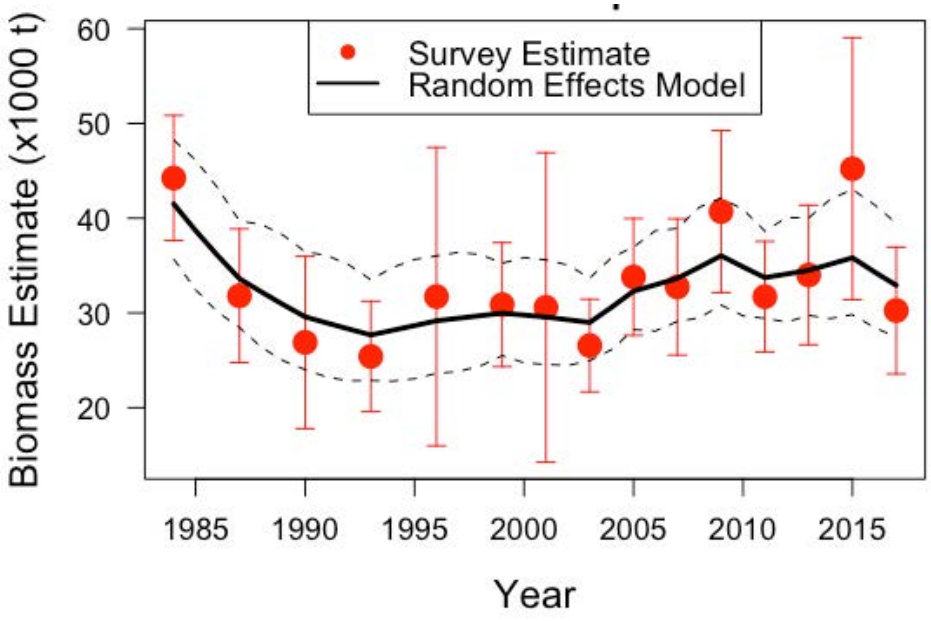


Figure 19.2. GOA sculpin complex biomass estimate (x1,000 t), derived from the sum of the biomass estimates for bigmouth, plain, great sculpin, other sculpin, and yellow Irish lord (solid black line). The 95% confidence intervals are shown as dotted lines, and the red circles and error bars indicate survey estimates and respective survey 95% confidence intervals.

