Sablefish, *Anoplopoma fimbria*, Populations on Gulf of Alaska Seamounts

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ABSTRACT—Sablefish, Anoplopoma fimbria, *were tagged and released on Gulf of Alaska seamounts during 1999–2002 to determine the extent, if any, of emigration from the seamounts back to the continental slope and of movement between seamounts. Seventeen sablefish from Gulf of Alaska seamounts have been recovered on the continental slope since tagging began, verifying that seamount to slope migration occurs. Forty-two sablefish were recovered on the same seamounts where they were tagged, and none have been recaptured on seamounts other than the ones where they were released.*

Sablefish populations on Gulf of Alaska seamounts are made up of individuals mostly older than 5 years and are male-dominant, with sex ratios varying from 4:1 up to 10:1 males to females. Males are smaller than females, but the average age of males is greater than that of females, and males have a greater range of age (4–64 yr) than females (4–48 yr). Otoliths of seamount fish frequently have an area of highly compressed annuli, known as the transition zone, where growth has suddenly and greatly slowed or even stopped. Because transition zones can be present in both younger and older seamount fish and are rare in slope fish, formation of otolith transition zones may be related to travel to the seamounts.

The route sablefish use to reach the seamounts is so far unknown. One possibility is that fish enter the eastward-flowing North Pacific Current off the Aleutian Islands or western Gulf of Alaska and travel more or less passively on the current until encountering a seamount. The route from seamount back to slope would likely be the northward-flowing Alaska Current. These routes are discussed in light of tag recovery locations of slope- and seamount-tagged fish.

Introduction

The Gulf of Alaska seamounts are a group of undersea mountains of volcanic origin rising from the ocean floor at depths of 3,200–4,000 m to within 400–800 m of the surface (Fig.1). They are located in the eastern and central Gulf of Alaska at distances of 270–465 km offshore. Half of the major seamounts in this group fall within the U.S. Exclusive Economic Zone and half are outside; all are separated from the continental slope by waters from 2,900 to about 5,000 m in depth.

NOAA's National Marine Fisheries Service (NMFS) first conducted exploratory fishing on nine Gulf of Alaska (GOA) seamounts in June and July 1979 (Hughes, 1981). Using trawls and traps, they found that sablefish, *Anoplopoma fimbria*, were the dominant finfish on each of the seamounts and that trap catch rates of sablefish were higher than those from NMFS survey sites off southeastern Alaska. There were more than twice as many males as females, and nearly all sablefish were ripe, spawning, or recently spent. However, only older and larger fish were caught on the seamounts, suggesting that the seamount populations are maintained by the migration of mature fish from the continental slope rather than by local recruitment.

Tagged sablefish released in the Bering Sea, Aleutian Islands (BSAI) region, and the western and central GOA have been recovered on GOA seamounts, verifying the occurrence of slope to seamount migration (Shaw and Parks, 1997). Of 99 tagged sablefish released on 5 GOA seamounts in 1979, 5 have been recovered on the seamount where they were tagged, and none have been recovered elsewhere.

NMFS revisited seven of the seamounts sampled in 1979 and one (Murray Seamount) that was not sampled in 1979. Sablefish were tagged and released on the seamounts during 1999–2002 to determine the extent, if any, of emigration from the seamounts back to the continental slope and movement between seamounts. A second objective was to gather biological information from the seamount sablefish populations.

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Materials and Methods

Seamount sampling was conducted aboard chartered commercial fishing vessels during NMFS longline surveys in 1999–2002. These longline surveys, conducted annually, sample stations along the continental slope of the Bering Sea and Aleutian Islands (alternate years) and the GOA (every year) to determine the relative abundance and size composition of commercially important species. During the survey each year, several thousand sablefish are tagged and released to provide information on growth and movement rates. Three seamounts per year were sampled during the first week of July. Giacomini, Surveyor, and Pratt Seamounts were sampled in 1999. In 2000, Surveyor and Pratt were revisited and Welker Seamount was sampled for the first time. Surveyor was sampled for the third time in 2001, Welker for the second time, and Dickens Seamount for the first time. Patton, Murray, and Durgin Seamounts were sampled in 2002. A total of 12 samples were taken at 8 seamounts from 1999 to 2002 (Table 1).

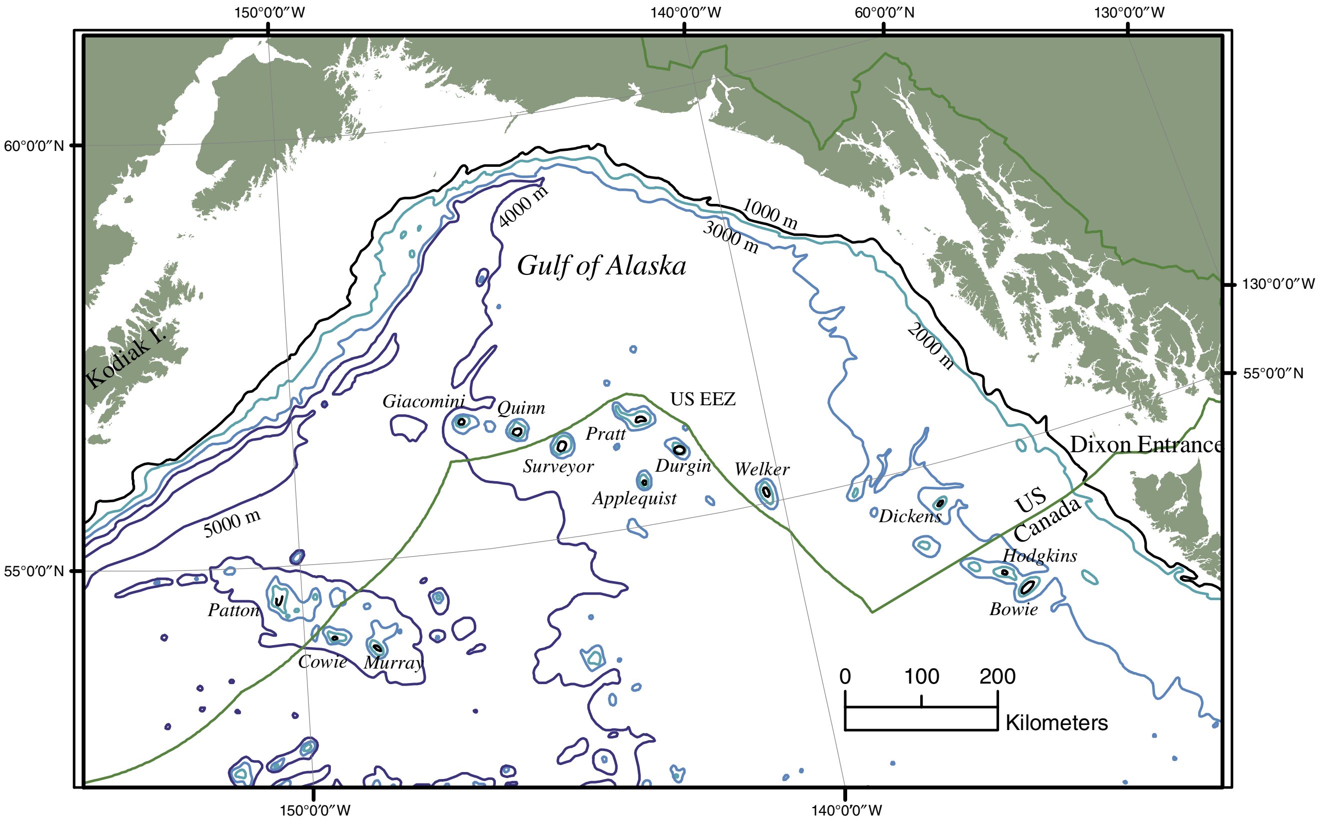

Figure 1.—Gulf of Alaska seamounts.

