Appendix 1 – Gulf of Alaska and Bering Sea/Aleutian Islands SAFE Reports

Assessment of Grenadiers in the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands

by
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November 2008

1.0 EXECUTIVE SUMMARY

Grenadiers are presently considered "nonspecified" by the NPFMC, which means they are not part of the groundfish fishery management plans (FMPs) for either the Gulf of Alaska (GOA) or the Bering Sea/Aleutian Islands (BSAI). Therefore, there are no limitations on catch or retention, no reporting requirements, and no official tracking of grenadier catch by management. However, a proposed joint management plan amendment for "other species" may change grenadiers to a "specified" status, in which case they would be included as managed groundfish species in the FMPs. In response to this possibility, an assessment of grenadiers in Alaska was prepared for the first time as an appendix to the 2006 SAFE report (Clausen 2006). Because there is a substantial amount of new information available for giant grenadier (*Albatrossia pectoralis*; the main species of interest in the group), a full update of the grenadier assessment was completed for the present 2008 SAFE report.

Of the seven species of grenadiers known to occur in Alaska, 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.

1.0.1 New Data

Major new data available for this assessment include: 1) updated catch estimates for 2003-2008; 2) trawl survey results for the GOA in 2007 and for the eastern Bering Sea (EBS) slope in 2008; 3) NMFS longline survey results for 2007 and 2008: 4) the first-ever observer data on giant grenadier length and sex in the commercial fishery for 2007; 5) good data for the first time on species composition of the grenadier catch in the fishery for 2008; 6) results from a new aging study of giant grenadier in the GOA that showed a maximum age of 58 years and that provided the first-ever von Bertalanffy growth parameters for this species; 7) based on the new age results, a new recommended natural mortality rate for giant grenadier of 0.078 was computed; and 8) results of an age- and size-at-50%-maturity study for giant grenadier that indicated these values were 22.9 years and 26 cm pre-anal fin length, respectively.

1.0.2 OFL and ABC Determinations

The previous (2006) SAFE report for grenadiers recommended a tier 5 approach for determining OFL and ABC, and we continue to recommend this approach in the present assessment. The tier 5 computations have been based on giant grenadier only and have 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. The two input parameters required for tier 5 are reliable estimates of biomass (B) and a reliable estimate of the natural mortality rate (M).

Biomass estimates in this assessment for giant grenadier in the EBS and GOA were calculated based on the average of the three most recent deep-water (to 1,000-1,200 m) trawl surveys in each area. In the EBS, these were in 2002, 2004, and 2008, and the average was 518,778 mt; in the GOA, these were in 1999, 2005, and 2007, and the average was 488,414 mt. No trawl surveys in the Aleutian Islands (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 NMFS longline surveys, biomass of giant grenadier for the period 1996-2008 was 2.50 times higher in the AI than in the EBS. If this ratio is applied to the estimated trawl survey biomass of 518,778 mt in the EBS, an indirect estimate of 1,297,643 mt can be computed for giant grenadier in the AI. Similarly, an alternative indirect biomass can be computed for the AI which is based on survey data from the AI and GOA, rather than from the AI and EBS. According to the NMFS longline surveys, biomass of giant grenadier for the years 1996-2008 was 1.35 times higher in the AI than in the GOA. Applying this ratio to the estimated biomass for the trawl surveys in the GOA of 488,414 mt yields an indirect biomass estimate for the AI of 660,869 mt. These two indirect biomass estimates for the AI are very different (1.3 million vs. 0.7 million mt), and a decision must be made as to which value should be used in the tier 5 computations. In the 2006 assessment, we recommended use of the higher estimate because it was believed the EBS and AI data for giant grenadier were more comparable. However, in the present assessment we are recommending a different approach that we believe is more appropriate: using the average of the two indirect biomass estimates for AI, which equals 979,256 mt. This average is more conservative than using the higher estimate, and it addresses the fact that both the indirect estimates are uncertain.

In the 2006 assessment, two estimates of M were presented: 0.074, which was based on data from a previous aging study of giant grenadier, and 0.057, which was a proxy *M* based on data for another grenadier species in the NE Pacific Ocean, Pacific grenadier. The final *M* recommended for the tier 5 computations was the lower, proxy value because of the uncertainty associated with the giant grenadier age results and because the proxy value was more precautionary. However, new age results for giant grenadier have recently become available, and these allowed the computation of a new estimate of natural mortality for giant grenadier, 0.078. The new mortality estimate agrees closely with the old estimate of 0.074, and we consider the data it is based on to be more reliable. Hence, it no longer appears justifiable to use a proxy *M* for giant grenadier, despite its more precautionary value. We now recommend using the new *M* of 0.078 in the tier 5 computations.

Therefore, based on the above recommendations for biomass and natural mortality, tier 5 recommendations for giant grenadier OFL and ABC are summarized as follows (biomass, OFL, and ABC are in mt):

Area	Biomass	Natural mortality *M*	OFL definition	OFL	ABC definition	ABC
EBS	518,778	0.078	biom x *M*	40,465	OFL x 0.75	30,349
AI	979,256	0.078	biom x *M*	76,382	OFL x 0.75	57,286
GOA	488,414	0.078	biom x *M*	38,096	OFL x 0.75	28,572
Total	1,986,448			154,943		116,207

These values are compared to the recommended values in the previous SAFE report for grenadiers in 2006 (biomass, OFL, and ABC are in mt):

	2006 Assessment				2008 Assessment			
Area	Biomass	Natural mortality *M*	OFL	ABC	Biomass	Natural mortality *M*	OFL	ABC
EBS	546,453	0.057	31,148	23,361	518,778	0.078	40,465	30,349
AI	1,363,858	0.057	77,740	58,305	979,256	0.078	76,382	57,286
GOA	488,627	0.057	27,852	20,889	488,414	0.078	38,096	28,572
Total	2,398,938	0.057	136,739	102,555	1,986,448	0.078	154,943	116,207

1.0.3 Recommendation to Include Grenadiers in the FMPs as Part of the "Other Species" Category

Although grenadiers are presently "nonspecified" and thus not included in either the BSAI or GOA FMPs, it would be much more appropriate for them to be in the "other species" category. The "other species" category is defined by the NPFMC as species that have "only slight economic value and are generally not targeted upon, but which are either significant components of the ecosystem or have economic potential". In contrast, "nonspecified" species are a "residual category of species and species groups of no current or foreseeable economic value or ecological importance, which are taken in the groundfish fishery as accidental bycatch and are in no apparent danger of depletion" and for which "virtually no data exists (that) would allow population assessments". Based on these definitions, grenadiers clearly belong in the "other species" group. Because of their abundance on the slope, giant grenadier are of great ecological importance in this habitat, and they also hold economic potential. In addition, there now exists considerable information on giant grenadier that can be used for population assessment. Therefore, we are very supportive of the proposal to move grenadiers from the "nonspecified" to the "other species" group and recommend that this proposal be implemented.

1.0.4 Response to SSC comments regarding the grenadier assessment

There were no directed comments by the SSC in their Dec. 2006 minutes regarding the previous (Nov. 2006) assessment of grenadiers.

1.1 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 "nonspecified 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 "nonspecified" 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 overfishing levels (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 Ocean to Japan, including the Bering Sea and the Sea of Okhotsk (Mecklenburg et al. 2002), and they are also found on seamounts in the Gulf of Alaska and on the Emperor Seamount chain in the North Pacific (Clausen 2008). 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 one individual in a Bering Sea trawl survey was 41.8 kg[1]. Previous publications (Clausen 2006 and 2008) speculated that more than one species of giant grenadier may exist in Alaska because two morphs of the fish have been observed, as well as two very different patterns of otolith morphology. However, recent DNA genetic analysis of tissue samples from the two morphs showed no evidence of any differentiation[2], which appears to refute the hypothesis that giant grenadier is comprised of two distinct 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; Rodgveller et al.[3]). 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

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[1] G. Hoff, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. March 2005.

[2] J. Orr, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. March 2008.

[3] Rodgveller, C. J., D. M. Clausen, J. Nagler, and C. Hutchinson. Maturity, fecundity, growth, and natural mortality of giant grenadier (*Albatrossia pectoralis*) in the Gulf of Alaska. Unpubl. manuscr., June 2008. Avail. from Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801.

either of these descriptions or to the description of a third form (Busby 2004) that is also giant grenadier-like[4]. Small, 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) in Russian waters and Clausen (2008) in Alaskan waters found that nearly all fish <600 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 migration patterns of giant grenadier in Alaska are unknown, as no genetics studies have been done (except for brief genetic investigation of the two morphs of this species that was previously mentioned), 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. Smaller studies of giant grenadier food habits in the Aleutian Islands (Yang 2003) and Gulf of Alaska (Yang et al. 2006) showed similar results. In the Aleutian Islands, the diet comprised mostly squid and bathypelagic fish (myctophids), whereas in the Gulf of Alaska, squid and pasiphaeid shrimp predominated as prey. The hypothesis regarding 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 (*Somniosus pacificus)* and Baird’s beaked whales (*Berardius bairdii*) have been documented as predators on giant grenadier (Orlov and Moiseev 1999; Walker et al. 2002). Sperm whales (*Physeter macrocephalus*) are another likely predator, as they are known to dive to depths inhabited by giant grenadier on the continental slope and have been observed in Alaska depredating on longline catches of giant grenadier[6].

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. For example, in a recent experimental longline haul in the western Gulf of Alaska at a depth of 1400-1500 m, 56% of the hooks caught Pacific grenadier[7]. This indicates that at least in some locations in deep water, abundance of Pacific grenadier in Alaska can be extremely high. Food studies off the U.S.

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[4] M. Busby, National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. Oct. 2006.
[5] D. Clausen, National Marine Fisheries Service, Alaska Fisheries Science, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. observ. Oct. 2004.
[6] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm. Oct. 2006.
[7] D. Clausen, National Marine Fisheries Service, Alaska Fisheries Science, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Unpubl. data. Aug. 2008.

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).

1.2 FISHERY

1.2.1 Catch History

As mentioned, no official catch statistics exist for grenadiers in Alaska because they are considered "nonspecified" 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 Fishery Monitoring and Analysis program (Table 1-1). 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). Although these estimates may not be as accurate as the official catch estimates determined for managed groundfish species, they are believed to be the best possible based on the data available. They do not appear unreasonable compared to the official catches of other species caught along with giant grenadier on the continental slope in Alaska, such as sablefish and Greenland turbot. The estimates for 2003-2008 were computed by the NMFS Alaska Regional Office based on their Catch Accounting System, which replaced the "blend" system in 2003. All the data are presented as "grenadiers, all species combined", because observers were not instructed to identify giant grenadiers until 2005. Even then, the catch data suggest that many observers in the years 2005-2007 did not properly identify giant grenadier to species; some observers in these years were still reporting a sizeable percentage of the grenadier catch as "grenadiers, unidentified". 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. The only other grenadier species encountered on the continental slope in Alaska are Pacific and popeye grenadier. 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 1.3.2.1, "Survey Data"). 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. Hence, this indirect evidence can be used to conclude that giant grenadier are the overwhelmingly predominant species in the grenadier catch. This conclusion is supported by the catch data available so far for 2008, when it appears that nearly every observer is properly identifying giant grenadier. The 2008 catch data show that giant grenadier comprises 97.8%, 98.1%, and 98.8% of the grenadier catch in the EBS, AI, and GOA regions, respectively.

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 1997-2008 have ranged between ~11,000-21,000 mt, with an average for this period of ~16,000 mt (Table 1-1). Highest catches have consistently been in the GOA, followed generally by the EBS and then the AI. By region, annual catches have ranged between ~7,000-15,000 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 1997-2006 ranged from about 14,00 to 18,000 mt (Hanselman et al. 2007). Thus, the amount of grenadier caught in these years was similar to the amount of sablefish taken.

1.2.2 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 analysis was done for the years 2003-2008 based on data from the NMFS Alaska Regional Office Catch Accounting System (Table 1-2). It also showed that the grenadier catch in the both the GOA and AI was taken predominantly in hauls that targeted sablefish, whereas that in the EBS came from hauls that targeted Greenland turbot. Historically, both the sablefish and Greenland turbot fisheries have been 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). In recent years, however, many sablefish and Greenland turbot fishermen in the BSAI have switched to using pots to protect their catches from whale depredation. It is now believed that over half the EBS catch of sablefish is taken in pots (Hanselman et al. 2007), and it is uncertain what effect this change may have on grenadier catches. Pot fishing for sablefish is currently not allowed in Federal waters of the GOA.

