# 18d. Bering Sea/Aleutian Islands sculpins

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## Executive Summary

This document summarizes the information currently known about the status of sculpins (Families Cottidae, Hemitripteridae, Psychrolutidae, and Rhamphocottidae) in the Bering Sea/Aleutian Islands (BSAI) .

## Summary of Major Changes

1. Catch data are updated with partial data for 2009. In addition, all sculpin and Other Species catch data from 2003-2008 has been updated as a result of changes to the Catch Accounting System.
2. Information on species composition of commercial catches is updated with complete 2008 data and partial 2009 data.
3. Biomass estimates and length compositions from the 2009 Bering Sea shelf survey have been added.
4. Layout and tables have changed somewhat as the result of there being a new assessment author.
5. A new approach to harvest specifications is recommended.

## Harvest recommendations

Sculpins are managed under Tier 5. We recommend that for species with recent, BSAI-specific natural mortality (*M*) estimates, the Hoenig estimate of M be used to specify OFL and maximum permissible ABC. For other species, the pre-2008 BSAI sculpin M of 0.19 should be used. Due to the uncertainty surrounding M, we recommend that ABC be set lower than the maximum permissible ABC by using the lowest BSAI-specific estimate of M for each species.

**2010-2011 BSAI sculpin harvest recommendations**

| region | species | M | biomass | max. $F_{ABC}$ | max. ABC | $F_{OFL}$ | OFL | rec. $F_{ABC}$ | rec. ABC |
|---|---|---|---|---|---|---|---|---|---|
| EBS shelf | warty | 0.23 | 14,134 | 0.17 | 2,438 | 0.23 | 3,251 | 0.12 | 1,696 |
| | great | 0.25 | 57,862 | 0.19 | 10,849 | 0.25 | 14,466 | 0.18 | 10,415 |
| | bigmouth | 0.21 | 29,128 | 0.16 | 4,588 | 0.21 | 6,117 | 0.16 | 4,588 |
| | plain | 0.26 | 65,687 | 0.20 | 12,809 | 0.26 | 17,079 | 0.13 | 8,375 |
| | threaded | 0.42 | 2,184 | 0.32 | 688 | 0.42 | 917 | 0.27 | 590 |
| | YIL | 0.15 | 28,651 | 0.11 | 3,223 | 0.15 | 4,298 | 0.03 | 860 |
| | other | 0.19 | 6,113 | 0.14 | 871 | 0.19 | 1,161 | 0.14 | 871 |
| EBS slope | all | 0.19 | 5,941 | 0.14 | 847 | 0.19 | 1,129 | 0.14 | 847 |
| **EBS total** | | | **209,700** | | **36,313** | | **48,417** | | **28,241** |
| AI | YIL | 0.16 | 6,946 | 0.12 | 834 | 0.16 | 1,111 | 0.09 | 625 |
| | other | 0.19 | 9,179 | 0.14 | 1,308 | 0.19 | 1,744 | 0.14 | 1,308 |
| **AI total** | | | **16,125** | | **2,142** | | **2,855** | | **1,933** |
| **total BSAI** | | | **225,825** | | **38,454** | | **51,272** | | **30,174** |
| **2009 BSAI sculpin specifications** | | | | | **31,000** | | **41,600** | | **31,000** |

### b) Responses to SSC Comments

*The SSC looks forward to seeing results of the proposed review of methods for estimating M for sculpin species, scheduled for the September 2009 plan team meeting, and encourage the authors to develop a set of most credible M estimates for use in the assessments.*

Partially as a result of the September meetings, we have chosen the best estimator of *M* for specifying harvests. We believe that the Hoenig approach gives the single best estimate of *M* for sculpins, and recommend using it to calculate OFL and maximum permissible ABC. We further recommend setting a lower ABC using the most conservative values of *M*, to account for uncertainty.

## Introduction

Description, scientific names, and general distribution

Sculpins are relatively small, benthic-dwelling, teleost fish. This group is especially speciose; during cooperative U.S.-Japan trawl surveys, 41 species of sculpins were identified in the Eastern Bering Sea (EBS) and 22 species in the Aleutian Islands (AI) region. Sculpin diversity remains high in recent surveys of both areas (Table 20.1). Sculpins are distributed throughout the Bering Sea/Aleutian Island region and they occupy all benthic habitats and depths. In this assessment, we focus on species from the genera *Myoxocephalus*, *Hemitripterus*, and *Hemilepidotus* that observers from the North Pacific Groundfish Observer Program have begun to identify to genus in commercial catches.

Management units

Sculpins are managed as part of the BSAI Other Species complex. Currently in the BSAI this includes sculpins, skates, sharks, and octopus. Specifications for this group are set by summing the individual ABCs and OFLs for each species group to create an aggregate OFL, ABC, and TAC. Beginning in 2011 skates will be removed from Other Species and managed as a separate group, and the remaining species groups may be separated in the near future. Sculpins are currently taken only as bycatch in fisheries directed at target species in the BSAI, and it is likely that future catch of sculpins will continue to be dependent on the distribution and limitations placed on target fisheries, rather than on any harvest level established for this category.

Life history and stock structure (general)

Recent studies on the reproductive biology of top 5 sculpin species in the Eastern Bering Sea Shelf area have given us much needed information of sculpin life history in Alaska. Prior to those studies much of the reproductive biology information came from studies in the western North Pacific. Most if not all sculpins lay adhesive eggs in nests, and many exhibit parental care for eggs (Eschemeyer et al. 1983). Markevich (2000) observed the sea raven, *Hemitripterus villosus*, releasing eggs into crevices of boulders and stones in shallow waters in Peter the Great Bay, Sea of Japan. This type of reproductive strategy may make sculpin populations more sensitive to changes in benthic habitats than other groundfish species such as walleye pollock, which are broadcast spawners with pelagic eggs. In the western Pacific, great sculpins (*Myoxocephalus polyacanthocephalus*) are reported to have relatively late ages at maturity (5-8 years, Tokranov, 1985) despite being relatively short-lived (13-15 years). This suggests a limited reproductive portion of the lifespan relative to other groundfish species. Fecundity for the great sculpin off East Kamchatka waters ranged from 48,000 to 415,000 eggs (Tokranov 1985).

The diversity of sculpin species in the FMP areas suggests that each sculpin population might react to similar environmental changes (whether natural or fishing influenced) in different ways. Within each sculpin species, observed spatial differences in fecundity, egg size, and other life history characteristics suggest local population structure (Tokranov 1985), which is very different from wide ranging species such as sharks. All of these characteristics indicate that sculpins as a group might be managed separately from the Other Species complex, and perhaps most efficiently within a spatial context rather than with a global annual aggregate TAC.

Life history (BSAI-specific)

Information such as depth range, distribution, and maximum length has been collected for several years for many species during surveys. There is limited BSAI-specific age and growth, maturity, or reproductive biology data for sculpins identified in this management region. New age and growth information is now available for the great sculpin, yellow Irish lord, bigmouth, plain and warty sculpin based on samples collected from the 2005-2008 EBS shelf survey. In addition, age and growth, maturity, and diet information are currently being collected for several species as part of a comprehensive study investigating large sculpins in the BSAI which include: great sculpin, plain sculpin (*Myoxocephalus jaok*), warty sculpin (*Myoxocephalus verrucosus)*, bigmouth sculpin (*Hemitripterus bolini)*, and yellow Irish lord (*Hemilepidotus jordani*). Known life history characteristics for the most abundant sculpin species along the EBS shelf are presented in Table 2.

## Fishery

Directed fishery

There is no directed fishing for any sculpin species in the BSAI at this time.

Background on sculpin bycatch

Skates and sculpins constitute the bulk of the Other Species catches in the BSAI, accounting for between 66-96% of the estimated totals in 1992-1997. Based on total catch estimates from 1998-2008 (Table 3), sculpins comprised 19-28% of the total Other Species catch during this time period (skates, approx. 70%). Sculpins are caught by a wide variety of fisheries, but trawl fisheries for yellowfin sole, Pacific cod, walleye pollock, Atka mackerel and flathead sole, and Pacific cod hook-and-line fishery catch the most (Table 4).

In 2002-2003, the observer program of the AFSC initiated a species identification project which was prompted by the need to gather basic population data for groups in the Other Species complex. Beginning in January 2004, sculpin catch was identified to genus for the larger sculpin species: *Hemilepidotus, Myoxocephalus, and Hemitripterus.* Several species of *Hemilepidotus* and *Myoxocephalus* have been identified from surveys. In the BSAI region, *Hemitripterus* probably represents only one species, the bigmouth sculpin (Stevenson 2004). Another member of this genus, the sea raven, may occur in Alaskan waters but has never been identified in any of the BSAI shelf and slope trawl surveys conducted by AFSC. It is reasonable to assume that all sculpins identified by observers as *Hemitripterus* sculpins were bigmouth sculpins. Beginning in 2008, all observers were required to identify to species all sculpins in the genera *Hemilepidotus, Myoxocephalus, and Hemitripterus.* According to observer catch totals, these genera form over 90% of all sculpin catch in the BSAI (Table 5).

## Data

Fishery Catch

Catch trend by genus is not available before 2004. Refer to Table 20.3 for total sculpin catch from 1998-2008. Table 4 shows that in 2007 *Myoxocephalus* spp. EBS catch makes up 50% of the sculpin total catch in the BSAI. *Hemilepidotus* spp. catch in the EBS makes up 16% of the total sculpin catch in the BSAI. *Hemitripterus* spp. (bigmouth sculpin) EBS catch is 8% of the total sculpin catch in the BSAI. All other sculpin species, identified as "sculpin unidentified' contributed only 9% of the total BSAI sculpin catch in 2008. Fishery catch of sculpins is shelf-wide with the majority of the catch along the middle (50-

100m) and outer shelf (100-200m) areas. The following table shows the catch to biomass ratios in 2007-2009 for the major sculpin genera and species (catch for 2007 is for the three major genera only, and catch for 2008 and 2009 is for the species within the genera; biomass for the EBS is from 2008 EBS shelf survey, and biomass for the AI is from the 2006 AI survey. The data suggest that the exploitation rate for sculpins has been quite low in recent EBS and AI fisheries.

**catch/biomass ratios**

| | EBS | | | AI | | |
|---|---|---|---|---|---|---|
| | **2007** | **2008** | **2009*** | **2007** | **2008** | **2009*** |
| *Hemitripterus* spp. | 0.02 | - | - | 0.08 | - | - |
| *H. bolini* | - | 0.02 | 0.02 | | 0.08 | 0.03 |
| *Hemilepidotus* spp. | 0.03 | - | - | 0.07 | - | - |
| *H. jordani* | - | 0.01 | 0.02 | - | 0.03 | 0.05 |
| *Myoxocephalus* spp. | 0.02 | - | - | 0.03 | - | - |
| *M. verrucosus* | - | 0.01 | 0.01 | - | - | - |
| *M. jaok* | - | 0.03 | 0.03 | - | - | - |
| *M. polyacanthocephalus* | - | 0.04 | 0.06 | - | 0.02 | 0.04 |

*Notes: Catch data for 2009 are incomplete; retrieved October 7, 2009. The most recent AI survey biomass estimates (2006) were used for all three years. For 2007, only catch by genera is available for the fishery data.*

Total sculpin catch was calculated for each target fishery responsible for sculpin bycatch (Table 4). This analysis indicates that in the Aleutian Islands both the Pacific cod and Atka mackerel fisheries were the main fisheries catching sculpins. In the EBS the Pacific cod fisheries and the yellowfin sole fishery were the main fisheries that caught sculpisn. Sculpins, in general, are not retained by fisheries in the BSAI region, although preliminary data indicate that the retention rate increased to 13% in 2009 (Table 3).

Survey Biomass Estimates

Biomass estimates are available for all identified sculpin species in the BSAI. The species composition of the sculpin complex as estimated by bottom trawl surveys of the EBS shelf, EBS slope, and AI demonstrates the diversity of this complex and the regional differences in its composition. The larger species dominate the EBS shelf, with *Myoxocephalus* spp. being the most common, followed by bigmouth sculpins and yellow Irish lords (Table 6. A low coefficient of variation for most of the biomass estimates of these more abundant species reflects that the EBS shelf bottom trawl survey adequately estimates the biomass of these species. It is interesting to note that the 2006 and 2007 biomass estimates for butterfly sculpin (*H. papilio*) were substantially higher than in previous years (Table 7). This may be in response to cooler waters observed in the Bering Sea in 2006 and 2007 since it is thought that this species follows the cold pool north, to areas that aren't surveyed, during warmer years. Biomass estimates for the 5 most abundant sculpin species in the Eastern Bering Sea shelf seem to be relatively stable (Figure 1). Three trawl surveys have also been conducted on the EBS slope (in 2002, 2004 and 2008), but no biomass trends for sculpin were apparent in this short time series (Table 7). Based on the EBS slope surveys, abundance of sculpins appears to be relatively low in the deeper waters sampled by this survey.

In the AI, biomass estimates of the six most abundant species of sculpin have been calculated since 1997. The yellow Irish lord, bigmouth sculpin, and darkfin sculpin having reliable estimates since 1982. In the AI, yellow Irish lord account for the highest proportion of sculpin biomass, followed by darkfin sculpin, great sculpin, spectacled sculpin, bigmouth sculpin and scissortail sculpin (Table 8). The spectacled and scissortail sculpins are two species not found on EBS surveys. The AI survey adequately assesses the biomass of the 5 most abundant sculpin species, which are the larger species of sculpin. Due to varying rates of selectivity, the biomass estimates for the less abundant, smaller species of sculpin are probably not reliable (CV range from 0.31 to 1.00). The smaller sculpin species may be less vulnerable to capture by the gear used during the bottom trawl survey because they may pass through the net. Biomass trends of sculpin species in the AI seem to be stable with an increase in yellow Irish lord biomass since 1991. (Figure 2).