Standard survey longline gear and techniques (Rutecki[1]) were used on the seamounts. At each seamount, 2 sets of 80 skates each with a total of 7,200 hooks were set and retrieved. Two exceptions to this were Giacomini Seamount in 1999 and Dickens Seamount in 2001, where only 120 skates were set. Some skates were also lost on Dickens Seamount due to entanglement in rough substrate. Catch data were recorded on a hand-held electronic data logger during gear retrieval and subsequently downloaded to a computer. Length frequency and sex data were collected with a bar-code-based measuring board and a bar-code reader/data storage device (Sigler, 1994). Usually, all sablefish that were not either tagged or sampled for otoliths were measured and sexed. Sablefish lengths were combined by year to ensure adequate sample sizes.

[1]Rutecki, T. 2004. Longline survey of the Gulf of Alaska and Eastern Bering Sea, May 28–September 1, 2003. Cruise Report OP-01-03. U.S. Dep. Commer., NOAA, NMFS, Auke Bay Lab., 11305 Glacier Hwy., Juneau, AK 99801.

Table 1.—Gulf of Alaska seamounts sampled by NMFS in 1979 and 1999–2002.

			Year sampled (X)				
Seamount	Lat.	Long.	1979	1999	2000	2001	2002
Applequist	55°28.5′N	142°46.4′W	X				
Dickens	54°31.3′N	136°56.0′W	X			X	
Durgin	55°50.0′N	141°51.5′W	X				X
Giacomini	56°27.5′N	146°24.0′W	X	X			
Murray	53°57.0′N	148°31.0′W					X
Patton	54°34.4′N	150°29.5′W	X				X
Pratt	56°14.4′N	142°32.0′W	X	X	X		
Quinn	56°18.3′N	145°13.1′W	X				
Surveyor	56°03.1′N	144°19.3′W	X	X	X	X	
Welker	55°06.7′N	140°20.6′W	X		X	X	

Starting with the fifth skate of each set, the first three sablefish of every tenth skate were set aside for age and condition sampling. These fish were weighed and measured, their stage of sexual maturity noted, and their otoliths collected and stored in a 50% ethyl alcohol solution for later ageing in the laboratory. Otoliths were read by experienced readers of the Age and Growth Program at the NMFS Alaska Fisheries Science Center (AFSC) in Seattle, Wash., using the ageing methods of Beamish and Chilton (1982). A total of 440 sablefish were aged. The first 150 sablefish of each set, except for fish set aside for otolith extraction or fish that were damaged during retrieval, were tagged with anchor tags, measured for length, and released. Release and recovery data discussed here were ob-

Table 2.— Numbers of individuals of fish and invertebrate species caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

	Common name	Total catch	Common name	Total catch	Common name	Total catch
1999	**Giacomini**		**Surveyor**		**Pratt**	
	Giant grenadier	1,019	Giant grenadier	1,448	Giant grenadier	985
	Sablefish	933	Sablefish	785	Sablefish	689
	Pacific grenadier	229	Rougheye, shortraker	124	Longspine thornyhead	72
	Pacific flatnose	9	Pacific flatnose	39	Pacific grenadier	15
	Coral	9	Longspine thornyhead	28	Tanner crab	10
	Longspine thornyhead	7	Shortspine thornyhead	16	Pacific flatnose	4
	Sponge	4	Tanner crab	7	Sponge	3
			Pacific grenadier	6	Starfish	2
			Coral	4	Shortspine thornyhead	2
			Starfish	2	Scarlet king crab	4
			Salmon	2	Coral	1
2000	**Surveyor**		**Pratt**		**Welker**	
	Giant grenadier	1,486	Giant grenadier	1,128	Sablefish	2,158
	Sablefish	666	Sablefish	684	Giant grenadier	330
	Shortspine thornyhead	33	Longspine thornyhead	41	Pacific flatnose	13
	Longspine thornyhead	27	Pacific grenadier	11	Pacific grenadier	10
	Pacific flatnose	13	Starfish	7	Longspine thornyhead	6
	Starfish	5	Shortspine thornyhead	5	Tanner crab	5
	Coral	5	Tanner crab	4	Sea anemone	5
	Brittle starfish	4	Pacific flatnose	4	Starfish	1
	Pacific grenadier	3	Scarlet king crab	6	Sponge	1
	Scarlet king crab	4	Spiny dogfish	2	Sea cucumber	1
	Rougheye, shortraker rockfish	2	Sea anemone	1		
	Tanner crab	1				
2001	**Surveyor**		**Welker**		**Dickens**	
	Giant grenadier	692	Sablefish	1,325	Sablefish	1,395
	Sablefish	326	Giant grenadier	488	Rougheye, shortraker rockfish	667
	Pacific flatnose	178	Pacific grenadier	168	Giant grenadier	52
	Longspine thornyhead	70	Pacific flatnose	58	Coral	10
	Shortspine thornyhead	66	Longspine thornyhead	8	Aurora rockfish	6
	Pacific grenadier	47	Tanner crab	8	Shortspine thornyhead	3
	Starfish	10	Coral	4	Scarlet king crab	3
	Coral	4	Sponge	2	Pacific sleeper shark	2
	Tanner crab	1			Starfish	1
	Sea anemone	1			Pacific flatnose	1
					Golden king crab	1
					Blackfin sculpin	1
					Pomfret	1
2002	**Patton**		**Murray**		**Durgin**	
	Giant grenadier	1,695	Giant grenadier	2,941	Giant grenadier	332
	Sablefish	957	Pacific grenadier	827	Sablefish	255
	Shortspine thornyhead	56	Sablefish	83	Longspine thornyhead	28
	Brittle starfish	54	Pacific flatnose	21	Pacific flatnose	22
	Rougheye, shortraker rockfish	41	Coral	14	Tanner crab	7
	Crinoid	29	Scarlet king crab	2	Scarlet king crab	6
	Pacific grenadier	4	Coho salmon	2	Pacific grenadier	3
	Longspine thornyhead	4	Tanner crab	1	Starfish	2
	Scarlet king crab	4	Sea anemone	1	Sea anemone	1
	Coral	4				
	Pacific flatnose	3				
	Aurora rockfish	2				
	Starfish	1				
	Golden king crab	1				
	Sponge	1				

tained from the NMFS Sablefish Tag Database, described in detail by Fujioka et al. (1988).

Results

Catch

Sablefish were the most numerous finfish on 3 of the 12 seamount visits between 1999 and 2002 (Welker Seamount in 2000 and 2001, and Dickens Seamount in 2001) (Table 2). Giant grenadier, *Albatrossia pectoralis*, dominated catches on the other nine visits. Pacific grenadier, *Coryphaenoides acrolepis*, were present in substantial numbers on several seamounts and replaced sablefish as the second-most common species on Murray Seamount in 2002. A list of scientific and common names of fish and crustaceans caught on the seamounts during 1999–2002 may be found in Table 3. Catch per unit of effort (CPUE), calculated as number of sablefish per 100 hooks, is shown for each seamount and year in Table 4.

CPUE varied greatly between seamounts, ranging from highs of 30.0 and 29.8 on Welker Seamount (2000) and Dickens Seamount (2001) to lows of 1.2 and 3.5 on Murray and Durgin Seamounts in 2002. CPUE on Surveyor Seamount, the only seamount to be sampled in three consecutive years, declined from 10.9 in 1999 to 4.5 in 2001.