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[8]. 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[9]. 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. 1999a and 1999b), and it is likely that Alaskan fishermen will continue their efforts at utilizing this species.

1.3 DATA

1.3.1 <u>Fishery Data</u>

1.3.1.1 <u>Catch</u>

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

1.3.1.2 <u>Size and Age Composition in the Fishery</u>

Beginning in 2007, length and sex data for giant grenadier in the commercial fishery were collected by at-sea observers. The sampling scheme was to collect these data for a random sample of about five giant grenadier per haul for those hauls in which sablefish was the predominant commercial species (i.e., hauls where a large bycatch of giant grenadier would be likely). Almost all the fish sampled were caught on either longlines or in pots. Results for 2007 showed that giant grenadier in the BSAI were considerably larger than those in the GOA (Figure 1-1), which agrees with results of fishery-independent surveys of the

[8] J. Ferdinand, National Marine Fisheries Service, Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115-0070. Pers. comm. Sept. 2004.
[9] T. Pearson, Kodiak Fisheries Research Center, National Marine Fisheries Service, Sustainable Fisheries, 302 Trident Way, Room 212, Kodiak AK 99615. Pers. comm. Oct. 2005.

two regions (see Clausen 2008). The length distributions in the BSAI, where giant grenadier are caught by both longline and pot gear, indicate that size of the fish is somewhat larger in longline-caught fish. This result is similar to that reported in analyses of longline versus trawl surveys, in which longlines were found to selectively catch larger-sized giant grenadier (Clausen 2008).

In each of the three observer datasets in 2007 (BSAI longline, BSAI pot, and GOA longline), female giant grenadier comprised approximately 80% of the fish sampled. This number is much lower than we expected based on sex compositions found in surveys. In particular, females have comprised >95% of the giant grenadier sampled in longline surveys at depths less than 800 m, where nearly all the commercial fishing effort in Alaska is believed to occur (see Table 1-8). Further analysis is needed to explain this discrepancy, especially to determine if bias is occurring in the observer sampling.

Age samples of giant grenadier have not been collected in the commercial fishery.

1.3.2 Survey Data

1.3.2.1 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 1-3. 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 1-3.

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, 2004, and 2008. Given the apparent longevity and slow growth of giant grenadier (see section 1.3.2.3), 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 three EBS slope surveys since 2002 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 encompassed more of the depth range of grenadiers, and they had good geographical coverage in all areas[10]. Also, in comparison to the steep and rocky slopes of the GOA and especially the AI, 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, 2004, and 2008 may be the most valid of any of the surveys in Table 1-3.

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

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

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 three most recent trawl surveys in the EBS and GOA can be examined to determine the comparative biomass of the three grenadier species (Table 1-4; Figures 1-2 and 1-3). In the GOA in 1999, 2005, and 2007, giant grenadier was by far the most abundant species and comprised 94%, 96%, and 96%, respectively, of the aggregate grenadier biomass. Next in abundance was popeye grenadier, followed by Pacific grenadier. In the EBS slope surveys in 2002, 2004, and 2008, giant grenadier also greatly predominated, with 89%, 93%, and 89% 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 the 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 be used to examine the variability of the biomass estimates for giant grenadier (Table 1-5). 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, and also that giant grenadier have a rather even distribution within the strata in which they are caught.

The recent trawl surveys provide information on the depth distribution of grenadiers in the EBS and GOA in terms of biomass and catch-per-unit-effort (CPUE; Figures 1-2, 1-3, 1-4, and 1-5). 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, whereas the 2008 survey showed a pronounced peak in biomass in the 600-800 m stratum. Each EBS survey showed a decline in giant grenadier biomass at the deepest stratum, 1,000-1,200 m depth stratum. Highest giant grenadier CPUE in the EBS surveys was consistently at 600-1,000 m. The GOA surveys were generally similar and indicated biomass and CPUE of giant grenadier was relatively high at depths 300-1,000 m, with a prominent 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 fish are considerably larger in the EBS (Figure 1-6). For example, in the 2004 EBS survey, mean PAFL was 28.1 cm, compared to 25.9 cm in the 2005 GOA survey. This difference in size is even greater than 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 1.4.2 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 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 had the highest overall CPUE. Likewise, the EBS slope surveys in 2002 and 2004 both ranked giant grenadier first in biomass among all species caught (Hoff and Britt 2003, 2005).

1.3.2.2 Longline Surveys

Longline surveys of the continental slope off Alaska have been conducted annually since 1979 (Hanselman et al. 2007). 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. It should be noted that although RPW is an index of biomass (weight), it is actually a unit-less value. Although the survey time series extends back to 1979, RPWs for giant grenadier are only available for the years since 1990[11]. Other measures of giant grenadier abundance in the surveys have been computed for the years 1979-1989, including CPUE 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 1990-2008 and an intermittent series in the AI and EBS (Table 1-6). 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 its all-time high of 1,420,000 in 1997, and diminished again to a low of 900,000 in 2004. In 2007, the RPW rose sharply to 1,404,000, followed by a large decline to 1,046,000 in 2008. 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 1-6 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 1-7). Highest catch rates are consistently seen in the eastern AI, Shumagin and Chirikof areas, and EBS areas 3 and 4, which are located NW of the Pribilof Islands. In the GOA, there is 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[12]). One anomaly in Table 1-7 is the extremely low catch rate in EBS area 4 in 2007 (1.1 fish/100 hooks). This meager catch rate was presumably a major factor contributing to the low RPW for the EBS in 2007.

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 1-7, 1-8, and 1-9). This difference in size between the EBS and the GOA agrees with that found in the recent trawl surveys of these two regions, which were discussed previously in this report. It also agrees with the

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[11] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm. July 2004.

[12] 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.

length data recently collected by observers in the commercial fishery. 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 1-8). Mean length in the GOA since 2000 has been consistently smaller than in the 1990s. Mean length in the eastern AI has also been smaller since 2004 compared to previous years. Further analysis is needed to better understand the reasons for this decrease in size.

A comparison between Figure 1-6 (size compositions for the GOA and EBS trawl surveys) and Figures 1-7 and 1-8 (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 has only been collected since 2006 (Table 1-8). Results show that females are the overwhelming majority of the catch, comprising 96-97% of the fish sampled in the GOA, 94-97% in the eastern AI, and 99% in the EBS. Females especially predominated in depths <800 m. Because most of the effort in the sablefish longline fishery in Alaska is believed to be in depths <800 m, this strongly suggests that nearly all 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 7-10% of the catch in the GOA, 7-25% in the eastern AI, and 7% in the EBS. 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 RPW for giant grenadier in the GOA has been remarkably consistent for all the years of the longline survey that have been examined (Clausen 2008). RPW is relatively high and nearly equal in value for each of the three deepest strata sampled in these surveys: 401-600 m, 601-800 m, and 801-1,000 m (Figure 1-10). 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. In comparison with the longline survey depth distributions of giant grenadier in the GOA, the trawl survey depth distributions in the GOA (Figure 1-2) are much less consistent. However, the trawl survey generally agrees with the longline survey that a relatively large biomass giant grenadier in the GOA extends to at least 1,000 m, and probably beyond.

Compared with the GOA, depth distribution of giant grenadier RPW in the eastern AI was generally similar, but was somewhat different in the EBS (Figure 1-10). The RPW in the AI, as in the GOA, was concentrated in the 401-600, 601-800, and 801-1,000 m depth strata, with relatively equal amounts in each stratum. In the EBS, most of the biomass was in the 601-800 and 801-1,000 m strata, with a lesser amount in the 401-600 m stratum. Similar to the GOA, the AI and EBS results show a high RPW at 801-1,000 m, which also implies the possibility that a considerable biomass may inhabit depths >1,000 in these latter two regions.

A possible factor that may have influenced the survey's catch rates for giant grenadier is competition amongst species for baited hooks. Rodgveller et al. (2008) demonstrated that there is a negative relationship between giant grenadier and sablefish catch rates on the longline survey at the depths where grenadier are caught; i.e., when sablefish catches were high, giant grenadier catches were low, and vice-versa. This relationship was also explored in the GOA trawl survey, but a negative relationship was not found, indicating that the negative correlations on the longline survey could be due to competition for 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 may not be proportional to actual trends in abundance. If competition is occurring between sablefish and giant grenadier, the lower abundance of sablefish in the AI and EBS could contribute to the higher catch rates of giant grenadier in these areas. 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 analyses and possibly experimental studies are needed to examine the catch probabilities of giant grenadier.

1.3.2.3 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 published 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 because there were very few small fish in the samples. 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.

Since the last SAFE report for grenadiers in Alaska (Clausen 2006), age readers at the AFSC REFM Division Age and Growth Program for the first time attempted to age giant grenadier, and results of this aging have recently become available[13]. The age samples (otoliths) were collected during the 2004 and 2006 NMFS longline surveys in the GOA for a female age-at-maturity study. A total of 338 fish were aged (all female), and ages ranged from 14 to 58 years. The maximum age of 58 is very close to the maximum age of 56 that was reported in Burton's 1999 study. This agreement lends credence to the results of both studies. The REFM aging staff found that an innovative aging procedure that involved two different methods seemed to yield the best results. Each otolith was first aged with the "ground distal surface" method, and if aging was still judged to be unsatisfactory, the otolith was then aged by a second method, "transverse thin-sectioning". Using these two techniques, the age-determination process appeared to be somewhat easier and perhaps more reliable than in Burton's study. However, even using REFM's new methods, age determination for giant grenadier is still difficult compared to many other groundfish species, and validation of the new aging methodology is needed. An initial attempt in 2008 to use carbon 14 to confirm some of the ages determined by REFM staff proved unsuccessful[14], and other means of validation will be necessary.

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

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[13] Rodgveller, C. J., D. M. Clausen, J. Nagler, and C. Hutchinson. Maturity, fecundity, growth, and natural mortality of giant grenadier (*Albatrossia pectoralis*) in the Gulf of Alaska. Unpubl. manuscr., June 2008. Avail. from Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801
[14] C. Hutchinson, National Marine Fisheries Service, Alaska Fisheries Science Center, REFM Division, 7600 Sand Point Way NE, Seattle WA 98115. Pers. comm. Sept. 2008.

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 quite 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).

1.4 ASSESSMENT PARAMETERS

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

The most recent and reliable aging studies for giant grenadiers (Burton 1999 and Rodgveller et al.[15]) found the maximum age to be 56 and 58 years, respectively, based on specimens 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 Hoenig's simplified maximum age method (1983) to estimate natural mortality (M) for these two 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 Burton's maximum age of 56 years for giant grenadier and and Andrews' maximum age of 73 years for Pacific grenadier, Hoenig's method estimates the following natural mortality rates:
Giant grenadier: 0.074
Pacific grenadier: 0.057
These were the estimates presented and used in the previous (Nov. 2006) SAFE report for grenadiers in Alaska.

The recent age determinations for giant grenadier by the AFSC REFM Division Age and Growth Program present new opportunities for estimating M. This is true because, unlike Burton's aging study, von Bertalanffy growth parameters were successfully calculated based on the REFM age results (see the next section, 1.4.2 "Length at Age, and Length-Weight Relationships"). The following table summarizes the various methods that were used to compute *M* based on the new dataset of female giant grenadier ages[16]:

[15] Rodgveller, C. J., D. M. Clausen, J. Nagler, and C. Hutchinson. Maturity, fecundity, growth, and natural mortality of giant grenadier (*Albatrossia pectoralis*) in the Gulf of Alaska. Unpubl. manuscr., June 2008. Avail. from Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801
[16] Ibid.

