21. Gulf of Alaska squids

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Executive Summary

In 2010, the North Pacific Fishery Management Council passed amendment 87 to the GOA Fishery Management Plan, which separated the Other Species complex into its constituent species groups. Thus, GOA squids are now managed as an independent complex with its own harvest specifications. Because the GOA bottom trawl survey is the chief source of data for this assessment and is a biennial survey, full assessments are performed only in odd years.

Summary of Changes

<u>Changes in the input data:</u>

1. Total catch and retention data for GOA squids has been updated with complete 2010 and partial 2011 data.
2. Biomass estimates from the 2011 GOA bottom trawl survey have been added.
3. An appendix containing data regarding non-commercial catches of squid has been added to the report.

Summary of Results

Because reliable estimates of squid biomass and natural mortality rate do not exist, we recommend using a modified Tier 6 approach setting OFL equal to maximum historical catch and ABC equal to 0.75 * OFL using the years 1997 - 2007 as a baseline .

	last year		**this year**	
Quantity/Status	*2011*	*2012*	**2012**	2013
M (natural mortality)	*n/a*	*n/a*	**n/a**	n/a
Specified/recommended Tier	*6*	*6*	**6**	6
Biomass	*n/a*	*n/a*	**n/a**	n/a
average historical catch 1997-2007	*272*	*272*	**272**	272
maximum historical catch 1997-2007	*1,530*	*1,530*	**1,530**	1,530
Recommended OFL (max. hist. catch; t)	*1,530*	*1,530*	**1,530**	1,530
Recommended ABC (0.75*OFL; t)	*1,148*	*1,148*	**1,148**	1,148
Status	*As determined last year for:*		As determined this year for:	
	2009	*2010*	2010	2011
Overfishing	*No*	*n/a*	No	n/a
Overfished	*n/a*	*n/a*	n/a	n/a
Approaching overfished	*n/a*	*n/a*	n/a	n/a
(for Tier 6 stocks, data are not available to determine whether the stock is in an overfished condition)				

Introduction

Description, scientific names, and general distribution

Squids (order Teuthoidea) are cephalopod molluscs which are related to octopus. Squids are considered highly specialized and organized molluscs, with only a vestigial mollusc shell remaining as an internal plate called the pen or gladius. They are streamlined animals with ten appendages (2 tentacles, 8 arms) extending from the head, and lateral fins extending from the rear of the mantle (Figure 1). Squids are active predators which swim by jet propulsion, reaching swimming speeds of up to 40 km/hr, the fastest of any aquatic invertebrate. Members of this order (*Archeteuthis* spp.) also hold the record for largest size of any invertebrate (Barnes 1987).

There are at least 15 squid species found in the mesopelagic regions of the Eastern Bering Sea (EBS; Table 1). Less is known about which squid species inhabit the GOA, but the species are likely to represent both EBS species and more temperate species in the genus *Loligo*, which are regularly found on the U.S. West Coast and in British Columbia, Canada, especially in warmer years (MacFarlane and Yamamoto 1974). Squid are distributed throughout the North Pacific, but are common in large schools in pelagic waters surrounding the outer continental shelf and slope (Sinclair et al. 1999). The most common squid species in the Eastern Bering Sea are all in the family Gonatidae. Near the continental shelf, the more common species are *Berryteuthis anonychus* and *Berryteuthis magister*. Further offshore, the likely common species are *Gonatopsis borealis*, *Gonatus middendorfi* and several other *Gonatus* species, according to survey information collected in the late 1980's (Sinclair et al. 1999). In addition, marine mammal food habits data and recent pilot studies indicate that *Ommastrephes bartrami* may also be common, in addition to *Berryteuthis magister* and *Gonatopsis borealis* (B. Sinclair, ASFC, personal communication). Much more research is necessary to determine exactly which species and life stages are present seasonally in the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish Fishery Management Plan (FMP) areas.

Management Units

The squid species complex is part of the Other Species FMP category. Historically, GOA squids were managed along with sharks, sculpins, and octopuses under an aggregate gulfwide TAC established annually as ≤5% of the sum of all target species TACs. Beginning in 2008, aggregate ABCs and OFLs for the Other Species complex have been set by summing the individual OFL and ABC recommendations for each species group. The 2008 assessment was the first one to be used in setting the Other Species TAC (Ormseth and Gaichas 2008). Since 2003, the NMFS Alaska Regional Office (AKRO) has reported total squid catch, without breaking down the squid catch by species. Prior to 2003, catch of squids was not reported separately from the Other Species category, but observer species composition sampling was used to estimate catches of each Other Species component (see below). Catch of GOA Other Species has never exceeded TAC over the course of the domestic fishery (Table 2).

Life history and stock structure

Relative to most groundfish, squids are highly productive, short-lived animals. They display rapid growth, patchy distribution and highly variable recruitment (O'Dor, 1998). Unlike most fish, squids may spend most of their life in a juvenile phase, maturing late in life, spawning once, and dying shortly thereafter. Whereas many groundfish populations (including skates and rockfish) maintain stable populations and genetic diversity over time with multiple year classes spawning repeatedly over a variety of annual environmental conditions, squids have no such "reserve" of biomass over time. Instead, it is hypothesized that squids maintain a "reserve" of biomass and genetic diversity in space with multiple cohorts spawning and feeding throughout a year and over a wide geographic area across locally varied environments (O'Dor 1998). Many squid populations are composed of spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski 1998). Most information on squids refers to *Illex* and *Loligo* species which support commercial fisheries in temperate and tropical waters. Of North Pacific squids, life history is best described for western Pacific stocks (Arkhipkin et al. 1995; Osako and Murata 1983).

The most commercially important squid in the north Pacific is the magistrate armhook squid, *Berryteuthis magister*. This species is distributed from southern Japan throughout the Bering Sea, Aleutian Islands (AI), and Gulf of Alaska to the U.S. West coast as far south as Oregon (Roper et al. 1984). The maximum size reported for *B. magister* is 28 cm mantle length. The gladius and statoliths (similar to otoliths in fish) were compared for ageing this species (Arkhipkin et al. 1995). *B. magister* from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 4 years). Males grew more slowly to earlier maturation than females. An analysis of *B. magister* in the EBS suggests that individuals there have shorter lifespans (approximately one year) and mature earlier than western populations (Drobny 2008). *B. magister* were dispersed during summer months in the western Bering Sea, but formed large, dense schools over the continental slope between September and October. Stock structure in this species is complex, with three seasonal cohorts identified in the region: summer-hatched, fall-hatched, and winter-hatched. Growth, maturation, and mortality rates varied between seasonal cohorts, with each cohort using the same areas for different portions of the life cycle. For example, the summer-spawned cohort used the continental slope as a spawning ground only during the summer, while the fall-spawned cohort used the same area at the same time primarily as a feeding ground, and only secondarily as a spawning ground (Arkhipkin et al. 1995).

Timing and location of fishery interactions with squid spawning aggregations may affect both the squid population and availability of squid as prey for other animals (Caddy 1983; O'Dor 1998). The essential position of squid within North Pacific pelagic ecosystems, combined with the limited knowledge of the abundance, distribution, and biology of many squid species in the FMP areas, make squid a good candidate for management distinct from that applied to other species (as has been done for forage species in the BSAI and GOA). In the EBS, fishery interactions with squid happen in predictable locations (Gaichas 2005), suggesting that in some cases, squid may be most effectively managed by spatial restrictions rather than by quotas.

Fishery

Directed fishery

There are no directed squid fisheries in Alaskan waters at this time, although squid were occasionally targeted by foreign vessels in Alaska prior to 1990. Squid in Alaska are generally taken incidentally in target fisheries for pollock. Squids could potentially become targets of Alaskan fisheries, as there are many fisheries directed at squid species worldwide. Most of these fisheries focus on temperate squids in the genera *Illex* and *Loligo* (Agnew et al. 1998, Lipinski et al. 1998). For instance, the market squid *Loligo opalescens* supports one of the largest fisheries in the Monterey Bay area of California (Leos 1998), and has also been an important component of bycatch in other fisheries in that region (Calliet et al. 1979). There are fisheries for *B. magister* in the Western Pacific, including Russian trawl fisheries with annual catches of 30,000 - 60,000 metric tons (Arkhipkin et al. 1995), and coastal Japanese fisheries with catches of 5,000 to 9,000 t in the late 1970's-early 1980's (Roper et al. 1984; Osaka and Murata 1983). Therefore, monitoring of catch trends for species in the squid complex is important because markets for squids exist and fisheries might develop rapidly.

Bycatch and discards

Squids have historically represented a small proportion (~1-2%) of the Other Species catch in the GOA (Table 2). This began to change in 2003, when the proportion rose to 5%, and increased to an especially large catch in 2006 (1,530 t, 39% of the Other Species catch; Table 2). The catch declined to 412 t in 2007 and 84 t in 2008. The 2009 catch as of October is similar to that in 2007 (Table 2). The 2006 GOA squid catch was similar to catch levels in the BSAI during the 2000s (Ormseth and Jorgenson 2007). Analysis of fishery observed data suggests that retention of squids varies considerably; estimates of retention rates range from 19% to 97%, although retention has been high for the last several years (Table 2).

Most squid are caught incidentally in the pollock fishery (Table 3), which has the highest observer coverage in the central Gulf of Alaska (areas 620 & 630). Thus, it is not surprising that most squid catch apparently comes from this area (Table 4). However, the distribution of squid catch in unobserved fisheries is not known. The spatial distribution of the observed portion of the squid catch has changed over time, with the highest catches shifting from areas 610 and 630 in the mid-1990s to area 620 since 2001 (Table 4 & Figure 2). Given the relatively low levels of observer coverage in GOA groundfish fisheries, and the generally low catches of squid in years before 2004, it is difficult to determine whether the apparent redistribution of squid catch results from changes in observer coverage over time, changing fishing patterns, or changes in squid distribution.

The predominant species of squid in commercial catches in the GOA is believed to be *B. magister* (often called “red squid”), although there is no way to verify this because the majority (99%) of squid catch is reported as “squid unidentified” (the remainder is identified as *Moroteuthis* spp, or “giant squid unidentified”). Squid catches from 1990-2002 are estimated using the Blend system, which combines observer catch data with landings data. Since 2003 the AKRO’s Catch Accounting System (CAS), using a similar approach, has reported catches of squid and Other Species groups. Because squids are delicate and almost certainly killed in the process of being caught, 100% mortality of discards is assumed.

The prevalence of *B. magister* in bottom trawl surveys (Table 5) and the spatial overlap of the surveys with incidental squid catches (Figs. 3 & 4) support the hypothesis that fishery catches are dominated by *B. magister*. However, incidental catches occur most often in pelagic trawls and differences in the depth distribution of squid species may confound this result.

The distribution of observed squid catches appears to be consistent from year to year (Figs. 4 & 5), with most catches occurring along the shelf break in deeper water and on the south end of Kodiak Island. A similar consistency in spatial patterns of catch is observed in the Bering Sea (Ormseth and Jorgensen 2009). Incidental catches of squids have a highly seasonal pattern, with the majority of the catch occurring during the 1st quarter of the year (Figs. 5 & 6). The annual spatial pattern is likely due to the geographical and depth distribution of B. Magister. In contrast, the seasonal pattern probably results from the timing of pollock fishing seasons and the fishing behavior of the GOA pollock fleet.

Data

Survey Data

Survey biomass in aggregate and by species

The AFSC bottom trawl surveys are directed at groundfish species, and therefore do not employ the appropriate gear or sample in the appropriate places to provide reliable biomass estimates for most squids, which are assumed to be generally pelagic and to reside off bottom. Biomass estimates for the GOA have fluctuated considerably since 1984, with the 2011 estimate for all squids being 4,431 t (Table 5). This may be due to variability in squid biomass and distribution, but may also reflect the poor nature of biomass estimates from bottom trawl surveys. However, the survey estimates have surprisingly low coefficients of variation (Table 5), suggesting that squid survey catch (especially of *B. magister*) is fairly evenly distributed throughout the survey area. Survey biomass estimates can be compared with biomass estimates from mass-balance ecosystem models. For example, salmon in the GOA are estimated to consume between 200,000 and 1.5 million t of squid each year and whales may consume 100,000-200,000 t of squid each year (see the ecosystem considerations section in this document). Thus, the ecosystem models suggest that the actual biomass of squids in the GOA may be many times greater than what the bottom trawl surveys indicate.