Hughes (1981) and Alton (1986) reported that sablefish was the dominant demersal finfish species on each of the nine GOA seamounts sampled in 1979. Because the 1999–2002 fishing was all by longline and the 1979 fishing was with trap, pot, or trawl, no direct comparisons can be made.

Biological Characteristics

Male sablefish were more abundant (Fig. 2) and smaller than females in all years, and the size ranges for males and females (Table 5) were similar to those found by Hughes (1981), although he found no males smaller than 52 cm and no females smaller than 58 cm. In 1999–2002 sampling, 51 cm males were caught on three seamounts, and several females smaller than 58 cm were caught, including one at 49 cm. The average length of males by year and seamount was similar, ranging between 61.7 and 63.7 cm (Table 5). The average length of females by year and seamount had a slightly wider range of 67.4–75.1 cm.

Most of the stations sampled during 1999–2002 had at least a 4:1 preponderance of males, and several stations approached or exceeded a 10:1 ratio (Table 6). Hughes (1981) found that male sablefish outnumbered females by about 2:1 on the seamounts he sampled in 1979.

Otoliths from seamount sablefish were far more difficult to age than otoliths of slope sablefish collected during the longline survey, due to the greater age and extremely compressed pattern of annuli of seamount fish. Compressed annuli indicate that growth is very slow; it even may stop with no increase in fish length with age.[2] This is illustrated by the combined plot of age vs. length for all the seamount samples (Fig.3).

Another characteristic of many otoliths from seamount fish was that growth patterns were typical for sablefish otoliths of young fish, but suddenly transitioned to the compressed pattern. A similar pattern is seen occasionally in fish sampled from the longline survey[2], but the pattern is common in otoliths from seamount sablefish. Referred to as the "transition age," the beginning of the compressed zone may indicate the age at which fish traveled to the seamounts. Transition ages of 152 sablefish were read. Most occurred between 5 and 15 years, regardless of age of the fish. The four oldest transition ages were those of three females and a male between 20 and 24 years old. The youngest transition ages were of six males at 3–4 years. The average transition age for males was 8.7 years (S.E. mean = 0.3) and the average for females was 11.7 years (S.E. mean = 1.8). The greatest number of ages at transition for males were between 6 and 8 years; the greatest number of ages at transition for females were between 8 and 11 years (Fig. 4).

The average age and the range of ages of males are greater than of females at all seamounts (Table 7). Except for Patton and Murray Seamounts in 2002, most of the females were younger than 18 years. Except for Dickens Seamount in 2001, where the oldest male was 29 years, males up to 40 years old were present, and there were some fish more than 60 years old (Fig. 5). Males from 55 year classes between 1936 and 1997 were present on the seamounts sampled during 1999–2002, while females from only 33 year classes between 1952 and 1997 were found (Fig. 6).

All of the sampling during 1999–2002 was in the first week of July. Most of the fish during these years were ripe, spawning, or recently spent, but there were some fish in the resting stage (Table 8). There was some difference in stage between the sexes: the highest per-

Table 3.—Scientific and common names of fish and crustaceans caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

Scientific name	Common name
Fish	
Albatrossia pectoralis	Giant grenadier
Anoplopoma fimbria	Sablefish
Antimora microlepis	Pacific flatnose
Bramidae	Unident. pomfret
Coryphaenoides acrolepis	Pacific grenadier
Malacocottus kincaidi	Blackfin sculpin
Oncorhynchus kisutch	Coho salmon
Oncorhynchus sp.	Unident. salmon
Sebastes aleutianus	Rougheye rockfish
Sebastes aurora	Aurora rockfish
Sebastes borealis	Shortraker rockfish
Sebastolobus alascanus	Shortspine thornyhead
Sebastolobus altivelis	Longspine thornyhead
Somniosus pacificus	Pacific sleeper shark
Squalus acanthias	Spiny dogfish
Crustaceans	
Chionoecetes tanneri	Grooved tanner crab
Lithodes aequispina	Golden king crab
Lithodes couesi	Scarlet king crab

Table 4.—Catch per unit effort (CPUE) of sablefish, calculated as number/100 hooks, caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

Year	Seamount	Sablefish	Hooks	CPUE
1999	Giacomini	933	5,400	17.3
	Surveyor	785	7,200	10.9
	Pratt	689	7,200	9.6
2000	Surveyor	666	7,200	9.3
	Pratt	684	7,200	9.5
	Welker	2,158	7,200	30.0
2001	Surveyor	326	7,200	4.5
	Welker	1,325	7,200	18.4
	Dickens	1,395	4,680	29.8
2002	Patton	957	7,200	13.3
	Murray	83	7,200	1.2
	Durgin	255	7,200	3.5

Table 5.—Mean length, standard error (SE), range of lengths, and sample size (N) of male and female sablefish sampled on Gulf of Alaska seamounts in 1999–2002.

		Males				Females			
Year	Seamount	Mean length	SE	Range	N	Mean length	SE	Range	N
1999	Giacomini	61.7	0.1	55–74	469	72.5	1.0	55–88	47
	Surveyor	63.1	0.1	54–79	445	73.2	0.6	61–87	77
	Pratt	62.3	0.2	51–76	365	71.2	0.5	61–87	77
2000	Surveyor	63.6	0.2	55–77	278	74.1	0.8	58–92	76
	Pratt	62.8	0.2	54–74	304	72.4	0.7	59–85	61
	Welker	62.0	0.1	51–77	1,429	70.0	0.3	57–82	241
2001	Surveyor	61.9	0.6	51–67	38	67.4	4.0	49–85	5
	Welker	62.6	0.1	52–75	737	70.9	0.4	56–84	181
	Dickens	62.5	0.1	53–76	870	72.6	0.6	56–87	107
2002	Patton	63.7	0.2	54–79	488	74.1	0.9	60–93	100
	Murray	62.2	0.6	57–68	22	75.1	2.5	67–91	9
	Durgin	62.0	0.7	56–68	24	72.0	2.1	69–76	3

[2]Anderl, D. Age and Growth Program, NMFS Alaska Fisheries Science Center, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115. Personal commun., November 2000.

Table 6.—Percentages of male and female sablefish in samples taken on Gulf of Alaska seamounts, 1999–2002.

Year	Seamount	Sex ratio	
		% Males	% Females
1999	Giacomini	90.9	9.1
	Surveyor	85.2	14.8
	Pratt	82.6	17.4
2000	Surveyor	78.5	21.5
	Pratt	83.1	16.7
	Welker	85.6	14.4
2001	Surveyor	81.4	18.6
	Welker	80.3	19.7
	Dickens	89.1	11.0
2002	Patton	83.0	17.0
	Murray	71.0	29.0
	Durgin	88.9	11.1

centage of males were in recently spent condition, while most females were still spawning. Hughes (1981) also found that nearly all sablefish were ripe, spawning, or recently spent during his sampling in June and July of 1979.

Tag Recoveries

A total of 3,327 sablefish were tagged and released on GOA seamounts during 1999–2002. Forty-two of these fish were recovered on the same seamount where they were tagged within 1, 2, or 3 years. No tagged fish has been recaptured on a seamount other than the one it was released on.

