Appendix F

GRENADIERS IN THE GULF OF ALASKA, EASTERN BERING SEA, AND ALEUTIAN ISLANDS

by
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EXECUTIVE SUMMARY

Of the seven species of grenadiers known to occur in Alaska, the giant grenadier appears to be most abundant and also has the shallowest depth distribution on the continental slope. As a result, it is by far the most common grenadier caught in the commercial fishery and in fish surveys. Therefore, this report focuses on giant grenadier.

No official catch statistics exist for grenadiers in Alaska because they are considered "non-specified" by the NPFMC. However, catches for the years 1997-2005 have been estimated for the eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA) based largely on data from the Alaska Fishery Science Center's Groundfish Observer Program. Average catches in the EBS have been 3,154 mt, in the AI 2,358 mt, and in the GOA 10,903 mt. Species breakdown of the grenadier catch is unknown, but is believed to be nearly all giant grenadier. Except for two very small attempts at targeted fishing, all the catch has been taken as bycatch and discarded. Discard mortality is 100%. The catch comes primarily from sablefish and Greenland turbot longline fisheries.

The only age-and-growth study for giant grenadiers found a maximum age of 56 years in the GOA, but the otoliths were extremely difficult to age and von Bertalanffy growth curves did not yield a reasonable fit to the data. This maximum age of 56 was used in the Hoenig method to compute a natural mortality estimate of 0.074.

Survey information on giant grenadiers is available from AFSC bottom trawl and longline surveys that sampled the slope. However, only a subset of the trawl surveys is useful for grenadiers, as most did not sample waters deeper than 500 m where giant grenadier are most abundant. In the last ten years, only four trawl surveys have sampled the slope to depths of 1,000 m: EBS surveys in 2002 and 2004, and GOA surveys in 1999 and 2005. Longline survey indices of abundance for giant grenadier in depths 200-1,000 m are available annually in the GOA for the years 1990-2006, and biennially in the AI and EBS for the years since 1996 (the AI and EBS are sampled in alternating years).

Because of a lack of information on the population dynamics of giant grenadier, these fish could be classified into either tier 5 or tier 6 in the NPFMC's definitions of overfishing level (OFL) and acceptable biological catch (ABC). However, a tier 5 approach is recommended.
Tier 6 computations of OFL and ABC are based on the simple average of past catches. Catch estimates for grenadiers are only available for 1997-2005, so tier 6 values can be computed as follows (catch, OFL, and ABC are in mt):

Area	Mean Catch	OFL	ABC Definition	ABC
EBS	3,154	3,154	0.75 x OFL	2,366
AI	2,358	2,358	0.75 x OFL	1,769
GOA	10,903	10,903	0.75 x OFL	8,178
Total	16,416	16,416	0.75 x OFL	12,312

These OFL and ABC values appear to be unreasonably low relative to the high abundances for giant grenadier that have been seen in the trawl and longline surveys. Moreover, if these values were actually adopted, they could unnecessarily affect or constrain the sablefish fishery, and they would not allow any development of a directed fishery for giant grenadier in the future. Therefore, use of tier 6 is not recommended.

Tier 5 assumes that a species has reliable estimates of biomass and natural mortality. Biomass estimates can be determined for giant grenadier, and an estimate of natural mortality is also available, so it is possible to compute tier 5 values of OFL and ABC. Tier 5 computations were based on giant grenadier only and excluded the other grenadier species because virtually none of the other species are caught in the commercial fishery and relatively few are taken in fish surveys. Therefore, in the tier 5 determinations, giant grenadier are serving as a proxy for the entire grenadier group. Biomass estimates for giant grenadier in the EBS and GOA were calculated based on the average of the two most recent deep-water (to 1,000-1,200 m) trawl surveys in each area. In the EBS, these were in 2002 and 2004, and the average was 546,453 mt; in the GOA, these were in 1999 and 2005 and the average was 488,627 mt. No trawl surveys in the AI have sampled depths >500 m since 1986, so an indirect method was used to determine biomass of giant grenadier in this region. According to biomass-weighted index values (relative population weights) in the longline surveys, biomass of giant grenadier for the period 1996-2006 was 2.50 times higher in the AI than in the EBS. If this ratio is applied to the estimated biomass of 546,453 mt in the EBS, an indirect estimate of 1,363,858 mt can be computed for the AI. Thus, using these biomass estimates together with the natural mortality rate for giant grenadier of 0.074, **initial tier 5 values** were computed as follows (biomass, OFL, and ABC are in mt):

Area	Biomass	Natural mortality *M*	OFL Definition	OFL	ABC Definition	ABC
EBS	546,453	0.074	Biom x *M*	40,437	0.75 x OFL	30,328
Aleutian Islands	1,363,858	0.074	Biom x *M*	100,925	0.75 x OFL	75,694
GOA	488,627	0.074	Biom x *M*	36,158	0.75 x OFL	27,119
Total	2,398,938	0.074	Biom x *M*	177,521	0.75 x OFL	133,141

However, a more conservative approach for determining OFLs and ABCs appears to be a prudent measure for a number of reasons, including: 1) the natural mortality rate is uncertain and may be too high; 2) the indirect AI biomass is unsure; 3) female giant grenadier may be caught disproportionately in the fishery; and 4) deep-sea fish such as grenadiers appear to be especially vulnerable to overexploitation. My recommended method for determining more conservative values of giant grenadier OFL and ABC is to use a lower estimate of natural mortality in the tier 5 computations. The suggested alternative value for natural mortality is 0.057, which corresponds to the rate determined for Pacific grenadier. Using this proxy value for *M*, revised OFLs and ABCs are shown below, which are my **final recommended tier 5 values** for grenadiers (biomass, OFL, and ABC are in mt):

Area	Biomass	Natural mortality *M*	OFL Definition	OFL	ABC Definition	ABC
EBS	546,453	0.057	Biom x *M*	31,148	0.75 x OFL	23,361
AI	1,363,858	0.057	Biom x *M*	77,740	0.75 x OFL	58,305
GOA	488,627	0.057	Biom x *M*	27,852	0.75 x OFL	20,889
Total	2,398,938	0.057	Biom x *M*	136,739	0.75 x OFL	102,555

Response to SSC comments regarding grenadier assessment in the minutes of their February 6-8, 2006 meeting.

SSC requests that the author prepare a more complete description of the potential market for grenadier. Although I appreciate this comment and agree that additional market information would be interesting, I believe a market analysis is outside the scope of a typical SAFE chapter. If there is a need for determining potential markets, it would probably be more appropriate to request that one of the economists on the AFSC or NMFS Regional Offices staffs conduct this work.

SSC encourages author to collect additional baseline life history information including maximum age. An official request was made to the AFSC age and growth task to begin examining giant grenadier otoliths to see if reliable aging methods can be developed. The age and growth task responded in timely fashion by undertaking an initial aging feasibility study for a selected sample. The preliminary results of this study were optimistic and are discussed in the SAFE report.

SSC encourages author to collect maturity from fish captured in the fishery. Because of the logistics involved and the limited number of special projects that can be done by the observer program, this was not done. However, work continued on collecting maturity information from female giant grenadier in this year's longline survey, and a full-fledged maturity study is in progress.

SSC requests that sex and length frequency data be collected from the commercial fishery. A request for this data collection was made to the observer program, and in 2007, observers in the sablefish longline fishery (major fishery that takes giant grenadier as bycatch) will be instructed to make these collections as a standard operating procedure.

SSC requests that author examine evidence for depth stratification of the sexes and sex ratio of the (longline) survey. I requested that sex be determined for the first time for giant grenadiers sampled in the 2006 longline survey, and this information is presented by depth strata in the revised SAFE report.

Author should carefully review the rationale for excluding GOA trawl and longline survey results from any determination of AI biomass. A discussion about this subject has been added to the document, and the results of using GOA data as a correction factor to compute AI biomass are presented, although not recommended.

SSC encourages author to evaluate the implications of a single sex fishery (because present catch appears to be comprised overwhelmingly of females). I did not have time to address this issue.

SSC requests author to consider recent publication by Devine et al. (2005) that discusses overfishing of grenadiers and other deep-water fishes in the Atlantic. A paragraph was added to the report that discussed this and two similar publications and how deep-sea fish appear to be especially vulnerable to overfishing.

INTRODUCTION

Grenadiers (family Macrouridae) are deep-sea fishes related to hakes and cods that occur world-wide in all oceans (Eschmeyer et al. 1983). Also known as "rattails", they are especially abundant in waters of the continental slope, but some species are found at abyssal depths. At least seven species of grenadier are known to occur in Alaskan waters, but only three are commonly found at depths shallow enough to be encountered in commercial fishing operations or in fish surveys: giant grenadier (*Albatrossia pectoralis*), Pacific grenadier (*Coryphaenoides acrolepis*), and popeye grenadier (*Coryphaenoides cinereus*) (Mecklenburg et al. 2002). Of these, giant grenadier has the shallowest depth distribution and the largest apparent biomass, and hence is by far the most frequently caught grenadier in Alaska. Because of this importance, this report will emphasize giant grenadier, but it will also discuss the other two species.

All species of grenadier in Alaska are presently considered "non-specified species" by the North Pacific Fishery Management Council (NPFMC), which means they are not included in any of the NPFMC fishery management plans. Therefore, there are no limitations on catch or retention, no reporting requirements, and no official tracking of grenadier catch by management. However, in 2005 the NPFMC initiated a joint Gulf of Alaska (GOA) and eastern Bering Sea/Aleutian Islands (BSAI) groundfish fishery management plan amendment that would modify the existing management structure for the "other species" category. The "other species" category includes miscellaneous fish and invertebrates that are mentioned by name in the management plan, but does not include "non-specified" fish such as grenadiers. One option in the proposed "other species" amendment is to add grenadiers to the "other species" category. If this option is adopted, the NPFMC would then need to establish levels of overfishing (OFL), acceptable biological catch (ABC), and total allowable catch (TAC) for grenadiers in Federal waters of Alaska. Consequently, this SAFE report has been written to prepare for the possible inclusion of grenadiers in the GOA and BSAI groundfish management plans.

Giant grenadier range from Baja California Mexico around the arc of the north Pacific to Japan, including the Bering Sea (Mecklenburg et al. 2002). In Alaska, they are especially abundant on the continental slope in waters >400 m depth. These fish are the largest in size of all the world's grenadier species (Iwamoto and Stein 1974); maximum weight of an individual in a Bering Sea trawl survey was 41.8 kg[1]. Based on recent observations, there is a possibility that more than one species of giant grenadier may exist in Alaska. Two distinct morphs have been reported in both the GOA and BSAI, one with a much larger eye than the other[2]. Also, at least two very different patterns of otolith morphology have been seen for these fish, which may correspond to separate species[3]. Detailed taxonomic and genetic studies need to be done to determine whether giant grenadier are actually comprised of two species.

Very little is known about the life history of giant grenadier. The spawning period is thought to be protracted and may even extend throughout the year (Novikov 1970). Two papers provide purported descriptions of larvae of giant grenadier in the North Pacific (Endo et al. 1993 and Ambrose 1996), but Busby (2004) points out that these descriptions appear so different that they probably represent separate species. At any rate, no larvae have ever been collected in Alaska that correspond to either of these descriptions or to the description of a third form (Busby 2004) that is also giant grenadier-like[4]. Small,

[1] G. Hoff, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. commun. March 2005.
[2] J. Orr, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. commun. March 2006.
[3] D. Kimura, National Marine Fisheries Service, Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. commun. March 2006.
[4] M. Busby, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. commun. October 2006.

juvenile fish less than ~15-20 cm pre-anal fin length (PAFL) are virtually absent from bottom trawl catches (Novikov 1970; Ronholt et al. 1994; Hoff and Britt 2003, 2005), and juveniles may be pelagic in their distribution. (Because the long tapered tails of grenadiers are frequently broken off when the fish are caught, PAFL is the standard unit of length measurement for these fish. PAFL is defined to be the distance between the tip of the snout and the insertion of the first anal fin ray). Bottom trawl studies indicate that females and males have different depth distributions, with females inhabiting shallower depths than males. For example, both Novikov (1970) and Britt and Martin (2001) found that nearly all fish <700 m depth were female, and the Novikov study was based on trawl sampling throughout the year. Presumably, some vertical migration of one or both sexes must occur for spawning purposes; Novikov (1970) speculates that females move to deeper water inhabited by males for spawning. Stock structure and migrational patterns of giant grenadier in Alaska are unknown, as no genetics studies have been done, and the fish cannot be tagged because all individuals die due to barotrauma when brought to the surface. One study in Russian waters, however, used indirect evidence to conclude that seasonal feeding and spawning migrations occur of up "to several hundred miles" (Tuponogov 1997).

The habitat and ecological relationships of giant grenadier are likewise little known and uncertain. Clearly, adults are often found in close association with the bottom, as evidenced by their large catches in bottom trawls and on longlines set on the bottom. However, based on a study of the food habits of giant grenadier off the U.S. west coast, Drazen et al. (2001) concluded that the fish feeds primarily in the water column. Most of the prey items found in the stomachs were meso- or bathypelagic squids and fish, and there was little evidence of benthic feeding. One study of giant grenadier food habits in the Aleutian Islands also found that the primary items consumed were squid and fish (myctophids) (Yang 2003). This hypothesis about the tendency of the fish to feed off bottom is supported by observations of sablefish longline fishermen, who report that their highest catches of giant grenadier often occur when the line has been inadvertently "clotheslined" between two pinnacles, rather than set directly on the bottom[5]. Pacific sleeper sharks have been documented as predators on giant grenadier (Orlov and Moiseev 1999).