Analytic Approach

The available data do not support population modeling or Tier 5 management for squids in the GOA, so many of the standard sections of text usually required for NPFMC SAFE reports are not relevant.

Tier 6 approach

Under the original Tier 6 designation, OFL is established as equal to the average historical annual catch from 1978-1995, and ABC is established as 0.75 * OFL. Tier 6 is problematic for squids because fishing pressure on squid appears to be low and average catch may not be a good indicator of productivity in a lightly fished population (see SSC minutes from 2006 at http://www.fakr.noaa.gov/npfmc/minutes/SSC206.pdf). In addition, squid catch has only been recorded since 1990. We recommend a Tier 6 approach setting OFL equal to the maximum, rather than average, historical catch, and ABC equal to 0.75*OFL. At the 2009 September Plan Team meetings, the Plan Teams discussed Tier 6 time periods to be used for species with only recent catch histories. The provisional decision was to use the years 1997-2007 as an alternative time period for octopus in both FMP areas. Thus, we recommend using the 1997-2007 time period so that the assessment is consistent with other Tier 6 stocks.

Results

Harvest recommendations 2012-2013

	Tier 6 (max)
time period used for catch	1997-2007
average survey biomass (t)	N/A
ABC (t)	**1,148**
OFL (t)	**1,530**

Ecosystem Considerations

Fishery management should attempt to prevent negative impacts on squid populations not only because of their potential fishery value, but also (and perhaps more so) because of the crucial role they play in marine ecosystems. Squid are important components in the diets of many seabirds, fish, and marine mammals, as well as voracious predators themselves on zooplankton and larval fish (Caddy 1983, Sinclair et al. 1999).

Squids are central in food webs in the GOA (Figure 7). These food webs were derived from mass balance ecosystem models assembling information on the food habits, biomass, productivity and consumption for all major living components in each system (Aydin et al. 2007). While it might appear convenient to apply similar management to squids in all Alaskan federal waters, the EBS, AI, and GOA are physically very different ecosystems, especially when viewed with respect to available squid habitat and densities. While direct biomass estimates are unavailable for squids, ecosystem models can be used to estimate squid densities based upon the food habits and consumption rates of predators of squid. The AI has much more of its continental shelf area in close proximity to open oceanic environments where squid are found in dense aggregations; hence the squid density as estimated by predator demand in each system is much greater in the AI relative to the EBS (labeled “BS” in the figures) and GOA (Figure 8, upper panel).

In contrast with predation mortality, estimated fishing mortality on squid is similarly low in all three ecosystems. Figure 8 (lower panel) demonstrates the estimated proportions of total squid mortality attributable to fishing vs. predation, according to food web models built based on early 1990’s information from the AI, EBS, and the GOA. Fishing mortality is so low relative to predation mortality that it is not visible in the plot, suggesting that current levels of overall fishery bycatch may be insignificant relative to predation mortality on squid populations. The fish predators of squids in the GOA are primarily salmon, which account for nearly half of the squid mortality in the ecosystem model (Figure 9). Marine mammals such as sperm whales and other toothed whales account for a total of 14% of squid mortality, and the primary groundfish predators of squids are sablefish, pollock, and grenadiers (labeled “deep demersals” and or “large demersals” in Figure 9) in the GOA, which combined account for another 10% of squid mortality. While estimates of squid consumption are considered uncertain, the ecosystem models incorporate uncertainty in partitioning estimated consumption of squid between their major predators in each system. The predators with the highest overall consumption of squid in the GOA are salmon, which are estimated to consume between 200 thousand and 1.5 million metric tons of squid annually, followed by sperm and toothed whales combined, which consume 100 to 200 thousand metric tons of squid annually.

Although salmon have the highest consumption of squids in the GOA and account for nearly half of their estimated mortality, squid are not dominant in salmon diets, so salmon do not appear to be as dependent on squids as some other predators are. Squid make up about 20% of the diet of GOA salmon, 86% of the diet of GOA sperm whales, 67% of the diet of other toothed whales, and 21% of the diet of sablefish (Figure 10). In addition, squids are important constituents of seabird diets (Figure 11). The input data for the AFSC ecosystem models suggests that squids make up nearly half the diet of fulmars, storm petrels, and the albatross/jaegers group (Figure 11; Aydin et al. 2007). These input data are largely based on diet composition and preference data reported by Hunt et al. (2000).

The importance of squids within the GOA ecosystem was assessed using a model simulation analysis where squid mortality was increased by 10% to determine the effects on other living GOA groups. This analysis also incorporated the uncertainty in model parameters, resulting in ranges of possible outcomes which are portrayed as 50% confidence intervals (boxes in Figure 12) and 95% confidence intervals (error bars in Figure 9). Species showing the largest changes from baseline conditions are presented in descending order from left to right. Therefore, the largest change resulting from a 10% increase in GOA squids mortality is a median 10% decrease in squid biomass (Figure 12), as might have been expected from such a perturbation. Of more ecological interest are the negative effects on the biomass of sperm and beaked whales (which includes only sperm whales in the GOA model), which significantly decrease in biomass in response to the decrease in squids. Similarly, grenadiers (the majority of the aggregation “miscellaneous fish deep”) are predicted to decrease significantly in response to a decrease in squids. Some other predators showed declines, but the 95% confidence interval included no change, so the declines are not certain; these were salmon sharks, porpoises, returning adult salmon (and the salmon fishery), and sablefish. Other groups in the ecosystem responded to simulated squid declines with increased biomass, including small forage fishes such as myctophids, eulachon, other pelagic smelts and forage fishes, juvenile (outgoing) salmon, and some zooplankton prey of squids including pelagic amphipods and chaetognaths (Figure 12). It is unclear to what extent these increases are competitive releases or direct predation releases caused by lower squid survival.

Diets of squids are poorly studied, but currently believed to be largely dominated by euphausiids, copepods and other pelagic zooplankton in the GOA (Figure 13, upper panel). Assuming these diets are assessed correctly, squids are estimated to consume on the order of one to five million metric tons of these zooplankton species in the GOA annually. Squids are also reported to consume forage fish as a small portion of their diet, which could amount to as much as one million metric tons annually in the GOA ecosystem (Figure 13, lower panel). In a simulation where each species group in the ecosystem had survival reduced by 10%, the strongest effects on GOA squids were from reduced survival of squids (the direct effect), followed by the bottom-up effects from large and small phytoplankton, and to a lesser extent by zooplankton (Figure 14). While there is much uncertainty surrounding the quantitative ecological interactions of squids, as is apparent in the wide ranges of these estimates from food web models, it is clear that squids are intimately connected with both very low trophic level processes affecting secondary production of zooplankton, and in turn they comprise a significant portion of the diet of both commercially important (salmon) and protected species (whales) in the GOA.

While overall fishing removals of squid are very low relative to predation at the ecosystem scale, local-scale patterns of squid removals should still be monitored to ensure that fishing operations minimize impacts to both squid and their predators. Many squid populations are composed of spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski 1998). The timing and location of fishery interactions with squid spawning aggregations may affect the availability of squid as prey for other animals as well as the age, size, and genetic structure of the squid populations themselves (Caddy 1983, O'Dor 1998). The essential position of squids within North Pacific pelagic ecosystems, combined with our limited knowledge of the abundance, distribution, and biology of squid species in the FMP areas, illustrates the difficulty of managing an important nontarget species complex with little information.

Ecosystem Effects on Stock and Fishery Effects on the Ecosystem: Summary

In the following table, we summarize ecosystem considerations for GOA squids and the entire groundfish fishery where they are caught incidentally. The observation column represents the best attempt to summarize the past, present, and foreseeable future trends. The interpretation column provides details on how ecosystem trends might affect the stock (ecosystem effects on the stock) or how the fishery trend affects the ecosystem (fishery effects on the ecosystem). The evaluation column indicates whether the trend is of: *no concern*, *probably no concern*, *possible concern*, *definite concern,* or *unknown.*

Ecosystem effects on GOA Squids *(evaluating level of concern for squid populations)*

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton Forage fish	Trends are not currently measured directly, only short time series of food habits data exist for potential retrospective measurement	Unknown	Unknown
Predator population trends			
Salmon	Increased populations since 1977, stable throughout the 1990s to present	Mortality higher on squids since 1977, but stable now	Probably no concern
Toothed whales	Unknown population trend	Unknown	Unknown
Sablefish	Cyclically varying population with a downward trend since 1986	Variable mortality on squids slightly decreasing over time	Probably no concern
Grenadiers	Unknown population trend	Unknown	Unknown
Changes in habitat quality			
North Pacific gyre	Physical habitat requirements for squids are unknown, but are likely linked to pelagic conditions and currents throughout the North Pacific at multiple scales.	Unknown	Unknown

Groundfish fishery effects on ecosystem via squid bycatch *(evaluating level of concern for ecosystem)*

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Squid catch	Stable, generally <100 tons annually except for 2005, 2006, and 2007	Extremely small relative to predation on squids	No concern
Forage availability for salmon	Depends on magnitude of squid catch taken in salmon foraging areas	Squid catch generally low, small change to salmon foraging at current catch	Probably no concern
Forage availability for toothed whales	Depends on magnitude of squid catch taken in toothed whale foraging areas	Squid catch generally low, small change to toothed whale foraging at current catch	Probably no concern
Forage availability for sablefish	Depends on magnitude of squid catch taken in sablefish foraging areas	Squid catch generally low, small change to sablefish foraging at current catch	Probably no concern
Forage availability for grenadiers	Squid catch overlaps somewhat with grenadier foraging areas along slope	Small change in forage for grenadiers	Probably no concern
Fishery concentration in space and time	Bycatch of squid is mostly in shelf break and canyon areas, no matter what the overall distribution of the pollock fishery is	Potential impact to spatially segregated squid cohorts and squid predators	Possible concern
Fishery effects on amount of large size target fish	Effects of squid bycatch on squid size are not measured	Unknown	Unknown
Fishery contribution to discards and offal production	Squid discard an extremely small proportion of overall discard and offal in groundfish fisheries	Addition of squid to overall discard and offal is minor	No concern
Fishery effects on age-at-maturity and fecundity	Effects of squid bycatch on squid or predator life history are not measured	Unknown	Unknown

Data gaps and research priorities

Clearly, there is little information for stock assessment of the squid complex in the GOA. However, ecosystem models estimate that the proportion of squid mortality attributable to incidental catch in groundfish fisheries in the GOA region is extremely small relative to that attributable to predation mortality. Therefore, improving the information available for squid stock assessment seems a low priority as long as the catch remains at its current low level.

However, investigating any potential interactions between incidental removal of squids and foraging by sensitive species (e.g. toothed whales, albatrosses) is a higher priority for research. Limited data suggest that squids may make up 67 to 85% of the diet (by weight) for toothed whales in the GOA. Research should investigate whether the location and timing of incidental squid removals potentially overlap with foraging seasons and areas of these species, and whether the magnitude of squid catch at these key areas and times is sufficient to limit the available forage.

In 2007, observers began measuring the length of squids caught in pollock target fisheries. Although these data are not yet available for the GOA, they will be useful for investigating potential ecosystem effects (e.g., "large" squid the size of *Moroteuthis robusta* are more predator than prey in the ecosystem, while smaller squid species may be most important as prey). In the future, it might also be important to be able to estimate the species composition of squid complex bycatch to determine relative impacts on marine mammals and other predators that depend on squids for prey, as well as relative impacts to the squid populations themselves.

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Tables

Table 1. Taxonomic grouping of squid species that have been found in the BSAI. It is not known whether all of these species occur in the GOA.