Seventeen of the tagged sablefish were recovered on the continental slope, verifying that seamount to slope migration occurs. Five of the slope recoveries were from Welker Seamount, four from Giacomini Seamount, three each from Surveyor and Dickens Seamounts, and one each from Pratt and Patton Seamounts (Fig. 7). Catch locations were unavailable for one each of the recoveries from Giacomini and Welker Seamounts. The remaining three recoveries from Giacomini were caught within 105 mi of each other and had the shortest distances from release to recovery location, averaging only 146.5 mi.

Although more than 150 sablefish tagged in Alaska coastal and continental slope waters have been recovered on seamounts off British Columbia and the Washington coast, only seven recoveries of fish released in Alaska waters have been made on GOA seamounts. This difference is due in part to the much

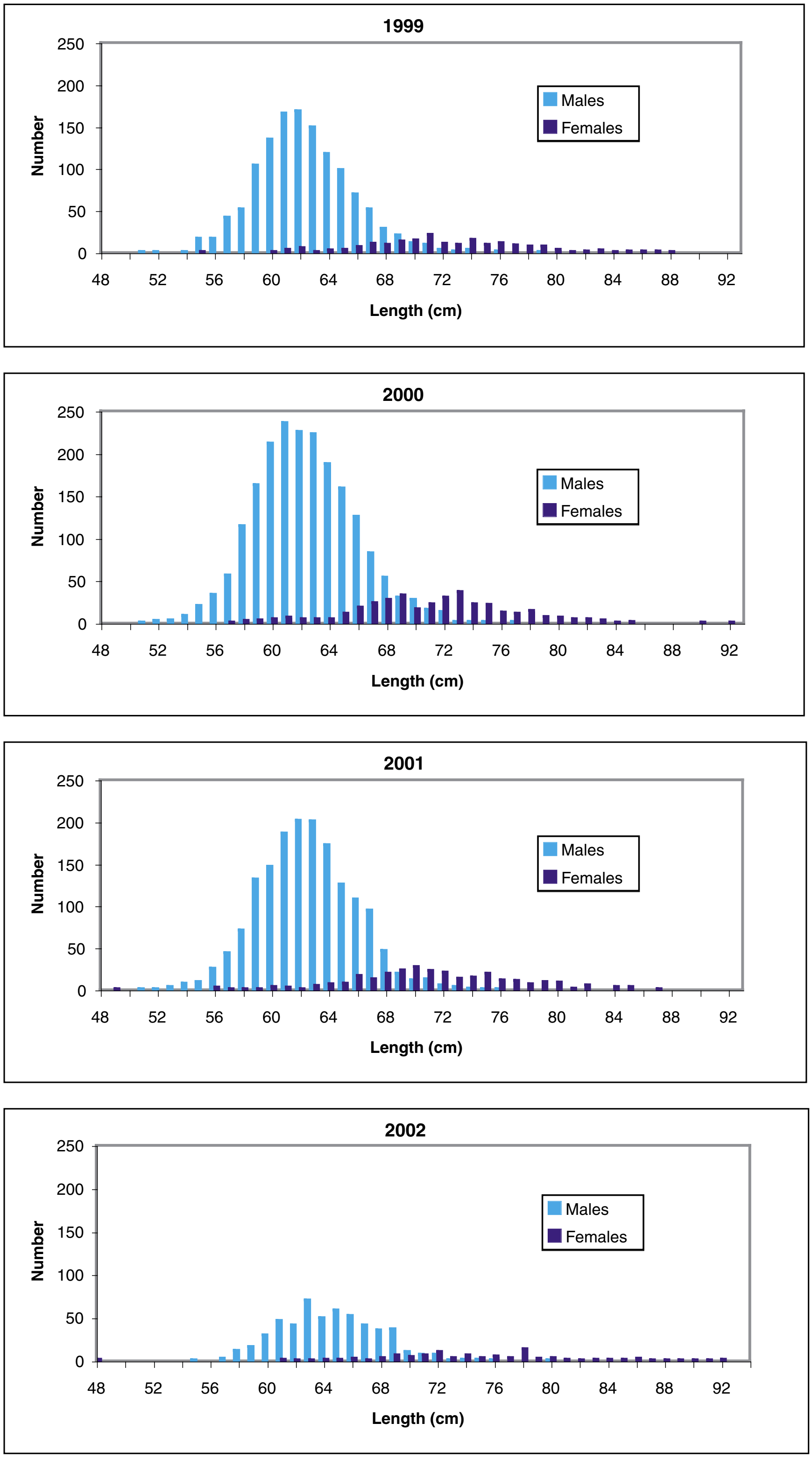

Figure 2.—Sablefish length frequency by sex and year for seamount samples taken during 1999–2002.

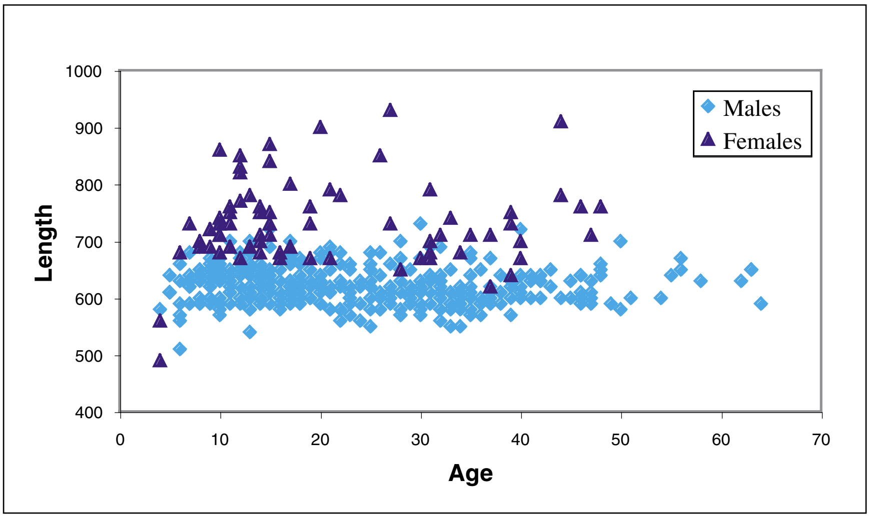

Figure 3.—Sablefish age vs. length for 440 seamount age samples taken during 1999–2002.

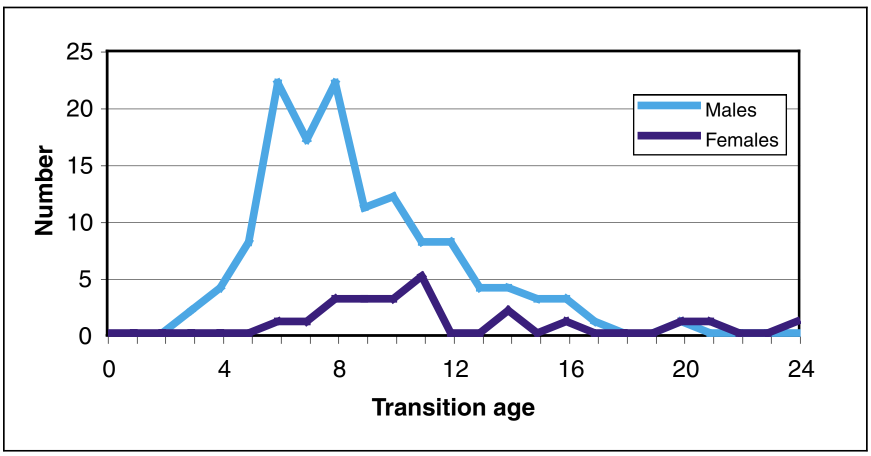

Figure 4.—Transition ages of 152 sablefish caught on Gulf of Alaska seamounts between 1999 and 2002.