Length frequency and sample size

*Eastern Bering Sea*

Length measurements (fork length, FL) have been collected for a variety of sculpin species during AFSC surveys. The five most abundant species from the EBS shelf survey have been measured annually since 2000: yellow Irish lord, plain sculpin, warty sculpin, great sculpin and bigmouth sculpin (Figure 3). Year by year analysis shows that the length composition by species is generally consistent. However, yellow Irish lord showed more small fish in the earlier years, and there was a conspicuous absence of fish <300 mm in 2007, but they returned in 2008. One interesting observation is that the surveys tend to catch bigmouth sculpins on the higher side of the length range. Although 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 or they are not fully selected by the gear. Fishery length data are still not available.

**Sample sizes for length frequency analysis for EBS shelf:**

| **Species** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** |
|---|---|---|---|---|---|---|---|---|---|
| yellow Irish lord | | | 369 | 516 | 604 | 492 | 272 | 627 | 938 |
| plain sculpin | 1263 | 997 | 1218 | 1736 | 1786 | 1778 | 1541 | 2892 | 2470 |
| warty sculpin | 288 | 130 | 192 | 245 | 323 | 383 | 224 | 468 | 323 |
| great sculpin | 327 | 346 | 635 | 681 | 786 | 845 | 749 | 1449 | 708 |
| bigmouth sculpin | 157 | 231 | 179 | 342 | 187 | 207 | 125 | 342 | 175 |

*Eastern Bering Sea Slope*

Size compositions of the most abundant species on the slope are shown in Figure 4. These data will be presented separately from the EBS shelf data, to show any size differences by species and the difference species composition of sculpins on the slope. Sample sizes for length frequency analysis for EBS Slope in 2008:

| **Species** | **2008** |
|---|---|
| Darkfin Sculpin | 220 |
| Spinyhead sculpin | 138 |
| Blob Sculpin | 123 |
| Bigmouth sculpin | 178 |

*Aleutian Islands*

In the AI, few samples have been taken for great and bigmouth sculpin, thus the length frequency analysis does not yield a complete representation of the sculpin species population’s size composition. Yellow

Irish lords have 5 survey years of data and show a consistent size composition (Figure 5). Darkfin and spectacled sculpin only have length data collected from the 2002 survey. Specimens smaller than 70 mm have not been collected for many sculpins, which may be a factor of size selectivity of the survey gear.

| **Sample sizes for length frequency analysis for AI** | | | | |
|---|---|---|---|---|
| **Species** | **2000** | **2002** | **2004** | **2006** |
| Yellow Irish Lord | 170 | 567 | 986 | 1,099 |
| Great sculpin | 12 | 23 | 58 | 65 |
| Big mouth sculpin | 8 | 29 | 27 | 41 |

Length at age and weight at age

In 2007 and 2008 as part of a grant from the North Pacific Research Board, the Age and Growth group at the AFSC aged the following species of sculpin from the Eastern Bering Sea shelf survey:

| **Species** | **Max. Age** | **# samples aged** |
|---|---|---|
| Yellow Irish Lord | 28 | 784 |
| Great sculpin | 17 | 578 |
| Big mouth sculpin | 20 | 88 |
| Warty | 18 | 683 |
| Plain | 16 | 777 |

*Yellow Irish lord*

Figure 6 shows the von Bertalanffy growth curves for yellow Irish lords in the eastern Bering Sea and Aleutian Islands. Below are age and growth data for yellow Irish lord in the eastern Bering Sea and Aleutian Islands. N = sample size; $L_\infty$, $k$, and $t_0$ are the parameters of the Von Bertalanffy equation; $t_{min}$, $t_{max}$, and $t_{mean}$ are the minimum, maximum, and mean ages observed, respectively. Asymptotic standard errors are shown in parentheses next to each parameter. The analysis of residual sum of squares (ARSS) was used to analyze growth, which was significantly different between sexes within the eastern Bering Sea ($P < 0.05$) and within in the Aleutian Islands ($P = 0.002$). Growth also differed significantly between regions for boths sexes ($P < 0.05$ for males and $P = 0.001$ for females).

| **Yellow Irish lord** | | | | | | |
|---|---|---|---|---|---|---|
| | Eastern Bering Sea | | | Aleutian Islands | | |
| | Combined | Males | Females | Combined | Males | Females |
| $N$ | 386 | 140 | 246 | 398 | 160 | 238 |
| $L_\infty$ (cm) | 43.0 (4.28) | 46.8 (10.86) | 42.1 (4.35) | 45.8 (6.99) | 52.2 (16.99) | 44.2 (7.60) |
| $k$ | 0.299 (0.018) | 0.257 (0.029) | 0.295 (0.019) | 0.179 (0.013) | 0.147 (0.018) | 0.171 (0.015) |
| $t_0$ | 0.056 (0.172) | -0.071 (0.311) | -0.022 (0.198) | -0.808 (0.291) | -0.851 (0.429) | -1.258 (0.393) |
| $r^2$ | 0.80 | 0.81 | 0.83 | 0.78 | 0.84 | 0.80 |
| $t_{max}$ | 28 | 24 | 28 | 26 | 20 | 26 |
| $t_{min}$ | 2 | 2 | 2 | 1 | 2 | 1 |
| $t_{mean}$ | 7.4 | 6.2 | 8.1 | 8.6 | 7.8 | 9.1 |

*Great sculpin*

Figure 7 shows the von Bertalanffy growth curves for great sculpins in the Bering Sea and parameters of the von Bertalanffy growth curves for males and females are listed below. Growth was significantly different between sexes ($P < 0.001$).

| great sculpin | | |
|---|---|---|
| Parameters | Males | Females |
| $n$ | 241 | 330 |
| $L_\infty$ | 60.8 (2.03) | 80.0 (2.82) |
| $k$ | 0.245 (0.033) | 0.169 (0.018) |
| $t_0$ | 0.540 (0.319) | 0.351 (0.257) |
| $r^2$ | 0.73 | 0.83 |
| $t_{mean}$ | 6.45 | 7.08 |
| $t_{min}$ | 2 | 3 |
| $t_{max}$ | 15 | 17 |

*Bigmouth sculpin*

Figure 8 shows the von Bertalanffy growth curves for bigmouth sculpins in the Bering Sea. Below are the parameters of the von Bertalanffy growth curves for sexes combined. Comparisons of male and female growth were not conducted due to small sample size.

| bigmouth sculpin | |
|---|---|
| Parameters | Combined |
| $n$ | 88 |
| $L_\infty$ | 78.4 (6.00) |
| $k$ | 0.132 (0.027) |
| $t_0$ | 0.555 (0.531) |
| $r^2$ | 0.77 |
| $t_{mean}$ | 8.61 |
| $t_{min}$ | 2 |
| $t_{max}$ | 20 |

*Warty sculpin*

Figure 9 shows the von Bertalanffy growth curves for warty sculpins in the Bering Sea, and parameters of the von Bertalanffy growth curves for males and females are listed below. Growth was significantly different between sexes ($P < 0.01$).

| Warty sculpin | | |
|---|---|---|
| Parameters | Males | Females |
| $n$ | 267 | 415 |
| $L_\infty$ | 43.4 (1.10) | 53.7 (0.74) |
| $k$ | 0.362 (0.059) | 0.259 (0.022) |
| $t_0$ | 0.039 (0.455) | -0.089 (0.283) |
| $r^2$ | 0.50 | 0.76 |
| $t_{mean}$ | 5.43 | 7.47 |
| $t_{min}$ | 2 | 2 |
| $t_{max}$ | 15 | 18 |

*Plain sculpin*

Figure 10 shows the von Bertalanffy growth curves for plain sculpins in the Bering Sea and parameters of the von Bertalanffy growth curves for males and females are listed below. Growth was significantly different between sexes (*P* = 0.001).

| **plain sculpin** | | |
|---|---|---|
| Parameters | Males | Females |
| $n$ | 300 | 477 |
| $L_\infty$ | 43.4 (1.70) | 54.8 (0.92) |
| $k$ | 0.240 (0.035) | 0.312 (0.022) |
| $t_0$ | -0.547 (0.372) | 1.030 (0.141) |
| $r^2$ | 0.57 | 0.74 |
| $t_{mean}$ | 4.94 | 5.83 |
| $t_{min}$ | 1 | 1 |
| $t_{max}$ | 15 | 16 |

**Analytical Approach and Results**

The available data do not currently support population modeling for sculpins in the BSAI; therefore, these stocks are managed as tier 5 in the NPFMC's definitions of OFL and ABC, where OFL and ABC are estimated as a function of biomass and natural mortality.

Parameters Estimated Independently

*Natural mortality*

An analysis was undertaken to estimate natural mortality (*M*) for sculpin species found in the BSAI. Several methods were employed based on life history parameters including growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993, Jensen 1996), longevity (Hoenig 1983), and reproductive potential (Rikhter and Efanov 1976). Prior to 2007, little information was available for sculpin stocks in the BSAI FMP area, so M was estimated using reproductive potential methods applied to data for Russian sculpin species (Rikhter and Efanov 1976). In 2007 and 2008, the results of the aging studies for EBS sculpin (discussed in the previous section) were used to produce *M* estimates specific to this area (Table 9). These estimates vary widely. At the Plan Team meeting in September 2009, the authors were encouraged to use the best available science in selecting a value of *M* to be used for setting OFL. We believe that the Hoenig method gives the single best estimate of *M*. It is based on maximum age, which we feel produces a solid basis for estimating natural mortality. Because we have only two years of data, the Hoenig estimator also provides for greater stability of the estimates (i.e. maximum age is less likely to change with the addition of new data). Finally, the Hoenig estimator is the most widely used and as a result, the most likely to be consistent with the fisheries theory upon which the sustainability of the Tier 5 approach is based.

Assemblage analysis and geographic differences

We recommend that management of sculpins be tailored to their specific life history characteristics. Sculpins have a life history that is very different from sharks, skates and other member of the Other Species assemblage. In addition, the varying estimates of M suggest that there are substantial differences in productivity among the BSAI sculpin species. Therefore, we recommend that sculpins be managed as a single species group (rather than as part of the Other Species complex) and that analyses be conducted to determine the best approach to management of a standalone sculpin complex.

Analysis of species composition, abundance and occurrence of sculpin species within the EBS and AI was done to determine if the complex should be split by region. Results of this analysis indicated that species composition in the EBS and AI is very different (Figure 11). Although a few species such as great sculpin, yellow Irish lord and bigmouth sculpin occur in the EBS shelf, EBS slope and AI regions, their proportion of biomass relative to the complex varies greatly (Table 7, 8 and 9). Plain and warty sculpins occur only on the EBS shelf, and are not found in the AI or EBS slope. In the AI, antlered sculpin may be endemic. Splitting the biomass to obtain separate ABC and OFL for each region will allow for adequate monitoring of those species in the AI.

### ABC and OFL recommendations

As in the past, we recommend a Tier 5 approach be applied to the sculpin complex within the EBS and AI regions as long as the catch remains incidental and no target fishery develops. Under Tier 5, $F_{OFL}$ = M and $F_{ABC}$ = 0.75*M. OFL = $F_{OFL}$ * average survey biomass, and maximum permissible ABC = $F_{ABC}$ * average survey biomass. We recommend using a 6 year average of aggregate biomass(2004-2009) so that we may include multiple estimates from each of the EBS shelf, slope, and AI bottom trawl surveys, but can still capture recent biomass trends. Individual OFLs and ABCs are calculated for those species with recent, BSAI-specific estimates of *M*. For the remaining species, we recommend using *M* = 0.19, which was the value used for all sculpins before the new estimates became available (Reuter and Tenbrink 2007). As described earlier, we believe that the Hoenig value of *M* is the single best estimate for calculating OFL and maximum permissible ABC. However, **to account for uncertainty in the estimates of *M*, we recommend using the most conservative BSAI-specific values of *M* to set the 2010-2011 sculpin ABC.** We also provide separate recommendations for the EBS and AI in support of separate management for the two areas.