Class Cephalopoda; Order Oegopsida	
Family Chiroteuthidae	
Chiroteuthis calyx	
Family Cranchiidae	"glass squids"
Belonella borealis	
Galiteuthis phyllura	
Family Gonatidae	"armhook squids"
Berryteuthis anonychus	minimal armhook squid
Berryteuthis magister	magistrate armhook squid
Eogonatus tinro	
Gonatopsis borealis	boreopacific armhook squid
Gonatus berryi	Berry armhook squid
Gonatus madokai	
Gonatus middendorffi	
Gonatus onyx	clawed armhook squid
Family Onychoteuthidae	"hooked squids"
Moroteuthis robusta	robust clubhook squid
Onychoteuthis borealijaponicus	boreal clubhook squid
Class Cephalopoda; Order Sepioidea	
Rossia pacifica	North Pacific bobtail squid

Table 2. Estimated total catches of squid (t) in the Gulf of Alaska groundfish fisheries, 1990-2011 (1990 is the earliest year for which GOA squid catch data are available), with estimated annual retention rates. Table also includes annual TACs for the Other Species complex and estimated Other Species catch, 1990-2010. "Squid %" shows the percentage of squids in the total Other Species catch.

	squid catch (t)	% squid catch retained	Other Species catch (t)	Other Species TAC (t)	squid % of Other Species	management method
1990	60		6,289		1%	Other Species TAC
1991	117		5,700		2%	Other Species TAC (incl. Atka)
1992	88		12,313	13,432	1%	Other Species TAC (incl. Atka)
1993	104		6,867	14,602	2%	Other Species TAC (incl. Atka)
1994	39		2,721	14,505	1%	Other Species TAC
1995	25		3,421	13,308	1%	Other Species TAC
1996	42		4,480	12,390	1%	Other Species TAC
1997	97	87%	5,439	13,470	2%	Other Species TAC
1998	59	50%	3,748	15,570	2%	Other Species TAC
1999	41	19%	3,858	14,600	1%	Other Species TAC
2000	19	52%	5,649	14,215	0%	Other Species TAC
2001	91	37%	4,804	13,619	2%	Other Species TAC
2002	43	61%	3,748	11,330	1%	Other Species TAC
2003	97	60%	6,266	11,260	5%	Other Species TAC
2004	162	78%	1,705	12,942	10%	Other Species TAC (no skates)
2005	636	88%	2,513	13,871	25%	Other Species TAC (no skates)
2006	1,530	97%	3,881	13,856	39%	Other Species TAC (no skates)
2007	412	94%	3,035	4,500	14%	Other Species TAC (no skates)
2008	84	84%	2,967	4,500	3%	Other Species TAC (no skates)
2009	337	91%	3,188	4,500	11%	Other Species TAC (no skates)
2010	131	91%	1,724	4,500	8%	Other Species TAC (no skates)
*2011**	*228*	*78%*	n/a	n/a	n/a	*squid complex*

Data sources and notes: squid catch 1990-1996, Gaichas et al. 1999; squid catch 1997-2002, AKRO Blend; squid catch 2003-2010, AKRO CAS; Other Species catch, AKRO Blend and CAS; TAC, AKRO harvest specifications. Other Species catch from 1990-2003 does not include catch of skates in the IFQ Pacific halibut fishery, and after 2003 includes no skate catch at all. Estimates of retention rates from 1997-2010 are from fishery observer data provided by the AFSC Fishery Monitoring and Analysis group; retention rates from 2011 onwards are from the Alaska Regional Office.

*2011 catch data are incomplete; reported as of November 3, 2011.

Table 3a. Estimated catch (t) of all squid species in the Gulf of Alaska combined by target fishery, 1997-2002. Data sources: AKRO Blend.

target fishery	1997	1998	1999	2000	2001	2002
deep flatfish	5	3	6	1	1	1
flathead sole	1	0	0	0	1	0
other target	14	0	0	0	0	0
Pacific cod	1	1	1	0	1	0
rex sole	1	1	4	2	3	1
rockfish	8	6	7	7	9	7
sablefish	0	0	2	0	0	0
shallow flatfish	0	0	0	0	0	0
arrowtooth	1	3	1	1	2	7
pollock	66	46	20	7	74	28
total	97	60	41	18	91	44

Table 3b. Estimated catch (t) of all squid species in the Gulf of Alaska combined by target fishery, 2003-2010. Data sources: AKRO CAS. *2011 are incomplete; reported November 3, 2011.

target fishery	2003	2004	2005	2006	2007	2008	2009	2010	*2011**
arrowtooth	3	1	2	1	2	0	7	2	*16*
deep flatfish	0	1	0	0	0	0	0	0	*0*
flathead sole	0	0	0	0	0	0	0	0	*0*
Pacific cod	14	0	0	0	0	0	0	0	*0*
rex sole	2	0	0	0	0	0	2	3	*1*
rockfish	9	12	2	10	3	5	14	4	*12*
sablefish	0	4	0	0	0	0	0	0	*0*
shallow flatfish	0	0	0	0	1	0	1	0	*0*
pollock	48	139	628	1,504	405	78	314	121	*199*
total GOA catch	77	157	632	1,516	412	84	337	131	*228*

Table 4. Estimated catch (t) of all squid species in the Gulf of Alaska combined by NMFS statistical area, 1997-2011. Data sources: 1997-2002, AKRO Blend; 2003-2010, AKRO CAS. *2011 are incomplete; reported November 3, 2011.

	NMFS statistical area							
	610	**620**	**630**	**640**	**649**	**650**	**659**	**total**
1997	46	4	36	2	6	4	0	98
1998	18	8	21	3	9	0	0	59
1999	6	11	14	2	8	0	0	41
2000	7	2	8	2	0	0	0	19
2001	19	54	17	1	0	0	0	91
2002	19	12	10	1	0	0	0	42
2003	19	43	13	2	20	0	0	97
2004	15	129	11	2	5	0	0	162
2005	13	607	11	2	3	0	0	636
2006	12	1,485	14	5	14	0	0	1,530
2007	3	403	5	0	0	0	0	412
2008	4	77	2	0	0	0	0	84
2009	12	315	10	1	0	0	0	337
2010	3	121	5	2	0	0	0	131
**2011*	*8*	*197*	*18*	*4*	*0*	*0*	*0*	*228*

Table 5. Biomass estimates (t) of squid species from NMFS GOA bottom trawl surveys, 1984-2011. CV = coefficient of variation.

	unidentified squids		*B. magister*		all squids	
year	biomass (t)	CV	biomass (t)	CV	biomass (t)	CV
1984	546	0.35	2,762	0.15	3,308	0.14
1987	577	0.30	4,506	0.34	5,083	0.30
1990	276	0.43	4,033	0.17	4,309	0.16
1993	1,029	0.73	8,447	0.13	9,476	0.14
1996	26	0.28	4,884	0.14	4,911	0.14
1999	254	0.46	1,873	0.13	2,127	0.13
2001	703	0.62	5,909	0.30	6,612	0.27
2003	71	0.23	6,251	0.18	6,322	0.18
2005	249	0.51	4,650	0.18	4,899	0.18
2007	310	0.45	11,681	0.20	11,991	0.20
2009	188	0.61	8,415	0.16	8,603	0.16
2011	392	0.65	4,039	0.13	4,431	0.14

Figures

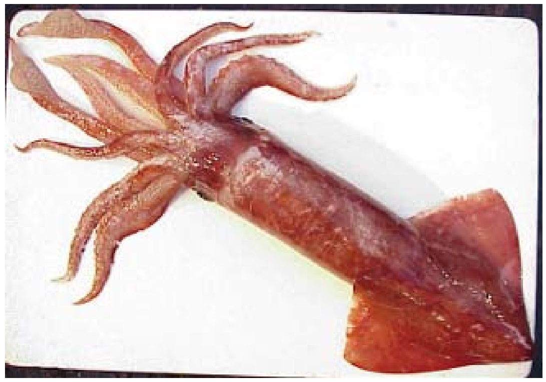


Figure 1. *Berryteuthis magister*, the magistrate armhook or red squid, is a common species in the GOA and shows the general physical characteristics of species in the Order Teuthoidea.

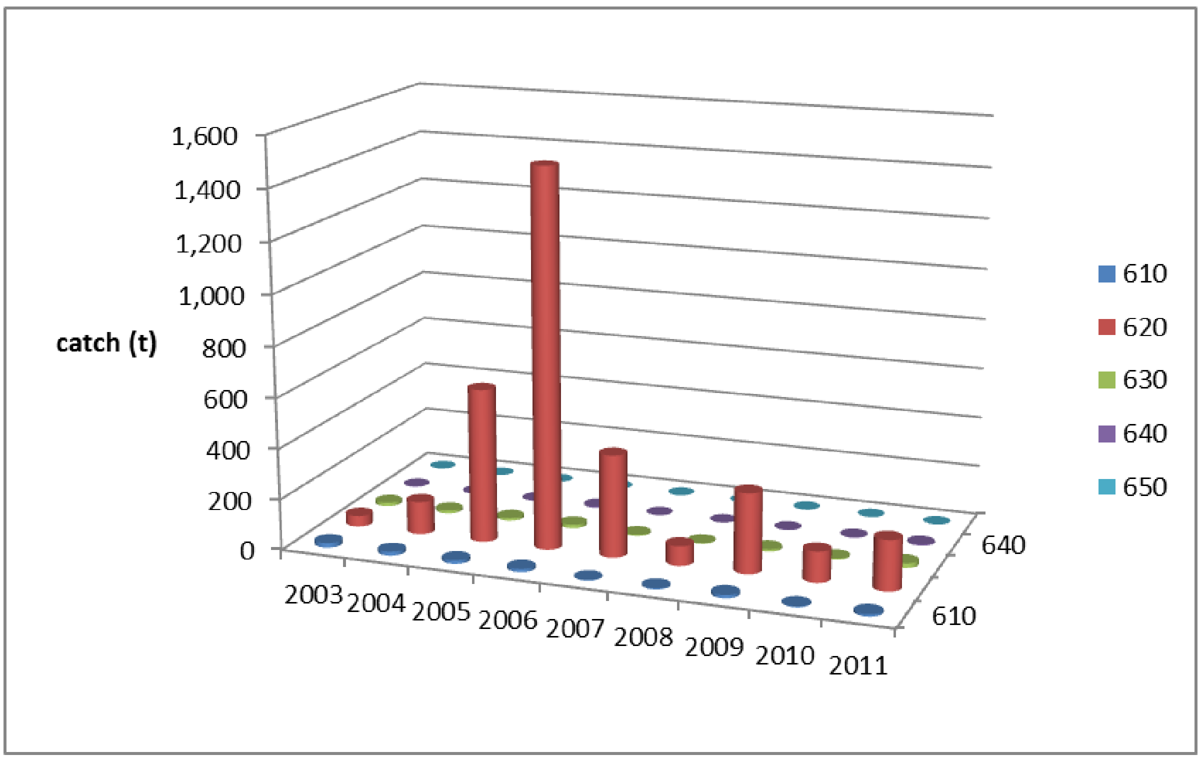


Figure 2. Estimated catch (t) of all squid species combined in the Gulf of Alaska by NMFS statistical area, 2003-2011. Data source: AKRO CAS. *2011 data are incomplete; reported November 3, 2011.