Method	Calculation	*M*
Hoenig Simplified Max Age (1983)	$\hat{M} = -\ln(P)/58$	
	$P = 0.01$	0.079
	$P = 0.02$	0.067
	$P = 0.03$	0.060
	$P = 0.04$	0.055
	$P = 0.05$	0.052
Hoenig (1983) longevity	$\ln(\hat{M}) = 1.44 - 0.982 \times \ln(58)$	0.078
Pauly (1980)	$\log \hat{M}$ = -0.654 x log 0.02 - 0.28 x log 52 + 0.463 x log 4	0.050
Alverson and Carney (1975)	$\hat{M} = \dfrac{3 \times 0.0217}{e^{0.38 \times 58 \times 0.0217} - 1}$	0.106

There are drawbacks to each of these methods or to the accuracy of the data that they use. Hoenig's (1983) and Alverson and Carney's (1975) approaches depend on accurate estimates of maximum age. The maximum age we report (58 years; see above) is likely not the true maximum age. Giant grenadier greater than 60 cm PAFL have been caught on the AFSC longline survey, whereas the greatest length in the age samples was 53 cm. Therefore, it is probable that fish older than 58 exist. An older maximum age would result in a decrease in *M*. When choosing between the two Hoenig methods shown above, Hewitt and Hoenig (2005) suggest using the longevity regression equation instead of the simplified maximum age approach because the regression is fit to extensive data sets, whereas the simplified maximum age is based on an arbitrary constant. When considering the Alverson and Carney (1975) and Pauly (1980) methods, it is also important to consider that Rodgveller et al.[17] found some variability in the von Bertalanffy parameters based on the year of sampling and other factors. In the calculations for *M* in the above table, the von Bertalanffy parameters that were used were from all 338 age samples pooled together. Taking into account all these considerations, we suggest using the Hoenig (1983) longevity equation because (1) it is preferable to the Hoenig simplified maximum age method, (2) the maximum age in the Burton (1999) and Rodgveller et al. studies were very similar, and (3) the variability in growth parameters cause too much uncertainty in the estimates generated from the Pauly (1980) and the Alverson and Carney (1975) methods. Thus, our current best estimate of natural mortality for giant grenadier, based on the Hoenig longevity regression equation, is 0.078. Because fish older than 58 years may exist, we suggest revisiting the determination of *M* for giant grenadier as more age samples become available in the future.

The only published information on sexual maturity of giant grenadier comes from Novikov (1970) who briefly 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. As an alternative to Novikov, a detailed study of age- and size-at-50%-maturity of female giant grenadier was recently completed based on samples from the NMFS longline survey in the GOA[18]. This study involved both macroscopic observations of fresh ovaries at sea, and microscopic/histological observations of preserved ovarian tissue samples in the laboratory. The microscopic method, which is

[17] Rodgveller, C. J., D. M. Clausen, J. Nagler, and C. Hutchinson. Maturity, fecundity, growth, and natural mortality of giant grenadier (*Albatrossia pectoralis*) in the Gulf of Alaska. Unpubl. manuscr., June 2008. Avail. from Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801

[18] Ibid.

considered the most reliable, indicated age-at-50%-maturity was 22.9 years, and size-at-50%-maturity was 26 cm PAFL. Therefore, female giant grenadier mature at a much older age than most other groundfish.

Length frequency distributions for giant grenadier in the commercial fishery (Figure 1-1) and size composition data for the longline surveys (Figures 1-7, 1-8, and 1-9) show that only fish >20 cm PAFL are taken by longlines and pots, and relatively few fish <25 cm PAFL are caught. This suggests that the size at 50% recruitment may be around 25 cm PAFL. If we assume the female size-at-50%-maturity is 26 cm PAFL (see preceding paragraph), it appears that immature fish comprise only a small percentage of the giant grenadier catch.

Previously, there was no information on fecundity of giant grenadier. However, as part of the recently completed maturity study of giant grenadier in the GOA, fecundity was also examined[19]. Only ovaries with advanced stage oocytes, based on both macroscopic observations and histology, were included in the analysis. Total fecundity ranged from 35,000-231,000 oocytes, with a mean of 107,000.

1.4.2 Length-at-Age, and Length-Weight Relationships

For the first time, length-at-age information is now available for female giant grenadier based on the AFSC REFM Division's recently completed aging of 338 individuals from the GOA longline survey. Unlike Burton's (1999) previous aging study of giant grenadier, enough small fish were included in the REFM age sample to allow the determination of a von Bertalanffy growth curve. The von Bertalanffy parameters are as follows[20] (L_{inf} is in cm):

	female
L_{inf}	54.9
K	0.022
t_0	-7.54

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

[19] Rodgveller, C. J., D. M. Clausen, J. Nagler, and C. Hutchinson. Maturity, fecundity, growth, and natural mortality of giant grenadier (*Albatrossia pectoralis*) in the Gulf of Alaska. Unpubl. manuscr., June 2008. Avail. from Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801.

[20] Ibid.

The following length-weight relationships have been computed for giant grenadier in the GOA based on data collected in the 1999 trawl survey[21]:
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

1.5 ANALYTIC APPROACH FOR DETERMINING OFL AND ABC

In the previous stock assessment for grenadiers (Clausen 2006), the NPFMC's tier 5 approach for determining the OFL and ABC was recommended, and this approach was supported by both the GOA Groundfish Plan Team and the NPFMC's Scientific and Statistical Committee. We again recommend using the tier 5 approach in the present assessment. Tier 5 assumes that a species has reliable estimates of biomass and natural mortality. Credible biomass estimates for giant grenadier are available from recent bottom trawl surveys in two major regions of Alaska, the GOA and the EBS. Compared to the 2006 assessment, we now have improved estimates of M for giant grenadier (see section 1.4.1 "Maximum Age, Natural Mortality, Female Age- and Size-at-50%-Maturity, Age and Size of Recruitment, and Fecundity"), so there is presently even stronger justification for using tier 5. In future assessments, it may be possible to move giant grenadier into tier 4 because data on female age-at-maturity is now available, as well as more reliable age compositions.

1.5.1 Discussion of Special Overfishing Concerns for Giant Grenadier

Before computing possible OFL and ABC values for grenadiers, a discussion is warranted regarding some unique concerns that may put giant grenadier at greater risk of overharvest than is the case for most other groundfish. These concerns may need to be taken into account when recommending OFL and ABC values.

Although currently there is no directed fishing for giant grenadier in Alaska, the estimated catch of these fish taken as bycatch in other fisheries (Table 1-1) may be large enough to raise concerns from a conservation standpoint, for at least three reasons:

a) All the giant grenadier caught are discarded, and none of these survive because the fish cannot withstand the pressure change caused by retrieval to the surface.

b) Because the sablefish and Greenland turbot fisheries are responsible for most of the giant grenadier catch, and they operate at depths where female giant grenadier greatly outnumber males, the majority of the giant grenadier catch is female. Disproportionate removal of females by the fishery clearly reduces the spawning potential of the stocks and could put them at greater risk of overfishing if catches were sufficiently large.

c) There have been several recent studies that indicate deep-sea fish such as grenadiers appear to be especially susceptible to overfishing, which suggests fishery managers need to exercise particular caution when setting catch levels for these fish. One study in the NW Atlantic Ocean 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

[21] 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 in the NMFS Alaska Fisheries Science Center"s "Racebase" trawl survey database, and the recalculated values are listed here.

"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, low metabolic rates, and not spawning in some years (Merrett and Haedrich 1997; Koslow et al. 2000; Drazen 2008). All these characteristics imply that the replenishment rate for these fish could be less than recruitment if they are subject to fishing pressure.

1.5.2 Tier 5 Computations of OFL and ABC

The NPFMC's tier 5 definitions for OFL and ABC are: OFL = M x B, where M is the estimated natural mortality rate, and B is the estimated biomass; and ABC is $\leq$(0.75 x OFL). Therefore, to apply tier 5, values of M and B must be determined.

Similar to the previous grenadier assessment, we have chosen to only include giant grenadier in the tier 5 calculations of OFL and ABC. Thus, for tier 5, giant grenadier is serving as a proxy for the entire grenadier group. The reasons for excluding Pacific and popeye grenadier are twofold: (1) at present, nearly all the grenadier catch in Alaska is comprised of giant grenadier, as Pacific and popeye grenadier are largely distributed in waters >800 m depth where very little commercial fishing takes place; 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 unreliable and are likely much less than their true values.

There have been various biomass estimates for giant grenadier in each of the three major management regions for groundfish in Alaska (Table 1-3), and a decision must be made as to which of these estimates are most appropriate for the OFL and ABC computations. For the EBS and GOA in the 2006 assessment, the mean biomasses of the two recent trawl surveys in each region at that time (2002 and 2004 in the EBS, and 1999 and 2005 in the GOA) were chosen as the best estimates available for the computations of OFL and ABC. We have elected to follow an identical procedure in the present assessment, but also include results of the two additional trawl surveys that have been conducted since the last assessment, the 2007 GOA survey and the 2008 EBS survey. Therefore, the new mean values of biomass for the EBS are based on the 2002, 2004, and 2008 surveys, and for the GOA, the 1999, 2005, and 2007 surveys. These mean values are: EBS, 518,778 mt; and GOA, 488,414 mt.

The Aleutian Islands present a special problem because no trawl surveys since 1986 have sampled deeper waters where most giant grenadier biomass is found. In the previous grenadier assessment (Clausen 2006), an indirect method was used to determine a more up-to-date biomass in this region. We recommend using this indirect method again in the present assessment. The method is based on using a combination of longline survey RPW values and trawl survey biomass estimates to compute biomass estimates for the AI. Since 1996 and 1997 when the longline survey first sampled the AI and the EBS, mean RPW values for each region (1,564,337 and 625,398, respectively; Table 1-6) 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 as an adjustment factor to the mean EBS trawl survey biomass in 2002, 2004, and 2008 of 518,778 mt, an indirect biomass estimate of 1,297,643 mt can be computed for the AI. Similarly, an alternative indirect biomass can be computed for the AI which is based on survey data from the AI and GOA, rather than from the AI and EBS. Using a procedure identical to that above, the mean longline RPW for giant grenadier in the years 1996-2008 is 1,564,337 in the AI and 1,156,120 in the GOA, which equals a ratio of 1.35. Using this ratio as an adjustment factor for the trawl survey's mean GOA biomass for 1999, 2005, and 2007 of 488,414 mt yields an indirect biomass estimate of 660,869 mt for the AI.

The two indirect biomass estimates for the AI differ greatly in value (1.3 million mt vs. 0.7 million mt), and selecting which to use in the determinations of OFL and ABC has a substantial effect on the results. Clearly, the difference is large enough that it indicates uncertainty concerning these estimates. In the 2006 assessment, the higher biomass estimate (based on the data from the AI and EBS surveys) was recommended and used in the final OFL and ABC computations because the EBS and AI longline survey data were thought to be more comparable than those of the GOA and the AI (Clausen 2006). However, in the present assessment, we believe the decision to use the higher biomass for the AI should be reconsidered. The 1.3 million mt biomass is a very large amount. Although no recent AI trawl surveys have sampled deeper waters to 1,000 m, trawl surveys there in 2000, 2002, 2004, and 2006 did cover depths to 500 m. Biomass estimates for giant grenadier in these surveys were 219,693, 218,147, 248,159, and 192,640 mt, respectively[22]. If we assume these estimates are reasonably accurate, abundance of the fish in depths 500-1,000 m would have to be proportionately very large to result in a total biomass of 1.3 million mt. This suggests that the 1.3 million mt amount may perhaps be overestimated. Furthermore, the concerns that giant grenadier may be particularly susceptible to overharvest (discussed previously) support the case for erring on the side of caution when we decide how to determine biomass for AI. Taking these factors into account, we suggest an alternative method for estimating biomass in AI. This new approach is based upon averaging the two indirect biomass estimates for the AI that have been presented above (1,297,643 and 660,869 mt), which yields an alternative biomass of 979,256 mt. We recommend using this biomass for AI in the determination of OFL and ABC for giant grenadiers in this assessment.

