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U.S DEPARTMENT OF COMMERCE

AFSC PROCESSED REPORT 2002-01

Report to Industry on the Alaska Sablefish Tag Program, 1972-2001

August 2002

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Report to Industry on the

Alaska Sablefish Tag Program, 1972-2001

by

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PREFACE

The National Marine Fisheries Service (NMFS) Alaska Sablefish Tag Program has released over 300,000 tagged sablefish in Alaska waters since 1972, and nearly 25,000 of those fish have been recovered by members of the fishing industry. Data from the releases and recoveries are maintained in the Sablefish Tag Database, which is one of the largest databases of its kind in the world.

Although a small reward (baseball cap) is offered for return of the tags to NMFS, many people are more interested in the brief letter which accompanies the reward and describes the history of the fish in terms of movement and growth. This report summarizes release and recovery data of the tag database and describes the results of studies by NMFS and others on sablefish age, growth, and migration. Hopefully it will prove both interesting and informative for those who have contributed the largest share of the data: individual members of the fishing industry.

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INTRODUCTION

The National Marine Fisheries Service (NMFS) has been tagging and releasing sablefish in Alaska waters since 1972. In that time, over 300,000 tags have been released, of which nearly 23,000 have been recovered. The purpose of this report is to inform the fishing community of progress that has been made in understanding sablefish age, growth, and migration, and of the part that the Sablefish Tag Program has played in gaining this knowledge.

Sablefish (*Anoplopoma fimbria*) are a wide-ranging and long-lived species of fish that inhabit the continental slope of the north Pacific Ocean from Baja California to the Gulf of Alaska and on through the Aleutian Islands and Bering Sea to the Asian coast down to southern Japan. Only adult sablefish are found along the coast of Asia (Kodolov 1968), so it is likely that they migrate there from the northeast Pacific Ocean. There is evidence, from tag recoveries and certain physical characteristics of the fish, of two populations of sablefish in the northeast Pacific Ocean (Kimura et al.1998, Beamish and McFarlane 1988). The "West Coast" population extends from southern California north to Vancouver Island, Canada, and the "Alaska" population from Queen Charlotte Sound/Hecate Strait north through the Gulf of Alaska to the Bering Sea and Aleutian Islands.

The State of Alaska has jurisdiction over sablefish in Chatham and Clarence Straits, Prince William Sound, and areas within 3 miles of the coast statewide. The sablefish fishery in the Bering Sea, Aleutian Islands, and Gulf of Alaska, seaward of the 3-mile line, is managed by the NMFS in cooperation with the North Pacific Fishery Management Council. The sablefish in these areas are considered to belong to the same population, for which a total allowable biological catch (ABC) is calculated. The ABC is apportioned among six management areas.

These annual quotas for each area are based on the distribution of biomass among the areas, which is estimated from annual longline survey and commercial catches. The method used to weight the catches for ABC allocation depends on migration rate estimates obtained from tag data. The total ABC is derived from a population model which incorporates age composition, growth rates, and survey and commercial catches. Much of the biological information for estimates of these factors comes from annual sablefish longline surveys and observer samples of the fishery, but tagging results also contribute directly or indirectly to the estimates.

TAG RELEASES

Tagging effort in Alaska has been centered in three main areas: 1) adult sablefish in offshore waters of the Gulf of Alaska (GOA), Bering Sea (BS), and Aleutian Islands (AI); 2) adult sablefish in the inside waters of Chatham and Clarence Straits; and 3) juvenile sablefish in Southeast Alaska.

Offshore Waters

Almost all GOA, BS, and AI tags have been released during annual sablefish longline surveys. Figure 1 shows the major release and recovery areas discussed here as well as the location of the annual longline survey stations. During the years of the Japan-U.S. Cooperative Longline Survey (1978-94) all tagging was done aboard Japanese vessels by Japanese and U.S. scientists working together. Since 1997, tagging in offshore waters has been done aboard chartered commercial vessels during the NMFS annual Domestic Longline Survey, which began in 1987 and replaced the Cooperative Survey in 1995. Table 1 shows the number of tags released by year on annual longline surveys.