Table 7.—Mean age of male and female sablefish on Gulf of Alaska seamounts, 1999–2002.

		Mean age			
Year	Seamount	Males	SE	Females	SE
1999	Giacomini	30.0	2.9	23.8	8.2
	Surveyor	24.0	2.6	14.8	1.3
	Pratt	22.5	2.1	16.7	3.4
2000	Surveyor	23.1	2.4	22.4	3.4
	Pratt	23.6	2.4	12.9	0.8
	Welker	21.1	1.7	11.3	1.7
2001	Surveyor	19.2	1.9	14.6	4.0
	Welker	16.9	1.6	12.8	2.0
	Dickens	13.7	1.1	9.8	0.6
2002	Patton	31.1	2.1	29.0	2.7
	Murray	31.3	2.3	32.3	4.0
	Durgin	29.3	3.2	12.7	2.2

greater fishing effort expended on British Columbia and Washington seamounts, especially Bowie Seamount. The seven recoveries made on GOA seamounts include two each from the Bering Sea, Aleutian Islands, and central GOA and one from the western GOA (Fig. 8). No fish tagged in the eastern GOA or east of Kodiak Island in the central GOA have been recovered on GOA seamounts. In contrast, about half of the 130 sablefish tagged in Alaska waters and recovered on Bowie Seamount were released in the eastern GOA, with the remainder coming from the Aleutian Islands (8.0%), the Bering Sea (11.5%), the western GOA (10.0%), and the central GOA (22.3%).

Discussion

Several biological characteristics of sablefish found on GOA seamounts are notably different from those of sablefish on the continental slope. The sablefish population on the slope is maintained by the movement of younger, immature fish from shallow inshore waters to deeper offshore waters as they mature (Sasaki, 1983). In contrast, only larger, mature sablefish are found on the seamounts, indicating that these populations are maintained by recruitment of adult fish from the slope rather than local reproduction. Of 440 seamount fish aged, only 7 were younger than 6 years old and none were younger than 4 years old.

Alton (1986) thought that the lack of young fish on the seamounts, together with the fact that males mature at a younger age than females and younger ages are usually more numerous than older ages, helped explain a preponderance of males on the seamounts. Hughes (1981) found twice as many males as females in his combined sample from eight seamounts. Murie et al. (1996) also found sex ratios biased toward males in their study of the Canadian trap fishery for sablefish on northeastern Pacific seamounts. Sixty-four percent of the recoveries from Bowie Seamount in the NMFS sablefish tag database are males. Results from the 1999–2002 samples were even more uneven, with ratios as high as 10:1 and 8:1 males to females on several seamounts, and 4:1 or 5:1 on most of the remaining seamounts

(Table 6). The sex ratio of sablefish taken by longline on the Alaska continental shelf and slope is reversed, with an estimated 1.5 female sablefish to every male.[3] Mason et al. (1983) found the same ratio in trawl studies along the west coast of Canada. In Alaska, this ratio is established in the population by age 2, so it is unlikely that it is a result of more males migrating to the seamounts.

As noted earlier, otoliths of many seamount fish typically start off with normal growth but suddenly transition into the compressed growth pattern. The fact that 55% of seamount otoliths examined in 1999 and 73% examined in 2002 had a well-defined transition zone, while transition zones are seen only occasionally in slope fish, suggests that transition age is related to presence on seamounts. The occurrence of transition zones at age 3 or 4 as well as the more common transition ages of 5–15 indicates that the formation of the transition zone may well take place during or just subsequent to migration to the seamounts.

If this is so, then the difference in the average transition age between males (8.7) and females (11.7) may help explain the disproportionate numbers of males and their higher average age and greater age range than females on the seamounts. Most of the males on seamounts leave the slope at age 6–8, within 1 or 2 years after reaching sexual maturity. Females of the same year class remain on the slope on average 3 years longer before travelling to the seamounts. During this time they are vulnerable to fishing and their numbers are consequently lowered, so that fewer females than males from any given year class travel to the seamounts. Assuming equal survival rates for males and females on the seamounts, higher average age and greater age range of males come about as, over time, the smaller numbers of females in each year class die off before the larger number of males.

Most sablefish undertake a migration from eastern areas of the Gulf of Alaska to western areas, including the Aleutian

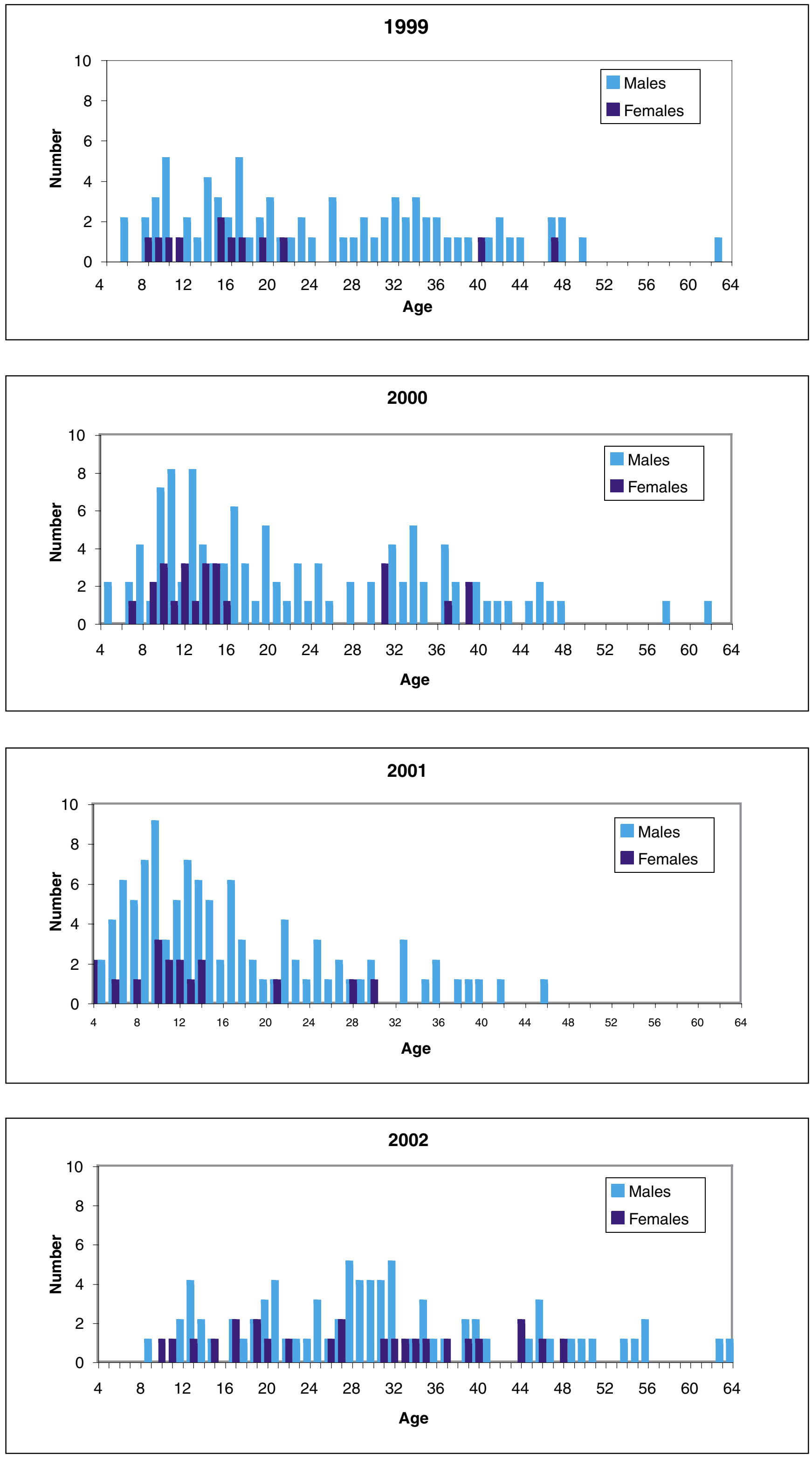

Figure 5.—Sablefish age by sex and year for seamount samples taken in 1999–2002.