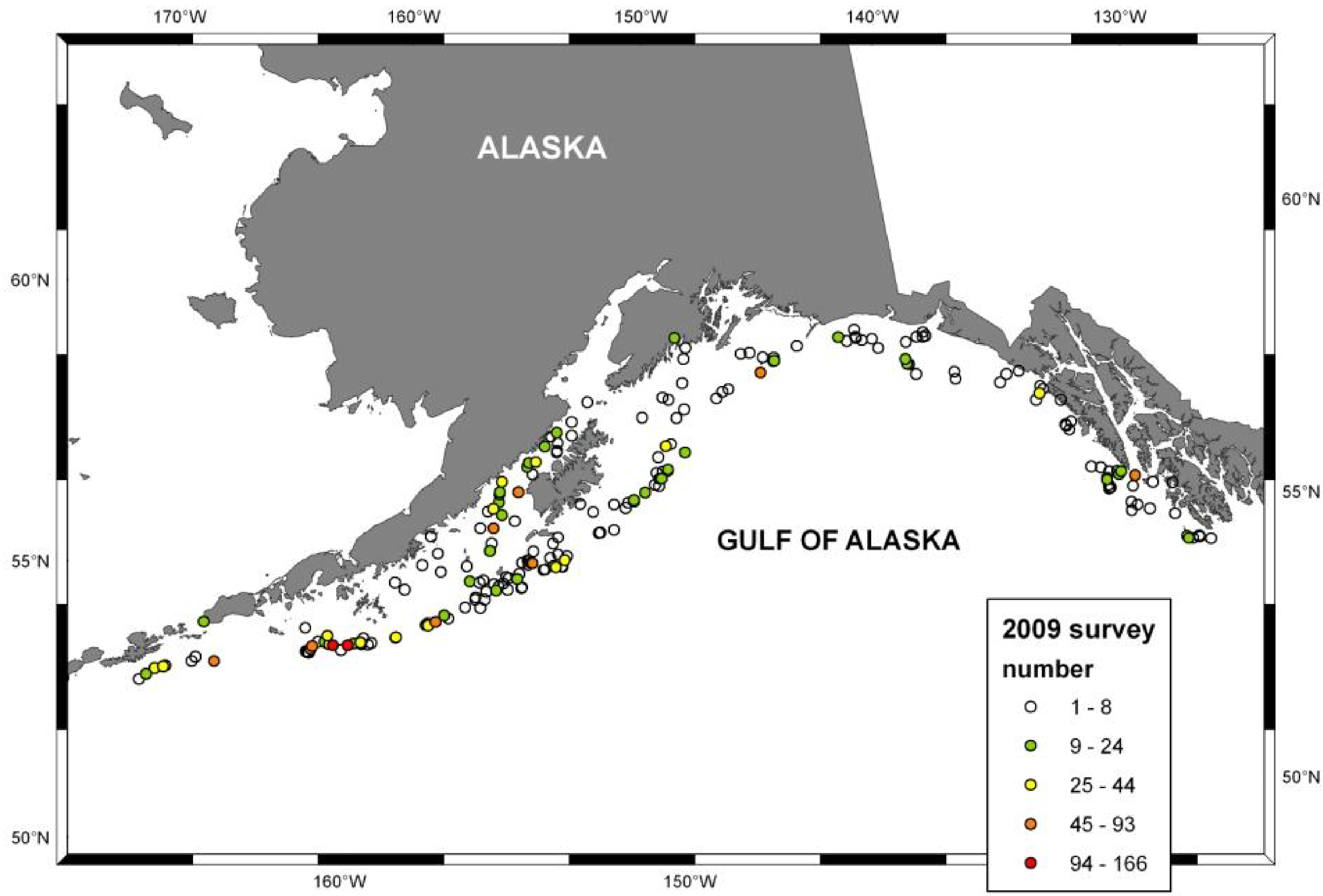


Figure 3. Distribution of <u>survey</u> catches of all squids in the GOA during 2009.

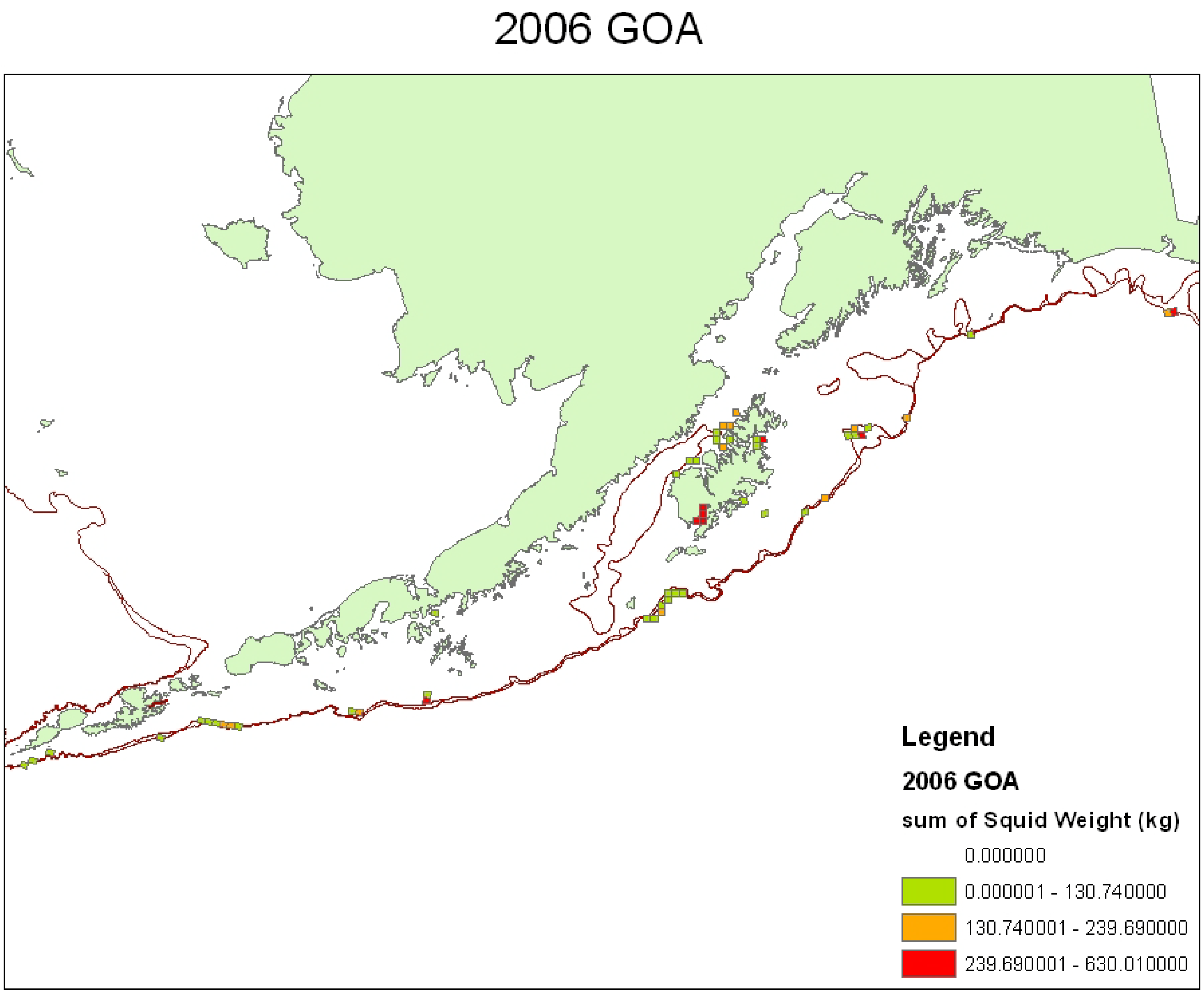


Figure 4. Distribution of incidental quid catches in the GOA by year. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown.

2007 GOA

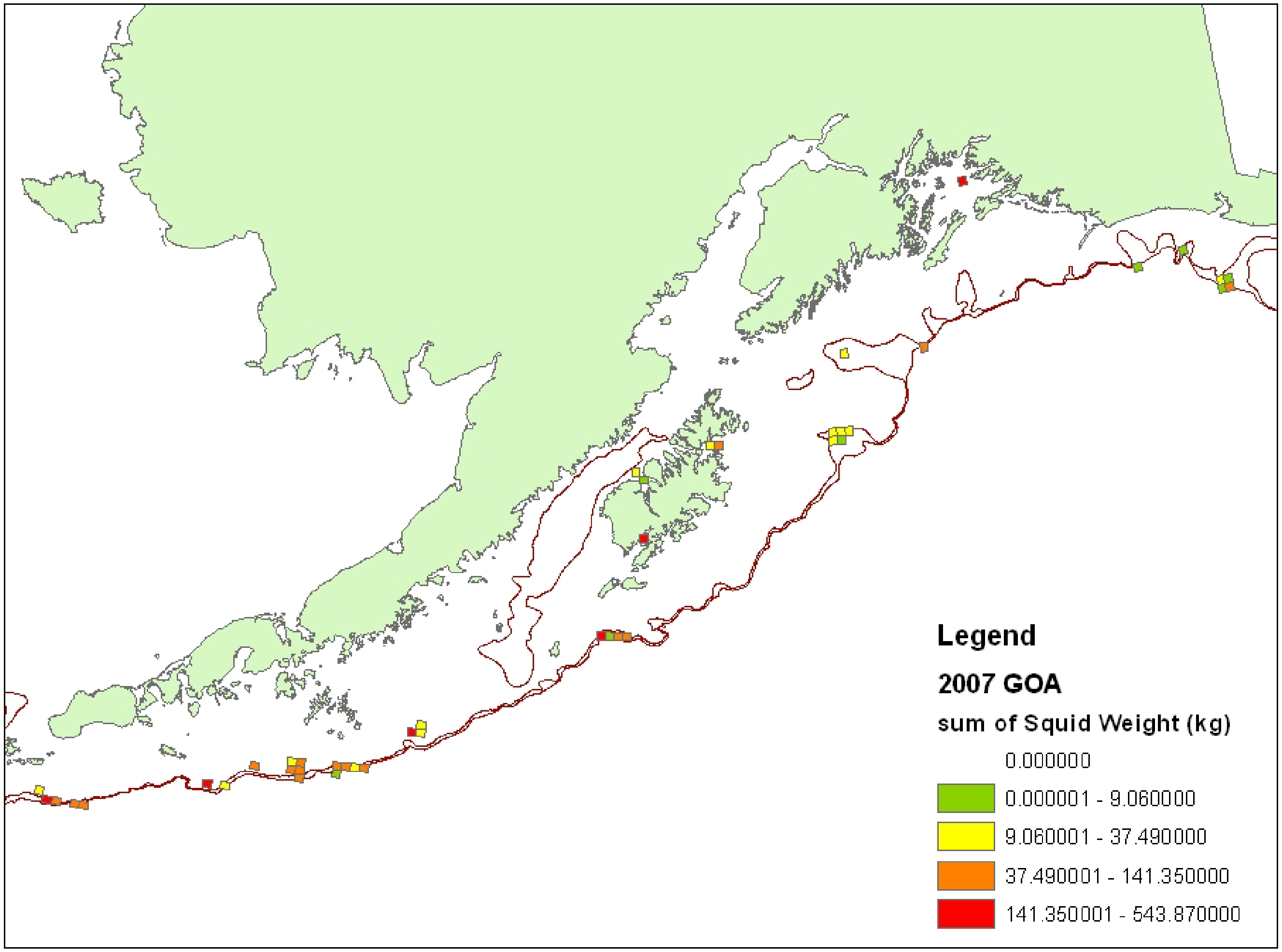


Figure 4 (continued). Distribution of incidental quid catches in the GOA by year. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown.