Pacific grenadier have a geographic range nearly identical to that of giant grenadier, i.e., Baja California Mexico to Japan. Popeye grenadier range from Oregon to Japan. Compared to giant grenadier, both species are much smaller and generally found in deeper water. They appear to be most abundant in waters >1,000 m, which is deeper than virtually all commercial fishing operations and fish surveys in Alaska. Food studies off the U.S. West Coast indicate that Pacific grenadier are more benthic in their habitat than are giant grenadier, as the former species fed mostly on bottom organisms such as polychaetes, mysids, and crabs (Drazen et al. 2001).

FISHERY

Catch History

As mentioned, no official catch statistics exist for grenadiers in Alaska because they are considered "non-specified" by the NPFMC. However, catches since 1997 have been estimated for the eastern Bering Sea (EBS), Aleutian Islands (AI), and GOA based largely on data from the Alaska Fishery Science Center's Groundfish Observer Program (Table 1). The estimates for 1997-2002 were determined by simulating the catch estimation algorithm used for target species by the NMFS Alaska Regional Office in what was formerly called their "blend catch estimation system" (Gaichas 2002 and 2003). The estimates for 2003-2005 were computed by the NMFS Alaska Regional Office based on their "catch accounting system", which replaced the "blend" system in 2003. Unfortunately, the data have to be presented as "grenadiers, all species combined", because observers were not instructed to identify giant grenadiers until 2005.

[5] D. Clausen, National Marine Fisheries Service, Alaska Fisheries Science, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Pers. observ. October 2004.

Even in 2005, the catch data suggest that many observers did not properly identify giant grenadier to species. However, as will be discussed later, indirect evidence indicates that almost all the catch is likely giant grenadier. Also, one important caveat is that the catch estimates for the BSAI may be more accurate than those for the GOA. In the catch estimation process, it is assumed that grenadier catch aboard observed vessels is representative of grenadier catch aboard unobserved vessels. This is a possible problem because observer coverage in the BSAI fisheries is considerably higher than those in the GOA. In general, smaller vessels fish in the GOA, especially in longline fisheries, and many of these vessels are not required to have observers, which could introduce a bias into the GOA estimates.

The estimated annual catches of grenadiers in Alaska for the years 1997-2005 have ranged between ~11,000-21,000 mt, with an average for this period of >16,000 mt (Table 1). By region, annual catches have ranged between ~6,000-15,000 mt in the GOA, ~2,000-5,000 mt in the EBS, and ~1,000-4,000 mt in the AI. To put these catches in perspective, the total annual sablefish catch in Alaska in the years 1997-2004 ranged from about 14,00 to 18,000 mt (Hanselman et al. 2005). Thus, the amount of grenadier caught in these years was similar to the amount of sablefish taken.

Description of the Fishery

Virtually all the catch of grenadiers in Alaska has been taken as bycatch in fisheries directed at other species, particularly sablefish and Greenland turbot. All the grenadier catch is discarded, and the discard mortality rate is 100% because the pressure difference experienced by the fish when they are brought to the surface invariably causes death. An analysis of catch estimates for 1997-1999 indicated that most of the grenadier catch in the GOA was taken in the sablefish fishery, whereas in the BSAI, it came from both the sablefish and the Greenland turbot fishery (Clausen and Gaichas 2004). The high bycatch of grenadiers in fisheries for sablefish and Greenland turbot is not surprising, as the latter two species inhabit waters of the continental slope where giant grenadier are abundant. For the present report, a similar updated analysis was done for the years 2003-2005, and it also showed that the grenadier catch in the GOA was taken predominantly in hauls that targeted sablefish, whereas that in the BSAI came from hauls that targeted sablefish and flatfish (Table 2). A species breakdown for flatfish targeted fishing was not available for the 2003-2005 data, but presumably most of the relatively large grenadier catch in flatfish hauls in the EBS for those years came from fishing directed at Greenland turbot. Both the sablefish and Greenland turbot fisheries are predominantly longline, and a previous analysis of grenadier catches by gear type showed most grenadiers in both the BSAI and GOA were caught on longlines (Clausen and Gaichas 2005). Recently, some sablefish fishermen in the BSAI have switched to using pots to protect their catches from whale depredation, and it is uncertain what effect, if any, this change may have on grenadier catches.

Although the species breakdown of the grenadier catch is unknown, it can be surmised that giant grenadier comprise by far the majority of the fish caught. Bottom trawl and longline surveys all show that very few Pacific and popeye grenadier are found shallower than 800 m deep, whereas giant grenadier are abundant in these depths (see section 3.2, "Survey Data", in this report). Although there are no analyses of the depth distribution of commercial fishing effort in Alaska, it is likely that very little effort occurs in depths >800 m. In the particular case of the sablefish longline fishery (the source of most of the grenadier catch in Alaska), the fishery is probably focused at depths of 400-800 m, where longline surveys have generally found the highest catch rates of sablefish (Zenger and Sigler 1992). Hence, this indirect evidence can be used to conclude that giant grenadier are the predominant species in the grenadier catch.

There have been only two known attempts to develop a directed fishery for grenadiers in Alaska. The first was an endeavor to process longline-caught giant grenadier for surimi at the port of Kodiak in 1998[6]. This small effort was apparently unsuccessful, as it ended in 1999. The second, also from the port of Kodiak, was an exploratory effort in 2005 using trawls to target giant grenadier and develop a fillet and roe market[7]. This second venture was not continued in 2006. Because of the large biomass of giant grenadier on the continental slope, however, research to develop marketable products from this species is ongoing (Crapo et al. 1999), and it is likely that Alaskan fishermen will continue their efforts at utilizing this species.

DATA

<u>Fishery Data</u>

Catch

Catch information for grenadiers in Alaska is listed in Table 1.

Size and Age Composition in the Fishery

No length or age samples for giant grenadier have been collected in the commercial fishery. However, starting in 2007, observers aboard commercial vessels will be requested to sample lengths and sex of giant grenadiers for hauls in which sablefish is the target species. As the sablefish fishery is the main fishery that takes giant grenadier as bycatch, these samples should provide valuable information on the length and sex distribution of giant grenadiers in the fishery.

<u>Survey Data</u>

Trawl Surveys

There have been many NMFS trawl surveys in the EBS, AI, and GOA since 1979, but relatively few have extended deep enough on the continental slope to yield meaningful biomass estimates for grenadier. For example, several surveys of the AI and GOA have sampled only to 500 m; thus, they barely entered the abundant depth range of giant grenadier and were well above the depths inhabited by Pacific and popeye grenadier. Giant grenadier biomass estimates for those surveys that have extended to 800 m or deeper are listed in Table 3. Prior to the early 1990's, it is believed that survey scientists did not always correctly identify Pacific and popeye grenadier in AI and GOA surveys, so historical biomass estimates for these species in these surveys have not been included in this report. Also, the earlier Bering Sea surveys (1979-1991) usually identified grenadiers only to the level of family, and it is these combined estimates that are listed in Table 3.

The biomass estimates indicate that sizeable populations of giant grenadier are found in each of the three regions surveyed, but the survey time series are too intermittent to show any trends in abundance. Highest estimates of giant grenadier biomass in each region were 667,000 mt in the EBS (2004), 601,000 mt in the AI (1986), and 587,000 mt in the GOA (2005). In the EBS, the biomass estimates for 1979-1991 appear to be unreasonably low compared to the biomass estimates in 2002 and 2004. Given the apparent longevity and slow growth of giant grenadier (see section 3.2.3), it is unlikely that its biomass could have increased nearly six-fold from 74,000 mt in 1991 to 426,000 mt in 2002. The EBS slope surveys in 2002 and 2004 are considered to be better than their predecessors because they were the only ones specifically designed to sample the continental slope, they trawled deeper water (to 1,200 m) that

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[6] J. Ferdinand, National Marine Fisheries Service, Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115-0070. Pers. commun. September 2004.
[7] T. Pearson, Kodiak Fisheries Research Center, National Marine Fisheries Service, Sustainable Fisheries, 302 Trident Way, Room 212, Kodiak AK 99615. Pers. commun. October 2005.

encompassed more of the depth range of grenadiers, and they had good geographical coverage in all areas[8]. Also, in comparison to the steep and rocky slopes of the AI and GOA, the EBS slope is easier to sample with a bottom trawl, which means a trawl survey in the latter region may yield more reliable results. Therefore, the biomass estimates in the EBS in 2002 and 2004 may be the most valid of any of the surveys in Table 3.

One factor that could have a significant effect on the biomass estimates is the extent that giant grenadier move off bottom. As discussed, there is indirect evidence from feeding studies that giant grenadier may be somewhat pelagic in their search for prey. If so, some of the population may be unavailable to the bottom trawl, which would result in an underestimate of biomass.

Results of the more recent trawl surveys in the EBS and GOA can be examined to determine the comparative biomass of the three grenadier species (Table 4; Figure 1). In the GOA in 1999 and 2005, giant grenadier was by far the most abundant species and comprised 94% and 96%, respectively, of the aggregate grenadier biomass. Next in abundance was popeye grenadier, followed by Pacific grenadier. In the EBS surveys in 2002 and 2004, giant grenadier also greatly predominated, with 89% and 93% of the aggregate biomass, respectively. Similar to the GOA, popeye grenadier was second in biomass, followed by Pacific grenadier. Popeye grenadier biomass was considerably larger in both EBS surveys than in the GOA survey, which may be partially due to the fact that the EBS surveys sampled deeper water to 1,200 m, whereas the GOA survey only went to a maximum depth of 1,000 m.

Data from recent GOA and EBS trawl surveys can also used to examine the variability of the biomass estimates for giant grenadier (Table 5). The low values for the coefficients of variation for each biomass estimate indicate that the estimates are relatively precise for giant grenadier compared with those of many other groundfish species.

The recent trawl surveys provide information on the depth distribution of grenadiers in the EBS and GOA (Figures 1 and 2). The surveys indicated that in both regions, giant grenadier accounted for nearly all the grenadier biomass at depths less than ~600-700 m, whereas Pacific and popeye grenadier did not become moderately abundant until deeper depths. The 2002 and 2004 EBS surveys showed giant grenadier biomass peaking at depths 400-1,000 m, and then declining at the 1,000-1,200 m depth stratum. Highest giant grenadier CPUE in the EBS surveys was at 600-1,000 m. The 1999 and 2005 GOA surveys were generally similar and indicated biomass and CPUE of giant grenadier was relatively high at depths 300-1,000 m, with a pronounced peak in CPUE at the 500-700 depth stratum. However, because the GOA surveys did not extend beyond 1,000 m, the abundance of giant grenadier in these deeper GOA waters is unknown.

Population size compositions for giant grenadier from the recent trawl surveys indicate that lengths of the fish are considerably larger in the EBS (Figure 3). For example, in the 2004 EBS survey, mean length was 28.1 cm, compared to 25.9 cm in the 2005 GOA survey. This difference is greater than what would outwardly seem, because PAFL is a much shorter measurement relative to the fish's size than standard length measurements such as fork length or total length. The mean lengths translate to a weight of 2.98 kg/fish in the EBS versus 2.39 kg/fish in the GOA, a difference of nearly 25% (see section 4.2 for giant grenadier length-weight relationships). In the EBS, a much greater percentage of the population appears to consist of fish >30 cm in length.

Results of the trawl surveys emphasize the important ecological role of giant grenadier in Alaskan waters. In a ranking of all species caught in the 1999 GOA trawl survey, giant grenadier was the fifth most

[8] G. Walters, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115-0070. Pers. commun. October 2004.

abundant species in terms of CPUE, after arrowtooth flounder, Pacific ocean perch, walleye pollock, and Pacific halibut (Britt and Martin 2001). It should be noted that this survey covered both the continental shelf and slope; if we consider just the slope deeper than 400 m, giant grenadier was the number one species in CPUE. Likewise, the EBS surveys in 2002 and 2004 (which sampled only the slope) both ranked giant grenadier first in biomass among all species caught (Hoff and Britt 2003, 2005).

Longline Surveys

Longline surveys of the continental slope off Alaska have been conducted annually since 1979 (Hanselman et al. 2005). The primary purpose of the surveys is assessment of sablefish abundance, and the standard depth sampled is 200-1,000 m. An index of relative biomass, called the "relative population weight" (RPW), is computed for all the major species caught in the survey. However, RPW values for giant grenadier are only available for the years since 1990[9]. Other measures of giant grenadier abundance in the surveys have been computed for the years 1979-1989, including catch-per-unit-effort values and an index of abundance by number, called "relative population number". These data for the surveys before 1990 are presented in Sasaki and Teshima (1988) and Zenger and Sigler (1992), but will be not be discussed in this report.