[3]Sigler, M. Groundfish Program, NMFS, Alaska Fisheries Science Center, NOAA, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Personal commun., March 2004.

Table 8.—Stages of maturity (%) of male and female sablefish sampled on Gulf of Alaska seamounts, 1999–2002.

		Stage of maturity (%)							
		Males				Females			
Year	Seamount	Resting	Ripe	Spawning	Spent	Resting	Ripe	Spawning	Spent
1999	Giacomini	26.8	2.4	2.4	68.3		20.0	80.0	
	Surveyor	2.4		11.9	85.7			75.0	25.0
	Pratt			7.3	92.7			100.0	
2000	Surveyor		23.5	2.9	73.5			85.7	14.3
	Pratt			32.5	67.5			100.0	
	Welker	35.0	7.5	2.5	55.0			100.0	
2001	Surveyor	11.4	11.4	2.9	74.3	25.0	62.5		12.5
	Welker	21.4		28.6	50.0			100.0	
	Dickens	58.6	20.7		20.7			100.0	
2002	Patton		2.9	11.8	85.3		46.2	53.8	
	Murray	22.7		18.2	59.1		22.2	77.8	
	Durgin	8.3		33.3	58.3		33.3	66.7	

Islands and the Bering Sea, during their younger years, and most return eastward along the continental slope after reaching maturity (Bracken, 1982; Heifetz and Fujioka, 1991). During the migration, young fish which have come from shallower (< 200 m) inshore waters move farther out on the continental shelf and eventually end up as adults in the deeper (> 500 m) waters of the continental slope, which is where spawning takes place.

Ocean circulation patterns can possibly explain the geographic patterns of sablefish releases and recoveries related to GOA seamounts. The route(s) sablefish follow between the continental slope and the seamounts and the depths at which they travel are unknown, but it seems likely that the fish are influenced to some degree by the major current systems of the Gulf of Alaska. Kimura et al. (1998) speculated that sablefish use currents to travel throughout the Gulf of Alaska and up and down North America's west coast.

Circulation in the GOA is driven by the North Pacific subarctic gyre. The southern boundary of the gyre, known as the North Pacific Current, flows eastward, reaching the west coast of North America at about Vancouver Island where it splits into the south-flowing California Current and the north-flowing Alaska Current. The Alaska Current moves north and northwestward on a broad front through the eastern Gulf of Alaska, flowing over the GOA seamounts and up the eastern Gulf coast along the shelf break toward the head of the Gulf (Fig. 9). As the flow leaves the head of the Gulf of Alaska and moves westward, it deepens, narrows to about 100 km, becomes stronger, and is known as the Alaska Stream, or the northern boundary of the subarctic gyre. It runs about 150 km offshore along the Alaska Peninsula and Aleutian Islands, with most of its flow entering the Bering Sea through Near Strait at long. 170°E (Reed and Stabeno, 1993).

The gyre is not circular, but paddle-shaped, with the broad end in the east tapering to the handle in the west. This creates the unusual situation of a close juxtaposition of the east-flowing North Pacific Current with the west-flowing Alaska Stream (Herman et al., 2002). It may also supply a mechanism whereby sablefish that have moved into the deeper waters of the continental slope for spawning might slip into the eastward-flowing North Pacific Current and be carried more or less passively toward the seamounts.

Most of the GOA seamounts lie from 55 to 120 km apart in a line extending more than 740 km, more or less perpendicular to the flow of the North Pacific Current (Fig. 9). Farther to the west, Patton, Cowie, and Murray Seamounts are from 55 to 83 km apart in a line also perpendicular to the current. Several studies describe oceanic features found

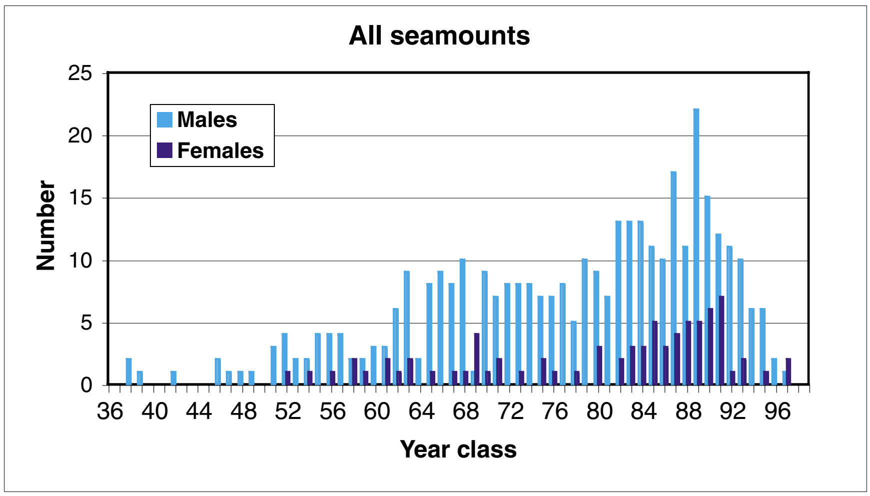

Figure 6.—Numbers by sex of year classes of sablefish present in Gulf of Alaska seamount samples. A total of 440 sablefish were aged.