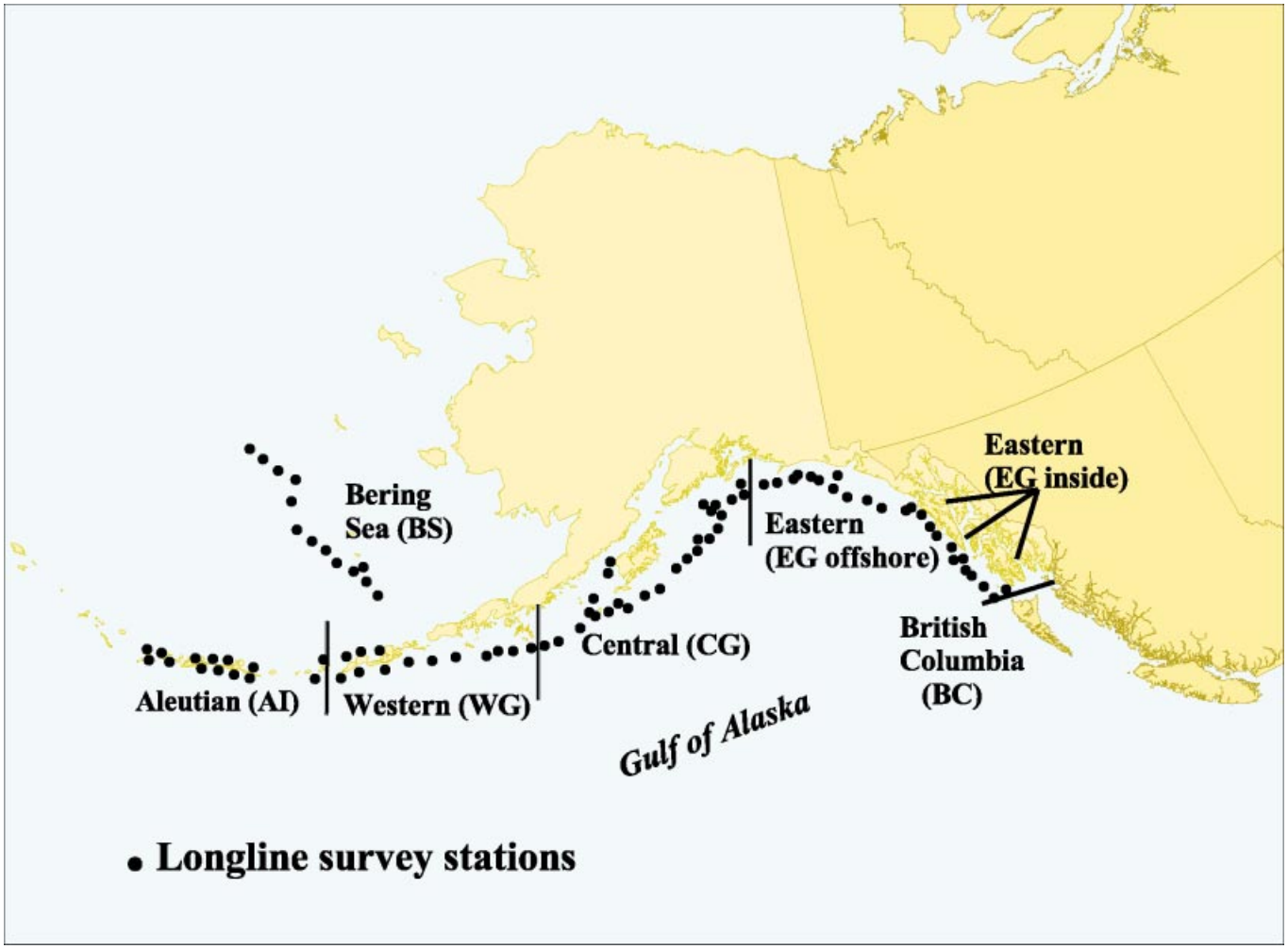

Figure 1. -- Sablefish tag release and recovery areas and the location of National Marine Fisheries Service annual sablefish longline survey stations.

Inside Waters

Most of the nearly 65,000 tags released by NMFS in Chatham and Clarence Straits over the years have been put out from various NOAA research vessels, especially the NOAA ships *John N. Cobb* and *Townsend Cromwell.* The State of Alaska has jurisdiction over fisheries in these waters, and many of the tag releases were made in cooperation with the Alaska Department of Fish and Game. The number of releases by year for Chatham and Clarence Straits is shown in Table 2; these tags are included in the "non-survey" tags shown in Table 1.