In the GOA and AI, the longline gear used in the surveys is able to sample a high proportion of the steep and rocky habitat that characterizes the slope in these regions. This is in contrast to bottom trawls used on the trawl surveys, which are often limited to fishing on relatively smooth substrate. Because of this difference, the longline surveys may do a better job of monitoring abundance of giant grenadier on the slope, although they do not provide estimates of absolute biomass.

The RPWs provide a standardized time series of annual abundance for giant grenadier in the GOA for the period 1990-2006 and an intermittent series in the AI and EBS (Table 6). The survey was expanded from the GOA into the AI in 1996 and to the EBS in 1997, but these latter two regions have only been sampled in alternating years since. Therefore, the time series is much less complete for the AI and EBS. In the GOA, definitive trends in RPW are difficult to discern. Generally, however, RPW decreased in the first three years to a low of 800,000, then increased to a high in 1997 of 1,420,000, and finally diminished again to a low of 900,000 in 2004. A rigorous analysis of the data will be required to determine whether the trends are statistically valid, such as the methods used by Sigler and Fujioka (1988) to analyze changes in the survey's RPWs for sablefish. The RPW values in Table 6 also indicate that giant grenadier are particularly abundant in the AI; in all years the AI was sampled, RPWs in this region were greater than those in the GOA, even though the area of the slope is much larger in the GOA.

Giant grenadier catch rates in the surveys can be used to examine the geographic distribution of abundance in more detail (Table 7). Highest catch rates are consistently seen in the eastern AI, Shumagin and Chirikof areas, and Bering areas 3 and 4, which are located NW of the Pribilof Islands. In the GOA, there appears to be a definite decline in catch rates as one progresses from the west (Shumagin area) to the east (Southeast area). The 1999 and 2005 GOA trawl surveys also showed a similar trend and found very low catch rates and biomass estimates in the eastern GOA (Britt and Martin 2001; Footnote[10]).

Population length frequency distributions for giant grenadier in the longline surveys indicate size of the fish is generally largest in the EBS, intermediate in the eastern AI, and smallest in the GOA (Figures 4, 5, and 6). This difference in size between the EBS and the GOA agrees with that found in the recent trawl

[9] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun. July 2004.

[10] Unpubl. data for 2005 GOA trawl survey in NMFS Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2005. Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115.

surveys of these two regions, which were discussed previously in this report. The length distributions of the longline surveys in the EBS tend to be spread over more lengths and include more large fish >35 cm PAFL (Figure 5). All three regions have shown a general decline in size since about 2000, with recent surveys (2005 for the GOA and EBS and 2006 for the eastern AI) showing the smallest mean length for any year in the time series. In particular, the GOA distribution has become skewed toward smaller fish in recent years, and mean length declined from 30.9 cm in 2000 to 27.9 cm in 2005 (Figure 4). However, this declining trend in the GOA ended in 2006, when mean length increased to 28.5 cm. Preliminary analysis of the longline survey data suggests that the decrease in size in the GOA for 2000-2005 was mostly caused by increased numbers of small fish, although a decline in the numbers of large fish also occurred[11]. Further analysis is needed, however, to better understand the reasons for this decrease.

A comparison between Figure 3 (size compositions for the GOA and EBS trawl surveys) and Figures 4 and 5 (size compositions for the GOA and EBS longline surveys) reveals that the size distributions were consistently smaller for giant grenadier in the trawl surveys. For example, mean length in the 1999 GOA trawl survey was 24.9 cm, whereas it was 30.4 cm in that year's GOA longline survey. This indicates that there is a substantial difference in the size selectivity between the gear types used in each survey. It appears that the longline surveys are not sampling many of the smaller giant grenadiers less than ~25 cm PAFL that are taken in the trawl surveys.

Information on sex distribution of giant grenadier caught in the longline survey was collected for the first time in 2006 (Table 8). Results show that females were the overwhelming majority of the catch, comprising 97% of the fish sampled in the GOA and 94% in the eastern AI. Females especially predominated in depths <800 m. Because these are the depths in which the longline fishery operates, this strongly suggests that most of the commercial catch of giant grenadier is female. There was a trend toward an increased number of males in progressively deeper strata, but even at the deepest stratum of 800-1,000 m, males were only 10% of the catch in the GOA and 25% in the eastern AI. These results imply that much of the male population may reside in depths >1,000 that are not covered by the survey, at least during the summer period when the survey is occurring.

The depth distribution of the RPW for giant grenadier in the GOA was very similar in the last five longline surveys (Fig. 7). RPW was relatively high for each of the three deepest strata sampled in these surveys: 401-600 m, 601-800 m, and 801-1,000 m, with the peak at 801-1,000 m in all years except 2006. These data indicate that additional sampling needs to be done at depths >1,000 m to determine where the abundance of giant grenadier begins to decline. The data also suggest that an unknown and perhaps significant portion of the giant grenadier population in the GOA may reside in depths beyond 1,000 m that are not currently surveyed. These depth results are similar to those depicted in Fig. 1 for the 1999 GOA trawl survey, which also showed a large biomass of giant grenadier extending to at least 1,000 m. The longline depth distributions, however, are somewhat different than those seen in the 2005 GOA trawl survey, which indicated a considerable decline in biomass at depths >700 m.

Depth distribution of giant grenadier RPW in the eastern AI and EBS was somewhat different than in the GOA (Figs. 8 and 9 vs. Fig. 7). In three of the five longline surveys in the AI and EBS that have available data for depth distribution, the RPW showed a substantial decline in the deepest stratum (801-1,000 m) that was not seen in the GOA data. For these three surveys (2002 and 2004 in the AI and 2003 in the EBS), these results suggest that the surveys may have covered a substantial portion of the biomass distribution of giant grenadier. However, the 2006 eastern AI and the 2005 EBS surveys were similar to the GOA, as they indicated the highest RPW was at 601-1,000 m and that additional sampling needs to be done in deeper waters to cover more of the depth range of giant grenadier.

[11] D. Clausen, National Marine Fisheries Service, Alaska Fisheries Science, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. observ. October 2005.

A possible factor that may have influenced the survey's catch rates for giant grenadier is competition amongst species for baited hooks. Zenger and Sigler (1992) suggest that giant grenadier may be out-competed on the longline by more energetic fish such as sablefish. If sablefish are more quickly attracted to and caught on the hooks, or are able to drive away giant grenadier when both species are competing for the hooks, the survey's catch rates for giant grenadier would not be a true indicator of their abundance. This could be a partial explanation for the survey's high catch rates of giant grenadier in the EBS and eastern AI, as the relatively low abundance of sablefish in these two regions could result in a greater number of unoccupied hooks available for catching giant grenadier. Similarly, it could also explain the large RPW values for giant grenadier in the deep 801-1,000 m stratum in the GOA surveys and in some of the AI and EBS surveys because the relatively low abundance of sablefish in this stratum may allow more giant grenadier to be caught. To investigate the problem of possible competition for hooks in the longline survey, additional analysis and possibly experimental studies are needed.

Survey Age Compositions

Although otolith samples of giant grenadier have been collected in recent trawl surveys, none of these have been aged. Only one aging study of giant grenadier has been conducted that used contemporary aging methods (thin-sectioning of otoliths), and it was based on 357 adult fish from the AI, GOA, and off Oregon and California. (Burton 1999). Results showed ages ranged between 13 and 56 years, and the 56 year-old came from the GOA. However, the otoliths were reported to be very difficult to age, and von Bertalanffy growth curves yielded an unreasonable fit to the size and age data. No analysis was done to determine if ages differed by geographic area. Radiometric aging methods were also applied to the otoliths, and confirmed that giant grenadier live to at least 32 years.

This year, age readers at the AFSC have begun examining otoliths of giant grenadier to determine if alternative aging methods may yield improvements to Burton's 1999 study. The initial results of these new studies, which are based on a distal grinding technique, appear promising[12], and it is possible that age results for giant grenadier may be available at some future date.

No aging studies have been done for Pacific grenadier in Alaska, but Andrews et al. (1999) conducted an aging study for this species off the U.S. west coast. Similar to giant grenadier, the study found that Pacific grenadier otoliths were extremely difficult to age. Both immature and adult fish were sampled, and ages ranged from 1 to 73 years. Radiometric aging was used to confirm the ages in this study, and it verified that Pacific grenadier live to at least 56 years. Another study off California also found that Pacific grenadier are slow-growing and long-lived, and it reported a maximum age of 62 years (Matsui et al. 1990). In contrast to Burton's study for giant grenadier, Andrew's Pacific grenadier study did successfully yield von Bertalanffy growth equations.

Recent age information for other Macrouridae species suggests that most are very long-lived. For example, the roundnose grenadier, *Coryphaenoides rupestris*, an important commercial species in the Atlantic, is thought to live up to 70 years (Merrett and Haedrich 1997). It appears that macrourids, including giant and Pacific grenadier, can be categorized as classic "*K*-selected species", as they possess the *K*-selected traits of longevity, slow growth, relatively large size, and residence in a stable and unproductive environment (the deep ocean).

[12] C. Hutchinson, National Marine Fisheries Service, Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. commun. August 2006.

ASSESSMENT PARAMETERS

Maximum Age, Natural Mortality, Female Age and Size at 50% Maturity, and Age of Recruitment

The only available aging study for giant grenadiers (Burton 1999) found the maximum age to be 56 years based on a specimen from the GOA. There have been no aging studies for Pacific grenadier in Alaska, but Andrews et al. (1999) found a maximum age of 73 years for this species off the U.S. west coast. Clausen and Gaichas (2004) used the method of Hoenig (1983) to estimate natural mortality for each species. This method uses the maximum age of a species in a regression equation to yield an estimate of total mortality. Clausen and Gaichas assumed that if stocks of giant and Pacific grenadier in Alaska are lightly fished, total mortality should approximately equal natural mortality. Based on a maximum age of 56 years for giant grenadier and 73 years for Pacific grenadier, Hoenig's method estimates the following natural mortality rates:
Giant grenadier: 0.074
Pacific grenadier: 0.057

The only published information on sexual maturity of giant grenadier comes from Novikov (1970) who stated that sexual maturity is reached at about 56 cm total length (= 14 cm PAFL based on a conversion factor in Burton (1999)), when the fish assume a more benthic existence. However, he gives no data as to how this value was determined or to which sex it applies, and the size seems unreasonably small. In contrast to Novikov's reported size of maturity, a study in progress by the author of the present SAFE report suggests that female size at 50% maturity may be ~25 cm PAFL based on macroscopic examination of ovaries. These results are very preliminary, however, and need to be confirmed by microscopic study of histology samples.

There is no information on the age or size of recruitment of giant grenadier to the fishery, although size composition data for the longline survey (Figs. 4, 5, and 6) suggest that only fish >20 cm PAFL are taken by longlines. Direct information on size of recruitment should be available starting in 2007, when observers will collect length samples for giant grenadier in the sablefish fishery.

<u>Length at Age, and Length-Weight Relationships</u>

Length and weight at age relationships are not available for giant grenadier. Burton's (1999) aging study on giant grenadier did not yield a reasonable fit of von Bertalanffy growth parameters to the size and age data.

Andrews et al. (1999) reported these von Bertalanffy parameters for Pacific grenadier off the U.S. west coast (L_{inf} is in mm):

	male	female	combined
L_{inf}	372	268	272
K	0.024	0.040	0.041
t_0	-1.79	0.20	0.25

The following length-weight relationships have been computed for giant grenadier in the Gulf of Alaska based on data collected in the 1999 trawl survey[13]:
W is weight in grams and PAFL is in mm:

males, $W = 1.054 \times 10^{-3}(PAFL^{2.622})$, n = 22
female $W = 1.333 \times 10^{-3}(PAFL^{2.597})$, n = 45
combined sexes, $W = 4.487 \times 10^{-4} (PAFL^{2.785})$, n = 67

ANALYTIC APPROACH FOR DETERMINING OFL AND ABC

Because of the lack of information on the population dynamics of grenadiers, these fish fall into either tier 5 or tier 6 in the NPFMC's current definitions of the overfishing level (OFL) and acceptable biological catch (ABC). However, the decision as to which of these two tiers is most appropriate for grenadiers is debatable. To be in tier 5, reliable estimates of biomass and natural mortality must be known; otherwise, a species is classified as tier 6. Biomass and mortality estimates can be computed for giant grenadier, but their reliability is uncertain. Therefore, OFL and ABC computations will be presented and discussed for each tier, although a tier 5 approach is recommended.