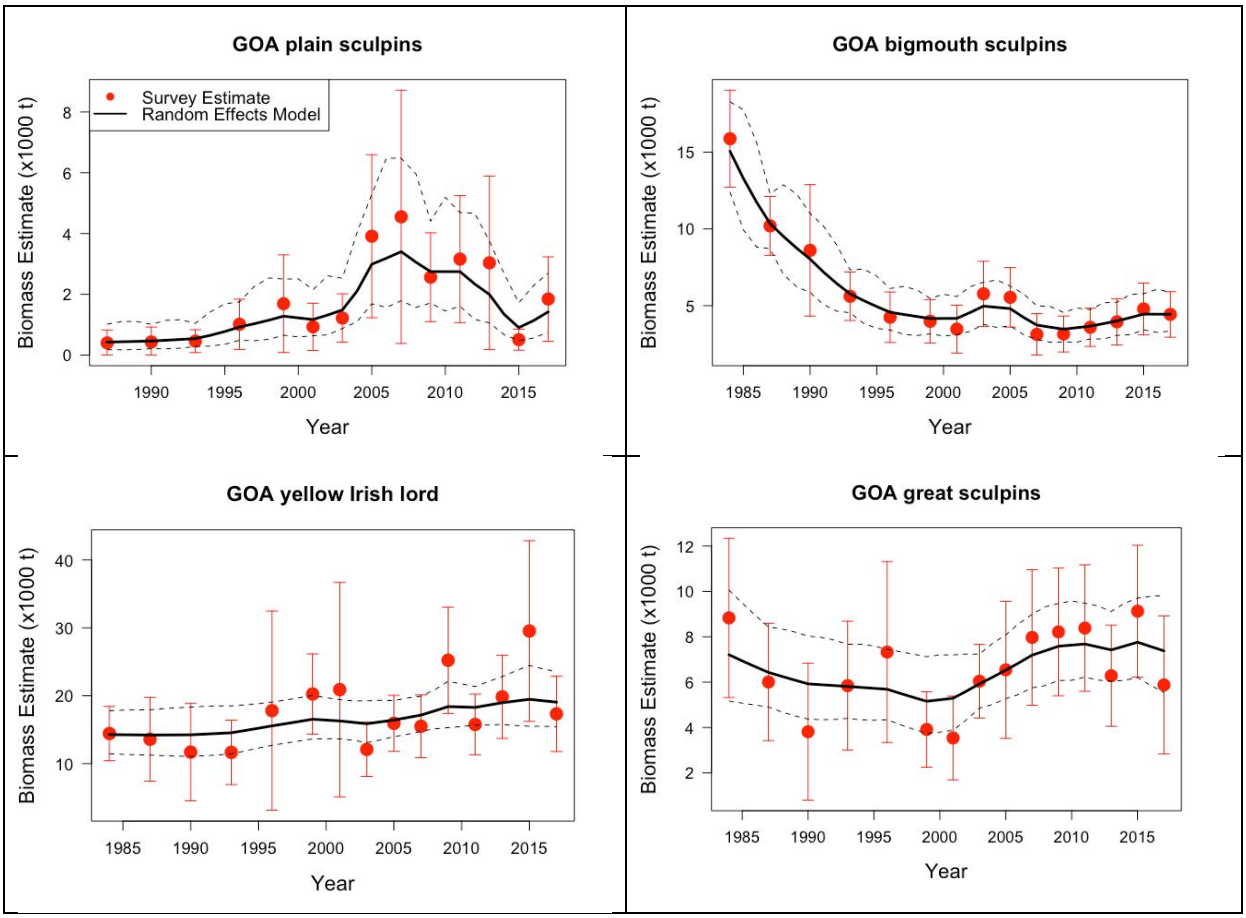


Figure 19.3. GOA sculpin biomass estimates (x1,000 t) for the four most abundant sculpin species, plain, bigmouth, yellow Irish lord, and great sculpin (solid black lines). The 95% confidence intervals are shown as dotted lines, and the red circles and error bars indicate survey estimates and respective survey 95% confidence intervals. The legend in the top left panel applies to all panels.