In addition to biomass, the NPFMC's other required parameter for tier 5 computations of OFL and ABC is an estimate of the natural mortality rate. In the 2006 grenadier assessment, two estimates of M were presented, both of which were computed based on the Hoenig (1983) simplified maximum age method. The first estimate, 0.074, used the maximum age of 56 years from Burton's (1999) giant grenadier aging study, whereas the second estimate, 0.057, used the maximum age of 73 years from Andrew's et al. (1999) aging study of Pacific grenadier as a proxy estimate for giant grenadier. The reason for computing a proxy estimate was due to the uncertainty of Burton's results, which found giant grenadier very difficult to age and did not yield a reasonable fit of von Bertalanffy parameters to the age data. In contrast, the Pacific grenadier age study did result in successful von Bertalanffy growth equations. Also, because of the possible susceptibility of grenadiers to overharvest, the proxy M would be more risk-averse in case the true maximum age of giant grenadier was older than 56 years. The final recommendation in the 2006 assessment was to use the lower-value, proxy M of 0.057 in the OFL and ABC computations for giant grenadier in order to be conservative and reduce the possibility of overfishing.

However, in the present assessment, new age-determination results and estimates of natural mortality are available for giant grenadier. As discussed previously (section 1.4.1), the new age results show a maximum age of 58 years for giant grenadier, which agrees closely with Burton's maximum age of 56 years. There is also increased confidence in the new age results because a von Bertalanffy growth curve could be fit to the data. Based on the new age results, several new estimates of giant grenadier natural mortality are possible (section 1.4.1), and the one we recommend as the best, 0.078, is very similar to the 0.074 value that was calculated previously from Burton's data. Because of the new age results and mortality estimates for giant grenadier, it no longer appears justifiable to use a proxy mortality estimate, from a completely different species in a different region (Pacific grenadier off the U.S. West Coast), for

[22] Based on data in NMFS Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2005 and Nov. 2008. Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle WA 98115.

giant grenadier. Therefore, for this assessment we recommend a natural mortality rate of 0.078 be used in the computations of giant grenadier OFL and ABC.

Based on our discussion above and our current recommendations for biomass and natural mortality of giant grenadier, tier 5 reommendations for OFL and ABC of grenadiers are listed below. For comparison, mean estimated catch of grenadiers for the years 1997-2008 is also shown (biomass, OFL, ABC, and mean catch are in mt).

Tier 5 Recommended OFL and ABC Values for Grenadiers in Alaska

Area	Biomass	Natural mortality *M*	OFL definition	OFL	ABC definition	ABC	Mean catch
EBS	518,778	0.078	biom x *M*	40,465	OFL x 0.75	30,349	2,901
AI	979,256	0.078	biom x *M*	76,382	OFL x 0.75	57,286	2,244
GOA	488,414	0.078	biom x *M*	38,096	OFL x 0.75	28,572	10,789
Total	1,986,448			154,943		116,207	15,934

Compared to the 2006 OFL and ABC recommendations, the OFLs and ABCs for the EBS and GOA have increased by 30% and 37%, respectively, due to the change in recommended natural mortality for giant grenadier. However, the OFLs and ABCs for the AI have decreased by 2% because the new method to estimate biomass for this region negates any increase that would have occurred as a result of the change in natural mortality. The recommended OFLs and ABCs in the above table are much larger than the mean catch, which indicates catches could increase without endangering the stocks. This is especially true for the EBS and AI, where the exploitation rate appears to be quite low. Therefore, even taking into account the special concerns for giant grenadier in Alaska that could make them particularly vulnerable to overfishing, the recommended OFLs and ABCs appear to be sufficiently conservative to protect the stocks.

1.6 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 2009 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	518,778	0.078	30,349	0.078	30,349	0.039	15,174	0.0045	2,319
Aleutian Islands	979,256	0.078	57,286	0.078	57,286	0.039	28,643	0.0021	2,021
Gulf of Alaska	488,414	0.078	28,572	0.078	28,572	0.039	14,286	0.0200	9,182
Total	1,986,448	0.078	116,207	0.078	116,207	0.039	58,104	0.0071	14,132

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 2003-2007 (i.e., the most recent five years with complete catch data).

1.7 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.

1.7.1 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 off-bottom on bathy- and mesopelagic food items that included gonatid squids, viperfish, deep-sea smelts, and myctophids (Drazen et al. 2001). Smaller studies of giant grenadier food habits in Alaska showed generally similar results. In the Aleutian Islands, the diet comprised mostly squid and myctophids (Yang 2003), whereas in the Gulf of Alaska, squid and pasiphaeid shrimp predominated as prey (Yang et al. 2006). 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 predators of giant grenadier are Pacific sleeper sharks (Orlov and Moiseev 1999) and Baird's beaked whales (Walker et al. 2002). According to Orlov's and Moiseev's 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[23]. 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. This habitat is likely more stable oceanographically than shallower waters of the upper slope or continental shelf. 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. However, no larvae or post-larvae for this species have ever been collected in Alaska. The absence of larvae or post-larvae giant grenadier in larval surveys in Alaska, which have nearly all been conducted in upper parts of the water column, implies that larval giant grenadier reside in deeper water, where they may be less affected by regime shifts.

[23] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm. Oct 2006.

1.7.2 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 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.

1.7.3 Data Gaps and Research Priorities

Many aspects of basic information are lacking for grenadiers in Alaska. Among the highest priorities of research are: 1) further analysis and study of the NMFS longline survey in Alaska to better determine the effects of competition for hooks among species on catch rates of giant grenadier; 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; 3) validation of the new AFSC REFM Division aging methodology for giant grenadier; and 4) analysis of the observer data for giant grenadier to determine why the sex composition is different than in the NMFS longline survey. Other areas of research on giant grenadier that would be beneficial include genetic studies to determine if subpopulations exist, and because early life history information is nil, studies to investigate where larvae and young juveniles reside. 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 off-bottom.

1.8 OTHER CONSIDERATIONS

1.8.1 Need for Including Grenadiers in the Fishery Mangement Plans as Part of the "Other Species" Category

As mentioned in the Introduction of this document, grenadiers are presently classified as "nonspecified" by the NPFMC. However, one alternative in a proposed joint GOA/BSAI amendment to the FMPs would move grenadiers from "unspecified" to the "other species" category, in which case they would then be included in the groundfish FMPs. We strongly recommend this change be implemented for grenadiers. The "other species" category was formally defined in Amendment 8 to the GOA FMP (which took effect in November 1980) as follows: species that have "*only slight economic value and are generally not targeted upon, but which are either significant components of the ecosystem or have economic potential*" (North Pacific Fishery Management Council 2008). In contrast, "nonspecified" species were defined in the amendment as: a "*residual category of species and species groups of no current or foreseeable economic value or ecological importance, which are taken in the groundfish fishery as accidental bycatch and are in no apparent danger of depletion*". Subsequent definitions of these two groups in the BSAI and GOA were similar, but added this to the definition for nonspecified: "*virtually no data exist which would allow population assessments*" (Witherell 1997; DiCosimo 2001). Based on these definitions, grenadiers clearly belong in the "other species" group. Because of their abundance on the slope, they are of great ecological importance in this habitat, and they also hold economic potential. In addition, there now exists considerable information on giant grenadier that can be used for population assessment.

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Table 1-1.--Estimated catch (mt) of grenadiers (all species combined) in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, 1997-2008.

	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	12,323	18,732
2004	2,225	1,123	11,966	15,313
2005	2,581	1,676	7,192	11,449
2006	2,068	2,222	8,293	12,583
2007	1,870	1,530	9,182	12,582
2008	2,479	1,955	10,639	15,073
mean	2,901	2,244	10,789	15,934

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; 2003-2008, NMFS Alaska Region, Sustainable Fisheries Division, P.O. 21668, Juneau, AK 99802. Catch Accounting System data query, Oct. 3, 2008.

Table 1-2.--Estimated catch (mt) of grenadiers (all species combined) in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska, by target species/species group, 2003-2008. G. turbot = Greenland turbot; halibut = Pacific halibut; other flat = flatfish species other than Greenland turbot or Pacific halibut; P. cod = Pacific cod; and other sp. = other species.

	Target species/species group						
Year	Sablefish	G. turbot	Halibut	Other flat	P. cod	Rockfish	Other sp.
			Eastern Bering Sea				
2003	600	1,452	354	152	235	9	50
2004	287	1,315	255	77	241	20	30
2005	113	1,982	75	48	338	9	16
2006	419	1,190	179	125	128	12	14
2007	198	1,336	72	8	179	12	65
2008	72	694	1,333	77	94	3	206
			Aleutian Islands				
2003	2,014	113	1,376	0	46	6	0
2004	749	14	285	0	14	38	24
2005	1,009	161	468	0	0	21	16
2006	1,094	345	229	350	124	81	0
2007	889	343	53	108	40	21	76
2008	592	67	890	324	23	55	3
			Gulf of Alaska				
2003	9,492	0	871	1,281	5	620	54
2004	8,542	0	164	417	0	2,836	8
2005	6,360	0	452	96	0	230	54
2006	7,263	0	519	88	22	343	59
2007	8,338	0	449	93	81	197	24
2008	8,186	0	1,870	88	104	158	233

Source: NMFS Alaska Region, Sustainable Fisheries Division, P.O. 21668, Juneau, AK 99802. Catch Accounting System data query, Oct. 3, 2008.

Table 1-3.--Estimated biomass (mt) of giant grenadier in NMFS trawl surveys in Alaska that sampled the upper continental slope to depths of at least 800 m.

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
2006	-	-	-
2007	-	-	487,987
2008	463,429	-	

[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, 2004, and 2008. Data sources: 1979 to 1988, Bakkala et al. (1992); 1991, Goddard and Zimmermann (1993); 2002, Hoff and Britt (2003); 2004, Hoff and Britt (2005); 2008, data on the Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2008, available from the National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115.

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, 2005, and 2007, data on the Alaska Fisheries Science Center's "Racebase" trawl survey database, Oct. 2008, available from the National Marine Fisheries Service, Alaska Fisheries Science Center, RACE Division, 7600 Sand Point Way NE, Seattle, WA 98115.

Table 1-4.--Comparative biomass estimates (mt) for the three common grenadier species in recent NMFS trawl surveys in Alaska that sampled the upper continental slope. Biomass estimates for the Gulf of Alaska include depths to 1,000 m; estimates for the eastern Bering Sea include depths to 1,200 m.

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
Gulf of Alaska	2007	487,987	3,046	15,593
Eastern Bering Sea	2002	426,397	2,461	50,329
Eastern Bering Sea	2004	666,508	4,039	44,361
Eastern Bering Sea	2008	463,429	4,221	50,665

Table 1-5.--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. The Gulf of Alaska surveys included depths to 1,000 m, whereas the eastern Bering Sea slope surveys included depths to 1,200 m.

			95% Conf. 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
Gulf of Alaska	2007	487,987	346,802	629,173	4,332,366,537	10.6
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
Eastern Bering Sea	2008	463,429	364,918	561,939	2,426,081,697	10.6

Table 1-6.--Giant grenadier relative population weight, by region, in NMFS longline surveys in Alaska, 1990-2008. 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 at depths 201-1,000 m and do not include continental shelf gullies sampled in the surveys. Note: relative population weight, although an index of biomass (weight), is a unit-less value.

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
2007	484,294	-	1,404,684
2008	-	1,162,392	1,045,541
mean	625,398	1,564,337	1,134,126

Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm., Oct. 2008.

Table 1-7.--Giant grenadier catch rates (number caught per 100 hooks), by area, in NMFS longline surveys in Alaska, 1990-2008. Dashes indicate years that the eastern Bering Sea or Aleutian Islands were not sampled by the survey.