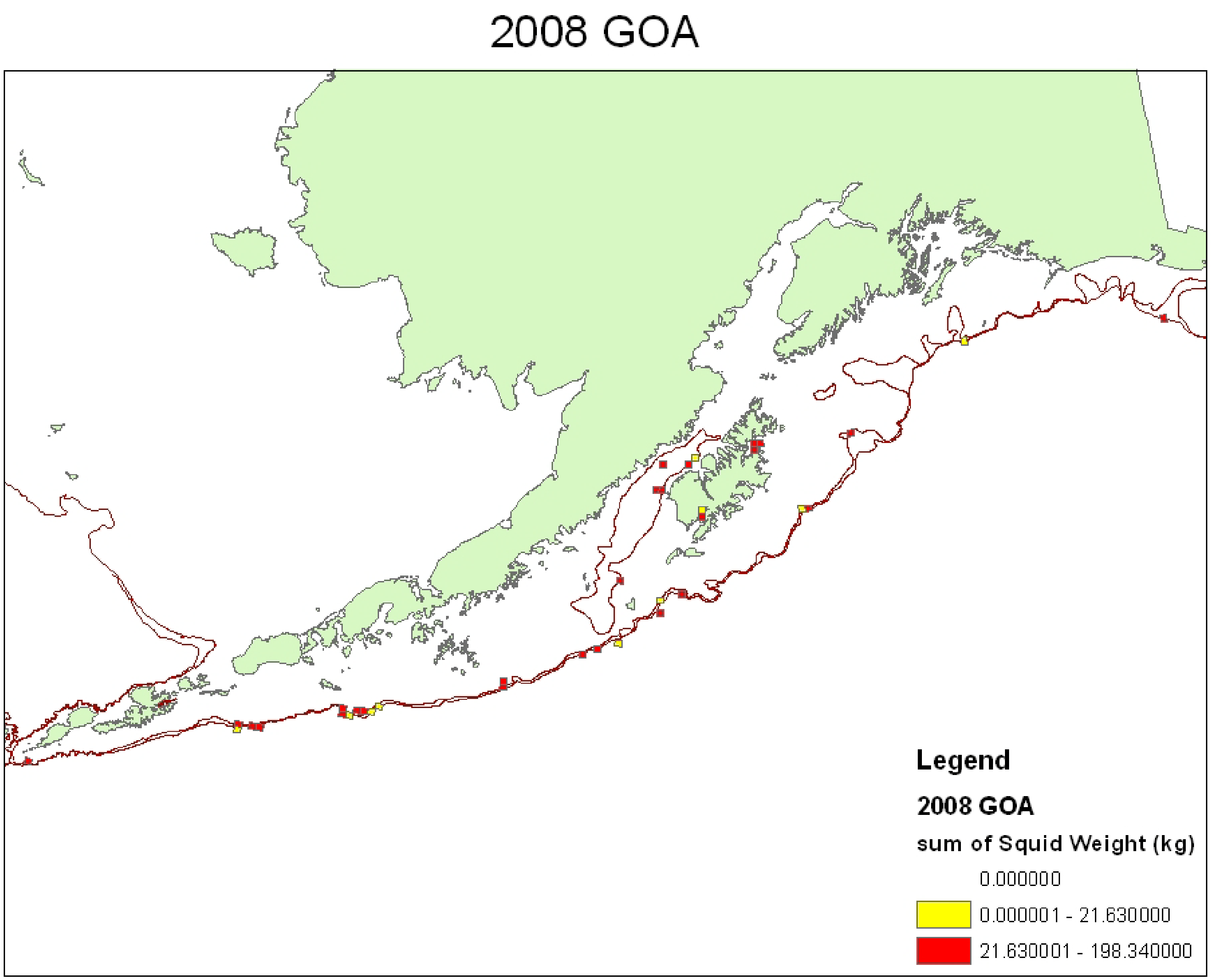


Figure 4 (continued). Distribution of incidental quid catches in the GOA by year. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown.

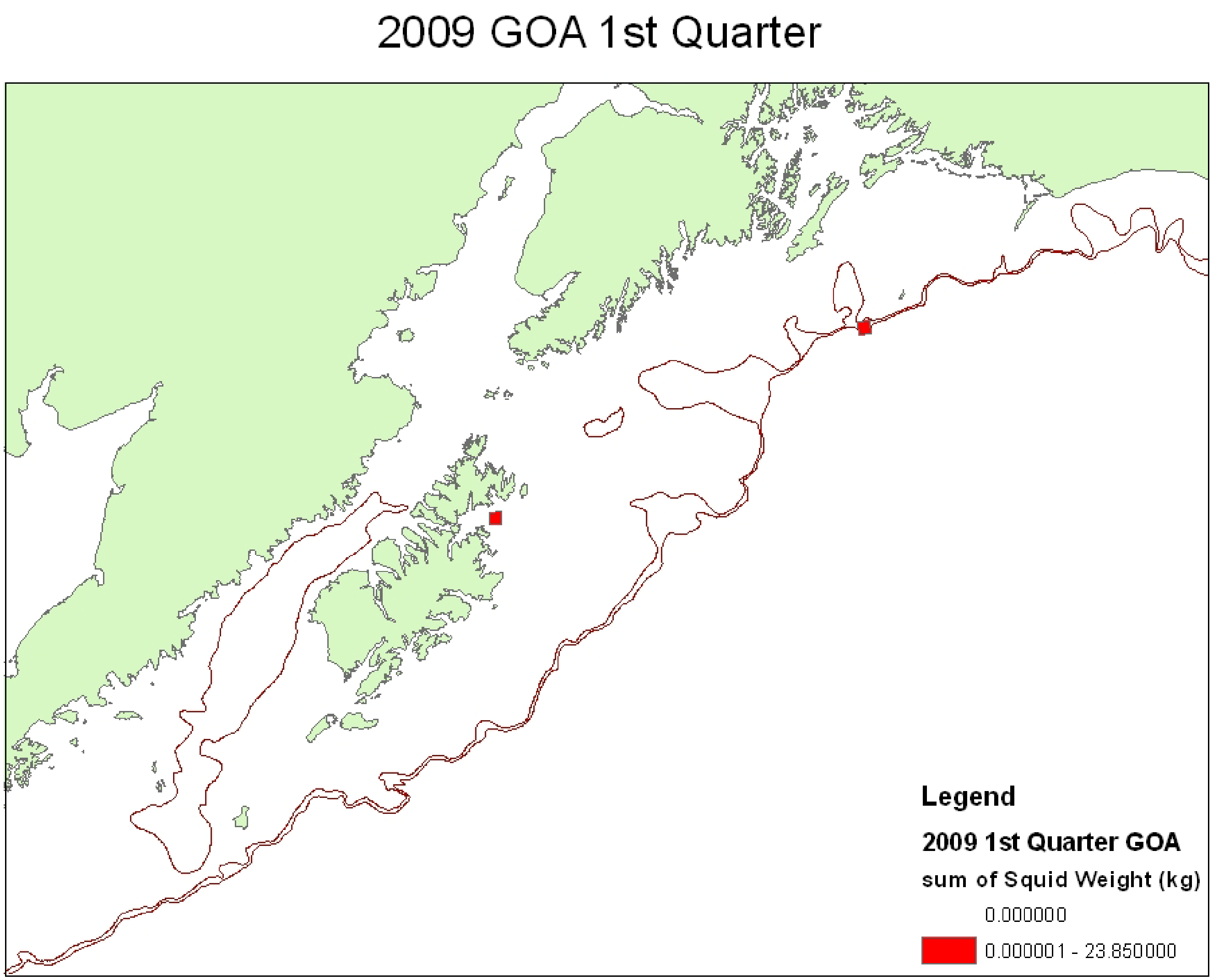


Figure 5. Incidental catch of squids in 2009, by quarter. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown. No non-confidential data were available for the 4th quarter.

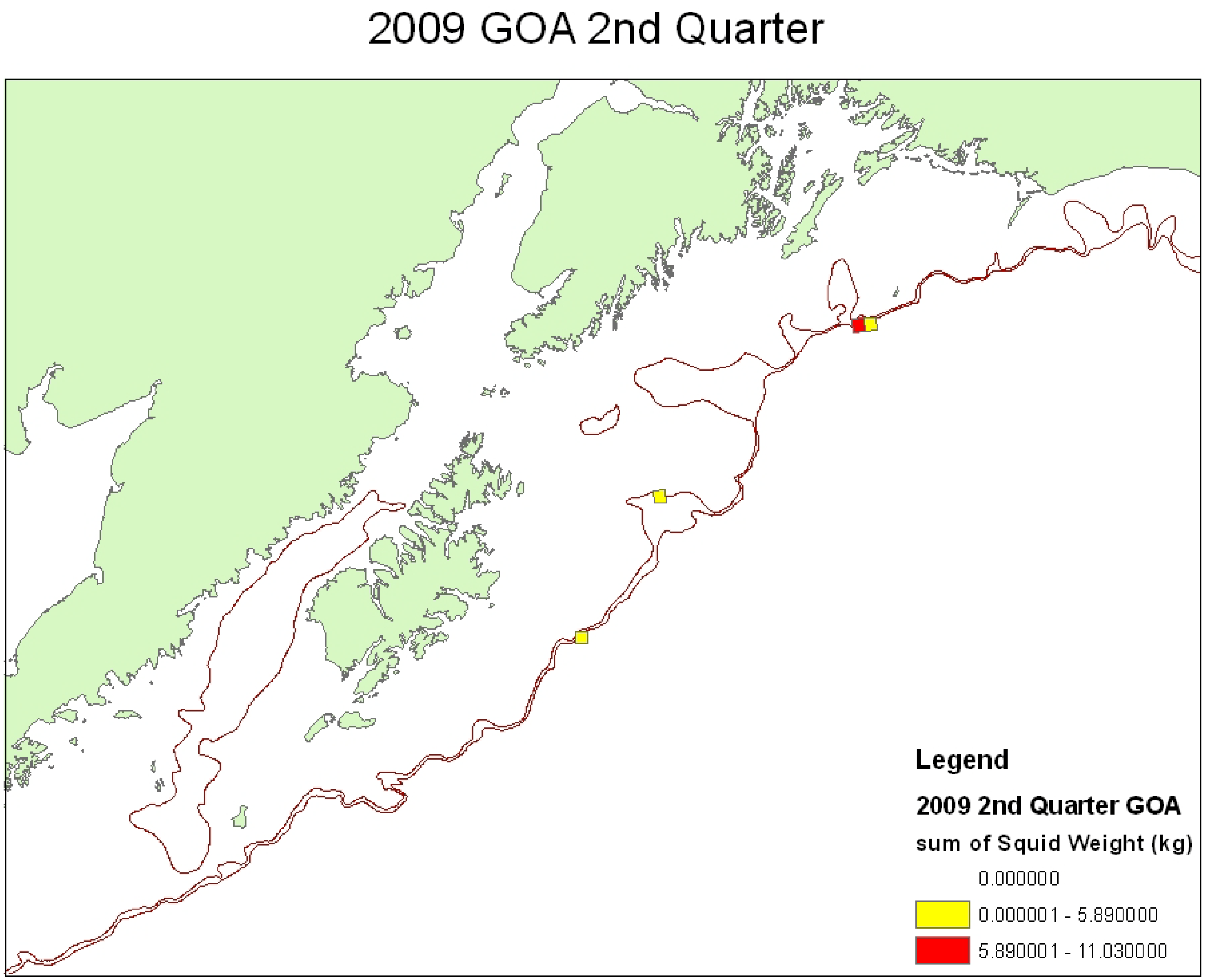


Figure 5 (continued). Incidental catch of squids in 2009, by quarter. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown. No non-confidential data were available for the 4^{th} quarter.