Tier 6 Approach

Tier 6 assumes the only reliable information for a species or species group is catch history. Under the Tier 6 definitions, OFL is equal to the average catch since 1978, and ABC is less than or equal to 0.75 x OFL. Because catch estimates for grenadier only extend back to 1997 (Table 1), the average catch must be based on the period 1997-2005, rather than back to 1978. Hence, the tier 6 results can be summarized as follows, with values in mt:

Area	Mean Catch	OFL	ABC Definition	ABC
EBS	3,154	3,154	0.75 x OFL	2,366
AI	2,358	2,358	0.75 x OFL	1,769
GOA	10,903	10,903	0.75 x OFL	8,178
Total	16,416	16,416	0.75 x OFL	12,312

If these relatively low values of grenadier ABC were actually adopted, one problem that would arise is that they could significantly affect or constrain the sablefish fishery. For example, in the years 1997, 1998, and 1999, estimated grenadier catches in the GOA sablefish fishery were 10,806, 14,023, and 10,531 mt, respectively (Clausen and Gaichas 2004). Each of these values exceeds the Tier 6 ABC of 8,178 mt shown above for the GOA, and the 1998 grenadier catch is so large that it exceeds the Tier 6 GOA OFL of 12,312 mt. To ensure the ABC and OFL were not exceeded, sablefish fishermen would either have to change their present fishing practices so as to minimize catch of grenadier, or management would have to close the sablefish fishery before the entire sablefish quota was taken. The economic cost to fishermen for either of these actions might be substantial, so it is unlikely that the Tier 6 approach would be practicable unless there was strong evidence of a conservation problem for grenadier. Present biomass and relative abundance estimates for grenadier do not provide such evidence (see the following three sections 5.2, 5.3, and 5.4); consequently, a different approach than tier 6 appears most appropriate for determining OFLs and ABCs for grenadiers.

[13] Values for the length-weight relationships of giant grenadier were reported for this survey by Britt and Martin (2001), but their listed values are incorrect. I recalculated these values based on the original data listed in the NMFS Alaska Fisheries Science Center"s "Racebase" trawl survey database, and the recalculated values are listed here.

The preceding paragraph's general argument against strict use of the tier 6 definition was also noted by the NPFMC's Scientific and Statistical Committee (SSC) at their February 2006 meeting[14]. If a bycatch species has been caught in relatively small amounts compared to its actual abundance, using catch history to determine its OFL and ABC could unnecessarily constrain existing target fisheries and also preclude any future development of a target fishery for the bycatch species.

Tier 5 Approach and Initial Tier 5 Computations

Tier 5 assumes that a species has reliable estimates of biomass and natural mortality (*M*). Biomass estimates for grenadier are available from recent bottom trawl surveys in Alaska, and an estimate of *M* has been computed for giant grenadier, so it is possible to apply this approach to grenadiers.

For this report, I have chosen to only include giant grenadier in the Tier 5 calculations of OFL and ABC. Thus, for tier 5, giant grenadier are serving as a proxy for the entire grenadier group. The reasons for excluding Pacific and popeye grenadier are twofold: (1) at present, virtually all the grenadier catch in Alaska is believed to be giant grenadier, as Pacific and popeye grenadier are largely distributed in waters >800 m depth where very little commercial fishing takes place (see discussion in section 2.2, "Description of the Fishery"); and (2) groundfish surveys in Alaska have extended only to 1,000-1,200 m depth, whereas the distribution of Pacific and popeye grenadier extends far deeper. Hence, biomass estimates for these two species are very inadequate and are certainly much less than their true values.

Biomass estimates that include deeper water (>700 m) on the upper continental slope inhabited by giant grenadier are only available for four trawl surveys in recent years: the 2002 and 2004 EBS slope surveys, and the 1999 and 2005 GOA surveys (Table 3). I recommend using the mean of the two surveys in each area, 546,453 mt in the EBS and 488,627 mt in the GOA, as the best estimates available for use in the Tier 5 computations of OFL and ABC. Other trawl surveys were done during these years in both the GOA and the AI, but only covered depths to a maximum of 500 or 700 m. These shallower surveys have been excluded from the present analysis because they only sampled a relatively small portion of the giant grenadier depth range. For example, in the 1999 and 2005 GOA surveys, biomass of giant grenadier in depths <500 m comprised 32% and 40%, respectively, of the total giant grenadier biomass in all depths (Figure 1).

Because no trawl surveys in the AI since 1986 have sampled deeper waters where most giant grenadier biomass is found, I recommend use of an indirect method of determining biomass to apply the Tier 5 methodology to this region. Starting in 1996, the NMFS longline survey has sampled the AI and EBS in alternating years to depths of 1,000 m. For this survey, an index of biomass, called "relative population weight" (RPW), has been computed for the major species caught, including giant grenadier (Table 6). The mean RPW values for the AI and EBS (1,631,328 and 653,619, respectively) indicate that the biomass of giant grenadier in the AI is approximately 2.50 times greater than in the EBS. If this ratio of 2.50 is then applied to the mean EBS trawl survey biomass in 2002 and 2004 of 546,453 mt, an indirect biomass estimate of 1,363,858 mt can be computed for the AI.

For the above estimation of giant grenadier biomass in the AI, I chose to use the longline and trawl survey results in the EBS and AI, rather than those for the GOA and AI, as the basis for my computations. The reason for this is that both the longline and trawl surveys in the GOA may not sample the abundance of giant grenadier as well as their corresponding surveys in the EBS. In particular, longline survey catch rates for grenadier in the GOA are likely affected by the fact that sablefish are very abundant there and

[14] Draft Report of the Scientific and Statistical Committee to the North Pacific Fishery Management Council, February 6-8, 2006. 14 p. Available from North Pacific Fishery Management Council, 605 W 4th Ave., Suite 306, Anchorage AK 99501.

may out-compete giant grenadiers for the hooks, which may introduce a bias into the survey results in this region for grenadier. In contrast, sablefish abundance is relatively low in both the EBS and AI, which may result in better and more comparable longline survey data for giant grenadier in these areas. To a lesser degree, GOA trawl surveys may also be hindered in their determination of giant grenadier abundance compared to trawl surveys in the EBS because of the more difficult trawling conditions along the slope in the GOA. However, it should noted that if data from the AI and GOA were used to estimate AI biomass, the results would be very different than the value computed above based on AI and EBS data. The mean longline RPWs for giant grenadier in the years 1996-2006 are 1,631,328 in the AI and 1,143,576 in the GOA, which equals a ratio of 1.43. Using this ratio as a correction factor for the trawl survey's GOA biomass of 488,627 mt yields an indirect biomass estimate of 697,034 mt for the AI. This latter biomass is much less than the 1,363,858 mt estimate for the AI that was computed based on data from the AI and EBS.

According to the definitions for Tier 5, $F_{OFL} = M$, and $F_{ABC} <= 0.75 \times M$. Therefore, using the recommended biomass estimates discussed above for giant grenadier in the EBS, AI, and GOA, together with the natural mortality estimate for this species of 0.074 that was presented in section 4.1, initial Tier 5 computations for giant grenadier can be summarized as follows (biomass, OFL, and ABC in mt):

Initial Tier 5 OFL and ABC Computations

Area	Biomass	Natural mortality *M*	OFL Definition	OFL	ABC Definition	ABC
EBS	546,453	0.074	Biom x *M*	40,437	0.75 x OFL	30,328
AI	1,363,858	0.074	Biom x *M*	100,925	0.75 x OFL	75,694
GOA	488,627	0.074	Biom x *M*	36,158	0.75 x OFL	27,119
Total	2,398,938	0.074	Biom x *M*	177,521	0.75 x OFL	133,141

Discussion of Initial Tier 5 Results

To evaluate the appropriateness of the computed Tier 5 OFL and ABC values and whether they are sufficiently conservative to prevent overharvest of giant grenadier, a number of factors must be considered. These include: 1) the reliability of the natural mortality rate used for giant grenadier; 2) the accuracy of the biomass estimates in all areas, but especially in the AI because this estimate was derived indirectly; 3) the possibility that female giant grenadier may be disproportionately harvested in the fishery because it operates at depths where most of the giant grenadier population is comprised of females; and 4) the susceptibility of deep-water, long-lived fish to be overharvested.

The reliability of the natural mortality estimate used in the computations is uncertain. As discussed previously in section 4.1, the natural mortality estimate of 0.074 was computed using Hoenig's method, which relies on the maximum age of the species as the basis for its estimation procedures. In the aging study that was used to compute the Hoenig estimate of mortality, a maximum age of 56 was reported, but the giant grenadier otoliths were found to be very difficult to age, and von Bertalanffy growth curves yielded an unreasonable fit to the size and age data (Burton 1999). The lack of fit of the von Bertalanffy parameters is indicative of extremely variable and uncertain age results. Hoenig's method is quite sensitive to the maximum age used in its estimation of mortality, so if the true maximum age is substantially different than 56, the mortality estimate used in this report may not be accurate. For example, several other grenadier species have maximum reported ages of 60 to 70+ years (Merrett and Haedrich 1997; Matsui 1990; Andrews 1999), and if giant grenadier grow to this age, Hoenig's method would yield a significantly lower estimate of mortality. Also, Hoenig's method computes an estimate of the total mortality, and the authors of the report that applied Hoenig's method to giant grenadier (Clausen and Gaichas 2004) assumed that total mortality was approximately equal to natural mortality. In reality, however, giant grenadier had been taken in rather substantial amounts as bycatch in the sablefish longline fishery for many years. Therefore, even if the maximum age of 56 years is correct, use of Hoenig's method to determine natural mortality would result in an overestimate of natural mortality

The biomass estimates for giant grenadier in the EBS and GOA used in the OFL and ABC determinations appear reasonable and may even be underestimated. The two trawl surveys in each area that were used to compute mean biomass for giant grenadier (2002 and 2004 EBS surveys and 1999 and 2005 GOA surveys) are believed to have done a relatively good job of sampling deeper waters of the slope inhabited by giant grenadier, at least in comparison with older surveys of the slope in the 1980's. These biomass estimates may actually be underestimates, for two reasons: (1) an unknown amount of the giant grenadier biomass likely extends below the maximum depths sampled in the trawl surveys, as shown by the survey depth distributions in Fig. 1 and 2. Depth distributions of giant grenadier RPW in the longline surveys (Fig. 7, 8, and 9) also suggest than an unknown and perhaps significant amount of the giant grenadier biomass may be found in waters >1,000 m. Additional evidence for the distribution of giant grenadier at depths > 1,000 m in Alaska comes from a recent visual survey of the deep-water slope habitat in the central Aleutian Islands that used a remotely operated vehicle[15]. This survey observed fish that could be positively identified as giant grenadier to depths of at least 2,000 m. (2) Food studies indicate that giant grenadier consume mostly meso- or bathypelagic prey items that are in the water column, rather than items on the bottom (Drazen et al. 2001). Hence, giant grenadier may have a significant midwater component to their distribution. If so, some of the population may be unavailable to the bottom trawl surveys, which would result in an underestimate of biomass.

In contrast to the direct EBS and GOA biomass estimates, the indirect estimate for the AI is much more uncertain. The AI estimate of nearly 1.4 million mt is a very large biomass, and use of this biomass in the Tier 5 computations results in large values of OFL and ABC for giant grenadier in the AI. This raises concern that if the AI biomass is an overestimate, the OFL and ABC values could potentially allow the species to be overharvested in this area. As discussed in the previous section, use of AI and GOA data (instead of AI and EBS data) to compute an alternative AI biomass results in a much lower estimate than 1.4 million mt. Although the 1.4 million mt estimate is believed to be more accurate, the fact that the alternative biomass is so much lower creates more uncertainty about the AI biomass estimate. The last trawl survey that sampled deeper waters of the AI occurred in 1986, and it showed a biomass estimate of 600,656 mt for giant grenadier for depths <900 m (Ronholt et al. 1994). Recent trawl surveys in the AI in 2000, 2002 and 2004 yielded biomass estimates for these fish of 219,693, 218,147, and 248,159 mt[16], respectively, for depths <500 m, where the abundance of giant grenadier is presumably less than in deeper waters that were not sampled. These three trawl surveys, along with the 1986 survey, clearly indicate that there is a substantial biomass of giant grenadier in the AI, but whether this biomass is as much as the 1.4 million mt estimated in this report remains unsure.

Female giant grenadier may be disproportionately harvested in the fishery, and this suggests the possible need to err on the conservative side when setting OFLs and ABCs for this species. Trawl and longline studies both indicate that females greatly predominate at depths <700-800 m (see section 1, "Introduction" and section 3.2.2, "Longline Surveys"), whereas males become increasingly common in deeper water. Because most of the giant grenadier catch is taken as bycatch in the sablefish fishery, and this fishery is thought to operate mostly in depths <800 m, it can be inferred that female giant grenadier

[15] R. Stone and D. Alcorn, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Unpubl. data. Aug 2006.
[16] Based on data in NMFS Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2005. Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115.

are disproportionately harvested. Disproportionate removal of females by the fishery could put stocks of giant grenadier at greater risk if catches were sufficiently high. Direct information on the sex composition of the giant grenadier catch in the sablefish fishery will become available in 2007, when observers will begin sampling giant grenadiers in this fishery.

There have been several studies that indicate deep-sea fish appear to be especially susceptible to overfishing, which suggests fishery managers need to exercise particular caution when setting catch levels for these fish. One recent study in the NW Atlantic examined the relative abundance over a 20 year period of five deep-water species that were taken in target fisheries or as bycatch, and abundance of all five progressively declined to the point that each could be considered "critically endangered" (Devine et al. 2006). Two of these species were grenadiers. The depletion of one of these grenadiers, the roundnose grenadier *Coryphaenoides rupestris*, has also been documented by Atkinson (1995). In the early years of the fishery for this species, catches were as high as 75,000 mt, but landings quickly declined in later years even though exploitation was only moderate. Roundnose grenadier stocks appear to have become depleted with little sign of recovery. The particular vulnerability of deep-sea fish such as grenadiers to overfishing is likely due to the life history traits they have evolved in response to living in the relatively unproductive environment of the deep ocean. These traits may include longevity, slow growth, low fecundity, late maturation, and not spawning in some years (Merrett and Haedrich 1997; Koslow et al. 2000). All these characteristics imply that the replenishment rate for these fish could be less than recruitment if they are subject to fishing pressure.