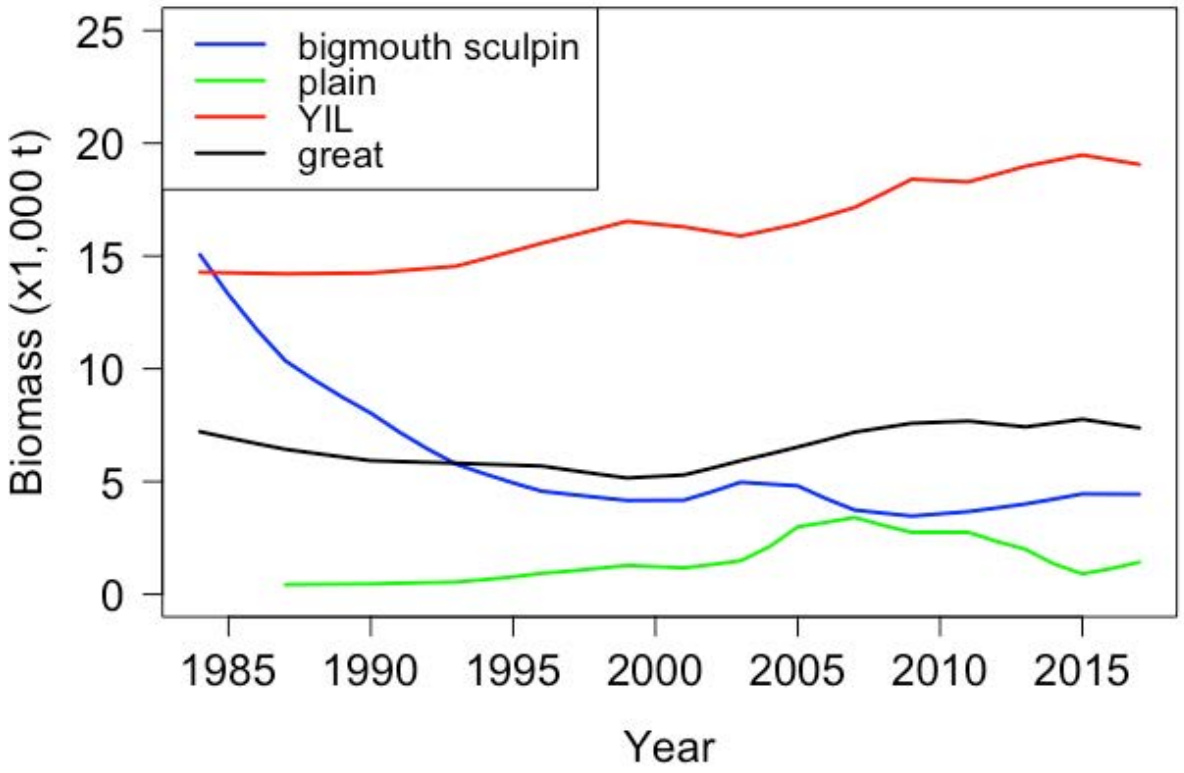


Figure 19.4. Random effect model estimate of biomass (x1,000 t) of the four most abundant sculpin species in the GOA from 1984-2017: great sculpin, yellow Irish lord (YIL), plain sculpin, and bigmouth sculpin.

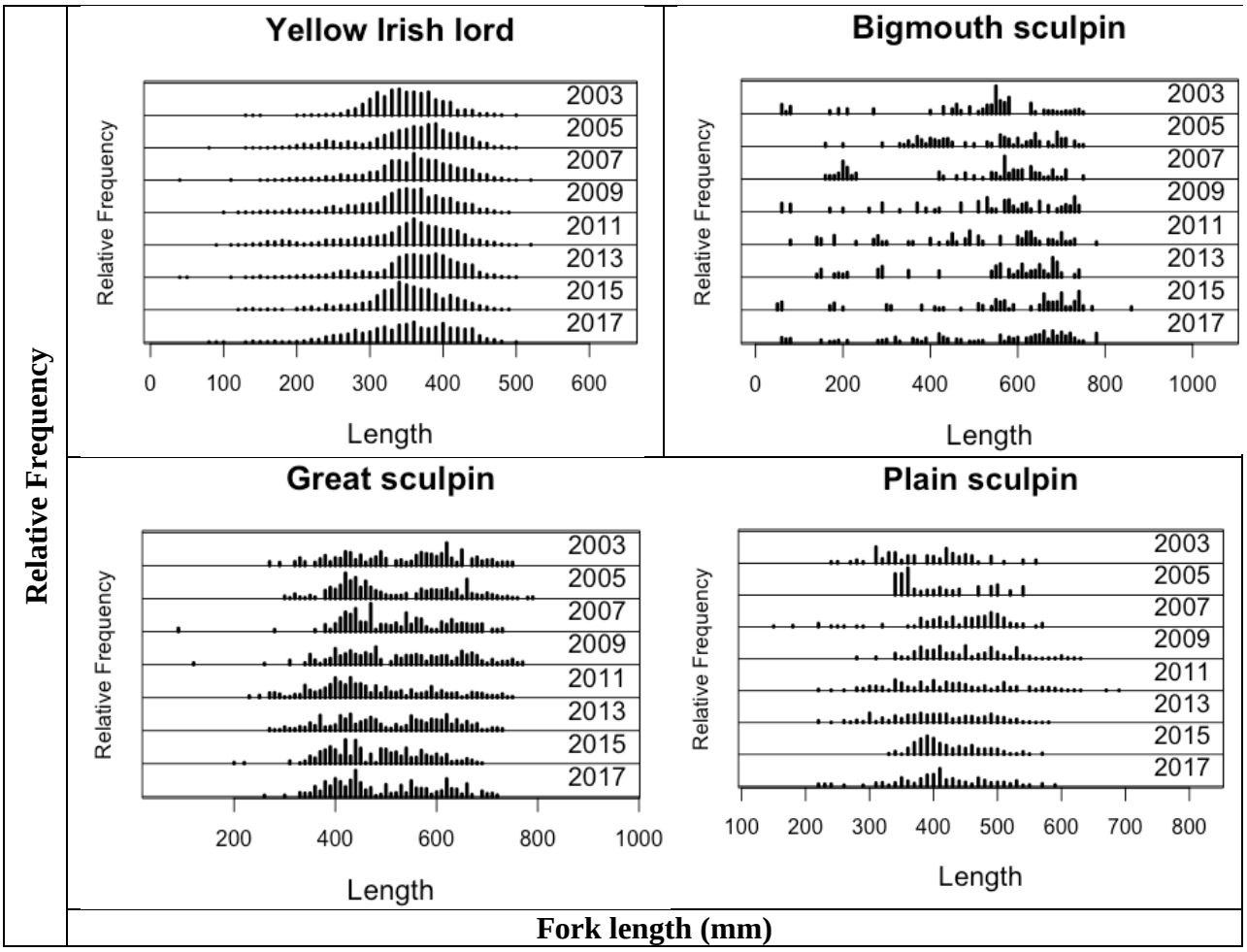
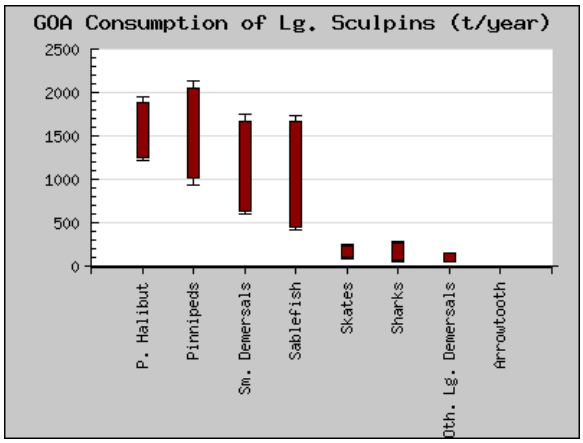
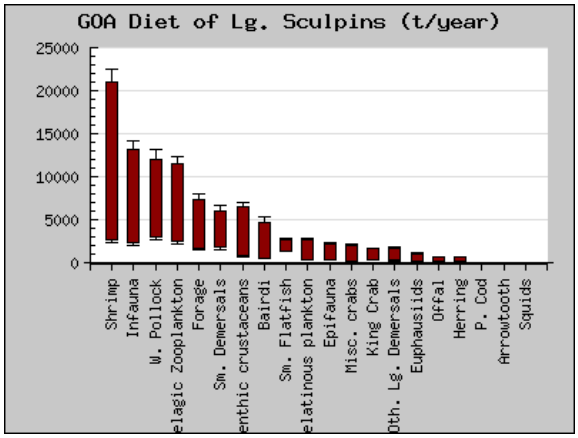