**2010-2011 BSAI sculpin harvest recommendations**

| region | species | M | biomass (t) | max. $F_{ABC}$ | max. ABC (t) | $F_{OFL}$ | OFL (t) | author rec. $F_{ABC}$ | author rec. ABC (t) |
|---|---|---|---|---|---|---|---|---|---|
| EBS shelf | warty | 0.23 | 14,134 | 0.17 | 2,438 | 0.23 | 3,251 | 0.12 | 1,696 |
| | great | 0.25 | 57,862 | 0.19 | 10,849 | 0.25 | 14,466 | 0.18 | 10,415 |
| | bigmouth | 0.21 | 29,128 | 0.16 | 4,588 | 0.21 | 6,117 | 0.16 | 4,588 |
| | plain | 0.26 | 65,687 | 0.20 | 12,809 | 0.26 | 17,079 | 0.13 | 8,375 |
| | threaded | 0.42 | 2,184 | 0.32 | 688 | 0.42 | 917 | 0.27 | 590 |
| | YIL | 0.15 | 28,651 | 0.11 | 3,223 | 0.15 | 4,298 | 0.03 | 860 |
| | other | 0.19 | 6,113 | 0.14 | 871 | 0.19 | 1,161 | 0.14 | 871 |
| EBS slope | all | 0.19 | 5,941 | 0.14 | 847 | 0.19 | 1,129 | 0.14 | 847 |
| **EBS total** | | | **209,700** | | **36,313** | | **48,417** | | **28,241** |
| AI | YIL | 0.16 | 6,946 | 0.12 | 834 | 0.16 | 1,111 | 0.09 | 625 |
| | other | 0.19 | 9,179 | 0.14 | 1,308 | 0.19 | 1,744 | 0.14 | 1,308 |
| **AI total** | | | **16,125** | | **2,142** | | **2,855** | | **1,933** |
| | | | | | | | | | |
| **total BSAI** | | | **225,825** | | **38,454** | | **51,272** | | **30,174** |

**Alternative specifications**

As in the 2008 assessment, we include several alternatives to the approach recommended above. One alternative to the Hoenig estimator is to use an average of all the various BSAI-specific estimates of M for each species. This would result in the following:

| region | species | M | biomass | max. $F_{ABC}$ | max. ABC | $F_{OFL}$ | OFL |
|---|---|---|---|---|---|---|---|
| EBS shelf | warty | 0.36 | 14,134 | 0.27 | 3,816 | 0.36 | 5,088 |
| | great | 0.30 | 57,862 | 0.23 | 13,019 | 0.30 | 17,359 |
| | bigmouth | 0.22 | 29,128 | 0.17 | 4,806 | 0.22 | 6,408 |
| | plain | 0.32 | 65,687 | 0.24 | 15,765 | 0.32 | 21,020 |
| | threaded | 0.48 | 2,184 | 0.36 | 786 | 0.48 | 1,048 |
| | YIL | 0.28 | 28,651 | 0.21 | 6,017 | 0.28 | 8,022 |
| | other | 0.19 | 6,113 | 0.14 | 871 | 0.19 | 1,161 |
| EBS slope | all | 0.19 | 5,941 | 0.14 | 847 | 0.19 | 1,129 |
| **EBS total** | | | **209,700** | | **45,927** | | **61,236** |
| AI | YIL | 0.22 | 6,946 | 0.17 | 1,146 | 0.22 | 1,528 |
| | other | 0.19 | 9,179 | 0.14 | 1,308 | 0.19 | 1,744 |
| **AI total** | | | **16,125** | | **2,454** | | **3,272** |
| | | | | | | | |
| **total BSAI** | | | **225,825** | | **48,381** | | **64,508** |

A second alternative is to use the pre-2008 approach, where a single estimate of M (0.19) is applied to all sculpin species combined:

| region | M | biomass | max. $F_{ABC}$ | max. ABC | $F_{OFL}$ | OFL |
|---|---|---|---|---|---|---|
| EBS | 0.19 | 209,700 | 0.14 | 29,882 | 0.19 | 39,843 |
| AI | 0.19 | 16,125 | 0.14 | 2,298 | 0.19 | 3,064 |
| **BSAI** | **0.19** | **225,825** | **0.14** | **32,180** | **0.19** | **42,907** |

In the unlikely event that target fisheries develop for some sculpin species, we recommend that each targeted sculpin species be managed separately, and that directed fishing only be allowed when sufficient life history information becomes available to make reasonable species specific estimates of productivity. Given that the most probable targeted sculpin species would be the most abundant, managing as single species may not be problematic under the current TAC setting regime, assuming the species was being identified to species level by the observer program. If a targeted species of sculpin is one with a low abundance and thus low TACs, then alternative management strategies should be considered.

## Ecosystem Considerations

### *Ecosystem Effects on Stock*

Little is known about sculpin food habits in the BSAI, especially during fall and winter months. Aydin et al. (2007) have produced some diet analyses and consumption/predation tables based on ecosystem modeling and direct species data for the BSAI. Limited information indicates that in the EBS the larger sculpin species prey on shrimp and other benthic invertebrates, as well as some juvenile walleye pollock (Figure 12). In the EBS the main predator of large sculpins (sculpins from the genera *Myoxocephalus, Hemitripterus* and *Hemilepidotus*) is Pacific cod (Figure 8). Although the greatest mortality of large sculpins is unexplained in the ecosystem model, their fishing mortality is due to the flatfish trawl fishery and Pacific cod longline, trawl and pot fisheries (Table 4). Other sculpins (those sculpins not in the above genera) in the EBS feed mainly on shrimp and benthic amphipods (Figure 13). Other sculpins are preyed upon by pinnipeds, Pacific cod and small demersal fish, but their main source of mortality is from consumption by eelpouts, wintering seals and the Alaska skate (Figure 13). In the AI large sculpin have a different diet than in the EBS, consisting of crabs, Atka mackerel and miscellaneous shallow water fish (Figure 14). Large sculpins in the AI are preyed upon mainly by Pacific halibut, but the main source of their mortality is from groundfish bottom trawl fishery (Figure 14). Diet of other sculpins in the AI consists of infauna such as polychaetes and benthic crustaceans (Figure 15). Pacific cod and walleye pollock are the main predators of other sculpins and are the main source of mortality of other sculpins in the AI (Figure 15).

### *Fishery Effects on the Ecosystem*

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

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

***Data gaps and research priorities***

Sculpin life history has been studied more extensively in the western Bering Sea and associated waters. Although we have recently acquired substantially more life history data for five species in the EBS concerning age and growth, data gaps continue to persist for other species in the eastern Bering Sea and Aleutian Island regions. Age validation studies could be conducted to validate the newly acquired age data from the five species in the EBS. Genetic analysis of species found in different regions would help determine if there are several stocks of sculpin species within the BSAI. Studies of habitat use and catchability studies of smaller sculpin species would be useful to understand why only the larger species make up most of the sculpin complex biomass. These data are necessary to improve management strategies and stock assessments for this non-target species group.

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

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

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

| Species | Common Name | Maximum Length (cm) | | | Maximum Age | | Fecundity (x1000) | Age at 50% Maturity |
|---|---|---|---|---|---|---|---|---|
| | | O | AI | EBS | O | BSAI | | |
| *Myoxocephalus joak* | Plain sculpin | 75 | NA | 63 | 15 | 16 | 25.4 - 147 | 5 - 8 |
| *M. polyacanthocephalus* | Great sculpin | 82 | 76 | 82 | 13 | 17 | 48 - 415 | 6 - 8 |
| *M. verrucosus* | Warty sculpin | 78 | NA | 78 | | 18 | 2.7 | |
| *Hemitripterus bolini* | Bigmouth sculpin | 83 | 83 | 78 | | 20 | | |
| *Hemilepidotus jordani* | Yellow Irish lord | 65 | 65 | 50 | 13 | 28 | 52 - 389 | 3 - 5 |
| *H. papilio* | Butterfly sculpin | 38 | | 38 | | | | |
| *Gymnocanthus pistilliger* | Threaded sculpin | 27 | | 20 | 13 | 10 | 5 - 41 | |
| *G. galeatus* | Armorhead sculpin | 46 | | 36 | 13 | | 12 - 48 | |
| *Dasycottus setiger* | Spinyhead sculpin | 45 | | 34 | 11 | | | |
| *Icelus spiniger* | Thorny sculpin | 17 | | 17 | | | | |
| *Triglops pingeli* | Ribbed sculpin | 20 | | | 6 | | 1.8 | |
| *T. forficata* | Scissortail sculpin | 30 | | 30 | 6 | | 1.7 | |
| *T. scepticus* | Spectacled sculpin | 25 | 25 | NA | 8 | | 3.1 | |
| *Malacoccottus zonurus* | Darkfin sculpin | | 30 | NA | | | | |

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

Table 3. Total catch (mt) of sculpin complex compared to Other species catch (including squid), 1998-2009. *Data sources: catch data from the AKRO Catch Accounting System; retention rates from fishery observer data obtained from the AFSC Fishery Monitoring and Analysis division.*

| Year | EBS sculpin catch | AI sculpin catch | BSAI sculpin catch | % retained | BSAI Other Species catch | Other Species TAC | % of sculpin in O. Species catch (BSAI) |
|---|---|---|---|---|---|---|---|
| 1998 | 5,204 | 1,081 | 6,285 | | 25,531 | 25,800 | 25% |
| 1999 | 4,503 | 967 | 5,470 | | 20,562 | 32,860 | 27% |
| 2000 | 5,673 | 1,413 | 7,086 | | 26,108 | 31,360 | 27% |
| 2001 | 6,067 | 1,603 | 7,670 | | 27,178 | 26,500 | 28% |
| 2002 | 6,043 | 1,133 | 7,176 | | 28,619 | 30,825 | 25% |
| 2003 | 5,184 | 599 | 5,783 | 1% | 25,731 | 32,309 | 22% |
| 2004 | 5,239 | 891 | 6,129 | 1% | 29,471 | 27,205 | 21% |
| 2005 | 5,114 | 621 | 5,735 | 2% | 29,575 | 29,000 | 19% |
| 2006 | 4,904 | 911 | 5,814 | 3% | 26,895 | 29,000 | 22% |
| 2007 | 6,506 | 1,016 | 7,522 | 6% | 26,649 | 37,355 | 28% |
| 2008 | 6,683 | 934 | 7,618 | 7% | 29,629 | 50,000 | 26% |
| 2009* | 5,504 | 900 | 6,404 | 13% | 23,948 | 50,000 | 27% |

* 2009 data are incomplete; retrieved October 7, 2009.

Table 4. Total catch (mt) of all sculpins by target fishery in the eastern Bering Sea and Aleutian Islands, 2003-2009. *Source: NMFS AK regional office catch accounting system. * 2009 catch data are incomplete; retrieved October 7, 2009.*

| **eastern bering Sea** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009*** |
| Alaska plaice | 0 | 0 | 0 | 3 | 10 | 2 | 3 |
| arrowtooth flounder | 23 | 48 | 121 | 78 | 29 | 78 | 63 |
| Atka mackerel | 7 | 44 | 46 | 26 | 91 | 5 | 6 |
| flathead sole | 402 | 571 | 525 | 513 | 478 | 619 | 405 |
| Greenland Turbot | 6 | 5 | 1 | 1 | 1 | 1 | 1 |
| IFQ halibut | 3 | 1 | 0 | 5 | 0 | 7 | 0 |
| other flat | 53 | 37 | 47 | 11 | 28 | 1 | 1 |
| other target | 14 | 6 | 0 | 2 | 4 | 0 | 0 |
| Pacific cod | 2,740 | 3,143 | 2,587 | 2,297 | 2,449 | 1,663 | 971 |
| rock sole | 438 | 270 | 474 | 643 | 762 | 1,094 | 1,257 |
| rockfish | 1 | 1 | 0 | 2 | 0 | 0 | 0 |
| sablefish | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| yellowfin sole | 1,395 | 962 | 1,162 | 1,146 | 2,473 | 2,897 | 2,502 |
| pollock | 102 | 151 | 149 | 176 | 180 | 316 | 295 |

| **Aleutian Islands** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009*** |
| arrowtooth flounder | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| Atka mackerel | 287 | 476 | 372 | 488 | 555 | 459 | 567 |
| flathead sole | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Greenland turbot | 0 | 0 | 0 | 0 | 1 | 2 | 1 |
| IFQ halibut | 4 | 8 | 1 | 4 | 0 | 5 | 0 |
| other target | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pacific cod | 260 | 358 | 214 | 376 | 403 | 394 | 281 |
| rock sole | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| rockfish | 47 | 49 | 34 | 40 | 54 | 72 | 41 |
| sablefish | 0 | 0 | 0 | 1 | 2 | 1 | 4 |
| pollock | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

Table 5. Extrapolated total catch (mt) of Large sculpins (*Hemilepidotus* spp., *Hemitripterus* spp. *and Myoxocephalus* spp.). Based on observer data. *Source: NMFS AFSC FMA program.*

| | EBS | | | AI | | |
|---|---|---|---|---|---|---|
| | **2007** | **2008** | **2009*** | **2007** | **2008** | **2009*** |
| *Hemitripterus* spp.** | 10.0% | | | 12.0% | | |
| *H. bolini* | | 9.2% | 7.2% | | 14.0% | 5.8% |
| *Hemilepidotus* spp. | 19.0% | | | 69.0% | | |
| *Hemilepidotus* unidentified | | 1.8% | 0.4% | | 15.7% | 4.3% |
| *H. hemilepidotus* | | < 1% | < 1% | | < 1% | < 1% |
| *H. jordani* | | 6.8% | 8.2% | | 35.3% | 64.0% |
| *H. spinosus* | | < 1% | 0.0% | | < 1% | < 1% |
| *Myoxocephalus* spp. | 58.0% | | | 6.0% | | |
| *Myoxocephalus* unidentified | | 4.2% | < 1% | | < 1% | < 1% |
| *M. verrucosus* | | 2.2% | 1.8% | | < 1% | < 1% |
| *M. jaok* | | 27.2% | 29.1% | | < 1% | < 1% |
| *M. polyacanthocephalus* | | 43.6% | 50.4% | | 4.6% | 9.0% |
| Miscellaneous sculpins§ | 13.0% | 4.8% | 2.1% | 13.0% | 30.0% | 16.9% |

* 2009 data are incomplete.