Conclusions and Final Recommendations for OFL and ABC Values

The biomass estimates for giant grenadier in the EBS and AI that were presented as part of the initial tier 5 calculations are so large relative to the mean historic catch that they indicate the tier 6 OFLs and ABCs for these areas are unreasonably low. Specifically, the tier 5 biomass estimates are 546,453 mt in the EBS and 1,363,858 mt in the AI, versus corresponding mean catches of 3,154 and 2,358 mt, respectively. (In tier 6 OFL is defined to be mean historical catch). Therefore, the abundance of giant grenadier in these areas is so large that it can almost certainly support these relatively modest levels of catch. This appears to be the case even taking into account the need for caution when determining harvest levels for long-lived, deep-water fishes such as grenadiers.

In the GOA, the ratio of tier 5 estimated biomass to mean historical catch (488,627 mt biomass versus 10,903 mt mean catch) indicates the exploitation rate is higher than in the EBS and AI, but it still appears acceptable from a conservation standpoint. Therefore, similar to the EBS and AI, tier 6 values for OFL and ABC in the GOA are likely lower than needed.

Thus, for the EBS, AI, and GOA, tier 5 values are recommended for grenadiers. However, given the concerns discussed in section 5.3 that the natural mortality rate and AI biomass are uncertain, that females may be caught disproportionately, and that deep-sea fish such as grenadiers appear to be especially vulnerable to overexploitation, it appears prudent to adopt more conservative values for OFL and ABC than those initially presented in Section 5.2.

A reasonable method for determining more conservative values of OFL and ABC for giant grenadier is to use a lower estimate of natural mortality in the tier 5 computations. As discussed, the originally computed mortality estimate of 0.074 is almost certainly too high due to the fact that giant grenadier have a long history of exploitation in Alaska. It is also very uncertain because it relies heavily on a maximum age value determined from an aging study that had equivocal results. Therefore, I suggest that a more conservative proxy natural mortality rate of 0.057 (the rate computed for Pacific grenadier; see section 4.1) be used for the tier 5 computations of OFL and ABC until such time that better aging information becomes available for giant grenadier. Based on this more conservative natural mortality rate, alternative OFL and ABC values for giant grenadier can be computed as follows (biomass, OFL, and ABC in mt):

Final Recommended OFL and ABC Values

Area	Biomass	Natural mortality *M*	OFL Definition	OFL	ABC Definition	ABC
EBS	546,453	0.057	Biom x *M*	31,148	0.75 x OFL	23,361
AI	1,363,858	0.057	Biom x *M*	77,740	0.75 x OFL	58,305
GOA	488,627	0.057	Biom x *M*	27,852	0.75 x OFL	20,889
Total	2,398,938	0.057	Biom x *M*	136,739	0.75 x OFL	102,555

These are my final, recommended values for grenadier OFL and ABC. Compared to the initial tier 5 OFLs and ABCs, these more conservative values are still considerably higher in each area than the corresponding grenadier catches for any of the years in Table 1. If the catch of grenadiers continues to be taken strictly as bycatch, these lower OFLs and ABCs should easily be able to accommodate this bycatch without causing any constraint on the existing sablefish fishery. At the same time, the lower OFLs and ABCs are large enough that they should permit the development of a directed grenadier fishery, especially in the EBS and AI where the abundance of giant grenadiers appears to be high and the amount of grenadier bycatch has been low. However, because the final OFLs and ABCs are more conservative than the initial values, there would be a reduced risk that a targeted grenadier fishery would overexploit the stocks.

HARVEST SCENARIOS TO SATISFY REQUIREMENTS OF NPFMC'S AMENDMENT 56, NEPA, AND MSFCMA

For species such as grenadiers that are not assessed with a age/length-structured model, multi-year projections are not possible but yields for just the year 2007 can be computed as follows (biomass and yields are in mt):

		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Area	Biomass	F	Yield	F	Yield	F	Yield	F	Yield
Eastern Bering Sea	546,453	0.057	23,361	0.057	23,361	0.0285	11,680	0.0043	2,368
Aleutian Islands	1,363,858	0.057	58,305	0.057	58,305	0.0285	29,152	0.0016	2,124
Gulf of Alaska	488,627	0.057	20,889	0.057	20,889	0.0285	10,444	0.0198	9,684
Total	2,398,938	0.057	102,555	0.057	102,555	0.0285	51,277	0.0059	14,177

Scenario 1: F is set equal to max F_{ABC}.
Scenario 2: F is set equal to the recommended $F_{ABC.}$
Scenario 3: F is set equal to 50% of max F_{ABC}.
Scenario 4: F is set equal to the average F for 2001-2005 (i.e., the most recent five years with complete catch data).

ECOSYSTEM CONSIDERATIONS

A determination of ecosystem considerations for grenadiers in Alaska is hampered by the extreme lack of biological and habitat information for these species and by limited knowledge in general on the deep slope environment inhabited by these fish.

Ecosystem Effects on the Stocks

Prey availability/abundance trends: The only food studies on grenadiers in the northeast Pacific have been on adults. One study of giant grenadier off the U.S. west coast concluded that the fish fed primarily ofbottom on bathy- and mesopelagic food items that included gonatid squids, viperfish, deep-sea smelts, and myctophids (Drazen et al. 2001). A much smaller study on food of giant grenadier in the Aleutian Islands also found squids and myctophids were the main prey items (Yang 2003). Research on these deep-sea prey organisms in Alaska has been virtually non-existent, so information on prey availability or possible variations in abundance of prey are unknown. Very few juvenile giant grenadier have ever been caught, so nothing is known about their food preferences.

In contrast to giant grenadier, a study of Pacific grenadier food habits off the U.S. west coast found a much higher consumption of benthic food items such as polychaetes, cumaceans, mysids, and juvenile Tanner crabs (*Chionoecetes* sp.), especially in smaller individuals (Drazen et al. 2001). Carrion also contributed to its diet, and larger individuals consumed some pelagic prey including squids, fish, and bathypelagic mysids.

Predator population trends: The only documented predator of giant grenadier is the Pacific sleeper shark (Orlov and Moiseev 1999). According to their study, giant grenadier was ranked third in relative importance as a food item in the diet of these sharks. Sperm whales are another potential predator, as they are known to dive to depths inhabited by giant grenadier on the slope and have been observed depredating on longline catches of giant grenadier[17]. Giant grenadier is a relatively large animal that is considered an apex predator in its environment on the deep slope (Drazen et al. 2001), so it may have relatively few predators as an adult. Predation on larval and juvenile giant grenadiers would likely have a much greater influence on the ultimate size of the adult population size, but information on predators of these earlier life stages is nil.

Changes in physical environment: Little or no environmental information has been collected in Alaska for the deep slope habitat in which grenadiers live. Certainly, this habitat is more stable oceanographically than shallower waters of the upper slope or continental shel Regime shifts on the continental shelf and slope in Alaska in recent decades have been well documented, but it is unknown if these shifts also extend to the deep slope. Regime shifts could have a pronounced effect on giant grenadier if their larvae or post-larvae inhabited upper portions of the water column, but no larvae or post-larvae for this species have ever been collected in Alaska.

Fishery Effects on the Ecosystem

Because there has been virtually no directed fishing for grenadiers in Alaska, the reader is referred to the discussion on Fishery Effects in the sablefish SAFE report. The sablefish longline fishery is the main fishery that takes giant grenadier as bycatch, so the Fishery Effects section in the sablefish report is applicable to giant grenadier and is an indication of what the effects might be if a directed fishery for giant grenadier were to develop. It should be noted that because all grenadiers presently caught in the

[17] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun. Oct 2006.

sablefish and Greenland turbot fisheries are discarded and do not survive, this constitutes a major input of dead organic material to the ecosystem that would not otherwise be there.

Data Gaps and Research Priorities

Many aspects of basic information are lacking for grenadiers in Alaska. Among the highest priorities of research are: 1) taxonomic and genetic studies on giant grenadier to determine if more than one species and/or subpopulations exist, and 2) extended survey coverage in waters >1,000 m to investigate the abundance of giant grenadier and other grenadiers in deep depths that have not been sampled in any past surveys. Two other important studies on giant grenadier are currently in progress and hopefully will provide useful information in upcoming years. These are age-and-growth research and female maturity and fecundity studies. Information from both these studies will be essential for population dynamics modeling to occur for this species. Results of the NMFS longline survey need to be analyzed to account for the effects of competition for hooks among species to determine what biases, if any, the survey abundance index has for giant grenadier. Knowledge on early life history of giant grenadiers is virtually nil and where larvae and young juveniles reside is unknown. Finally, to evaluate the accuracy of giant grenadier biomass estimates from bottom trawl surveys, studies are needed on whether this fish is a completely benthic species or if individuals sometimes move ofbottom.

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Table 1.--Estimated catch (mt) of grenadiers (all species combined) in the Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, 1997-2005.

	Eastern Bering Sea	Aleutian Islands	Gulf of Alaska	Total
1997	2,964	2,887	12,029	17,881
1998	5,011	1,578	14,683	21,272
1999	4,505	2,883	11,388	18,776
2000	4,067	3,254	11,610	18,931
2001	2,294	1,460	9,685	13,439
2002	1,891	2,807	10,479	15,177
2003	2,853	3,556	11,165	17,573
2004	2,225	1,123	10,511	13,858
2005	2,581	1,676	6,581	10,838
mean	3,154	2,358	10,903	16,416

Sources: 1997-2001, Gaichas (2002); 2002, S. Gaichas, Unpubl. data, Jan. 2005. NMFS Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115-0070; 2003-2005, NMFS Alaska Region, Sustainable Fisheries Division, P.O. 21668, Juneau, AK 99802. Data query, Aug. 2006.

Table 2.--Estimated catch (mt) of grenadiers (all species combined) in the Eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, by target species/species group, 2003-2005.

	Target species/species group					
Year	Sablefish	Flatfish	P. cod	Rockfish	Other	Total
			Eastern Bering Sea			
2003	598	1,959	235	9	52	2,853
2004	285	1,647	240	20	33	2,225
2005	111	2,104	338	9	18	2,581
			Aleutian Islands			
2003	2,014	1,489	46	6	trace	3,556
2004	749	299	14	38	24	1,123
2005	1,009	630	0	21	16	1,676
			Gulf of Alaska			
2003	8,495	1,991	5	620	54	11,165
2004	7,684	573	trace	2,246	8	10,511
2005	5,765	533	trace	230	54	6,581

Source: NMFS Alaska Region, Sustainable Fisheries Division, P.O. 21668, Juneau, AK 99802. Data query, Aug. 2006.

Table 3.--Estimated biomass (mt) of giant grenadier in NMFS trawl surveys in Alaska that sampled the upper continental slope.

Year	Eastern Bering Sea	Aleutian Islands	Gulf of Alaska
1979	91,500[a]	-	-
1980	-	313,480	-
1981	90,500[a]	-	-
1982	104,700[a]	-	-
1983	-	349,538	-
1984	-	-	169,708
1985	107,600[a]	-	-
1986	-	600,656	-
1987	-	-	135,971
1988	61,400[a]	-	-
1989	-	-	-
1990	-	-	-
1991	73,520[a]	-	-
1992	-	-	-
1993	-	-	-
1994	-	-	-
1995	-	-	-
1996	-	-	-
1997	-	-	-
1998	-	-	-
1999	-	-	389,908
2000	-	-	-
2001	-	-	-
2002	426,397	-	-
2003	-	-	-
2004	666,508	-	-
2005	-	-	587,346

[a]Estimates are for all species of grenadiers combined

Notes and data sources:

a) Eastern Bering Sea: Depths sampled were to 1,000 m in 1979, 1981, 1982, and 1985; to 800 m in 1988 and 1991; and to 1,200 m in 2002 and 2004. Data sources: 1979 to 1988, Bakkala et al. (1992); 1991, Goddard and Zimmermann (1993); 2002, Hoff and Britt (2003); 2004, Hoff and Britt (2005).
b) Aleutian Islands: Depths sampled were to 900 m in each survey. Data source: Ronholt et al. (1994).
c) Gulf of Alaska: Depths sampled were to 1,000 m in each survey. Data sources: 1984, 1987, 1999, and 2005, data on the Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2006, available from the National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115.

Table 4.--Comparative biomass estimates (mt) for the three common grenadier species in recent NMFS trawl surveys in Alaska that sampled the upper continental slope.

Region	Year	Giant grenadier	Pacific grenadier	Popeye grenadier
Gulf of Alaska	1999	389,908	8,240	16,260
Gulf of Alaska	2005	587,346	2,252	21,297
Eastern Bering Sea	2002	426,397	2,461	50,329
Eastern Bering Sea	2004	666,508	4,039	44,361

Table 5.--Biomass estimates (mt) and associated 95% confidence bounds (mt), variances, and coefficients of variation (cv) for giant grenadier in recent NMFS surveys in Alaska that sampled the upper continental slope.