Year	EBS 4	EBS 3	EBS 2	EBS 1	NE AI	SE AI	Shum	Chir	Kod	W Yak	E Yak	SE
1990	-	-	-	-	-	-	22.1	22.1	10.4	5.8	2.4	1.4
1991	-	-	-	-	-	-	21.8	17.8	8.4	4.3	3.2	1.4
1992	-	-	-	-	-	-	19.4	19.3	6.5	3.6	2.3	1.8
1993	-	-	-	-	-	-	24.2	21.8	7.6	5.9	3.3	1.6
1994	-	-	-	-	-	-	25.5	20.4	10.9	3.9	2.0	1.7
1995	-	-	-	-	-	-	30.1	28.4	13.8	6.0	4.0	2.8
1996	-	-	-	-	12.8	22.8	21.5	27.4	16.1	4.5	4.1	2.4
1997	26.1	27.0	10.7	1.9	-	-	27.9	28.3	16.9	9.8	3.2	2.6
1998	-	-	-	-	10.2	25.3	31.6	17.1	11.7	7.7	4.1	3.6
1999	22.3	23.0	7.7	0.2	-	-	24.4	22.2	17.5	8.8	3.9	5.5
2000	-	-	-	-	17.8	28.2	24.7	21.0	13.4	9.1	3.3	4.3
2001	8.0	14.5	7.0	1.6	-	-	26.5	24.4	13.1	8.7	3.6	5.2
2002	-	-	-	-	21.0	27.9	28.3	15.4	11.6	3.4	4.6	4.8
2003	13.3	26.5	7.2	1.3	-	-	26.6	26.6	15.4	7.6	5.1	3.2
2004	-	-	-	-	25.3	24.6	27.6	16.7	8.2	4.9	3.8	2.6
2005	25.9	28.4	10.2	1.6	-	-	25.4	19.7	14.5	8.3	4.0	3.2
2006	-	-	-	-	34.4	24.8	31.6	17.4	9.2	5.9	3.6	3.8
2007	1.1	30.4	7.5	1.7	-	-	34.7	26.6	20.1	13.2	6.0	4.6
2008	-	-	-	-	17.9	22.5	28.7	20.9	13.4	10.7	3.9	3.9
mean	16.1	25.0	8.4	1.4	19.9	25.2	26.5	21.8	12.6	6.9	3.7	3.2

Areas:
EBS 4 = eastern Bering Sea survey area 4
EBS 3 = eastern Bering Sea survey area 3
EBS 2 = eastern Bering Sea survey area 2
EBS 1 = eastern Bering Sea survey area 1
NE AI = Northeast Aleutian Islands
SE AI = Southeast Aleutian Islands
Shum = Shumagin
Chir = Chirikof
Kod = Kodiak
W Yak = West Yakutat
E Yak = East Yakutat
SE = Southeastern

Note: Data not available for the NW and SW Aleutians.

Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm., Oct. 2008.

Table 1-8.--Sex distribution, by depth stratum, of giant grenadier sampled in the 2006, 2007, and 2008 NMFS longline surveys in Alaska. Dashes indicate that a stratum was not sampled.

Depth stratum (m)	No. fish sampled	Percent male	Percent female	No. fish sampled	Percent male	Percent female
			2006 Survey			
	Eastern Aleutian Islands			Gulf of Alaska		
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
			2007 Survey			
	Eastern Bering Sea			Gulf of Alaska		
201-300	220	0.0	100.0	79	0.0	100.0
301-400	415	0.0	100.0	1,013	0.9	99.1
401-600	605	0.3	99.7	2,251	2.0	98.0
601-800	774	1.0	99.0	1,977	5.2	94.8
801-1000	322	6.8	93.2	923	9.9	90.1
All depths	2,336	1.4	98.6	6,243	4.0	96.0
			2008 Survey			
	Eastern Aleutian Islands			Gulf of Alaska		
201-300	57	0.0	100.0	280	1.4	98.6
301-400	263	0.4	99.6	1,242	1.1	98.9
401-600	797	2.1	97.9	2,547	2.8	97.2
601-800	692	3.9	96.1	2,138	3.9	96.1
801-1000	211	7.1	92.9	1,120	7.2	92.8
1,001-1,200	-	-	-	79	29.1	70.9
All depths	2,020	3.0	97.0	7,406	3.7	96.3

Source: C. Lunsford, NMFS Alaska Fisheries Science Center, Auke Bay Laboratories, 17109 Point Lena Loop Rd., Juneau, AK 99801. Pers. comm., Oct. 2006 and Oct. 2008.

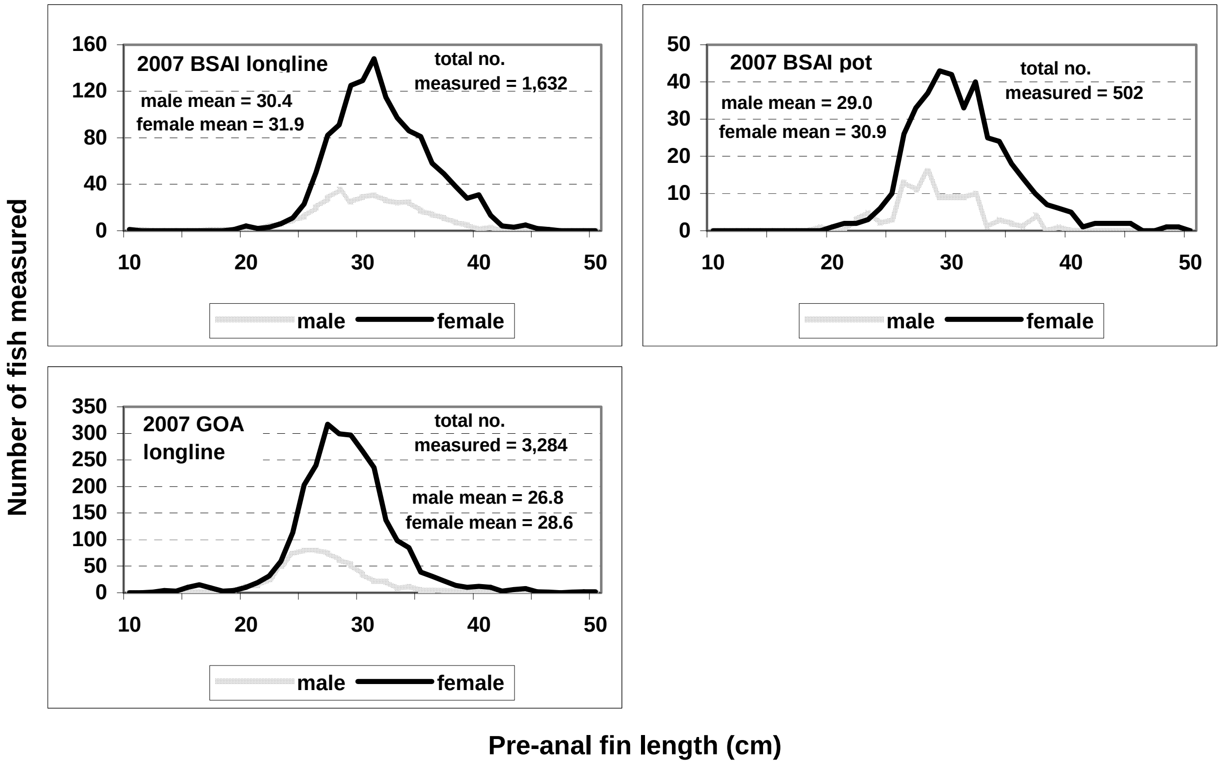


Figure 1-1.--Raw length frequency distribution of giant grenadiers sampled at sea by observers in the 2007 commercial sablefish fishery. GOA = Gulf of Alaska; BSAI = eastern Bering Sea and Aleutian Islands.

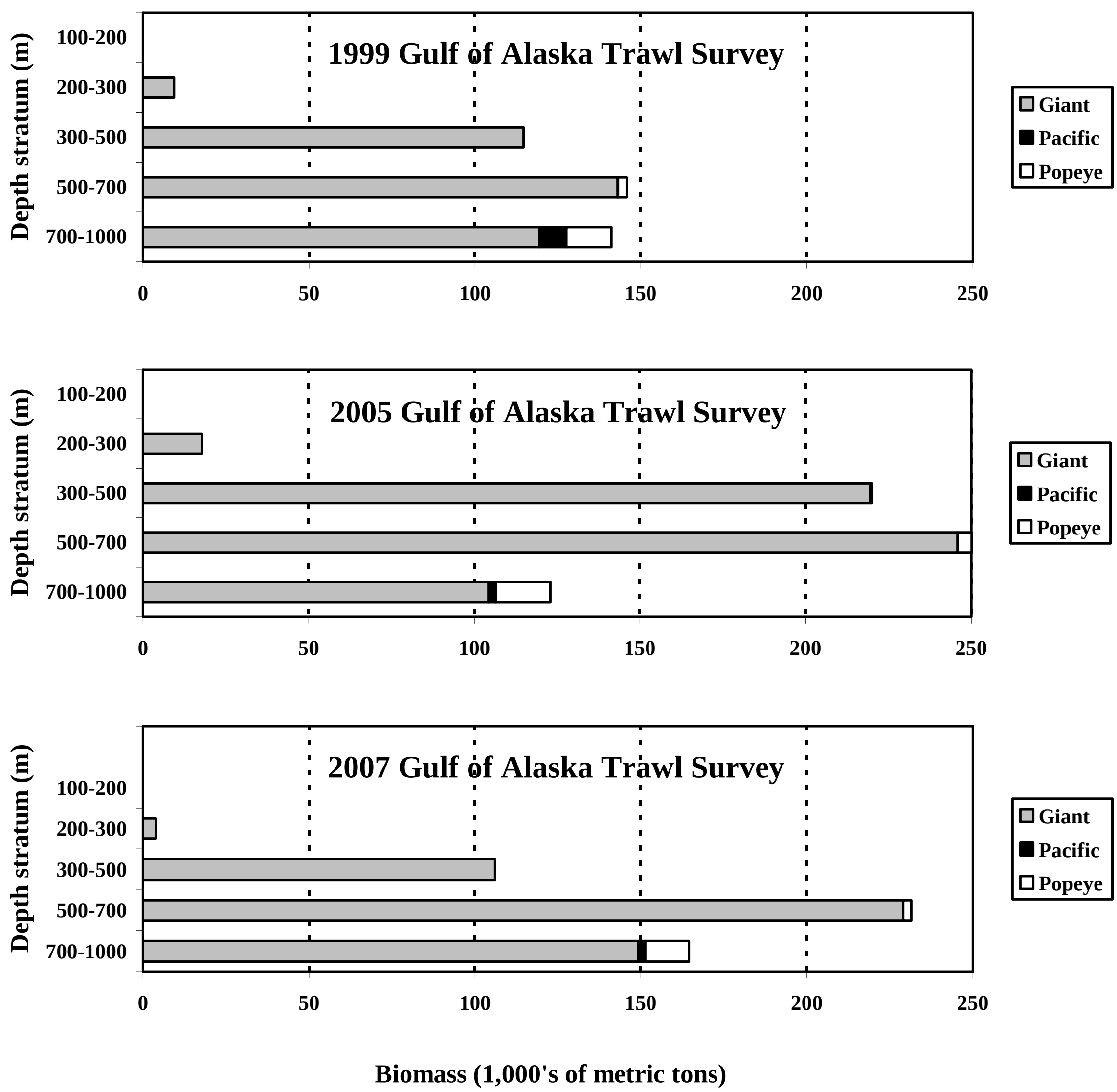


Figure 1-2.--Depth distribution of giant, Pacific, and popeye grenadier biomass estimates in the 1999, 2005, and 2007 Gulf of Alaska trawl surveys. Note: depth strata shown in this figure for the Gulf of Alaska are different than those shown in Figure 1-3 for the eastern Bering Sea slope survey because the surveys had different stratification schemes for depth.