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

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

Table 6. Sculpin complex biomass (mt) from the 2003-2009 Eastern Bering Sea shelf survey and the coefficient of variation (CV) in biomass for 2009.

| | **Biomass** | | | | | | | **CV** |
|---|---|---|---|---|---|---|---|---|
| **species** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2009** |
| plain | 79,337 | 68,671 | 76,540 | 66,819 | 77,836 | 56,935 | 47,322 | 0.09 |
| great | 64,486 | 58,505 | 55,957 | 54,456 | 63,132 | 70,223 | 44,901 | 0.12 |
| bigmouth | 29,274 | 34,748 | 31,002 | 30,116 | 27,859 | 30,846 | 20,196 | 0.16 |
| yellow Irish lord | 14,220 | 33,630 | 27,380 | 31,684 | 23,765 | 32,389 | 23,056 | 0.43 |
| warty | 7,058 | 10,089 | 25,897 | 16,099 | 13,370 | 11,397 | 7,952 | 0.26 |
| threaded | 1,137 | 1,275 | 1,977 | 2,385 | 4,126 | 2,174 | 1,167 | 0.30 |
| spinyhead | 1,274 | 1,019 | 4,469 | 2,479 | 1,949 | 870 | 1,586 | 0.20 |
| armorhead | 720 | 785 | 1,551 | 1,732 | 990 | 2,113 | 1,859 | 0.59 |
| thorny | 715 | 616 | 543 | 596 | 478 | 940 | 1,159 | 0.19 |
| ribbed | 142 | 556 | 264 | 400 | 309 | 368 | 581 | 0.64 |
| butterfly | 628 | 379 | 370 | 1,491 | 1,653 | 543 | 799 | 0.50 |
| darkfin | 11 | 122 | 35 | 69 | 46 | 1 | 3 | 0.78 |
| roughspine | 10 | 62 | 111 | 168 | 57 | 176 | 64 | 0.75 |
| spectacled | 298 | 29 | 112 | 365 | 217 | 184 | 224 | 0.58 |
| spatulate | 3 | 13 | 20 | 46 | 49 | 23 | 60 | 0.16 |
| hookhorn | 0 | trace | 3 | 1 | 4 | 3 | 8 | 0.39 |
| scissortail | 0 | 0 | 0 | 0 | 0 | | 77 | 1.00 |
| staghorn | 0 | 0 | 210 | 91 | 0 | 20 | | |
| antlered | 0 | 0 | 0 | 0 | 0 | | | |
| crested | | | | 23 | 0 | | 5 | 0.71 |
| red Irish lord | | | | | 5 | | 106 | 1.00 |
| eyeshade | | | | | 1 | | | |
| smoothcheek | | | | | 4 | | | |
| sailfin | | | | | | | 0.1 | 1.00 |
| unID sculpins | 0 | 10 | 0 | 0 | 0 | 42 | 0 | |
| | | | | | | | | |
| **total sculpins** | **199,313** | **210,509** | **226,441** | **209,020** | **215,850** | **209,247** | **151,153** | |

Table 7. Sculpin complex biomass (mt) from the 2002, 2004 and 2008 Eastern Bering Sea slope survey and the coefficient of variation (CV) for 2008.

| | | Biomass | | | CV |
|---|---|---|---|---|---|
| **Sculpin species** | **common** | **2002** | **2004** | **2008** | **2008** |
| *Gymnocanthus galeatus* | armorhead | <1 | | | |
| *Myoxocephalus polyacanthocephalus* | great | 44 | 5 | 9 | 1 |
| *Hemitripterus bolini* | bigmouth | 1,920 | 1,289 | 3,216 | 0.15 |
| *Hemilepidotus jordani* | yellow Irish lord | | 113 | 7 | 0.74 |
| *Dasycottus setiger* | spinyhead | 1,158 | 701 | 381 | 0.16 |
| *Malcocottus zonurus* | darkfin | 1,525 | 1,798 | 1,109 | 0.33 |
| *Icelus spiniger* | thorny | 74 | 39 | 6 | 0.74 |
| *Icelus canalictulatus* | blacknose | 122 | | 40 | 0.45 |
| *Icelus euryops* | wide-eye | 11 | | 4 | 0.6 |
| *Icelus spatula* | spatulate | | | <1 | 0.71 |
| *Triglops scepticus* | spectacled | 58 | 57 | 30 | 0.39 |
| *Psychrolutes phrictus* | blob | 1,471 | | 1,145 | 0.19 |
| *Zesticelus profundorum* | flabby | <1 | | <1 | 0.33 |
| *Rastrinus scutiger* | roughskin | <1 | | | |
| sculpin unid (all others) | | | 1,486 | | |
| **Total** | | **6,386** | **5,488** | **5,948** | **0.11** |

Table 8. Sculpin complex biomass (mt) from the 1997-2006 Aleutian Islands trawl survey and the coefficient of variation (CV) for 2006.

| Species | Common Name | Biomass | | | | | CV |
|---|---|---|---|---|---|---|---|
| | | **1997** | **2000** | **2002** | **2004** | **2006** | **2006** |
| *Hemilepidotus jordani* | Yellow Irish lord | 4,667 | 6,624 | 4,282 | 8,361 | 10,797 | 0.16 |
| *Malacocottus zonurus* | Darkfin sculpin | 3,442 | 2,533 | 3,971 | 4,493 | 4,520 | 0.17 |
| *Myoxocephalus polyacanthocephalus* | Great sculpin | 2,138 | 1,161 | 1,547 | 1,519 | 2,121 | 0.20 |
| *Triglops scepticus* | Spectacled sculpin | 1,344 | 1,121 | 2,393 | 1,038 | 993 | 0.29 |
| *Hemitripterus bolini* | Bigmouth sculpin | 1,617 | 1,026 | 1,191 | 790 | 1,647 | 0.32 |
| *T. forficata* | Scissortail sculpin | 219 | 66 | 442 | 2,073 | 136 | 0.43 |
| *Gymnocanthus galeatus* | Armorhead sculpin | 105 | 287 | 207 | 506 | 424 | 0.34 |
| Sculpin unid. (all others) | | 75 | 49 | 137 | 101 | 181 | 0.31 |
| *Dasycottus setiger* | Spinyhead sculpin | 71 | 19 | 23 | 72 | 12 | 0.62 |
| *Enophrys diceraus* | Antlered sculpin | 0 | 0 | 20 | 17 | 8 | 1.00 |
| *Myoxocephalus jaok* | Plain sculpin | 0 | 0 | 32 | 0 | 0 | |
| *Leptocottus armatus* | Pacific staghorn sculpin | 0 | 0 | 0 | 9 | 0 | |
| **Total** | | **13,678** | **12,886** | **14,245** | **18,979** | **20,839** | |

Table 9. List of available natural mortality information for sculpins.

| Species | Area | Sex | Hoenig | Rikhter & Efanov | Alverson & Carney | Jensen | Charnov |
|---|---|---|---|---|---|---|---|
| Red Irish lord | Puget Sound | | 0.70 | | | | |
| Longfin Irish lord | Kuril Islands | *F* | 0.47 | | 0.70 | | 0.22 |
| Yellow Irish lord | Kamchatka | *M* | 0.32 | 0.24 | | | |
| | Kamchatka | *F* | 0.35 | 0.24 | | | |
| | E. Bering Sea* | *M* | 0.17 | | 0.08 | 0.41 | 0.45 |
| | E. Bering Sea* | *F* | 0.15 | | 0.04 | 0.47 | 0.51 |
| | Aleutian Is.* | *M* | 0.21 | | 0.21 | 0.23 | 0.27 |
| | Aleutian Is.* | *F* | 0.16 | | 0.12 | 0.27 | 0.31 |
| Pacific staghorn sculpin | California | *F* | 0.42 | | | | |
| Threaded sculpin | E. Bering Sea | *M* | 0.42 | | 0.36 | 0.60 | 0.65 |
| | E. Bering Sea | *F* | 0.47 | | 0.58 | 0.36 | 0.40 |
| Armorhead sculpin | Kamchatka | *M* | 0.38 | | | | |
| | Kamchatka | *F* | 0.32 | | | | |
| Great sculpin | Kamchatka | *M* | 0.47 | 0.26 | | | |
| | Kamchatka | *F* | 0.32 | 0.19 | | | |
| | E. Bering Sea* | *M* | 0.28 | | 0.24 | 0.39 | 0.43 |
| | E. Bering Sea* | *F* | 0.25 | | 0.26 | 0.27 | 0.30 |
| Plain sculpin | E. Bering Sea* | *M* | 0.28 | | 0.25 | 0.38 | 0.42 |
| | E. Bering Sea* | *F* | 0.26 | | 0.17 | 0.27 | 0.55 |
| | Kamchatka | *M* | 0.47 | 0.32 | | | |
| | Kamchatka | *F* | 0.35 | 0.22 | | | |
| Warty sculpin | E. Bering Sea* | *M* | 0.28 | | 0.16 | 0.58 | 0.63 |
| | E. Bering Sea* | *F* | 0.23 | | 0.16 | 0.41 | 0.47 |
| Bigmouth sculpin | E. Bering Sea* | *Both* | 0.21 | | 0.23 | 0.21 | 0.24 |

References: AFSC; Jensen 1996; Panchenko 2001; Panchenko 2002; Tokranov 1985; Tokranov 1988; Tokranov 1989; Tokranov 1995; Hoff 2000; Tokranov and Orlov 2001, Tokranov et al. 2003; Weiss 1969
* Natural mortality estimates new for 2008 (based on unpublished data from TenBrink).

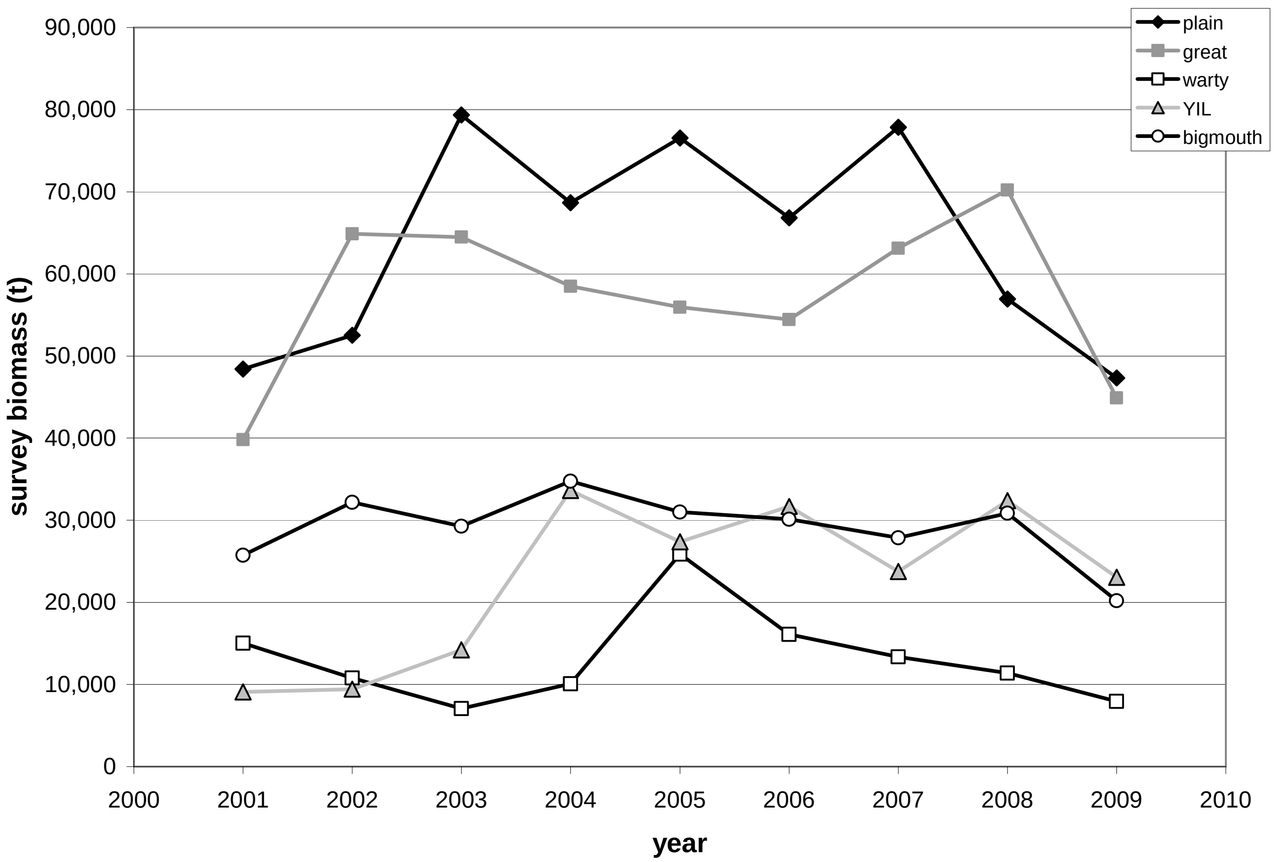



Figure 1. Survey biomass estimates for the five most abundant sculpin species from annual EBS shelf bottom trawl surveys for selected sculpin species, 2001-2009.