Figure 19.5. Length composition (fork length, FL in mm) from survey data for the 4 most abundant sculpin species in the GOA, 2003-2017.





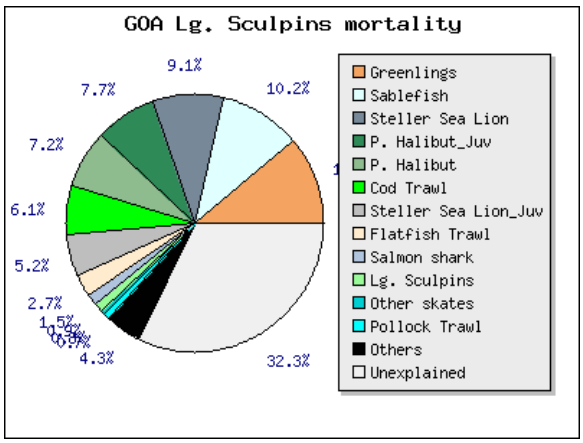
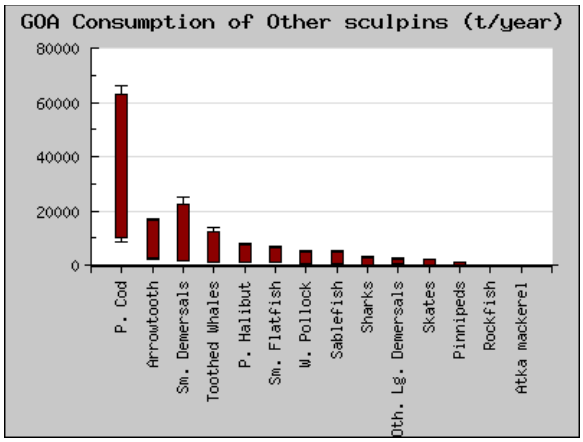
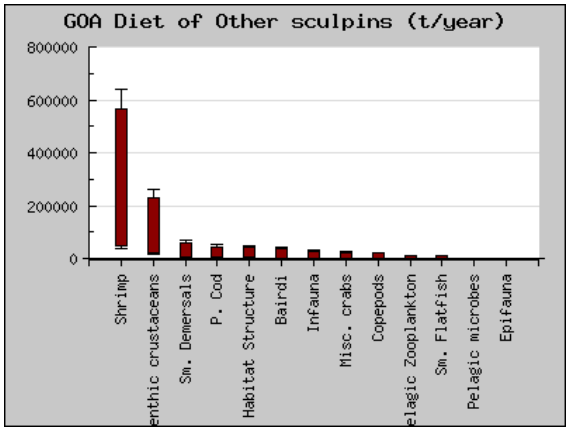