Juvenile Sablefish

Juvenile sablefish in southeast Alaska make up a third group of NMFS tag releases. Beginning in 1985, juvenile sablefish were tagged and released in a number of bays and inlets in southeast Alaska, ranging from Ketchikan to Juneau. Most of these fish were tagged from the two NOAA ships *John N. Cobb* and *Murre II* or from docks in Sitka, Ketchikan, and Juneau. A total of 74 sites were tried at one time or another, but most tagging effort since 1987 has been in St. John Baptist Bay near Sitka because it is easily accessible and juvenile sablefish are consistently found there. Table 1 lists the number of releases of juvenile sablefish by year for all areas combined.

AGE AND GROWTH

Sablefish grow rapidly for the first 3 to 4 years of life, after which growth rates slow and remain low for the remainder of their lives. Females grow faster and mature at a larger size than males, and there is some evidence that growth rates vary among regulatory areas (McDevitt 1990, Saunders et al.1997). Age-length relationships are similar between areas on the slope (401-

1,000m) but different between areas on the shelf, possibly because fish on the slope are older and have had more time to mix (Sigler et al. 1997).

The annular growth zones found on sablefish otoliths and the size of the fish at the time of sampling provide a means to age the fish and estimate growth rates. Otoliths and length data are collected throughout annual sablefish longline surveys and these data are used in the assessment of the stock. Sablefish otoliths, however, are difficult to read with complete accuracy past 6 or 7 years of age. Tagging data, consisting of release and recovery sizes and the length of time fish were at liberty, provide an independent estimate of growth rates and a means to validate otolith ages. Fork length measurements are made on all tagged fish when they are released. A fork length measurement taken at recovery, together with the recovery date, provides a direct growth observation for the period that the fish was free (McDevitt 1990). If the sex of the fish is also provided together with date, position, depth, and size, then comparisons between migration and growth rates of males and females can be made.

Sablefish tagged as juveniles are sometimes referred to as "known-age" fish. Rutecki and Varosi (1997) monitored juvenile sablefish in several bays in southeast Alaska from 1985 to 1991. They measured fish at various times from spring through fall each year and found that they could readily distinguish between 0, 1, and 2-year-old fish by means of non-overlapping length frequency distributions. Recoveries of known-age fish provide information on the age at which fish become available to the fishery. They can also serve as validators for other less exact methods of ageing, such as otolith readings (Heifetz et al. 1999).

MIGRATION

Accurate tag recovery position information helps identify major migration routes. If recovery dates are available, it is possible to calculate movement rates as well as routes. Analysis of tag data is the primary method used to study sablefish movements.

Several tagging studies have shown sablefish to be highly migratory for at least part of their life cycle (Bracken 1982, Sasaki 1985, Fujioka et al. 1988, Heifetz and Fujioka 1991, Maloney and Heifetz 1997), with the pattern of movement related to fish size. Young sablefish routinely undertake migrations of a thousand miles or more, and older fish commonly travel the same distance in a return journey. In general, these studies showed that, as first suggested by Bracken (1982), small fish in the eastern areas of the GOA travel north and westward from their release sites and large fish tagged in the western areas of the GOA move eastward. Large fish tagged in the eastern areas of the GOA have a tendency to remain there. Figure 2 is a diagrammatic representation of this basic migration pattern. The stages of sablefish migration coincide with the stages of maturity: small fish moving west are young and immature and large fish returning eastward are older and mature. During the migration, younger fish, which have come from shallow inshore waters, move further out on the continental shelf and eventually end up as adults in the deeper waters of the continental slope, which is where spawning takes place.

Tag data from the NMFS Alaska Sablefish Tag Database for sablefish tagged and released at exploitable size (i.e., > 40cm) are summarized here with reference to the migration pattern described above. Release size categories are based on length frequency data: small (41 - 56 cm), medium (57-66 cm), and large (>66 cm). In general, these size ranges correspond to ages 3-4