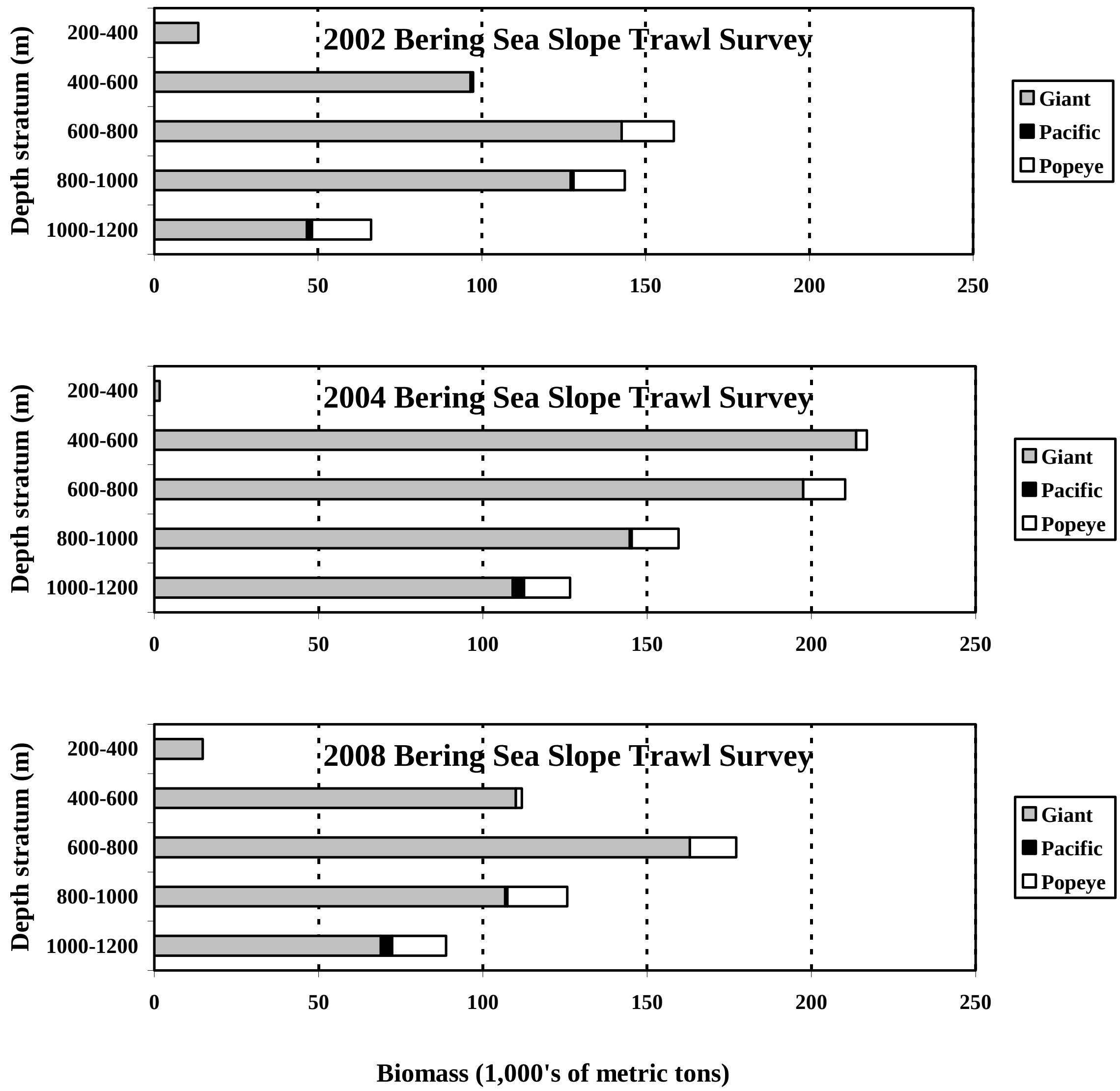


Figure 1-3.--Depth distribution of giant, Pacific, and popeye grenadier biomass estimates in the 2002, 2004, and 2008 eastern Bering Sea slope trawl surveys. Note: depth strata shown in this figure for the eastern Bering Sea slope are different than those shown in Figure 1-2 for the Gulf of Alaska survey because the surveys had different stratification schemes for depth.

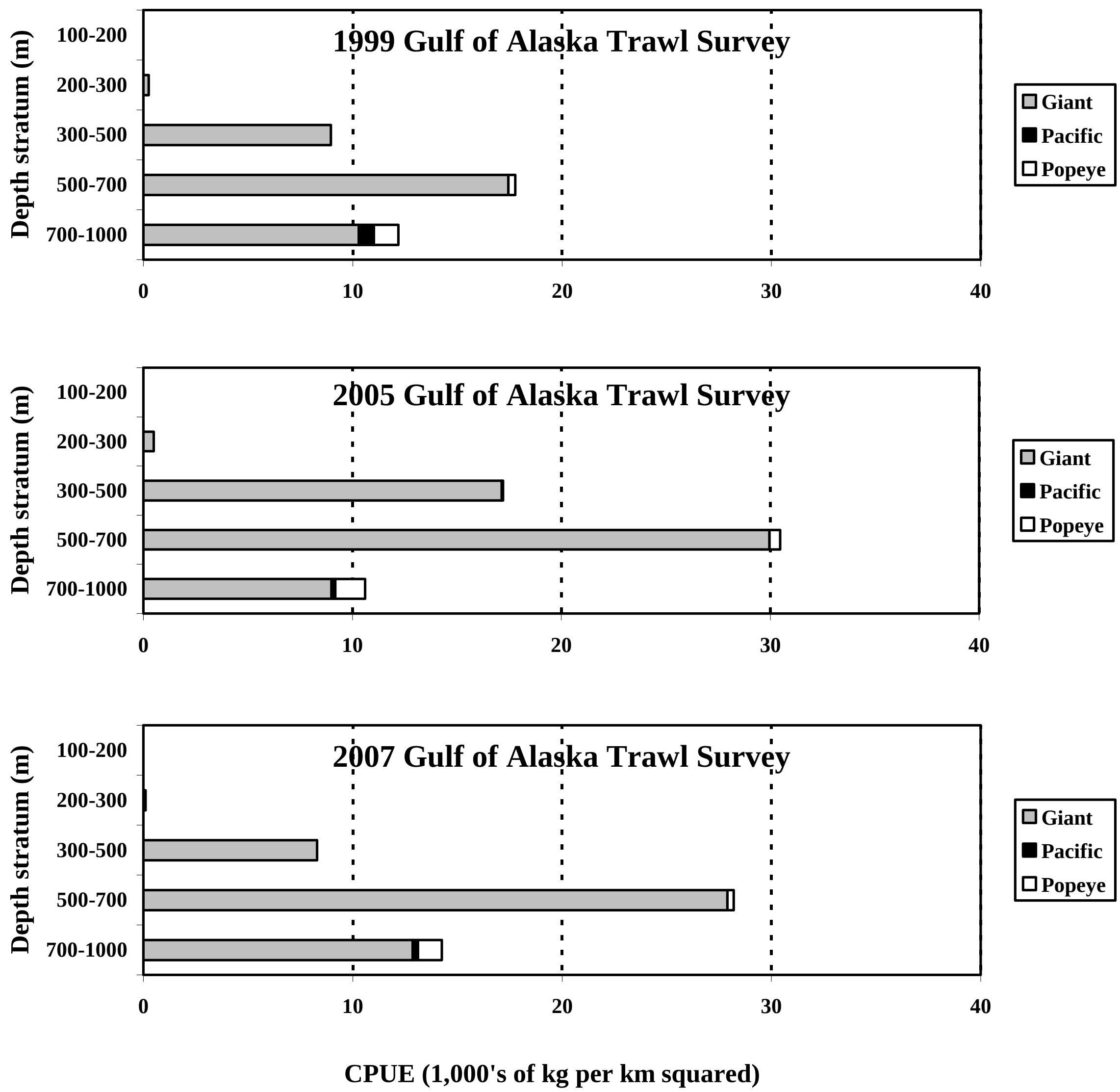


Figure 1-4.-- Depth distribution of giant, Pacific, and popeye grenadier catch per unit effort (CPUE) in the 1999, 2005, and 2007 Gulf of Alaska trawl surveys. Note: depth strata shown in this figure for the Gulf of Alaska are different than those shown in Figure 1-5 for the eastern Bering Sea slope survey because the surveys had different stratification schemes for depth.

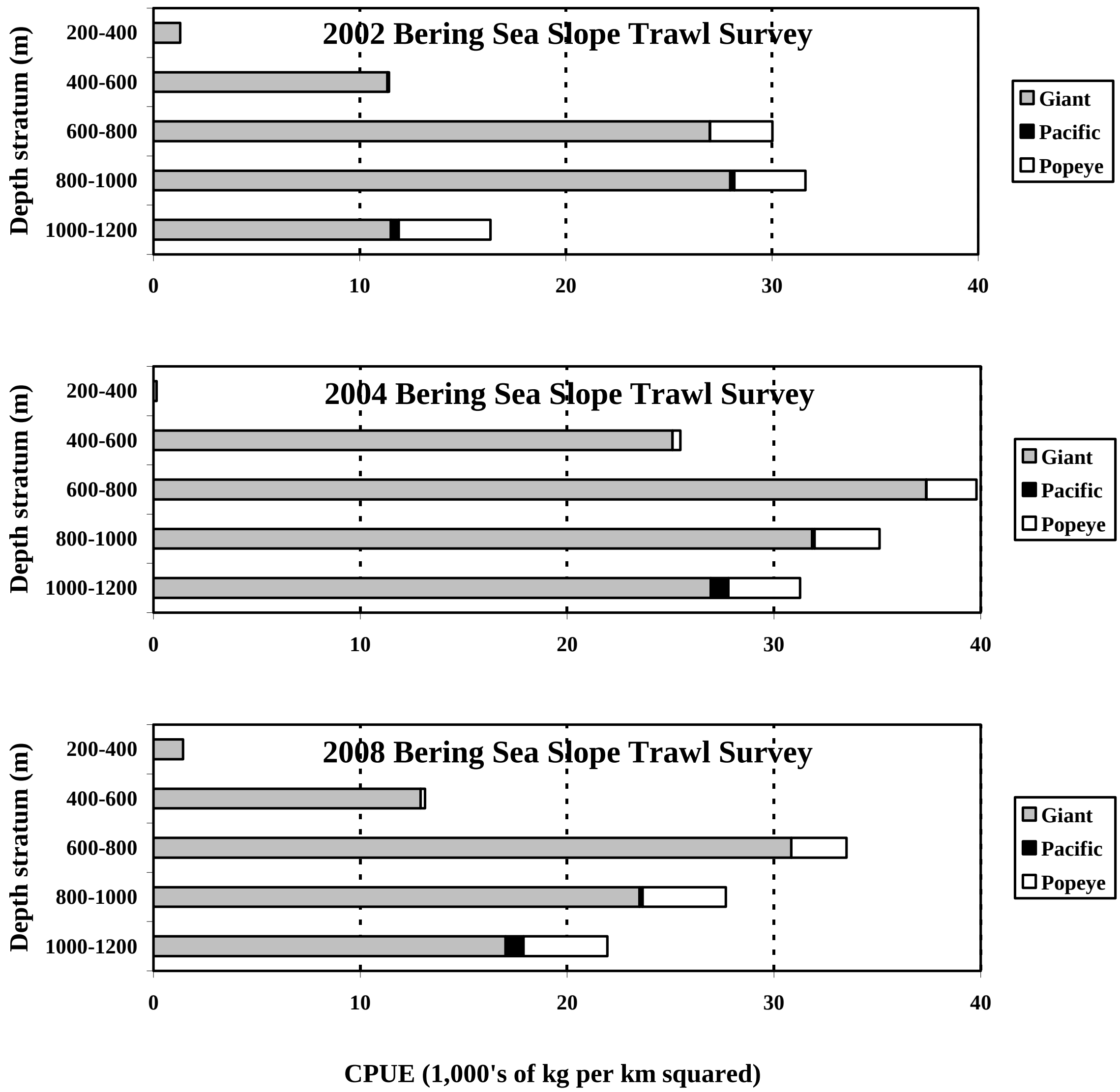


Figure 1-5.--Depth distribution of giant, Pacific, and popeye grenadier catch per unit effort (CPUE) in the 2002, 2004, and 2008 eastern Bering Sea slope trawl surveys. Note: depth strata shown in this figure for the eastern Bering Sea slope are different than those shown in Figure 1-4 for the Gulf of Alaska survey because the surveys had different stratification schemes for depth.