Figure 19.6. Diet, consumption and mortality information for large sculpins in the GOA.





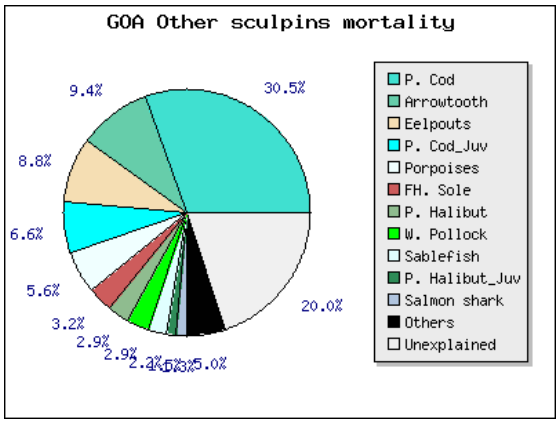


Figure 19.7. Diet, consumption and mortality information for other sculpins in the GOA.

Appendix: Examination of whether a combination of low fecundity and fishing mortality explain long term decline of bigmouth sculpin.

There appears to be some decline in bigmouth sculpin in the Aleutian Islands and the Gulf of Alaska (Figure 19.3), but not in the Bering Sea shelf or slope (Figure 19.A1). Fecundity is not known in bigmouth sculpin. Examination of a single female indicated that bigmouth sculpin have fewer, larger eggs than great, plain, or yellow Irish lord (T. TenBrink, AFSC, pers.comm.). Fishing mortality in the Gulf of Alaska for bigmouth sculpin appears to be low when examined over the entire management unit (Table 19.A1). The proportion of bigmouth sculpin in observer catches in 2011, 2013, 2015, and 2017 ranged from approximately 8%-14% (Table 19.5). The resulting catch/biomass ratio can serve as a rough estimate of fishing mortality, and it ranges from 0.02-0.04, which is much lower than the estimate of natural mortality for bigmouth sculpins of 0.21.

Another factor to consider when examining the data that indicate a decline in bigmouth sculpin biomass is the type of trawl net used in the 1984, 1987, and 1990 surveys. The following table shows the number of hauls for each net type for each GOA survey. Net 172 is the Poly Nor 'Eastern net that is used in the standardized surveys. Net descriptions are given in Table 19.A3. Different nets, particularly 710 and 717 were quite large and may have fished differently than nets currently used.

To summarize, there is consistency in the apparent trends of decline of bigmouth sculpin in the Aleutian Islands and Gulf of Alaska. However, upon closer examination, differences in net type lead to uncertainty in the biomass estimates of bigmouth sculpin, particularly in the 1984 and 1987 surveys. Fecundity is not well understood in bigmouth, so it is not clear if that might be a factor if the species is declining. Fishing mortality of bigmouth sculpin appears to be below recommended levels in the Gulf of Alaska, so it is unlikely to lead to a decline in this species.