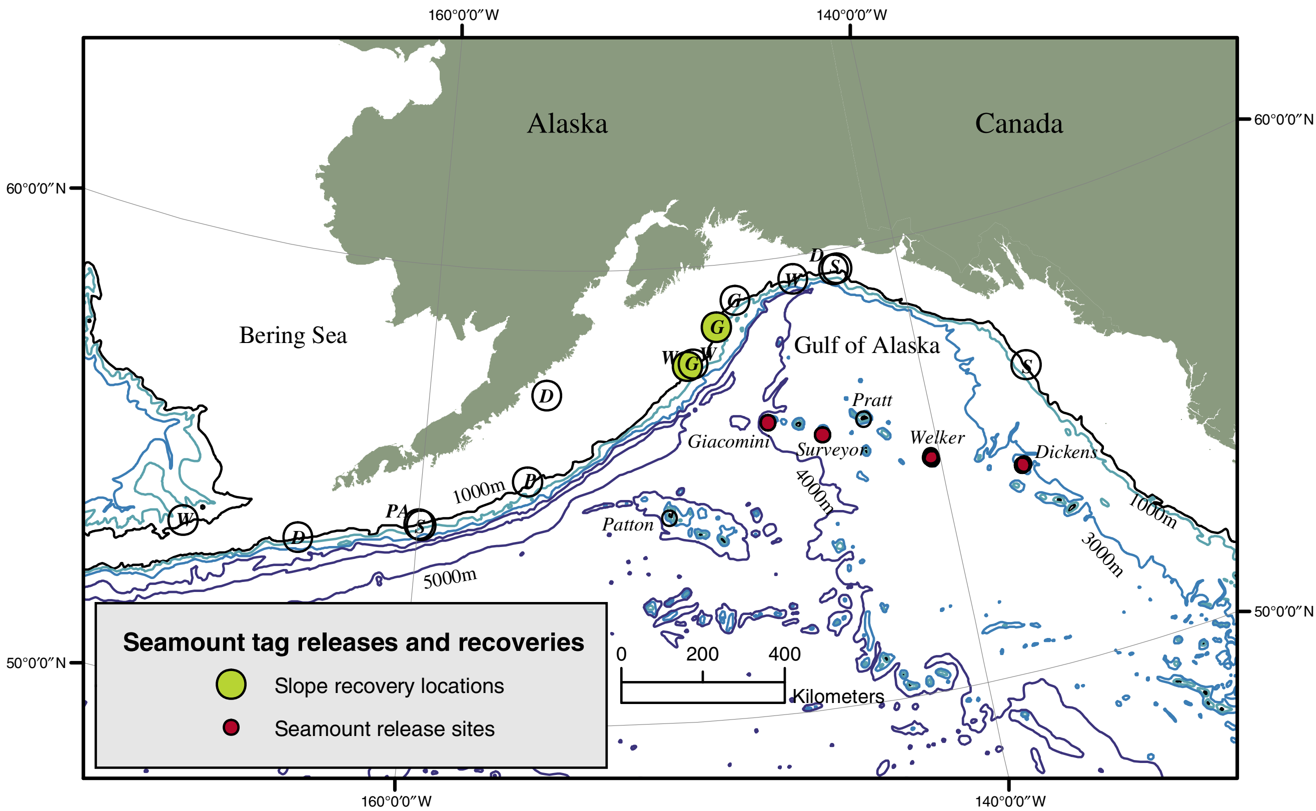

Figure 7.—Slope recovery locations of seamount-tagged sablefish. Letters inside the recovery symbols indicate the seamount of origin. D = Dickens, G = Giacomini, P = Pratt, S = Surveyor, W = Welker, PA = Patton.

in the neighborhood of seamounts that increase the likelihood that sablefish travelling in the North Pacific Current would encounter a seamount in the middle of the GOA. Taylor Columns are eddies of nutrient-rich waters that originate from upwelling of deep ocean waters. The eddies form over seamounts, entrapping the rich waters and increasing productivity in the area of the seamount (Owens and Hogg, 1980; Gould et al., 1981; Dower et al., 1992). Dower and Mackas (1996) describe a "seamount effect" on composition of the zooplankton community up to 30 km from the summit of Cobb Seamount off the Washington coast. Royer (1978) noted the existence of ocean eddies in at least the upper 1,000 m of the water column downstream from seamounts north of Hawaii, and postulated that they were the result of interaction between the North Pacific Current and the seamounts. In modelling studies of oceanic circulation, Hermann et al. (2002) found a clockwise pattern of disturbances around the seamounts. The presence of some or all of these features at each seamount in the line would create an almost unbroken belt of disturbance across the current and greatly increase the chances that sablefish would encounter a seamount.

All of the seven slope-tagged fish recovered on GOA seamounts were tagged and released south or west of Kodiak Island, indicating that they did not strike out for the seamounts during the first part of their westward migration from the eastern GOA. In fact, five of the seven fish were tagged in the Bering Sea or Aleutian Islands, making it likely that the seamount journey began at some point on the return leg of their westward migration, after they had reached maturity (Fig. 8). Sablefish leaving the seamounts would be carried by the same current, here known as the Alaska Current, back to the continental slope. The flow of the current as it passes over the seamounts is back toward the head of the Gulf, so that sablefish using this route would be expected to encounter the slope waters first in the area of the head of the Gulf. Of the 15 slope recoveries with known recovery location, all but 2 were recovered north and west of their seamount release locations. Eight of the 15 fish were recovered between long. 143°W and long. 150°W at the head of the Gulf. Of the remaining 7, 1 was recovered in the Bering Sea, 3 in the western GOA, 2 in the central GOA, and 1 in the eastern GOA (Fig. 7).

Bowie Seamount is directly in line with the North Pacific Current where it reaches the northern British Columbia coast. Fish released in the Bering Sea, Aleutian Islands, and western GOA and recovered on Bowie Seamount may also have travelled there by way of the eastward-flowing North Pacific Current. However, it is likely that Bowie

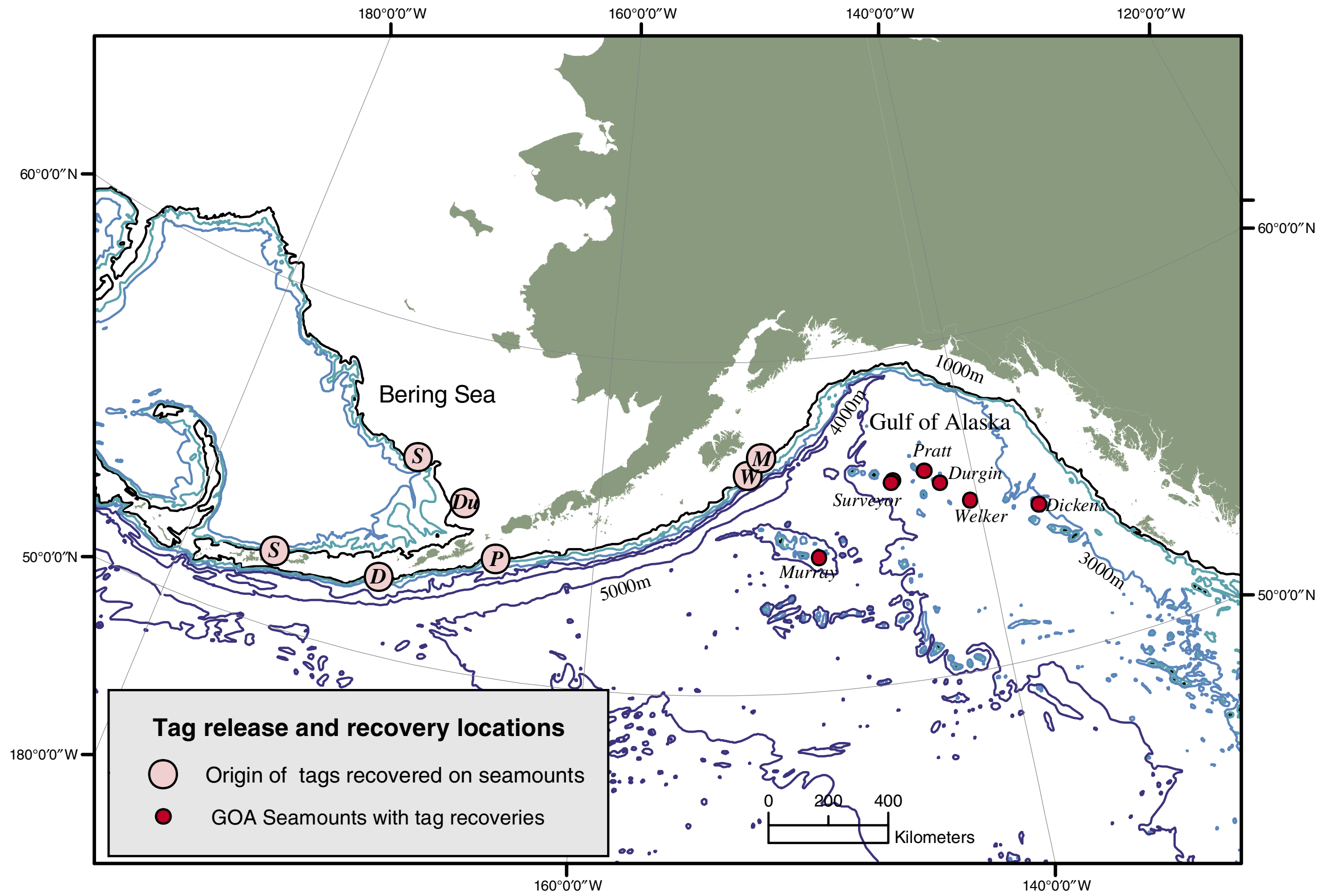

Figure 8.—Seven recovery locations of slope sablefish on Gulf of Alaska seamounts. Letters inside the recovery symbols indicate on which seamount the fish were recovered. D = Dickens, Du = Durgin, M = Murray, P = Pratt, S = Surveyor, W = Welker.