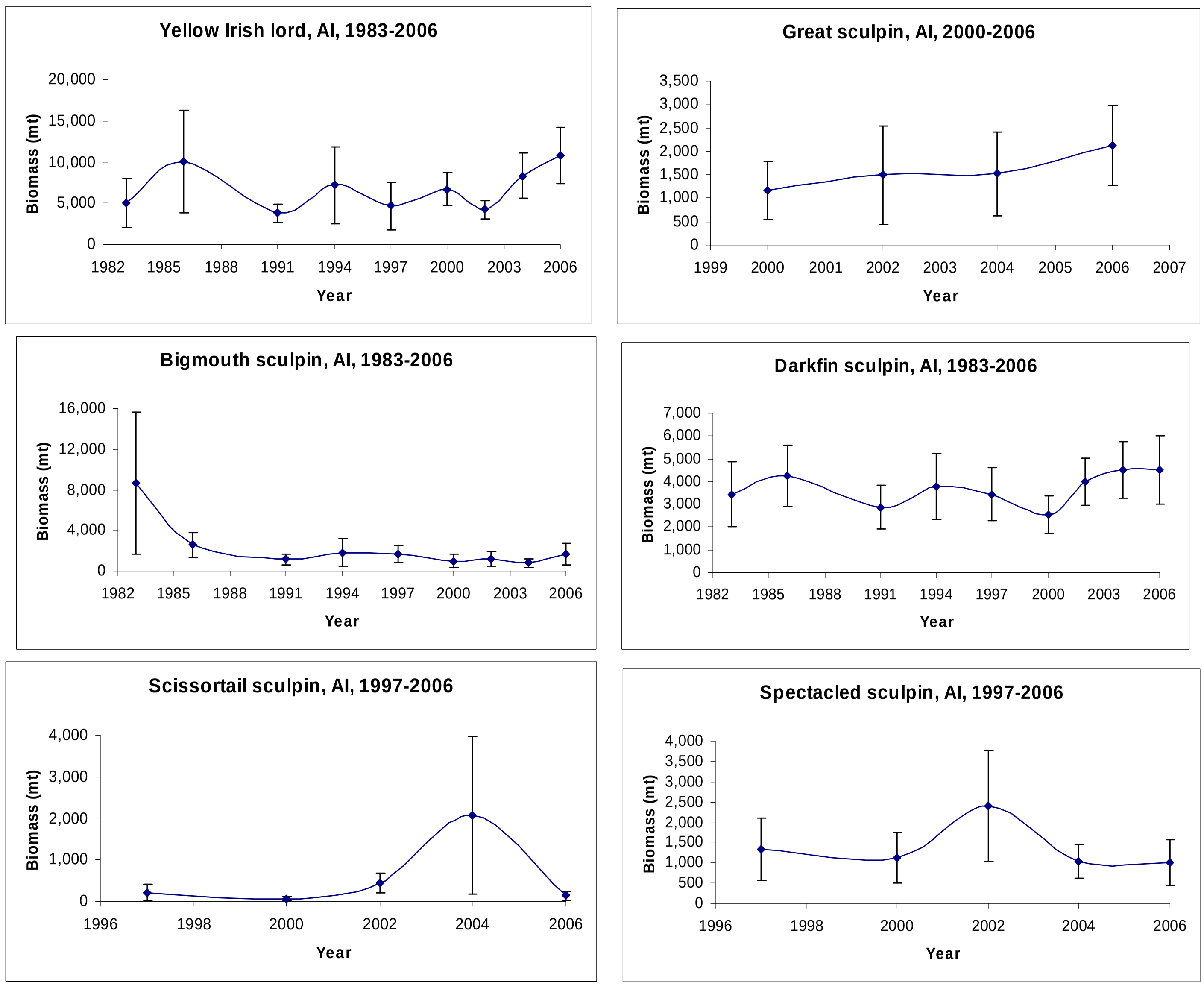
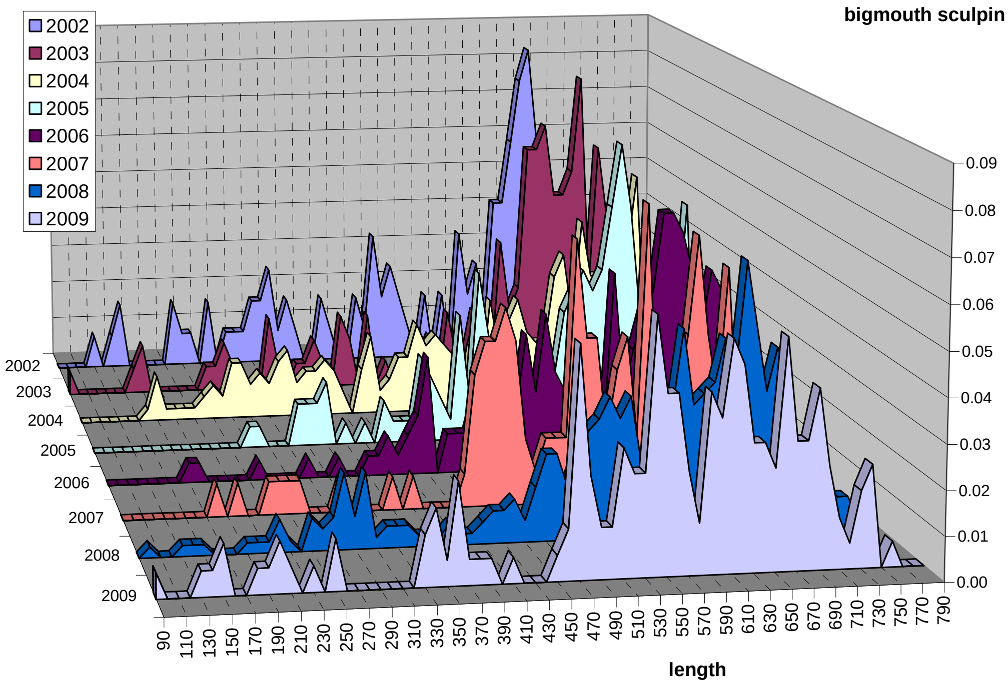



Figure 2. Biomass time series (with 95% confidence intervals) for the six most abundant sculpin species in Aleutian Islands trawl survey 1980-2006. Note: Some sculpin species were not regularly identified to species-level until recent surveys.



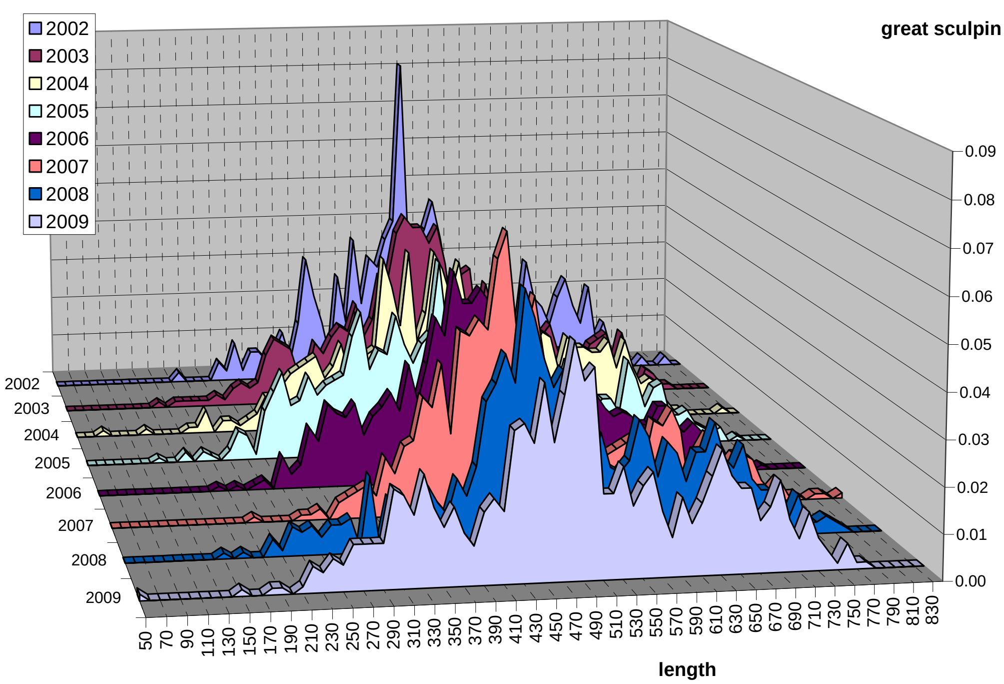
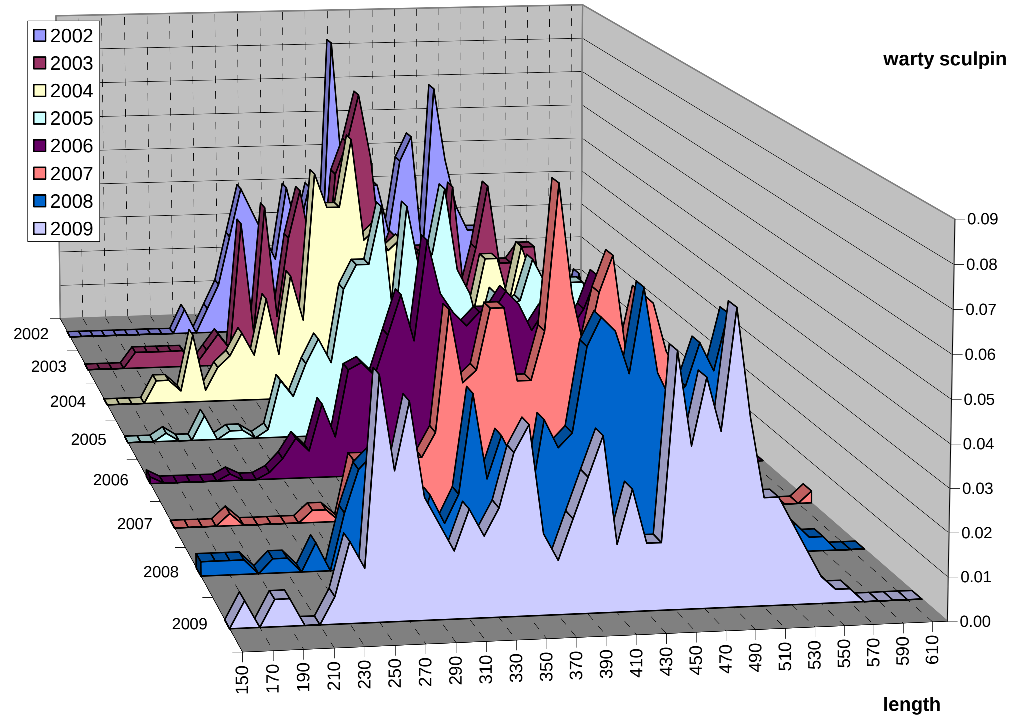




Figure 3. Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2002-2009. Length scale differs among plots.



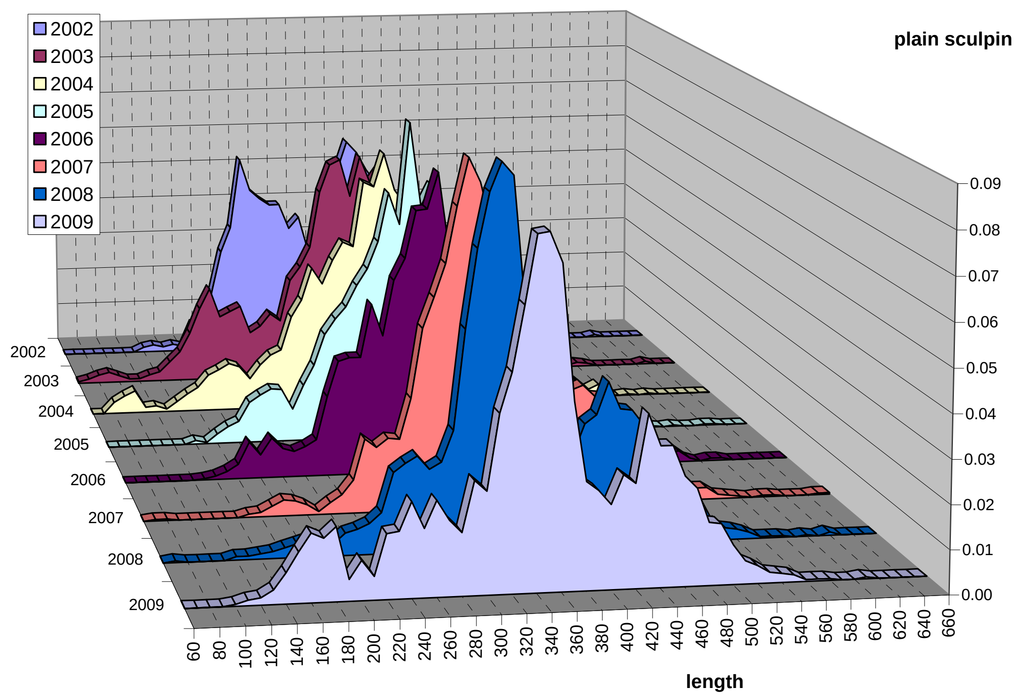




Figure 3 (continued). Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2002-2009. Length scale differs among plots.