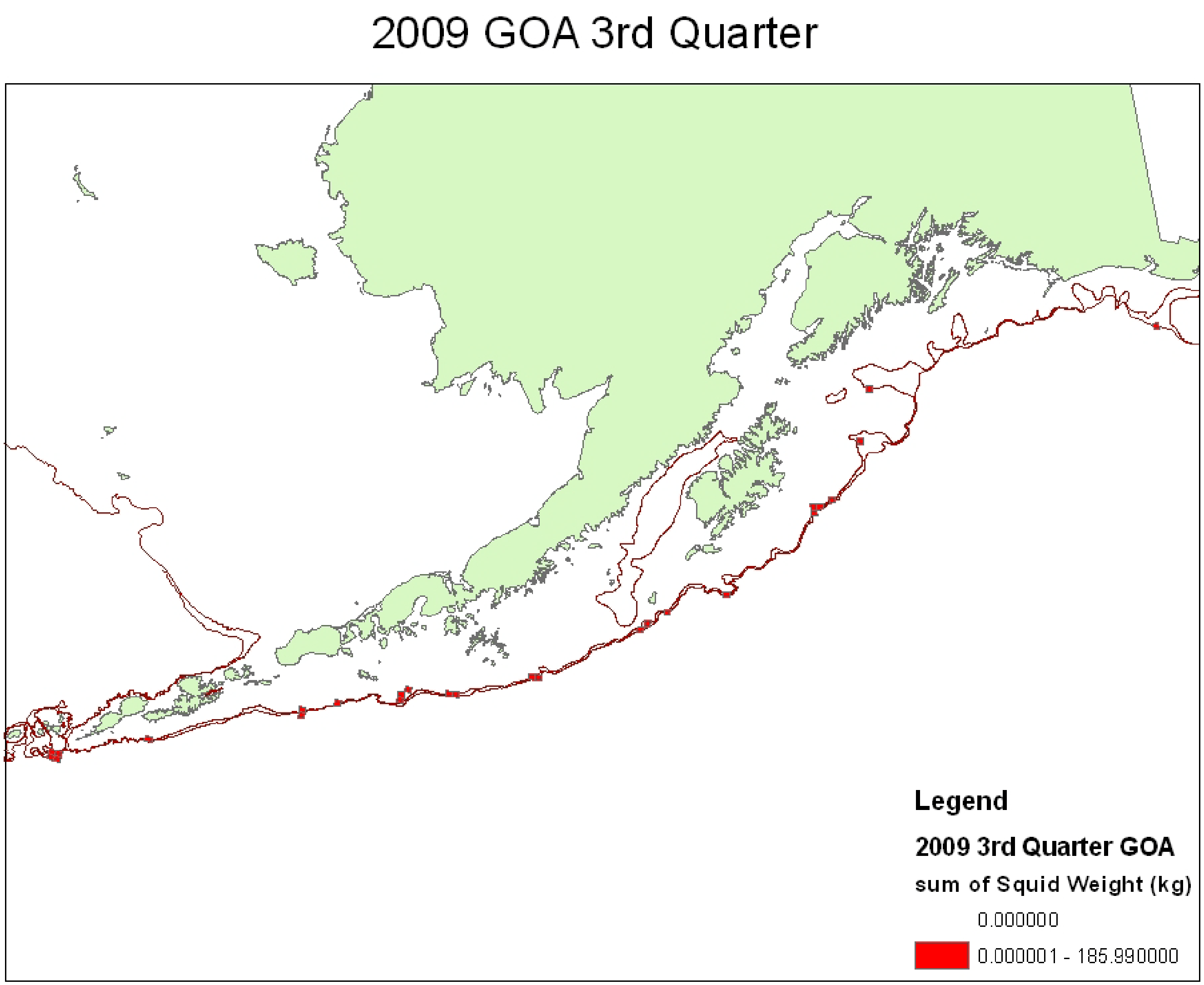


Figure 5 (continued). Incidental catch of squids in 2009, by quarter. Data have been screened for confidentiality, so only 100 km^2 grid cells with data for 3 or more vessels are shown. No non-confidential data were available for the 4^{th} quarter.

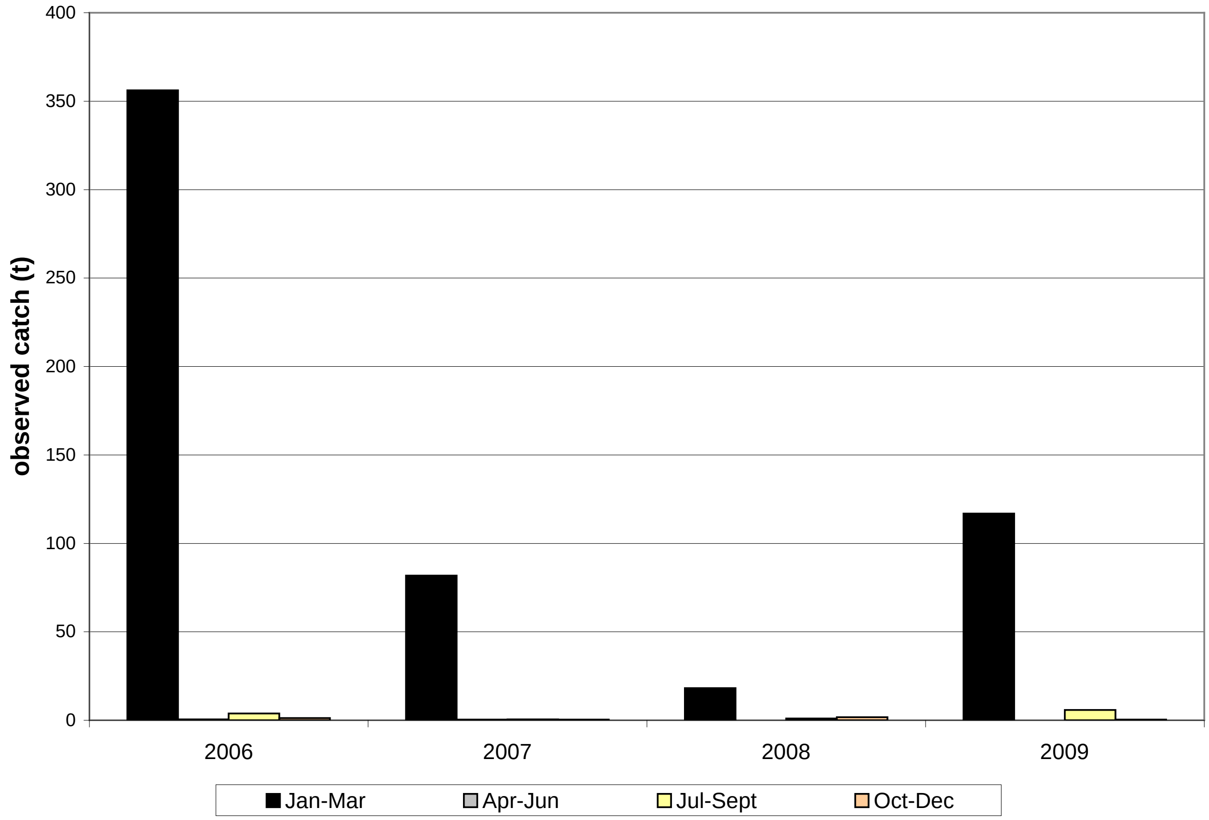


Figure 6. Observed squid catch by quarter, 2006-2009.

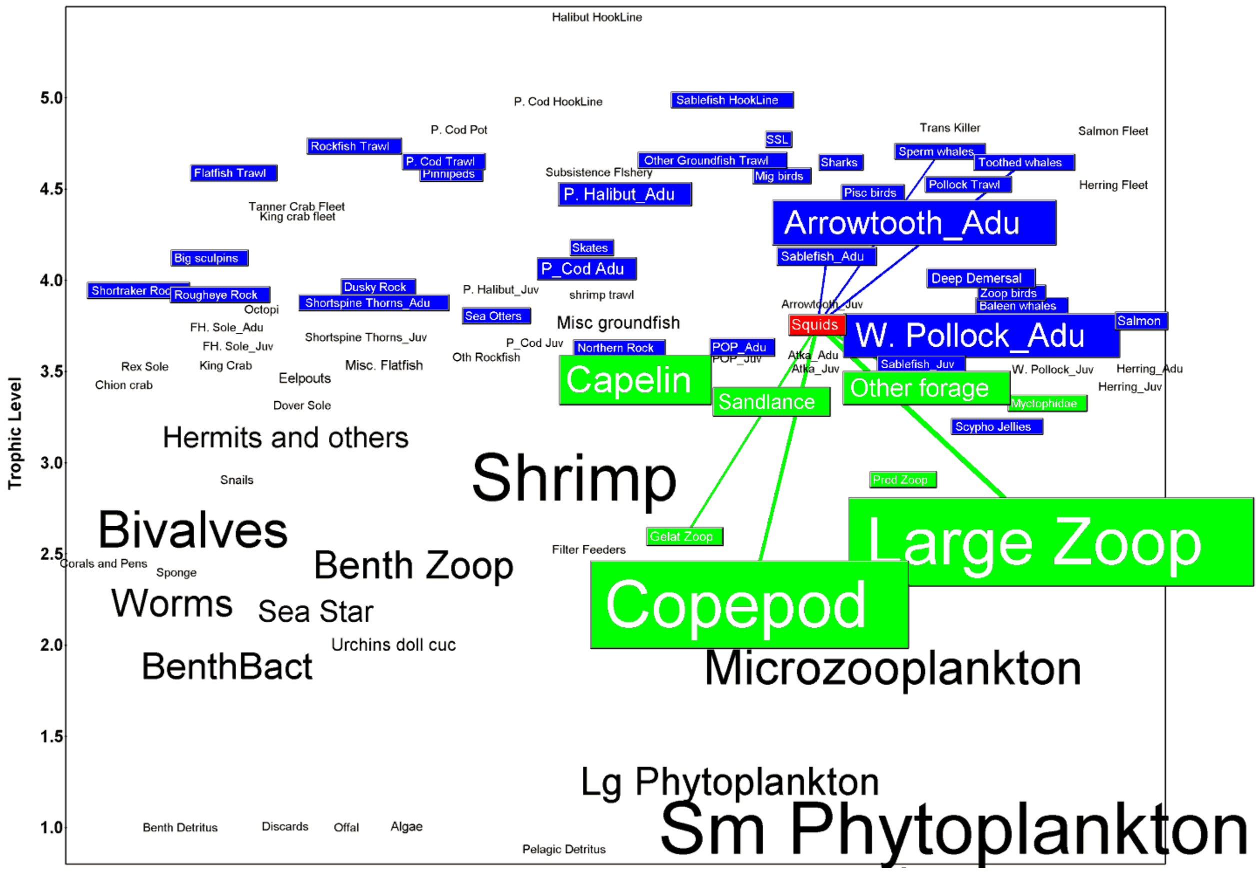


Figure 7. Food web of squids in the Gulf of Alaska, with squids highlighted in red, their predators in blue, and prey in green. Box size is proportional to the biomass of the group in the Gulf of Alaska, and lines between boxes indicate the strength of the flow between groups. If a group is highlighted but there is no line connecting it to squid, then the flow between those groups is less than 5% of all energy flows into or out of squid. Wider lines indicate stronger flows, for instance the strongest prey flow into squid comes from large zooplankton, followed by copepods.

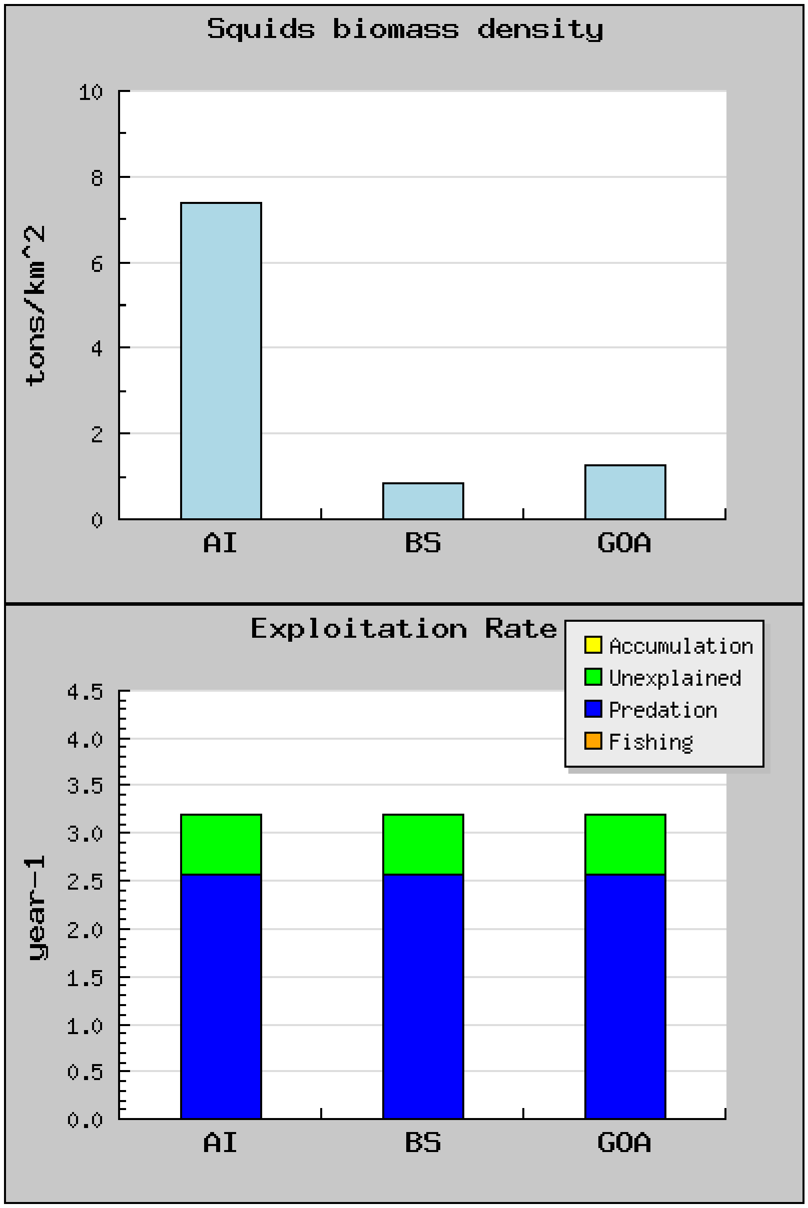


Figure 8. (Upper) Biomass density (tons per square kilometer) estimated by ecosystem models of the AI, EBS, and GOA. (Lower) Exploitation rates partitioned into mortality due to predation, fishing, and unexplained sources. (Fishing mortality has been included in this calculation, but is too small to show on the plot.)