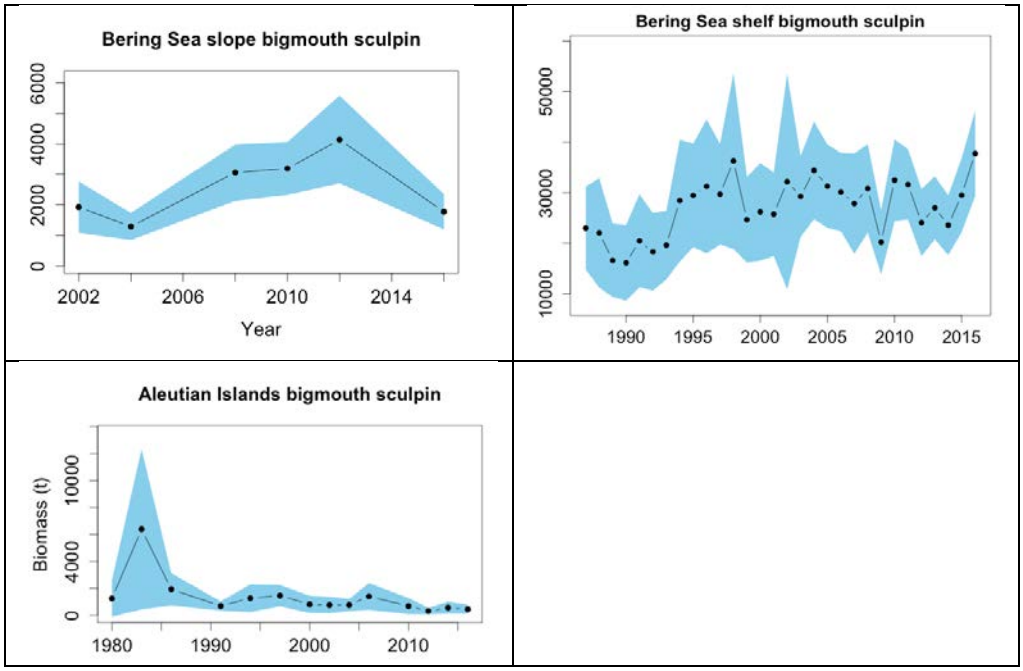


Figure 19.A1. Biomass trends in bigmouth sculpin in the Bering Sea shelf and slope and the Aleutian Islands, based on survey estimates.

Table 19.A1. Examination of fishing mortality in bigmouth sculpin. Catch/biomass ratio serves as an estimate of fishing mortality.

	2011	2013	2015	2017
Proportion of bigmouth in sculpin catch (observer data)	13.99%	8.01%	8.38%	11.31%
Total sculpin biomass estimate (t)	31,720	34,007	45,222	30,256
Bigmouth sculpin biomass estimate (t)	3,591	3,947	4,783	4,430
Extrapolated bigmouth catch (proportion caught x total catch estimate)	107	157	85	139
Sculpin total catch	763	1,966	1,016	1,226
Bigmouth catch/biomass ratio	0.03	0.04	0.02	0.03

Table 19.A2. The number of hauls that used each type of net for GOA surveys from 1984-2015.

	Net type			
Cruise Number	160	172	710	717
198401	384	127	334	
198402	21	25		
198403	133			
198701		259		399
198702		126		
199001		542		
199008	166			
199301		621		
199309		153		
199601		807		
199901		764		
200101		560		
200301		809		
200501		837		
200701		816		
200901		823		
201101		670		
201301		548		
201501		772		

Table 19.A3. Description of net types used in the 1984, 1987, and 1990 NMFS GOA surveys.

Net type	Description
172	Poly-nor'eastern, four seam, hard bottom, high rise rock-fish trawl constructed of polyethylene. 27.2M (89'1") headrope is galvanized wire rope wrapped with 3-strand polypropylene. 37.4M (122'8") footrope: 24.7M (81'7") middle section is galvanized wire rope wrapped with polypropylene, connected to lower "flying wings" with 6.4M (19'6") sections of wire rope with rubber disks. Codend is 8.9Cm (3 1/2") stretch mesh poly, liner of 3.2Cm (1 1/4") nylon, 315 meshes circumference and 200 meshes deep.
160	Nor'eastern trawl, 90' headrope, 105' footrope. 22 13"Diameter plastic floats on headrope, 5" mesh in body, 3.5" Mesh in intermediate and codend. Mean effective path width = 13.44M, range 11.6M-16.5M. Mean vertical opening = 9.2M, range 8.2M-9.9M.
710	Japanese bottom trawl. Four-seam polyethylene with 49.1M headrope, 57.0M footrope. Mesh sizes from 240mm in wings to 100mm (triple-layered mesh) in codend. Approx. 20 400Mm floats on headrope. (Used on daikichi maru no.37 Cr.841.)
717	Japanese polytrawl with roller gear. Polyethylene web, 55.6M (182.4') Headrope, 65m (213.3') Footrope. Wingspread varied from 26.6M (87.3') At depths under 100m, to 30.0M (98.4') At depth over 200m. (Used on taisei maru cr.871.)