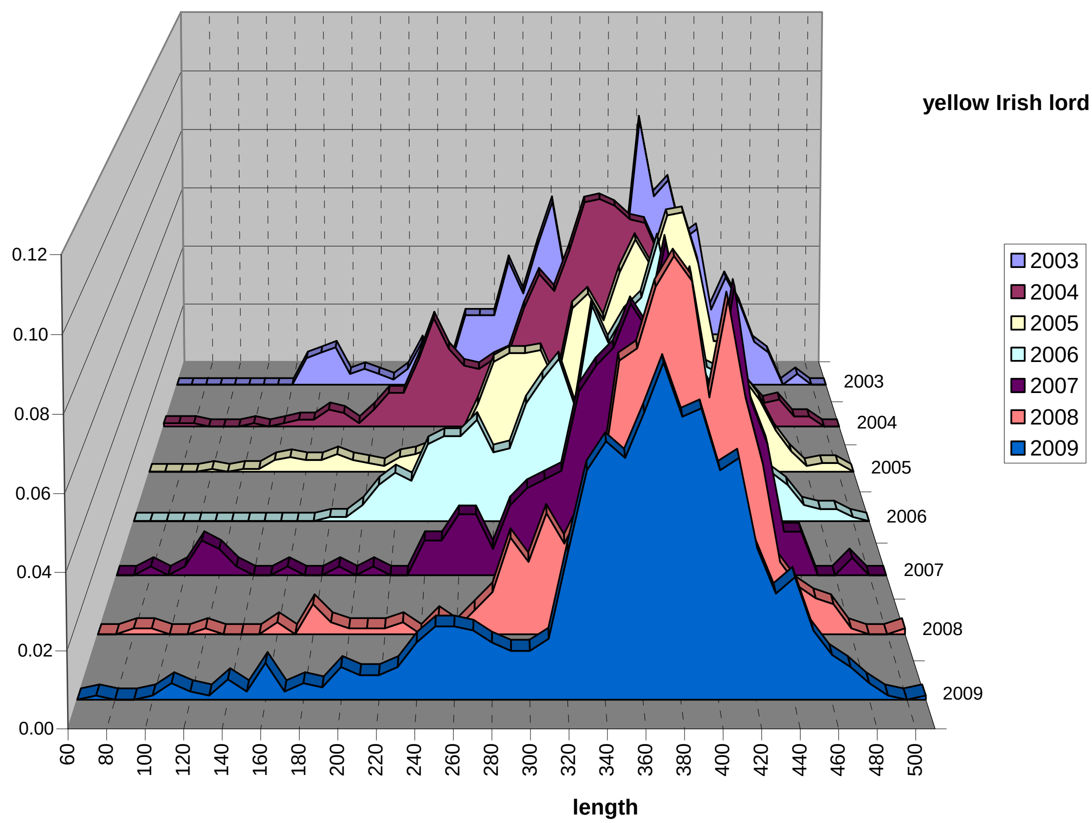



Figure 3 (continued). Length frequencies (fork length, FL in mm) from EBS shelf survey data for the five most abundant sculpin species in EBS, 2002-2009. Length scale differs among plots.

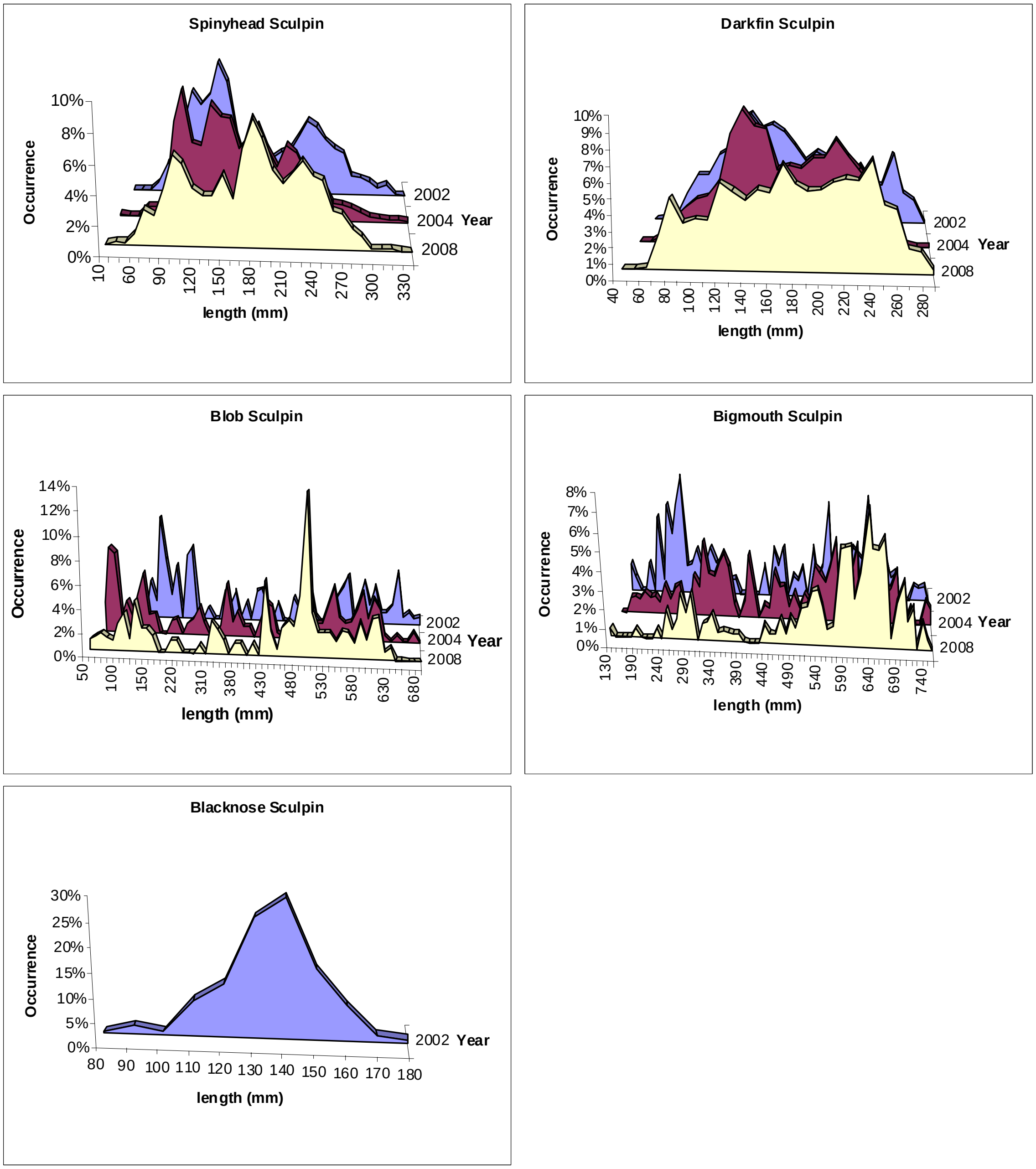



Figure 4. Length frequencies (fork length, FL in mm) from EBS slope survey data for the five most abundant sculpin species in EBS slope.

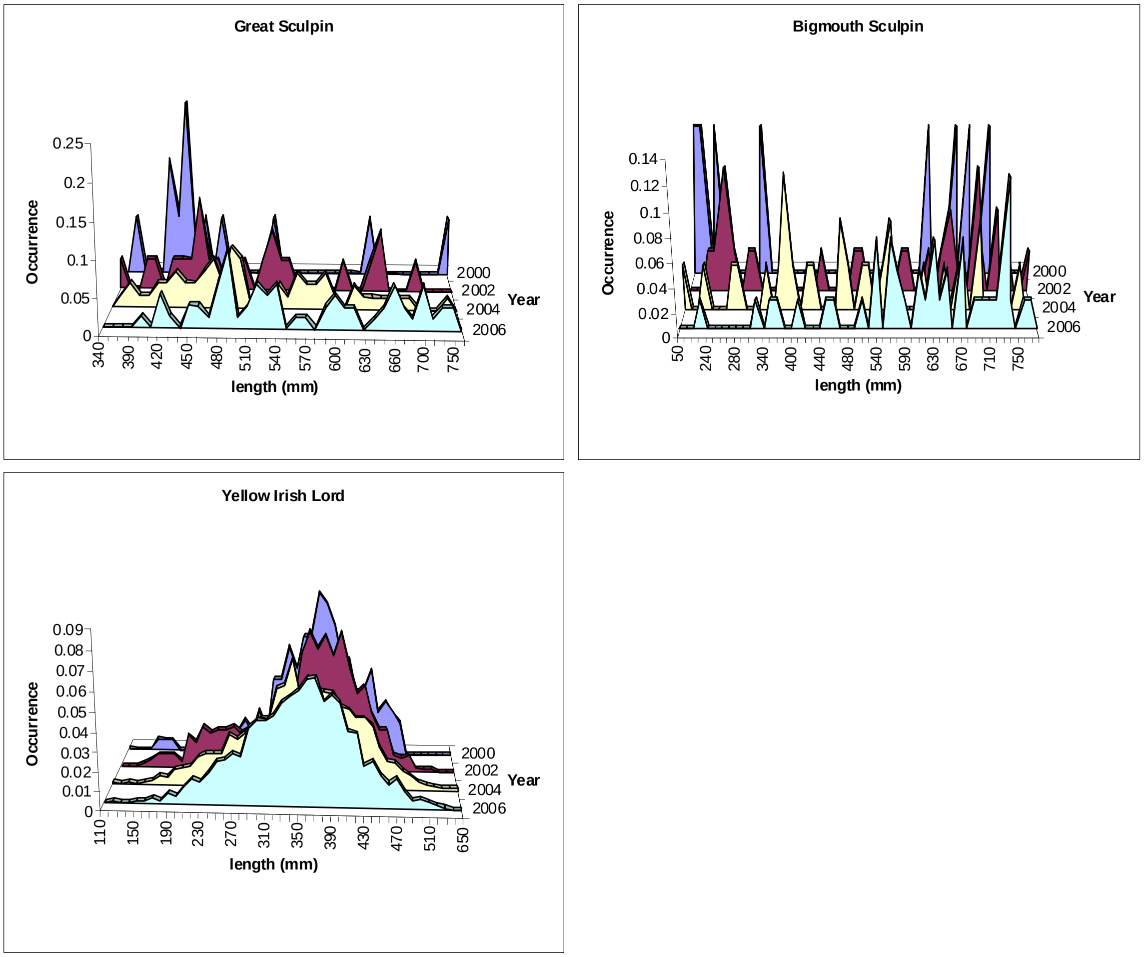
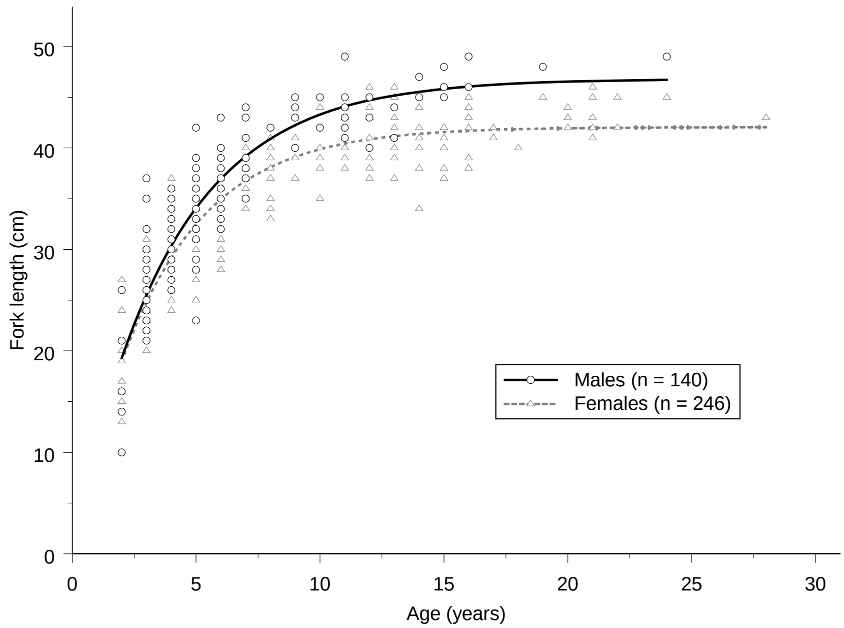



Figure 5. Length frequencies (fork length, FL in mm) from survey data for the 3 most abundant sculpin species in AI.



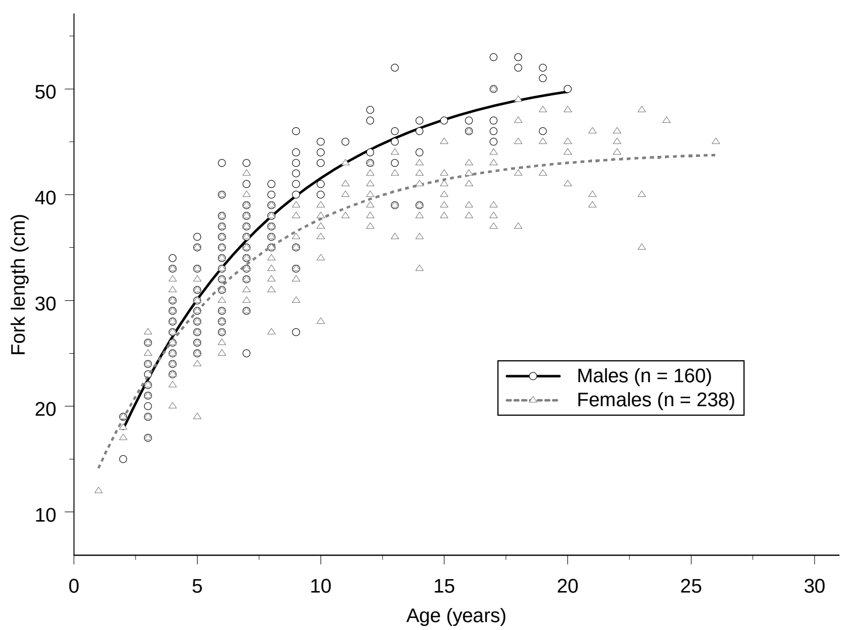




Figure 6. von Bertalanffy graphs for yellow Irish lords in the eastern Bering Sea (top) and Aleutian Islands (bottom).