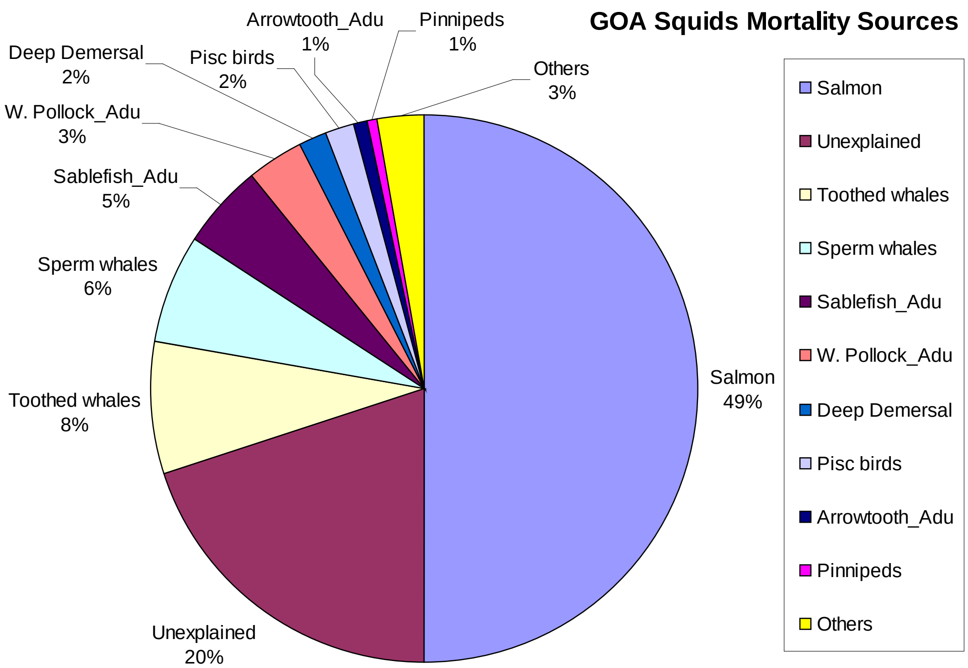


Figure 9. Proportion of mortality of squids attributable to each of their predators in the Gulf of Alaska. Lg. or Deep demersals is primarily grenadiers (Macrouridae) in the GOA.

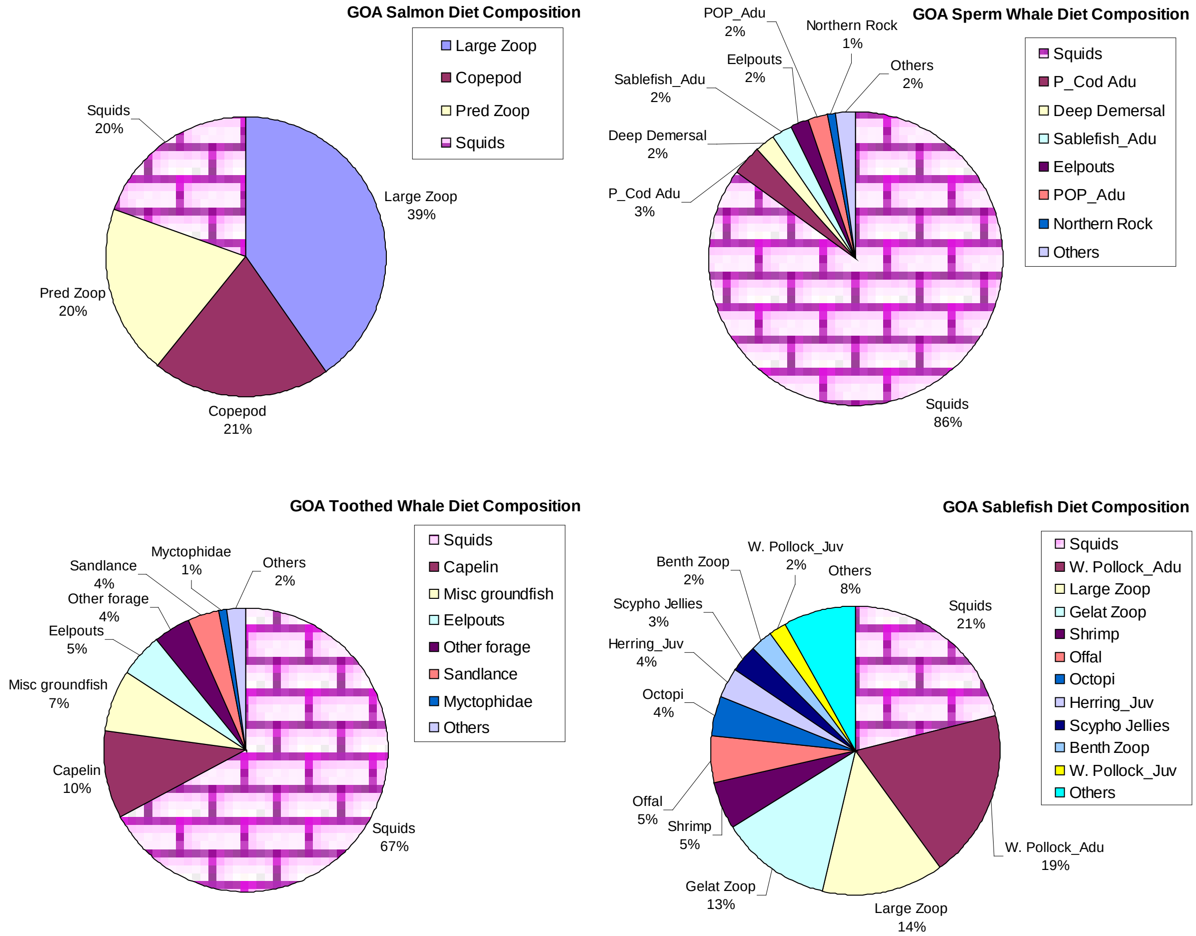


Figure 10. Proportion of squids in diets of major squid consumers in the GOA: salmon (top left), sperm whales (top right), other toothed whales (bottom left), and sablefish (bottom right). Note that squids are always the patterned section of each plot; colors for other species groups are not consistent between plots.

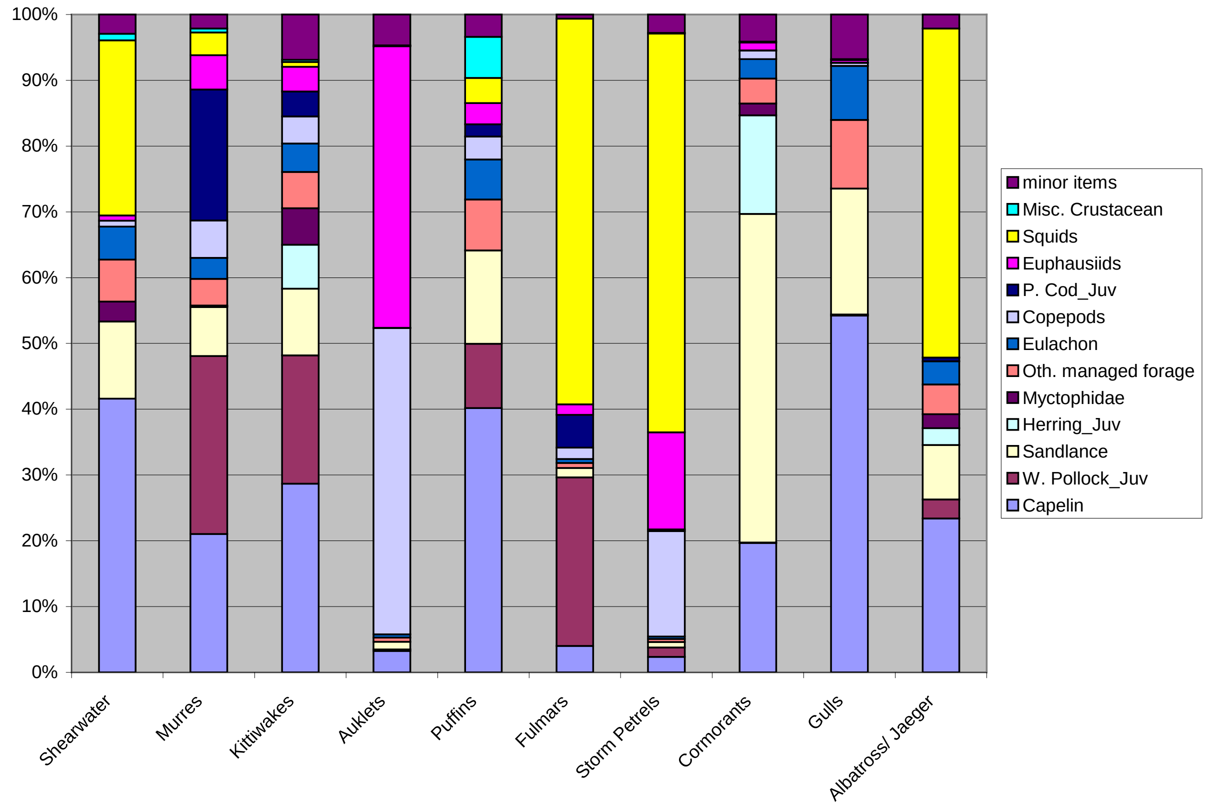


Figure 11. Estimated diet composition of seabirds in the GOA. Data are the inputs used in ecosystem modeling performed at the AFSC (Aydin et al. 2007) and are based largely on Hunt et al. (2000). Albatrosses and jaegers are considered a single functional group for modeling purposes.