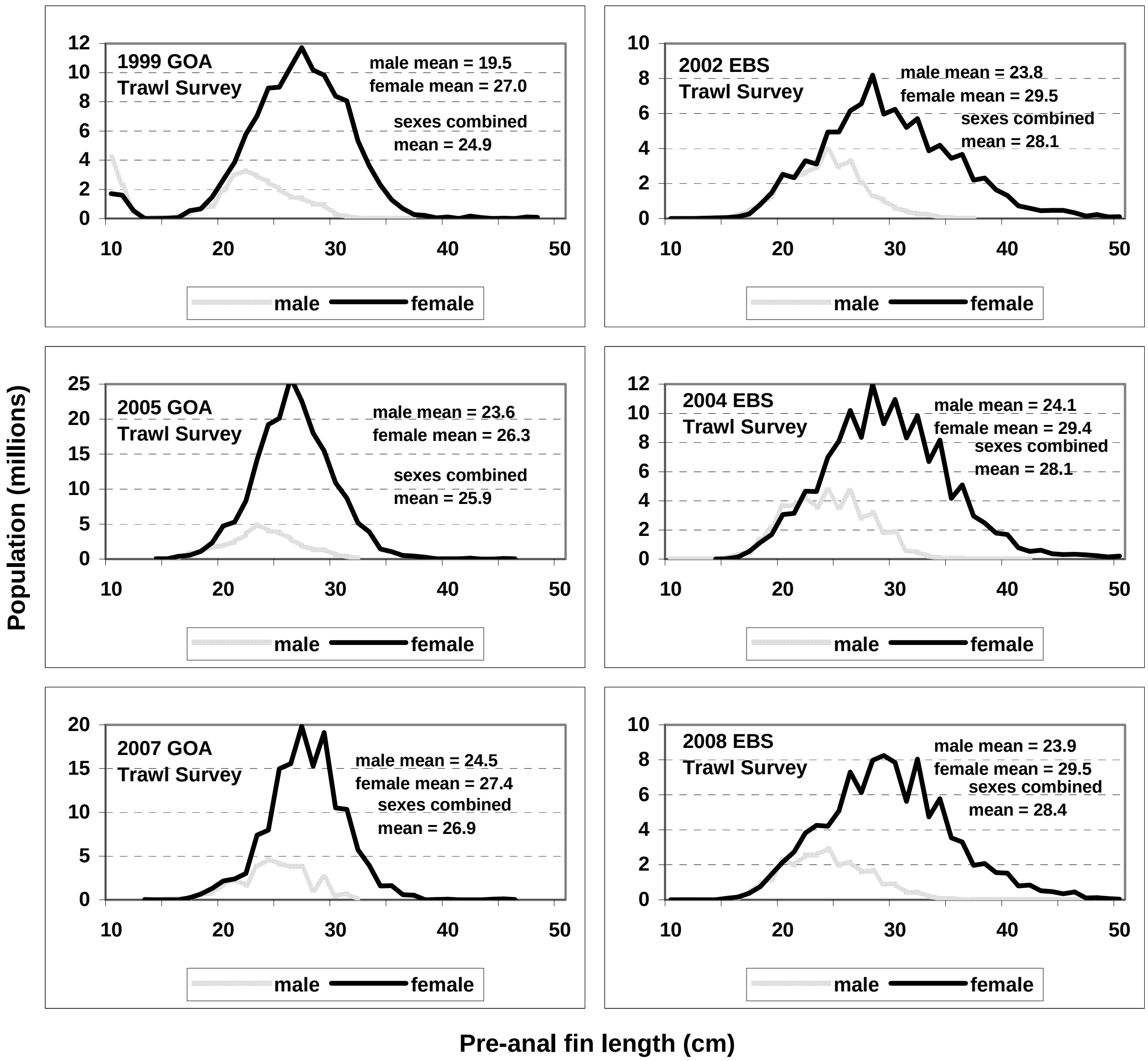


Figure 1-6.--Estimated population size compositions for giant grenadier in recent Alaskan trawl surveys. (GOA = Gulf of Alaska; EBS = eastern Bering Sea slope).

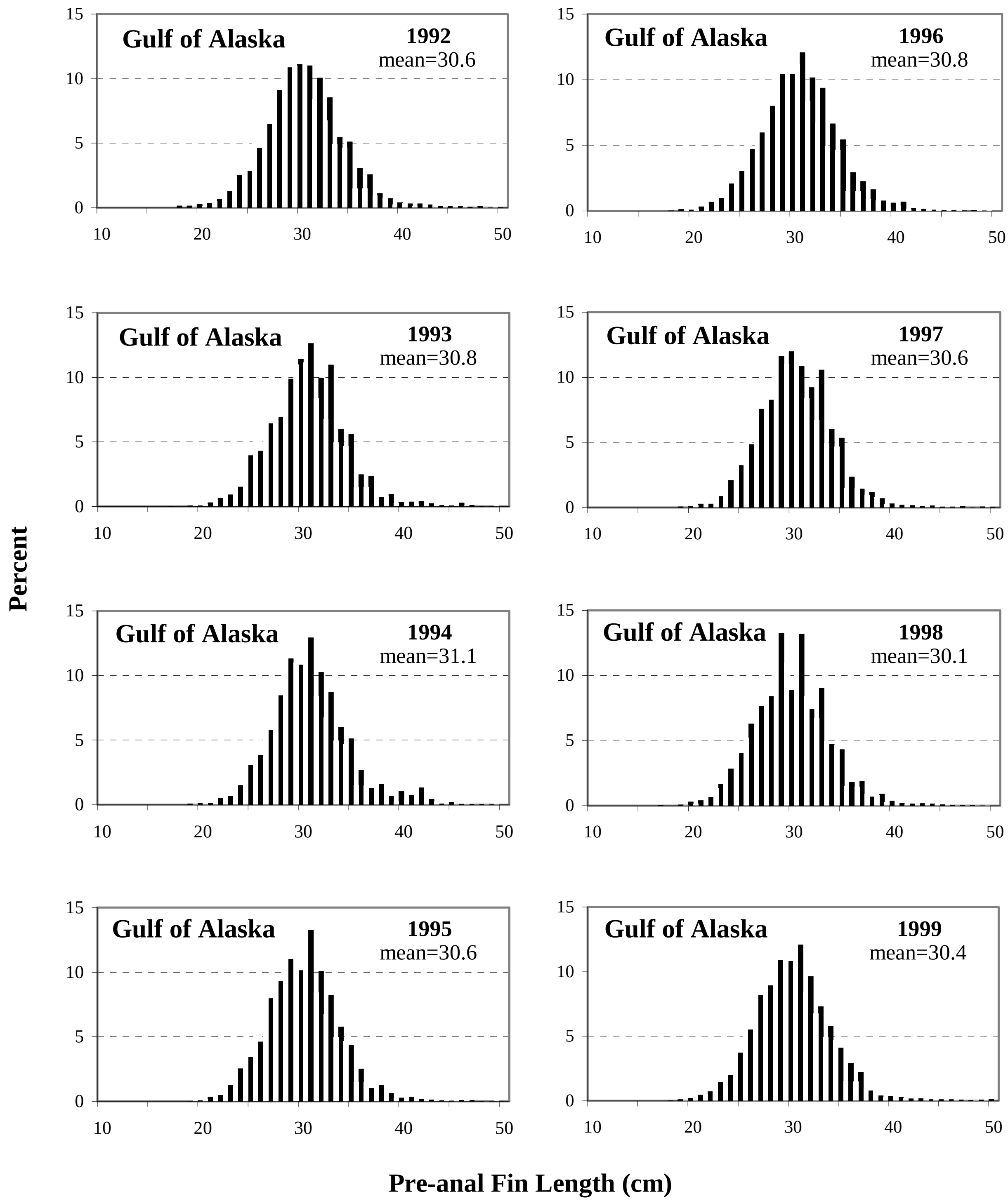


Figure 1-7.--Estimated population size compositions for giant grenadier in the 1992-2008 longline surveys of the Gulf of Alaska. (Figure continued on next two pages).

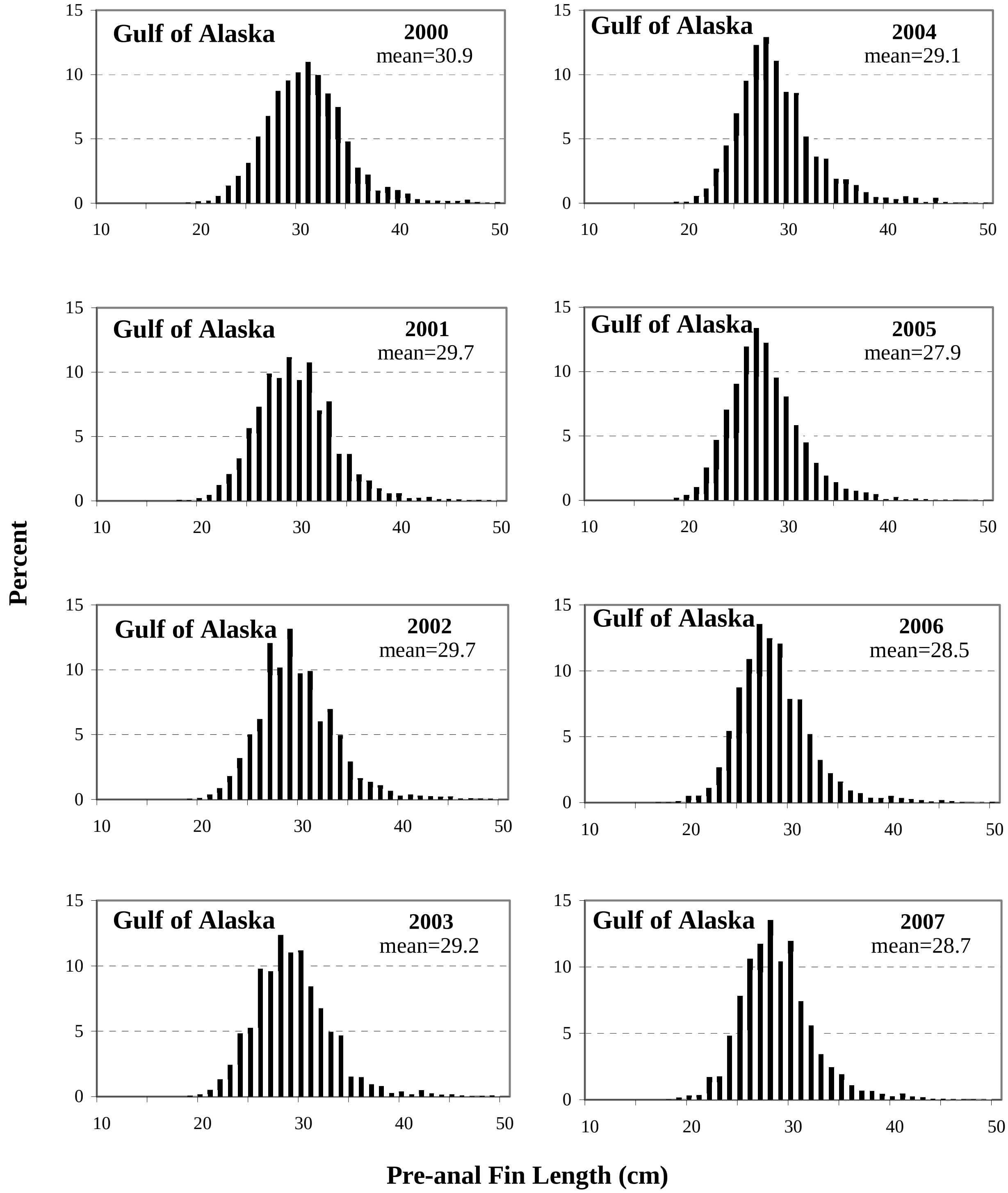
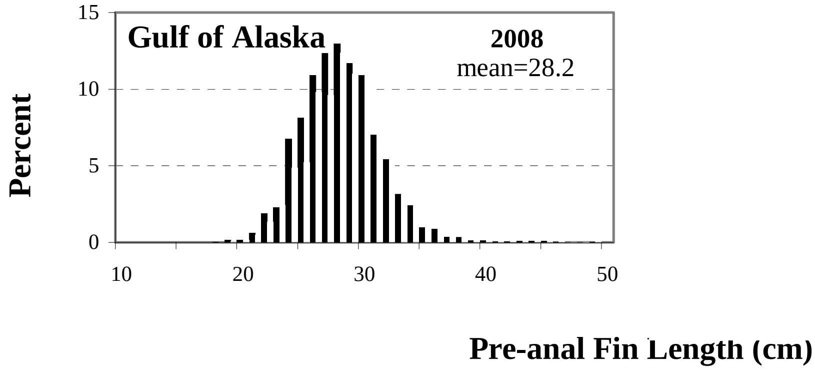


Figure 1-7. (continued from preceding page).