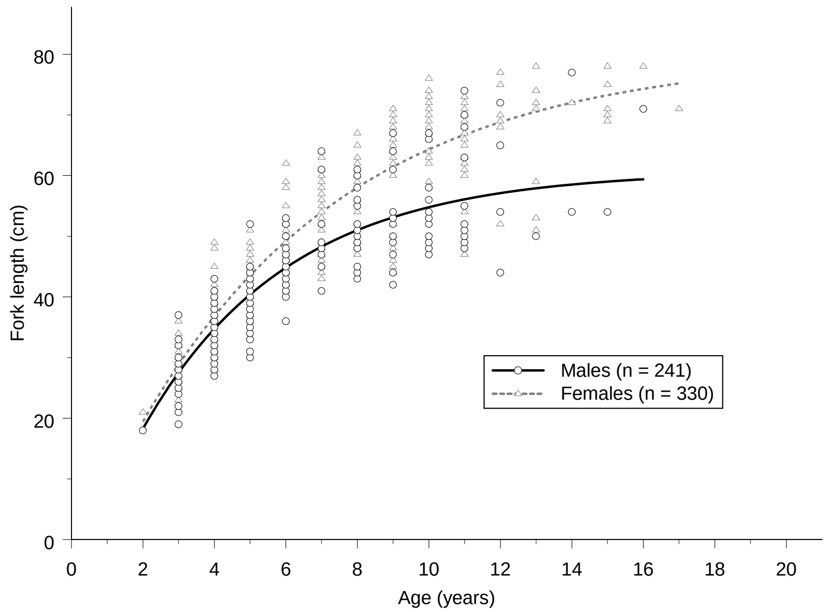



Figure 7. von Bertalanffy graph for great sculpin in the eastern Bering Sea.

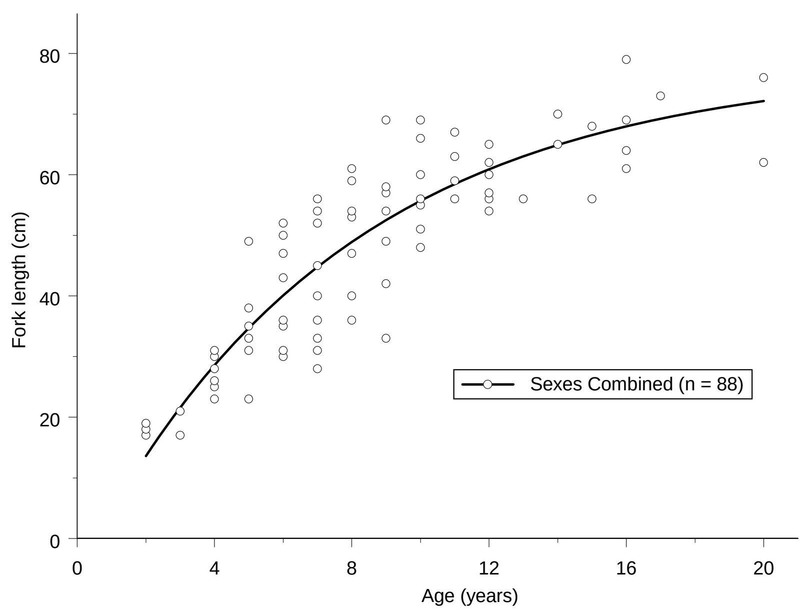



Figure 8. von Bertalanffy growth curves fitted to bigmouth sculpin length-at-age data.

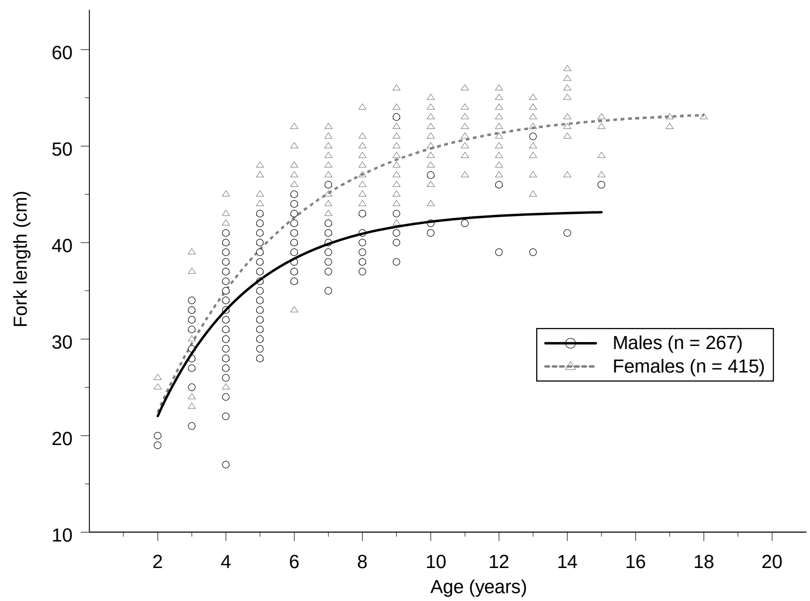



Figure 9. von Bertalanffy growth curves fitted to warty sculpin length-at-age data.

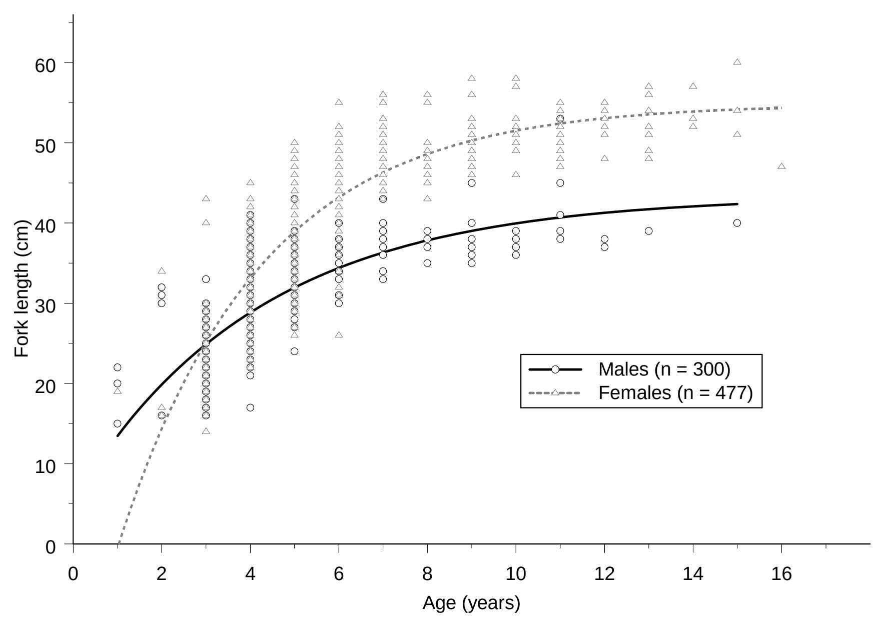



Figure 10. von Bertalanffy graph for plain sculpin in the eastern Bering Sea.

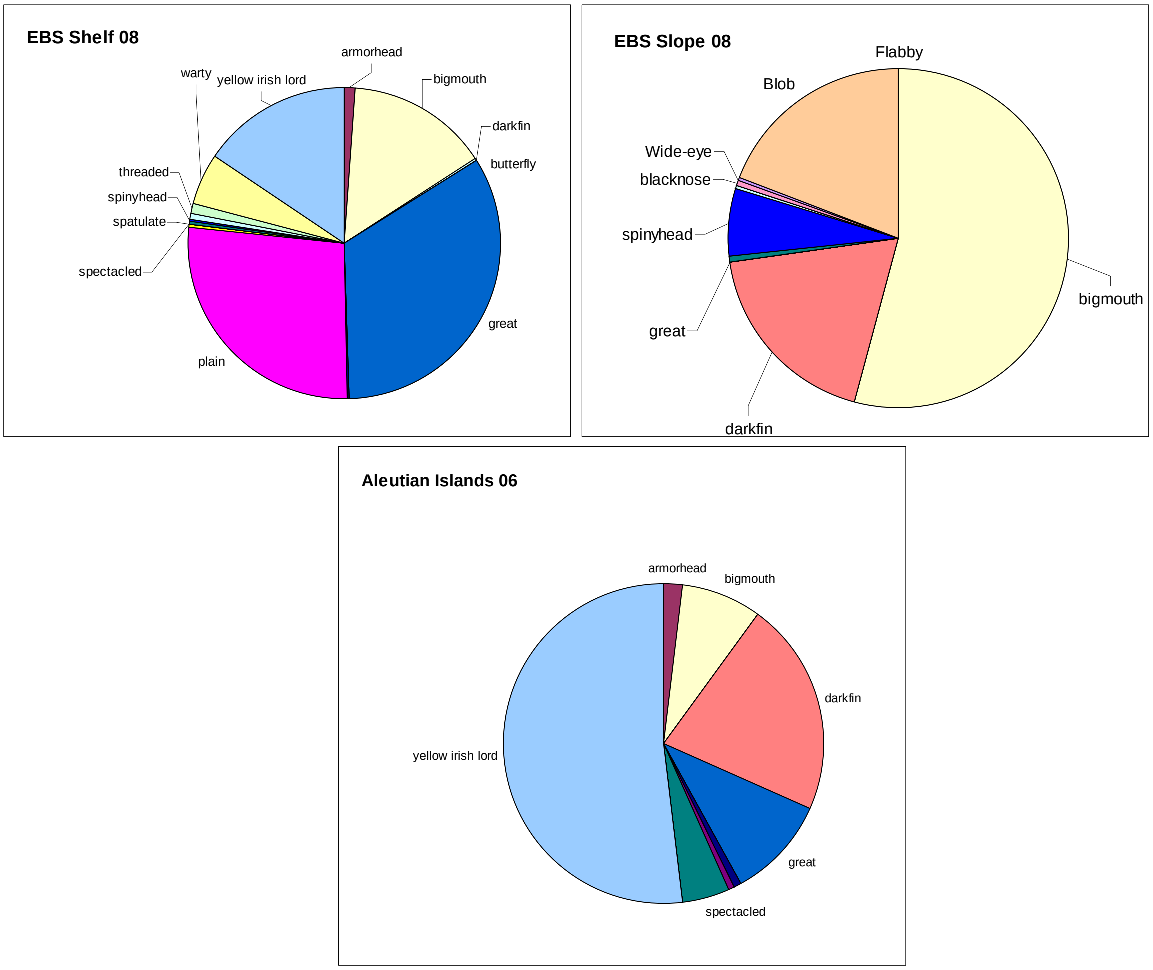



Figure 11. Sculpin Biomass estimates from the 2008 EBS shelf, 2008 EBS slope and 2006 AI surveys to show differences in species composition. Although shelf data are available from the 2009 survey, 2008 estimates remain here to allow direct comparison with the slope.

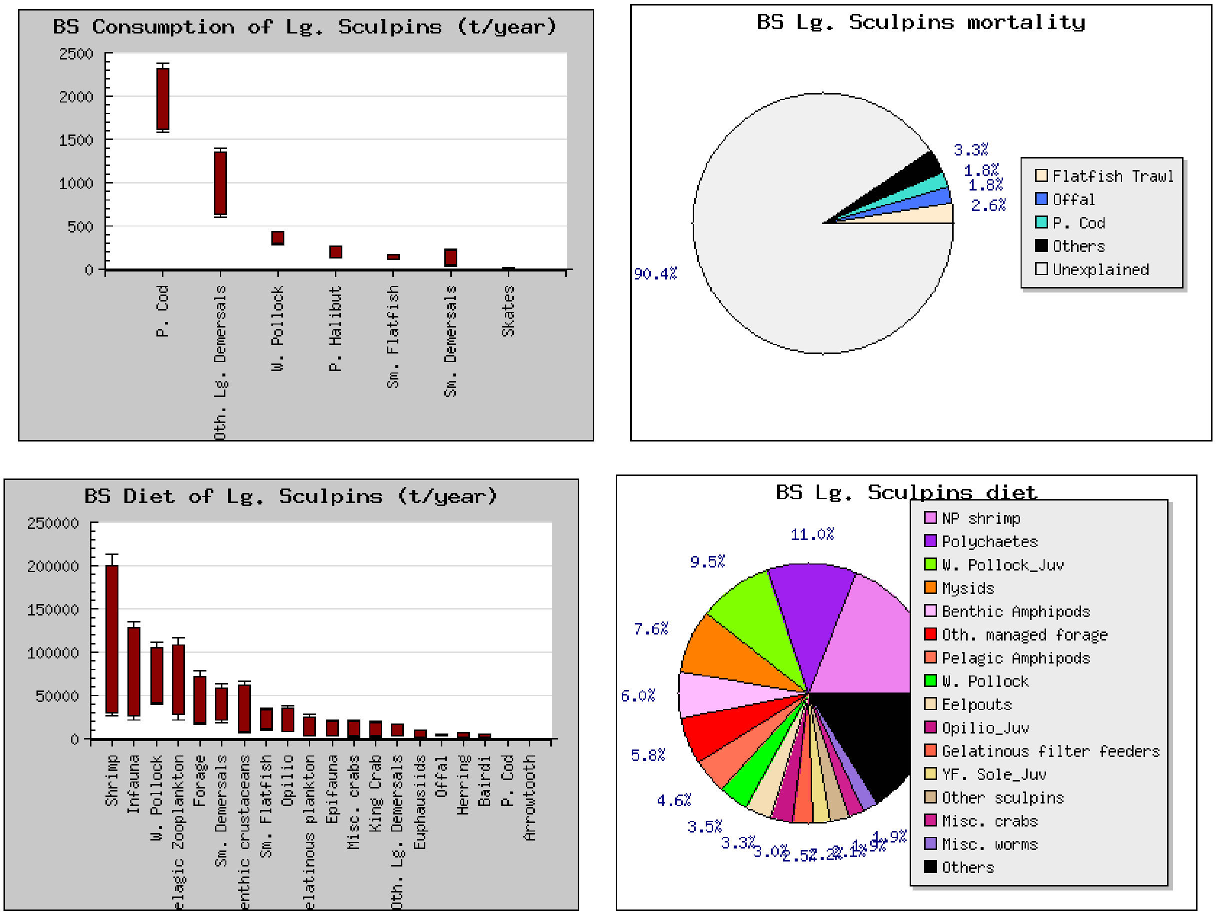



Figure 12. Figures showing Consumption, mortality, and diet of large sculpins from the eastern Bering Sea. Source: REEM ecosystem website.