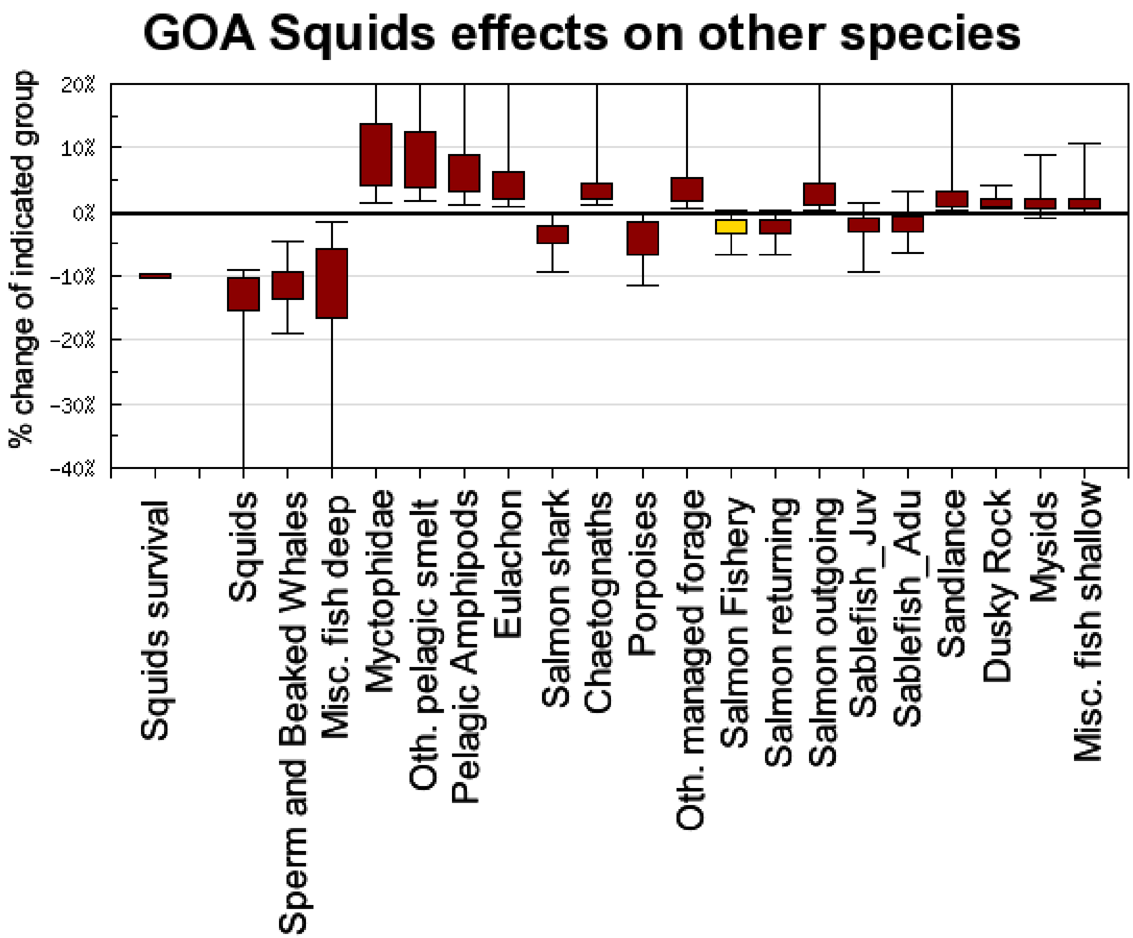
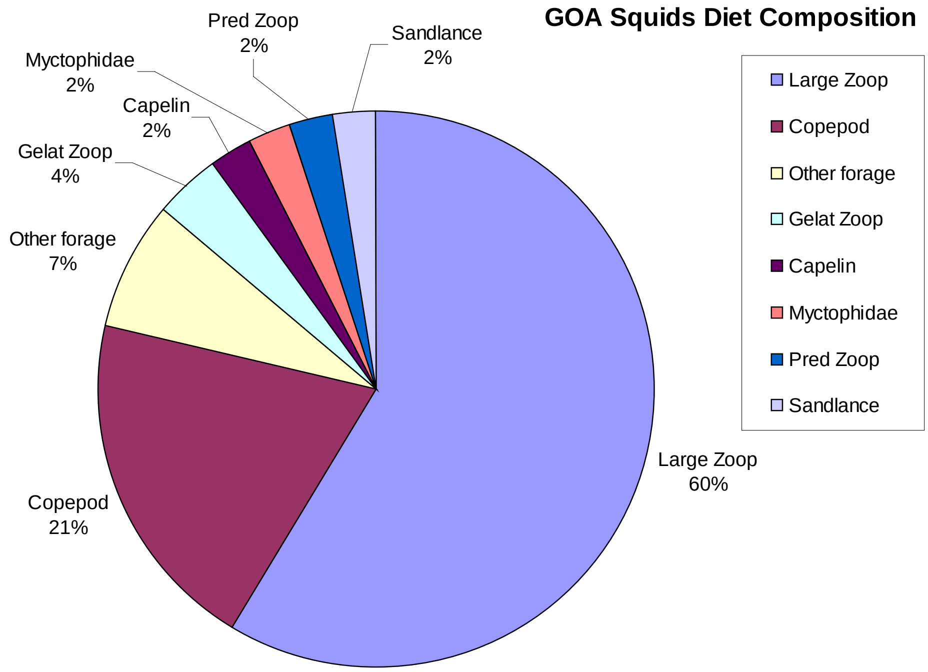


Figure 12. Results of a simulation analysis where squid mortality was increased (survival was decreased) by 10% in the GOA ecosystem model. Boxes represent the 50% confidence interval, and error bars reflect the 95% confidence interval of the percent change in biomass relative to the baseline condition in the model. The leftmost bar indicates the type of perturbation (Squids survival decreases 10%), and every other bar from left to right shows the outcome to each living group in the GOA ecosystem model in order of descending effect from largest to smallest (effects to groups not shown were insignificant). In this simulation, the group aggregated as “toothed whales” in previous plots are included in the groups “Sperm and beaked whales” and “Porpoises.” This change was made for comparison across the GOA, EBS, and AI models. In all cases, the underlying model is the same.



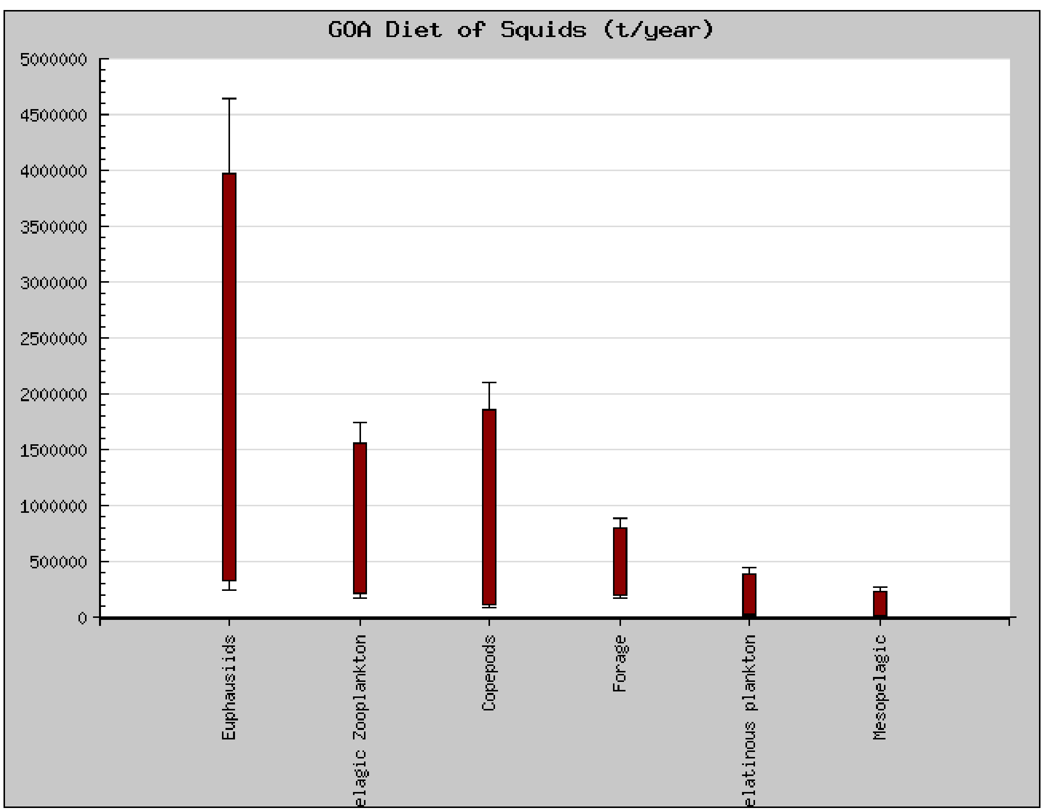


Figure 13. Diet composition (upper) and consumption (lower) by squid in the Gulf of Alaska.

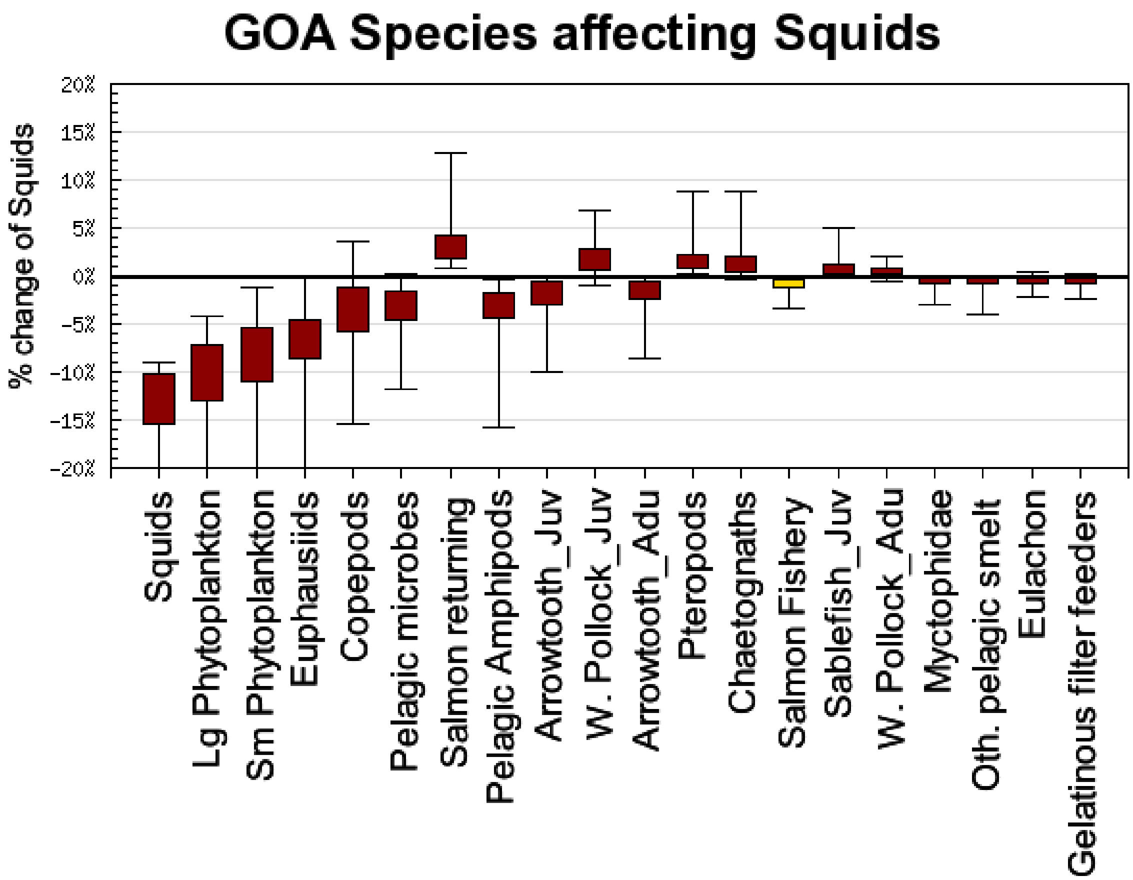


Figure 14. Predicted change in GOA squid biomass resulting from a series of perturbations where each species group in the ecosystem had its survival decreased by 10%. Species groups affecting squids are listed in descending order from left to right by the largest percent change in squid biomass resulting from that species decreased survival. Therefore, biomass of GOA squids is most affected by a 10% reduction in squid survival, as might be expected. Following the direct effect on squid is the bottom up effect felt by the entire ecosystem of reducing survival of large and small phytoplankton.

Appendix: Summary of research catches

Table 1. Catches in GOA research surveys conducted by the Resource Assessment and Conservation Engineering Division of the AFSC, 1954-2011.

year	squid catch (kg)		year	squid catch (kg)
1954	4.3		1990	585.1
1957	0.7		1991	34.2
1958	0.2		1992	76.6
1959	0.5		1993	1,366.4
1960	0.2		1994	173.4
1961	12.0		1995	17.0
1962	7.7		1996	950.2
1963	3.9		1997	40.2
1964	1.5		1998	232.3
1965	54.4		1999	2,018.4
1967	0.9		2000	24.7
1970	18.8		2001	508.3
1971	0.5		2002	28.8
1972	3.2		2003	597.0
1973	49.5		2004	114.5
1974	42.8		2005	406.8
1975	29.2		2006	363.6
1976	42.9		2007	1,026.3
1977	55.5		2008	41.2
1978	296.0		2009	768.8
1979	193.8		2010	60.4
1980	134.7		2011	291.8
1981	2,909.2			
1982	4,967.0			
1983	329.9			
1984	2,166.5			
1985	5,047.9			
1986	4,123.1			
1987	3,131.9			
1988	11.3			
1989	129.9			

Table 2. Squid catch during GOA research activities in 2010.

research activity	catch (kg)
2010 MACE Shelikof Acoustic Survey	13.4
2010 MACE Shumigans Acoustic Survey	1.2
2010 ADF&G small-mesh trawl survey	56.9
WGOA Pollock Acoustic Cooperative Survey	0.01

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