			95% Con bounds			
Region	Year	Biomass	Lower	Upper	Variance	cv (%)
Gulf of Alaska	1999	389,908	313,786	466,030	1,418,688,152	9.7
Gulf of Alaska	2005	587,346	420,489	754,202	6,503,760,627	13.7
Eastern Bering Sea	2002	426,397	344,922	507,871	1,659,519,194	9.6
Eastern Bering Sea	2004	666,508	527,524	805,491	4,829,084,657	10.4

Table 6.--Giant grenadier relative population weight, by region, in NMFS longline surveys in Alaska, 1990-2006. Dashes indicate years that the eastern Bering Sea or Aleutian Islands were not sampled by the survey. Gulf of Alaska values include data only for the upper continental slope and do not include continental shelf gullies sampled in the surveys.

Year	Eastern Bering Sea	Aleutian Islands	Gulf of Alaska
1990	-	-	1,069,723
1991	-	-	959,567
1992	-	-	805,356
1993	-	-	1,148,754
1994	-	-	1,133,409
1995	-	-	1,402,019
1996	-	1,281,800	1,251,843
1997	840,693	-	1,418,428
1998	-	1,348,632	1,185,404
1999	632,379	-	1,277,141
2000	-	1,743,203	1,230,161
2001	431,114	-	1,198,183
2002	-	1,760,703	1,011,721
2003	592,467	-	1,194,939
2004	-	1,662,371	903,906
2005	771,441	-	943,662
2006	-	1,991,259	963,947
mean	653,619	1,631,328	1,123,421

Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun., October 2006.

Table 7.--Giant grenadier catch rates (number caught per 100 hooks), by area, in NMFS longline surveys in Alaska, 1990-2006. Dashes indicate areas or years in the Bering Sea and Aleutian Islands that were not sampled by the survey. Overall catch rates for combined areas or years are not available at this time.

Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bering 4	-	-	-	-	-	-	-	26.1	-	22.3	-	8.0	-	13.3	-	25.9	-
Bering 3	-	-	-	-	-	-	-	27.0	-	23.0	-	14.5	-	26.5	-	28.4	-
Bering 2	-	-	-	-	-	-	-	10.7	-	7.7	-	7.0	-	7.2	-	10.2	-
Bering 1	-	-	-	-	-	-	-	1.9	-	0.2	-	1.6	-	1.3	-	1.6	-
NE Aleutians	-	-	-	-	-	-	12.8	-	10.2	-	17.8	-	21.0	-	25.3	-	34.4
SE Aleutians	-	-	-	-	-	-	22.8	-	25.3	-	28.2	-	27.9	-	24.6	-	24.8
Shumagin	22.1	21.8	19.4	24.2	25.5	30.1	21.5	27.9	31.6	24.4	24.7	26.5	28.3	26.6	27.6	25.4	31.6
Chirikof	22.1	17.8	19.3	21.8	20.4	28.4	27.4	28.3	17.1	22.2	21.0	24.4	15.4	26.6	16.7	19.7	17.4
Kodiak	10.4	8.4	6.5	7.6	10.9	13.8	16.1	16.9	11.7	17.5	13.4	13.1	11.6	15.4	8.2	14.5	9.2
W Yakutat	5.8	4.3	3.6	5.9	3.9	6.0	4.5	9.8	7.7	8.8	9.1	8.7	3.4	7.6	4.9	8.3	5.9
E Yakutat	2.4	3.2	2.3	3.3	2.0	4.0	4.1	3.2	4.1	3.9	3.3	3.6	4.6	5.1	3.8	4.0	3.6
Southeast	1.4	1.4	1.8	1.6	1.7	2.8	2.4	2.6	3.6	5.5	4.3	5.2	4.8	3.2	2.6	3.2	3.8

Note: Data not available for the NW and SW Aleutians.
Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun., October 2006.

Table 8.--Sex distribution, by depth stratum, of giant grenadier sampled in the 2006 NMFS longline survey in Alaska.

	Eastern Aleutian Islands			Gulf of Alaska		
Depth stratum (m)	No. fish sampled	Percent male	Percent female	No. fish sampled	Percent male	Percent female
201-300	5	0.0	100.0	176	0.0	100.0
301-400	134	0.0	100.0	1,097	0.5	99.5
401-600	824	1.2	98.8	1,970	1.5	98.5
601-800	684	5.8	94.2	1,876	3.8	96.2
801-1000	278	24.8	75.2	871	10.1	89.9
All depths	1,925	6.2	93.8	5,990	3.2	96.8

Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun., October 2006.

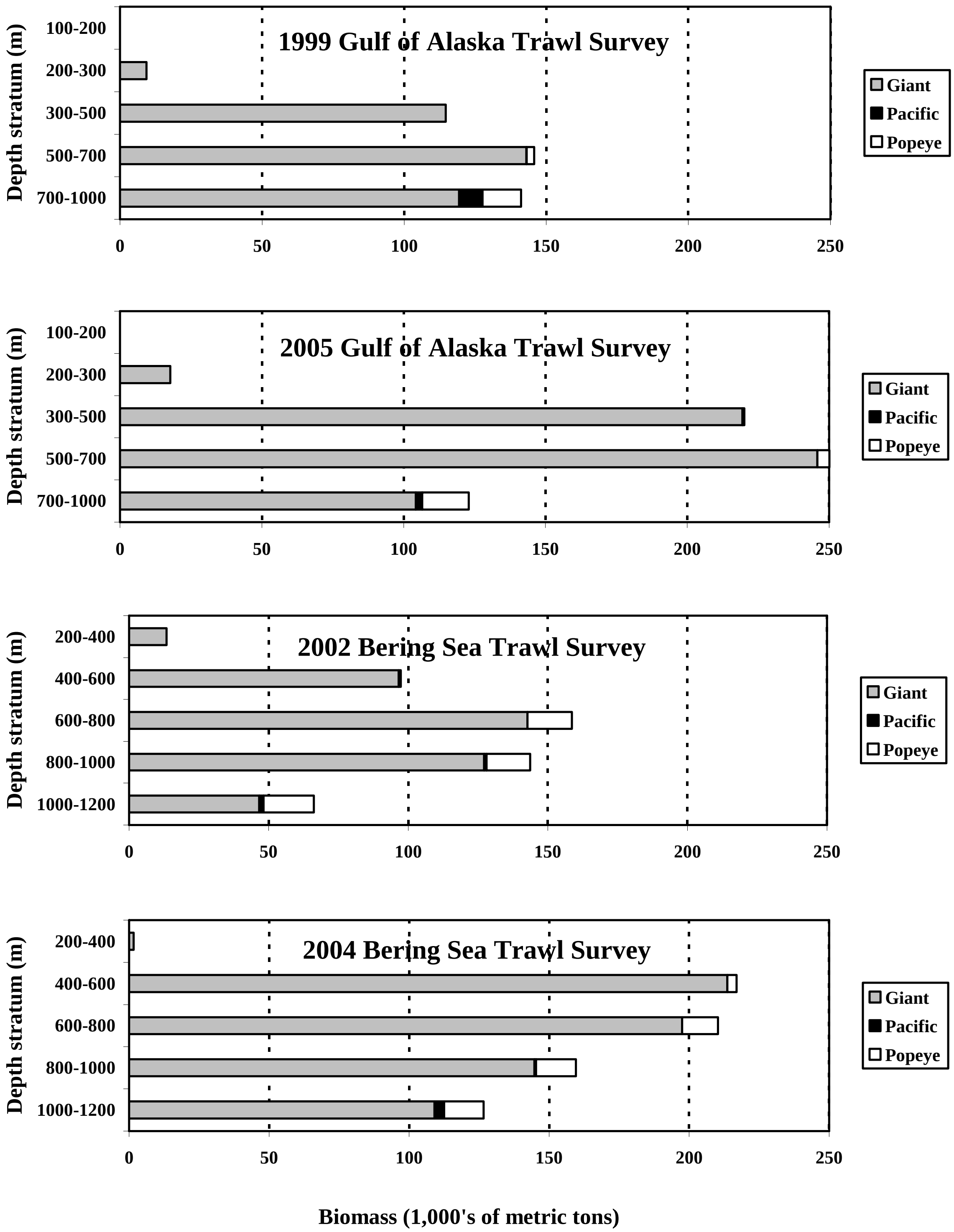

Figure 1.--Depth distribution of giant, Pacific, and popeye grenadier biomass estimates in the 1999 and 2005 Gulf of Alaska trawl surveys and the 2002 and 2004 eastern Bering Sea slope trawl surveys. Note: depth strata shown for each survey are not the same because the surveys had different stratification schemes for depth.

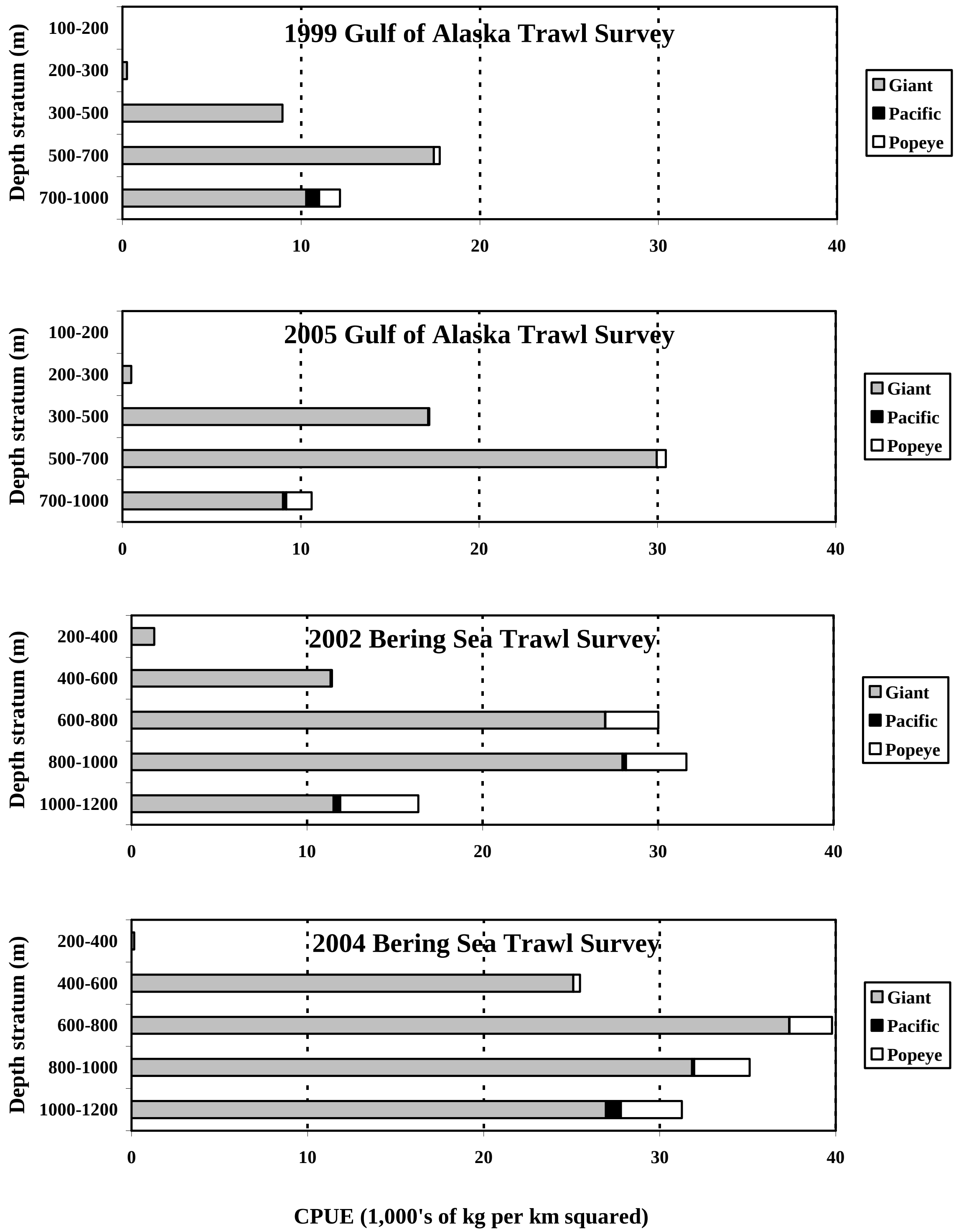

Figure 2.--Depth distribution of giant, Pacific, and popeye grenadier catch per unit effort (CPUE) in the 1999 and 2005 Gulf of Alaska trawl surveys and the 2002 and 2004 eastern Bering Sea slope trawl surveys. Note: depth strata shown for each survey are not the same because the surveys had different stratification schemes for depth.