*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

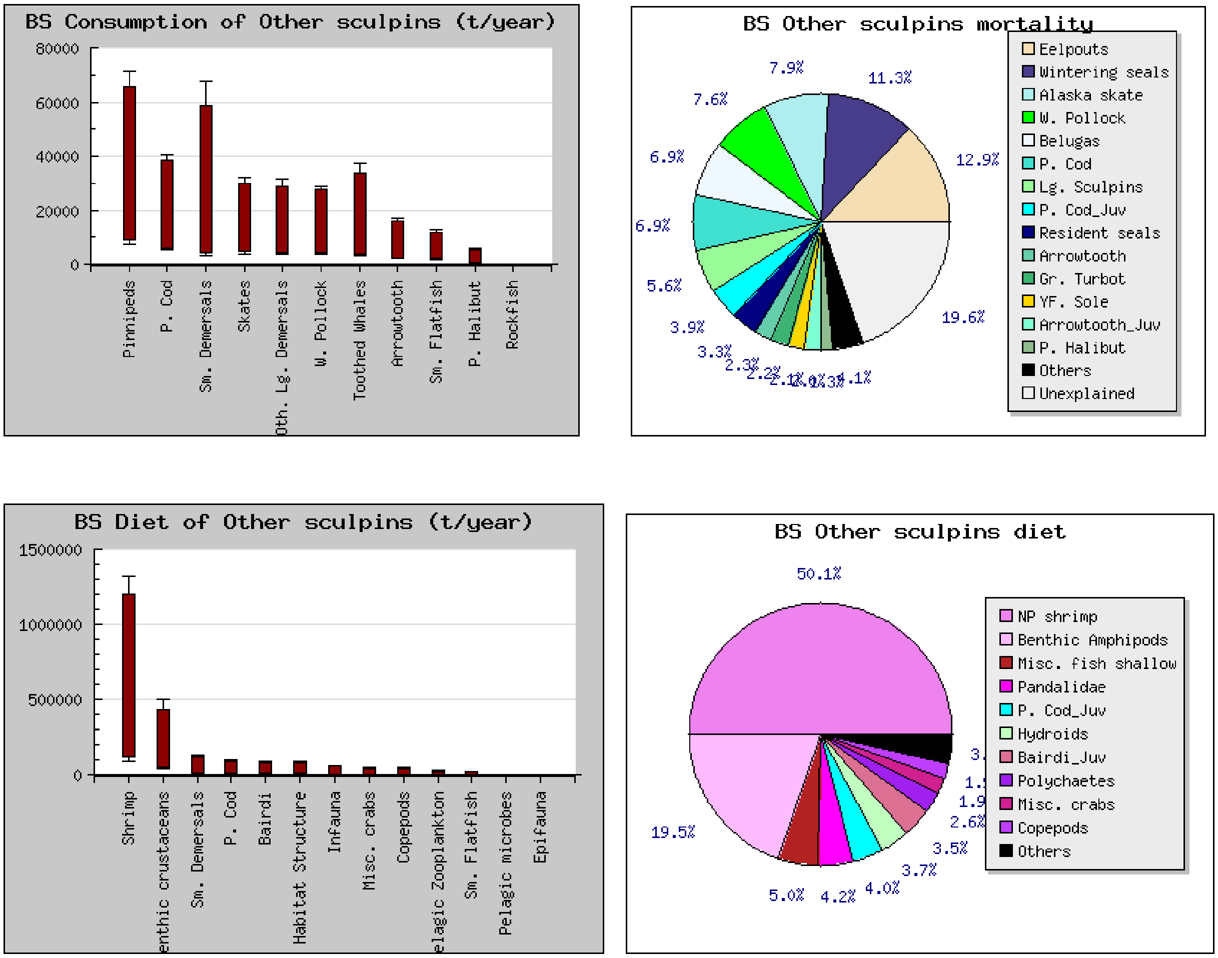



Figure 13. Figures showing Consumption, mortality, and diet of other sculpins from the eastern Bering Sea. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

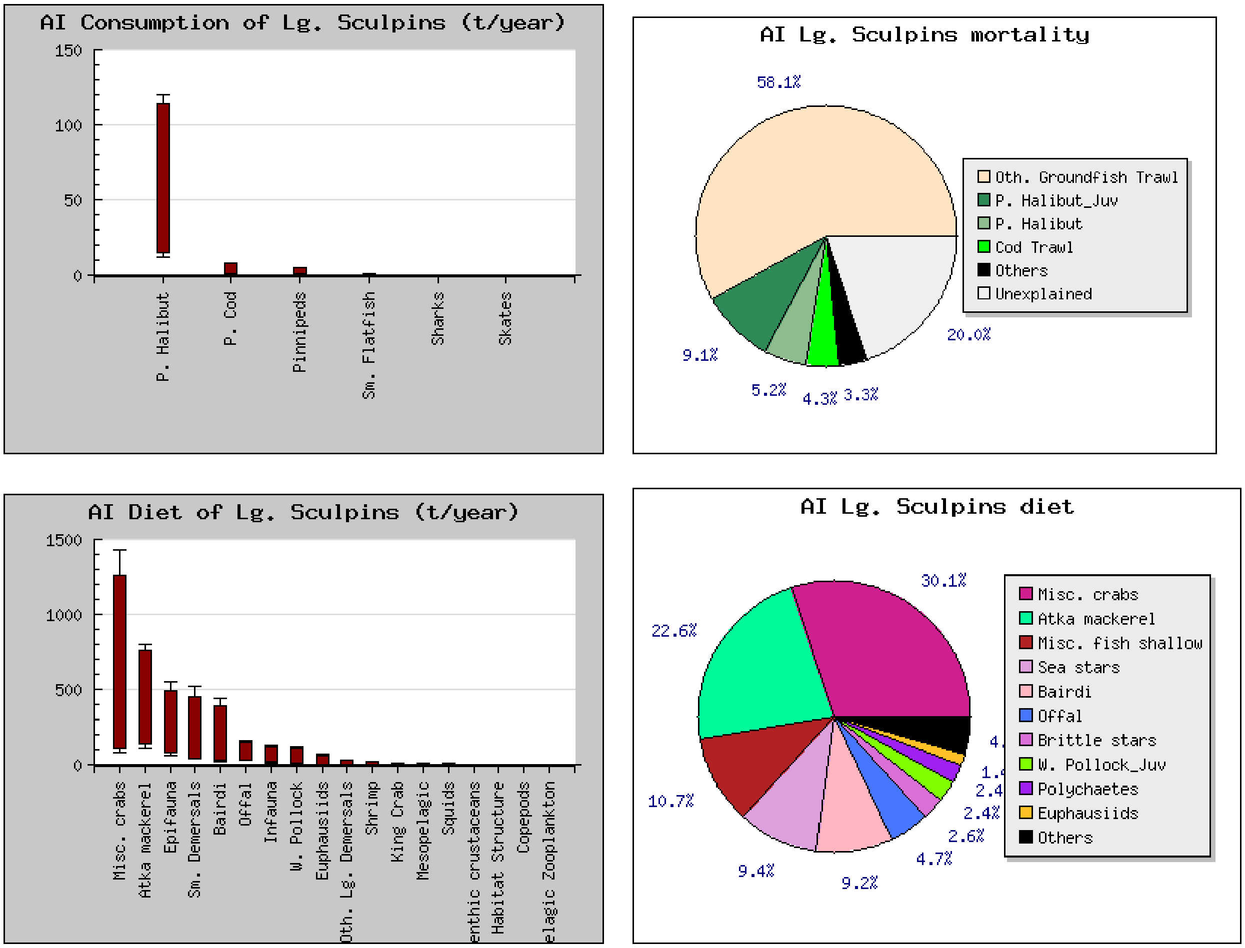



Figure 14. Figures showing Consumption, mortality, and diet of large sculpins from the Aleutian Islands. Source: REEM ecosystem website.
*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.

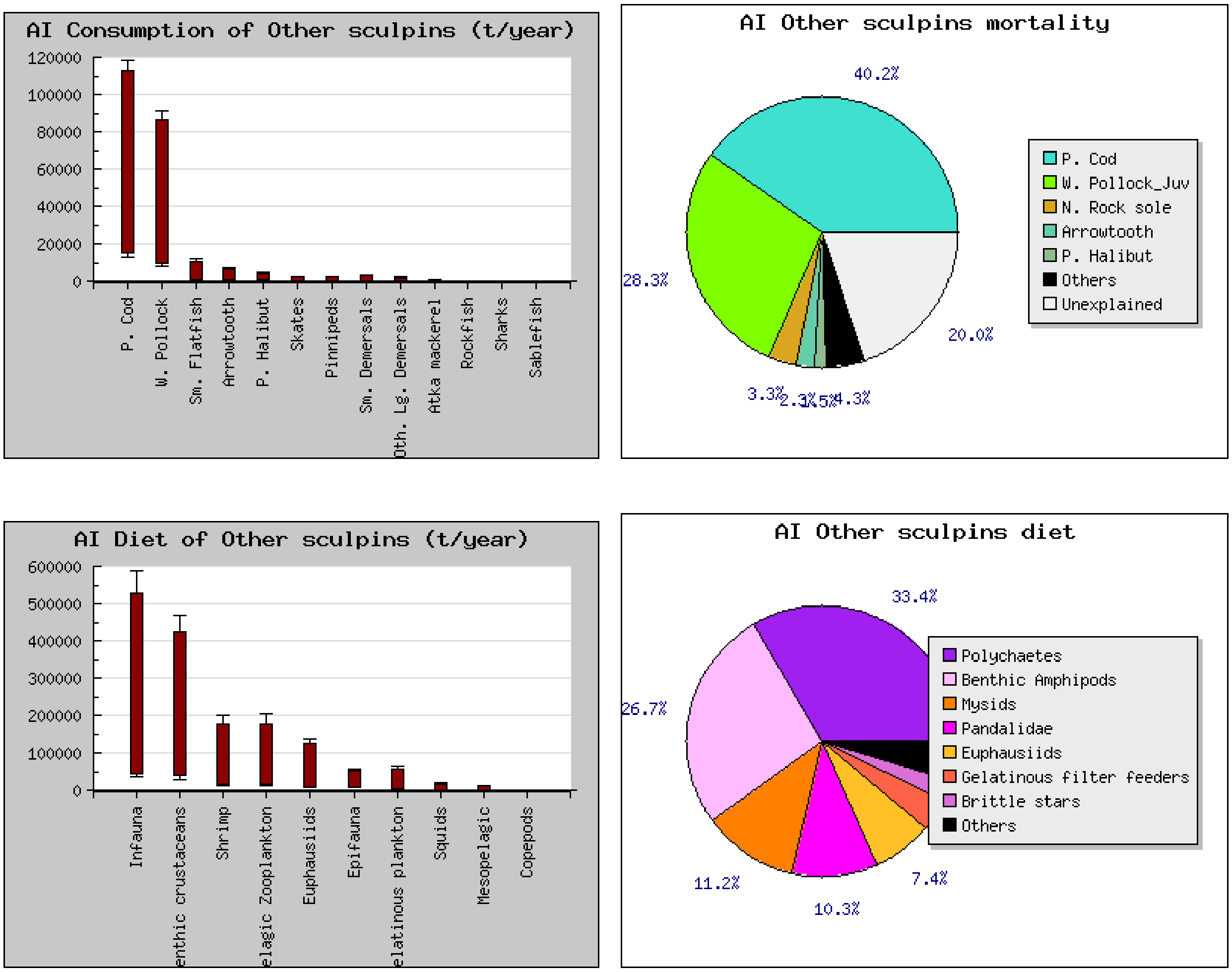



Figure 15. Figures showing Consumption, mortality, and diet of other sculpins from the Aleutian Islands. Source: REEM ecosystem website.

*Disclaimer: The above figures are in part the result of ecosystem modeling. The use of direct diet data for sculpins in the BSAI is limited.