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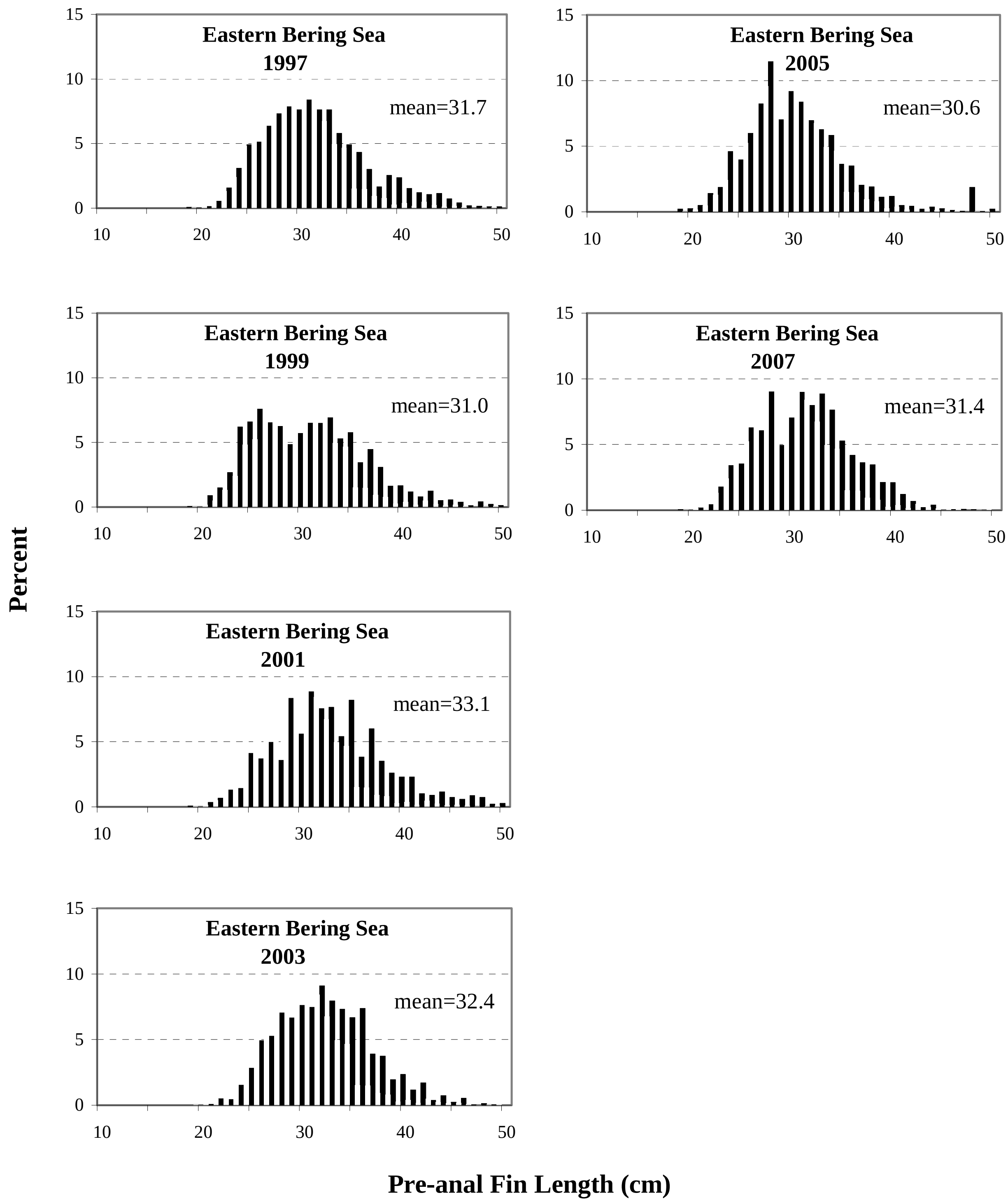

Figure 1-8.--Estimated population size compositions for giant grenadier in the 1997-2007 longline surveys of the eastern Bering Sea.

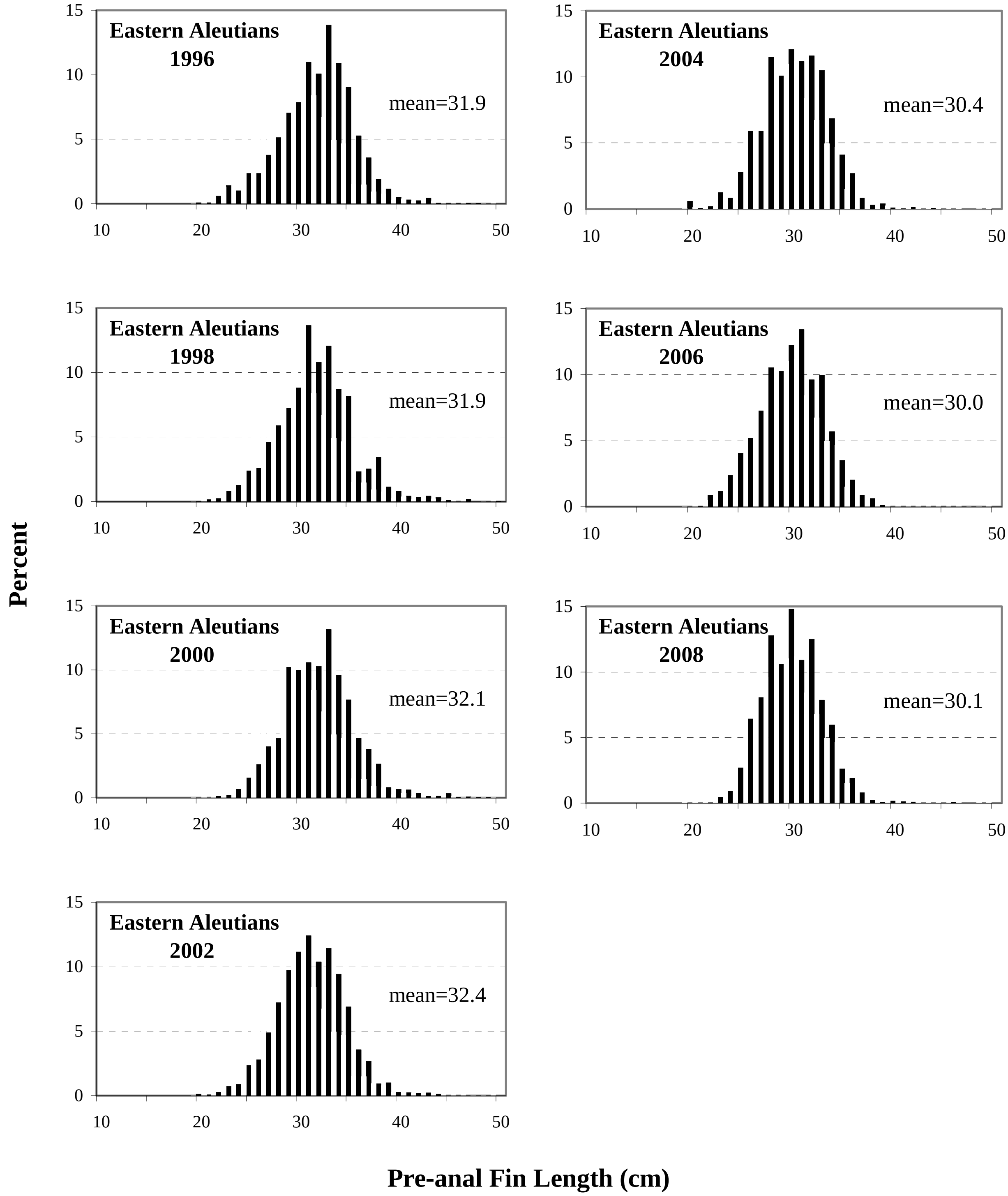

Figure 1-9.--Estimated population size compositions for giant grenadier in the 1996-2008 longline surveys of the eastern Aleutian Islands (area of the Aleutian Islands east of 180^{o} w. longitude). Size composition data are not available for the western Aleutian Islands.

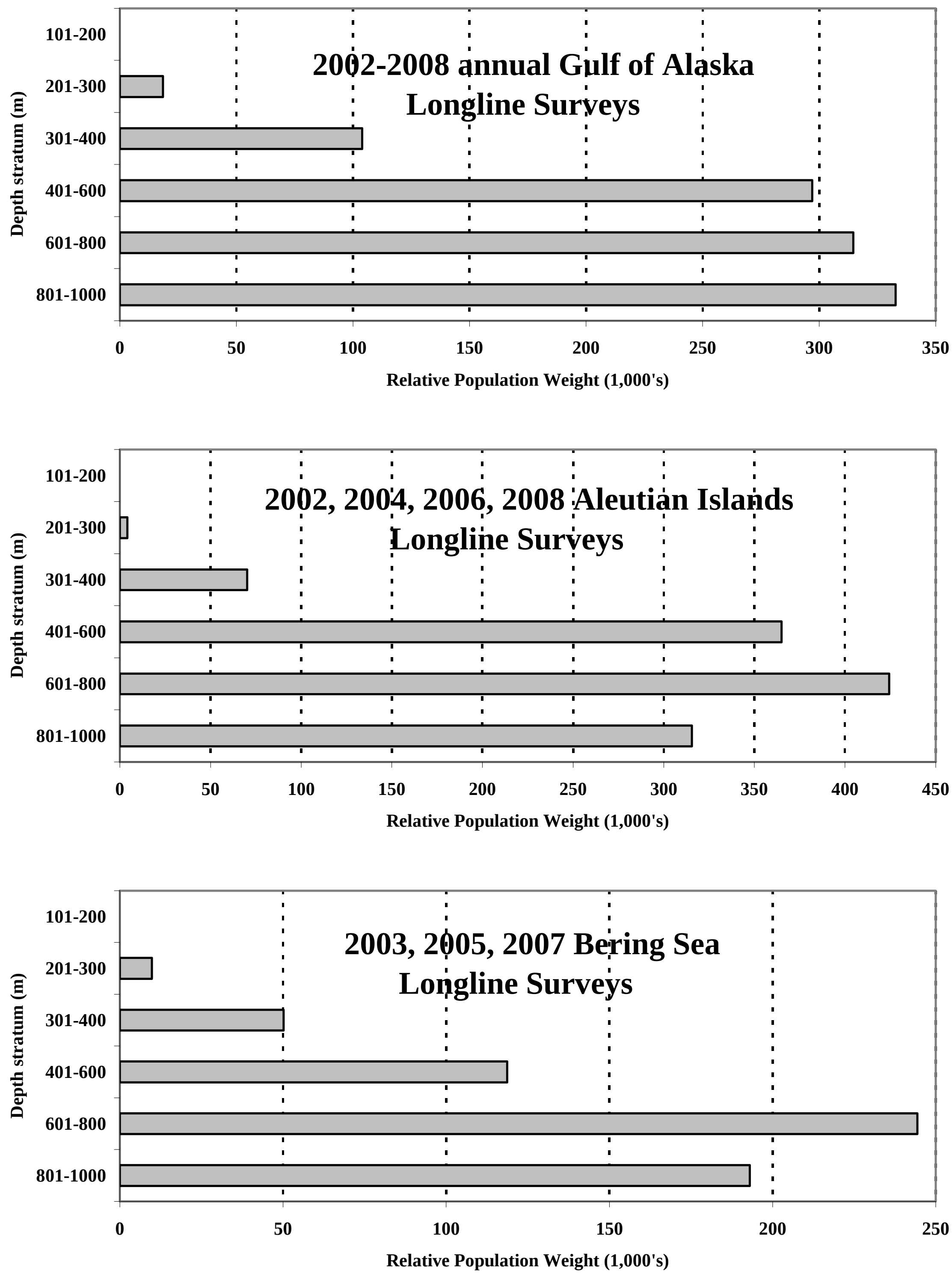

Figure 1-10.--Average depth distribution of giant grenadier relative population weight in longline surveys of the Gulf of Alaska, eastern Aleutian Islands (area of the Aleutian Islands east of 180^{o} w. longitude) , and eastern Bering Sea since 2002. Data on depth distribution are not available for the western Aleutian Islands.