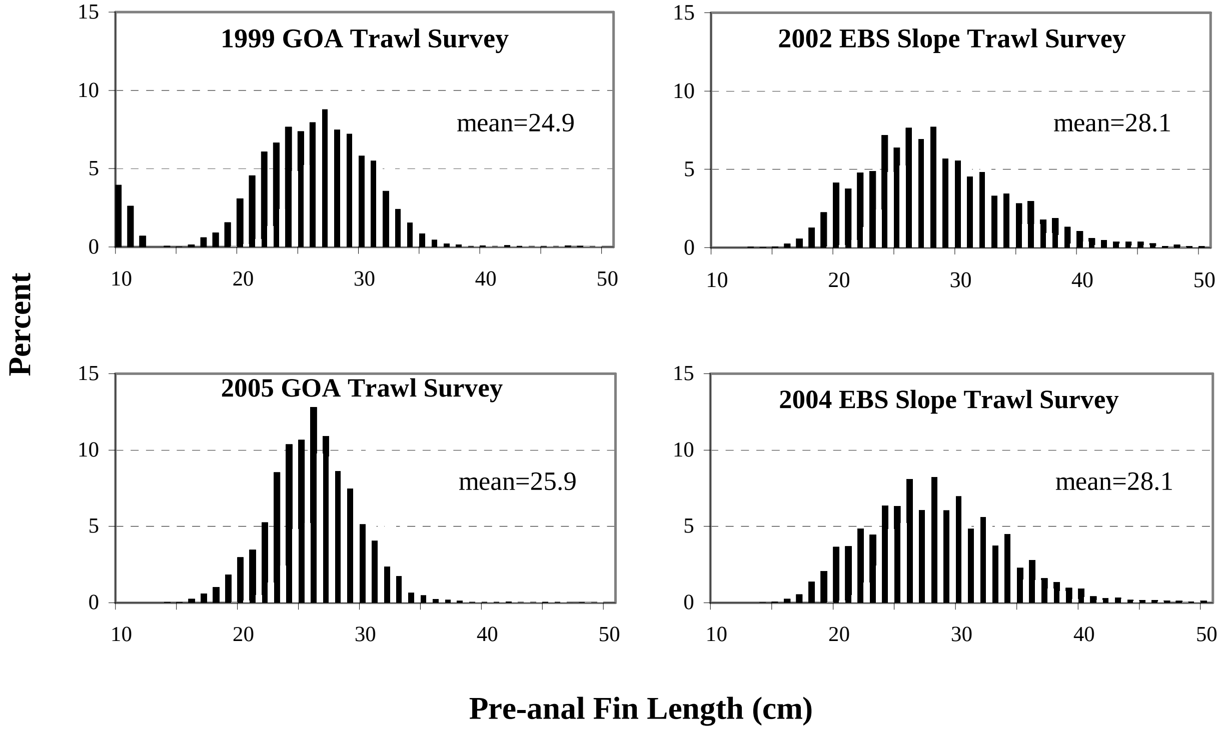

Figure 3.--Estimated population size compositions for giant grenadier in recent Alaskan trawl surveys. (GOA = Gulf of Alaska and EBS = Eastern Bering Sea).

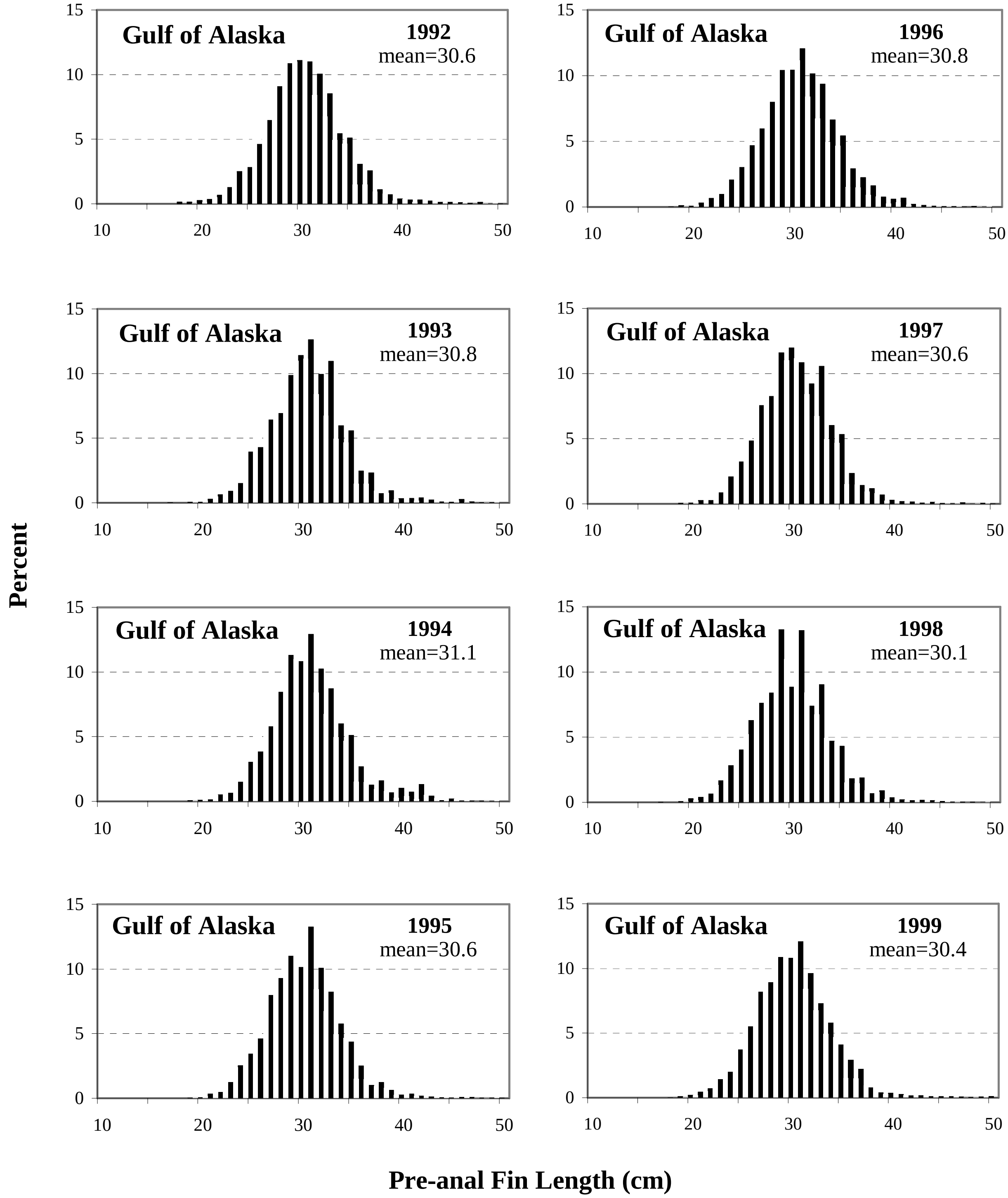

Figure 4.--Estimated population size compositions for giant grenadier in the 1992-2006 longline surveys of the Gulf of Alaska. (Figure continued on next page).

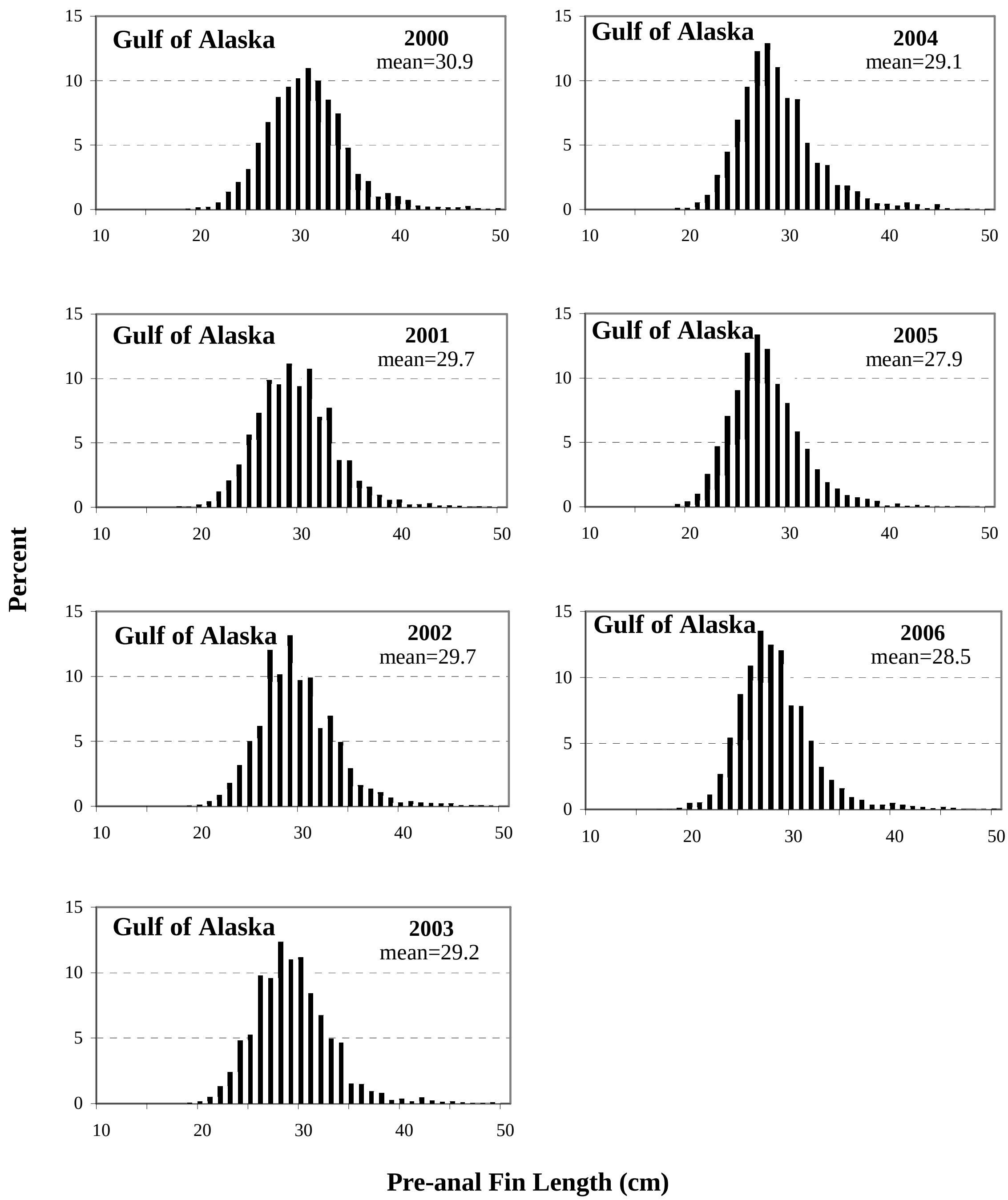

Figure 4. (continued from preceding page).

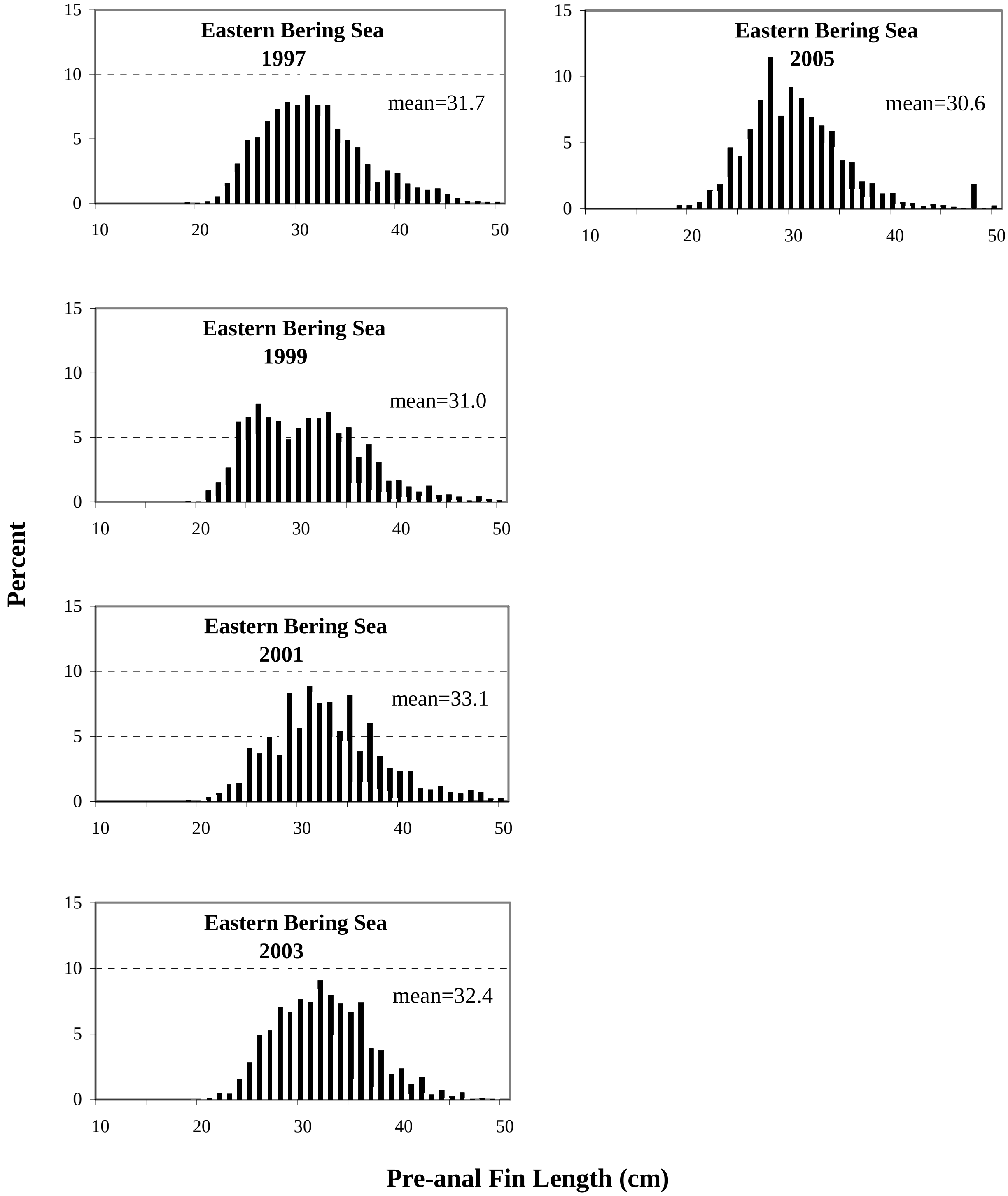

Figure 5.--Estimated population size compositions for giant grenadier in the 1997-2005 longline surveys of the Eastern Bering Sea.