Seamount recoveries originating in the eastern GOA travelled directly to the seamount rather than westward and then eastward by way of the North Pacific Current. Maloney and Heifetz (1997) showed that most sablefish tagged in the inside waters of Chatham or Clarence Strait and most large sablefish tagged in the outside waters of the eastern GOA were recovered in the eastern GOA itself or offshore of British Columbia. Bowie Seamount is only about 185 km off the British Columbia coast, within easy reach for sablefish once they have reached Canadian waters. Water depths between the coast and the seamount are less than those coming from the west, and sablefish travelling from the British Columbia coast to Bowie Seamount may well travel on the bottom to get there.

The population size of sablefish on the GOA seamounts is unknown, but can be inferred to be small based on CPUE or, in the case of Surveyor and Welker Seamounts, the drop in CPUE in successive years of sampling (Table 2). Relatively high catches, as on Welker Seamount in 2000, likely suggest a lack of fishing pressure for a number of years prior to our sampling. The presence of males from 55 of the 61 year classes during 1936–1997 and of females from 33 of those year classes suggests that some travel to the seamounts takes place every year, but there is no way at present to estimate what proportion of the slope population is involved. Likewise, tag recoveries have shown that some fish on the seamounts return to the slope, but it is too soon after tagging to estimate percentages.

Summary

GOA seamount sablefish populations are made up of fish mostly older than 5 years that have migrated from the continental slope, either by way of the North Pacific Current or directly from some point on the slope, either at middepths or on the bottom. The population on each seamount is heavily male-dominant, while the population on the slope is slightly female-dominant. Although seamount males are generally smaller than females, the average age of seamount males is greater than that of seamount females, and males also have a greater range of ages than females. Little or no growth appears to take place in either males or females once the fish arrive on the seamounts.

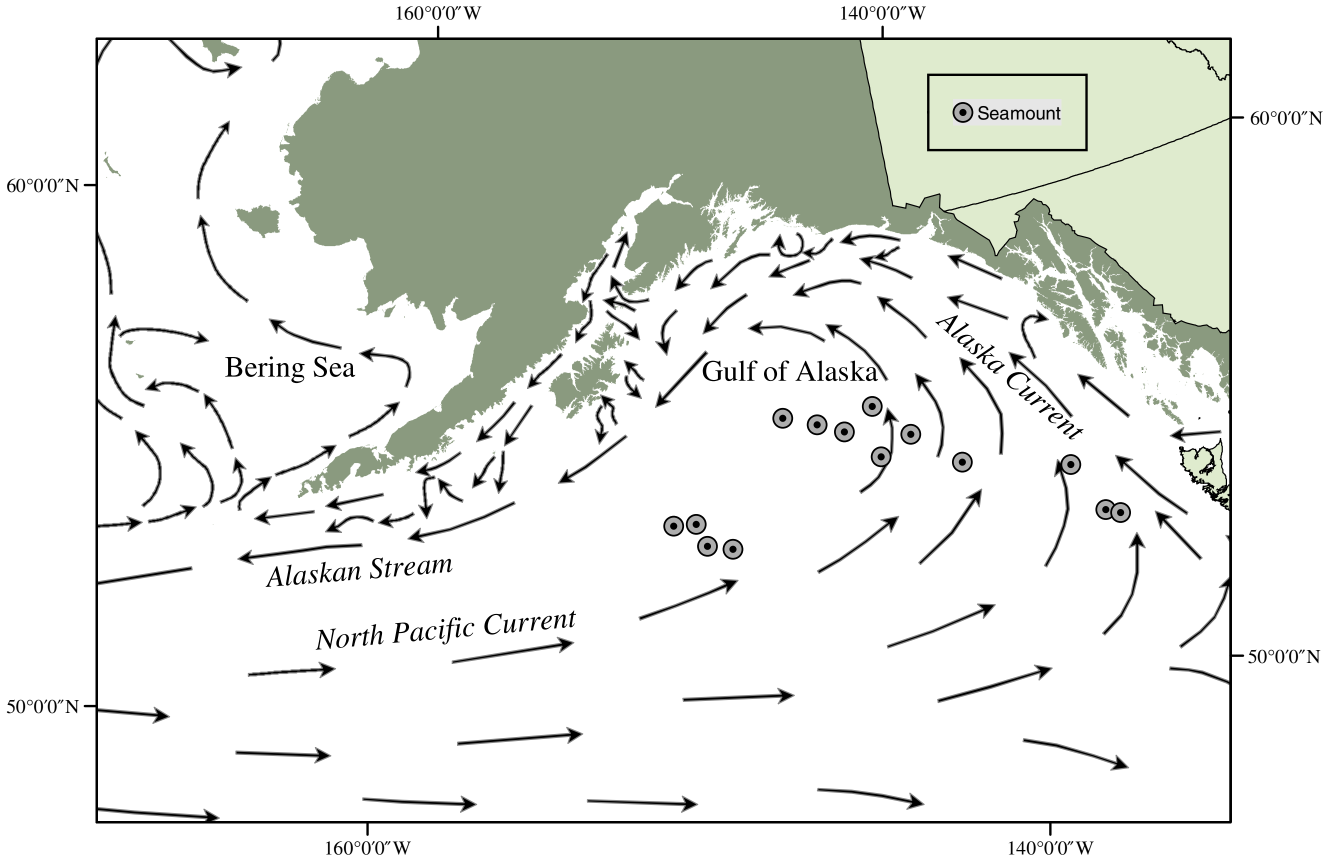

Figure 9.—Circulation in the Gulf of Alaska.

Small populations of sablefish have existed for many years on the GOA seamounts, and they can continue to do so in the absence of concentrated fishing pressure. Many seamounts in both the Atlantic and Pacific Oceans, with larger initial fish populations than the GOA seamounts, have suffered severe declines in these populations after just a few years of concentrated fishing (Clark, 1999; Koslow et al., 2001). The GOA seamounts, isolated out in the middle of the Gulf of Alaska, have been only occasionally fished and are still relatively unspoiled. In 2005, the North Pacific Fishery Management Council declared 16 named seamounts within the EEZ off Alaska to be Alaska Seamount Habitat Protection Areas. Most of these seamounts are in the GOA and the total area involved is 5,329 nmi^2. In these areas, all bottom-contact fishing (longlines, trawls, or pots) by Council-managed fisheries, including sablefish, is prohibited.

Acknowledgments

I thank Mike Sigler, Phil Rigby, and Jon Heifetz for reviews and helpful comments. I also thank Delsa Anderl of the NMFS Alaska Fisheries Science Center's Age and Growth Program in Seattle, Wash., who aged all of the sablefish in this 4-year study. Special thanks go to the captains and crews of the F/V *Ocean Prowler* and F/V *Alaskan Leader* for their great assistance in the collection of data for this study in the summers of 1999–2002.

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