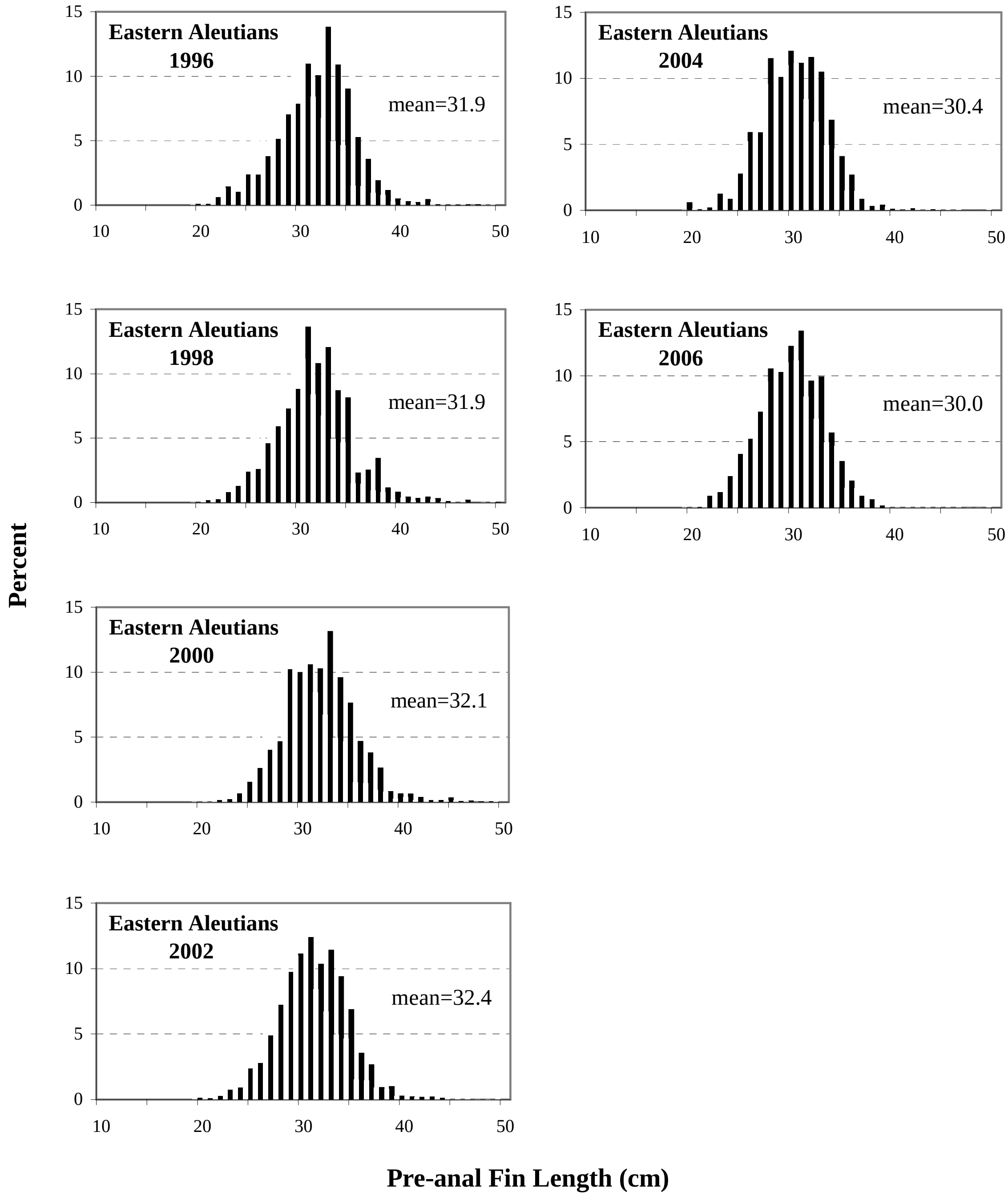

Figure 6.--Estimated population size compositions for giant grenadier in the 1996-2006 longline surveys of the Eastern Aleutian Islands (area of the Aleutian Islands east of 180^{o} w. longitude). Size composition data are not available for the Western Aleutian Islands.

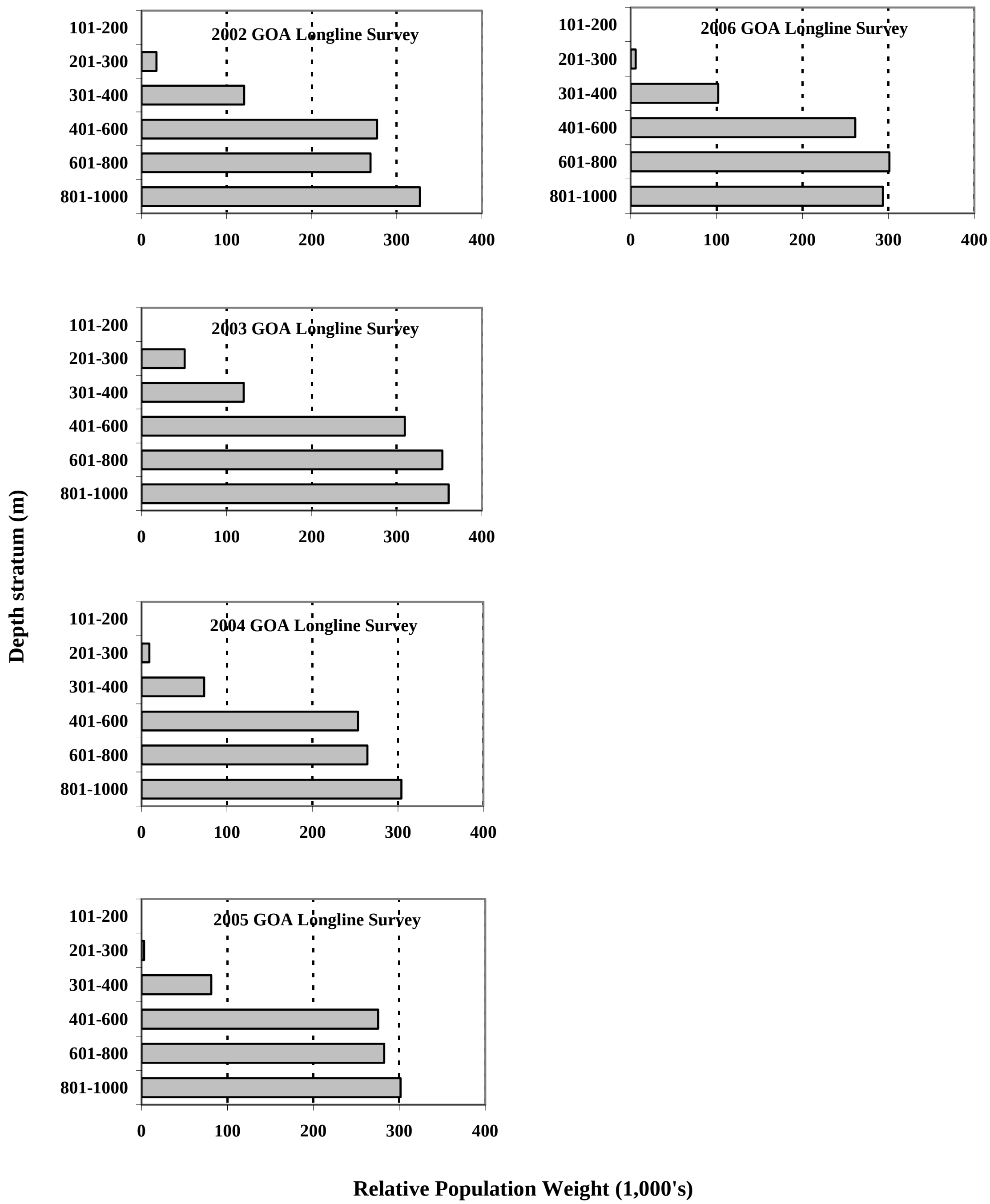

Figure 7.--Depth distribution of giant grenadier relative population weight in the 2002-2006 longline surveys of the Gulf Alaska (GOA).

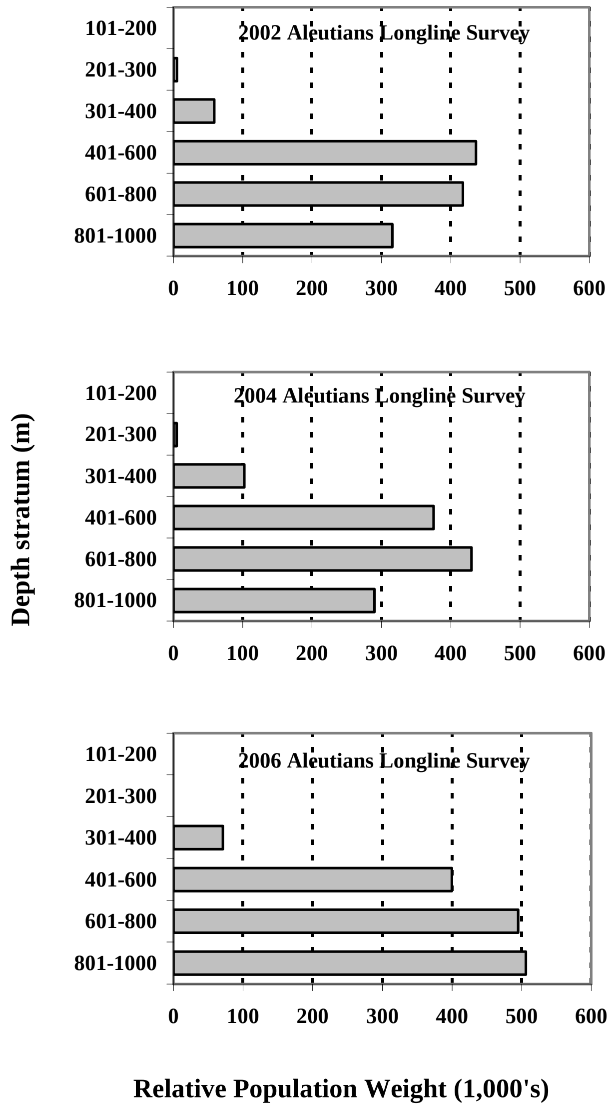

Figure 8.--Depth distribution of giant grenadier relative population weight in the 2002, 2004, and 2006 longline surveys of the Eastern Aleutian Islands (area of the Aleutian Islands east of 180^{o} w. longitude). Data on depth distribution are not available for the Western Aleutian Islands.

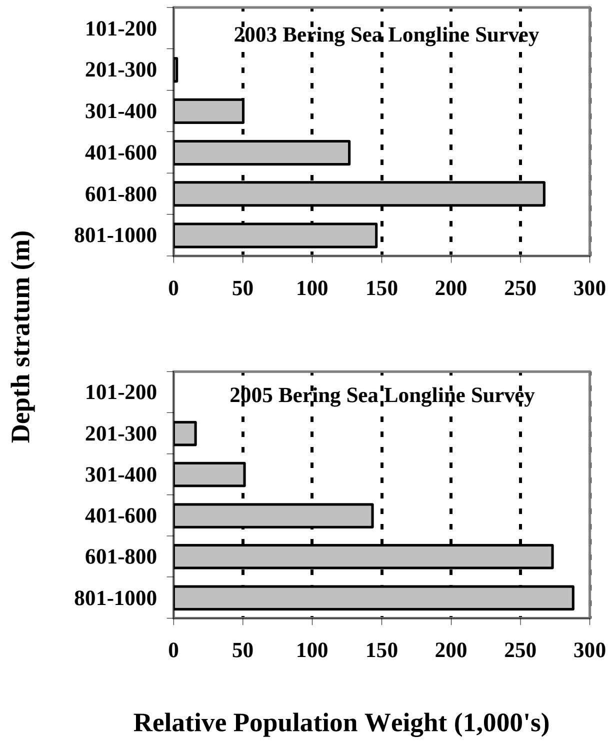

Figure 9.--Depth distribution of giant grenadier relative population weight in the 2003 and 2005 longline surveys of the Eastern Bering Sea.