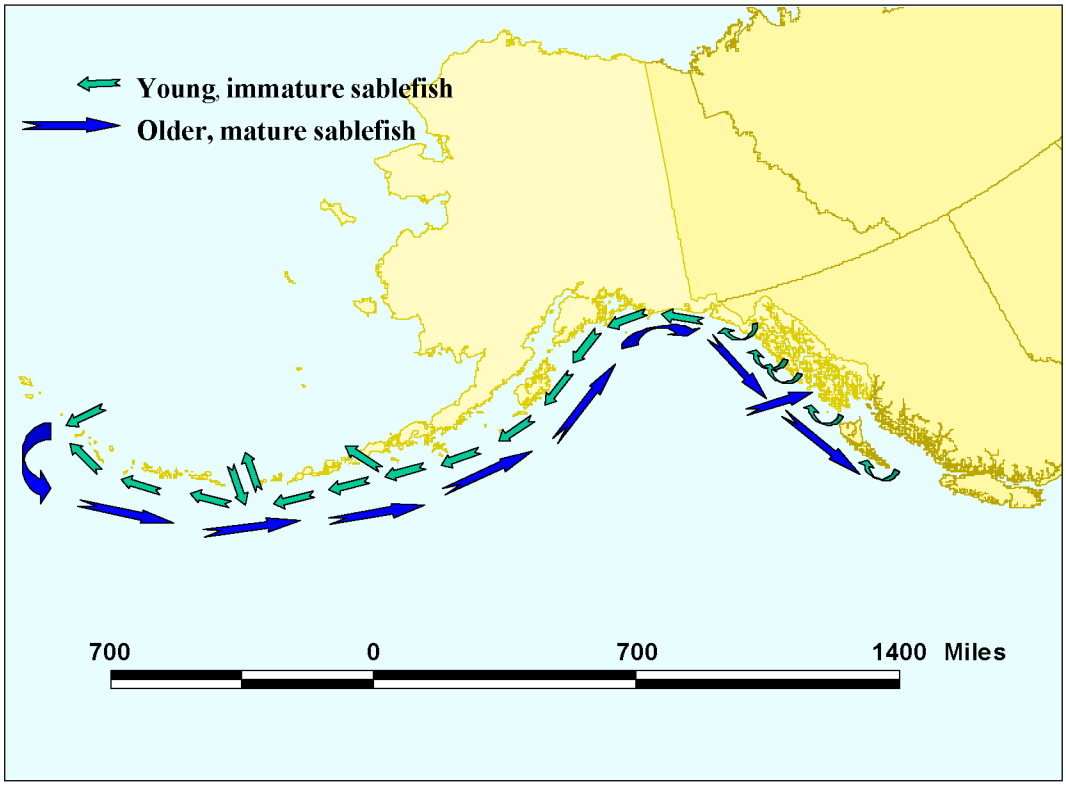

Figure 2.-- The basic migration pattern of sablefish in the northeast Pacific Ocean. Young, immature fish travel north and west from inshore nursery areas in Canada and the Eastern Gulf of Alaska to the Western Gulf of Alaska, Bering Sea, and Aleutian Islands. Older, mature fish move offshore and return eastward.

(small), 5-7 (medium) and 8 and over (large) although, as mentioned earlier, males grow more slowly than females; for example, a 5-year-old female would probably have reached "medium" size while a 5-year-old male might still be of "small" size. The size categories “small”, “medium”, and “large” refer to the size of the fish at release and not the actual size at recovery, unless otherwise stated. For purposes of this discussion, the "eastern areas" include the Eastern and Central Gulf of Alaska, and the "western areas" are the Western Gulf of Alaska, Bering Sea, and Aleutian Islands.

Eastern Area Releases

According to the movement pattern illustrated in Figure 2, small fish released in the Eastern Gulf (EG) or Central Gulf (CG) would be expected to move north and west through the CG, Western Gulf (WG), BS and AI before returning eastward. Fish tagged at large size in the EG or CG would most likely be recovered in the EG or British Columbia (BC). Movements of medium fish would be less clearcut since younger fish of medium size would likely travel west while older medium fish would be more apt to remain in the EG or move south into BC.

EG releases include those from Chatham and Clarence Straits (EG Inside) and those from outside waters (EG Offshore). They are discussed separately here because of differences in recovery patterns.

Eastern Gulf Offshore and Central Gulf Releases

Releases of small fish in the eastern areas (EG Offshore and CG) and recoveries of these fish 1 to 5 years after release are shown in Figure 3. Because it is difficult to see individual recoveries on this scale, the actual number of recoveries (N) is shown under each area name. A few fish were recovered in BC or EG Inside, but most fish that moved out of the tagging area

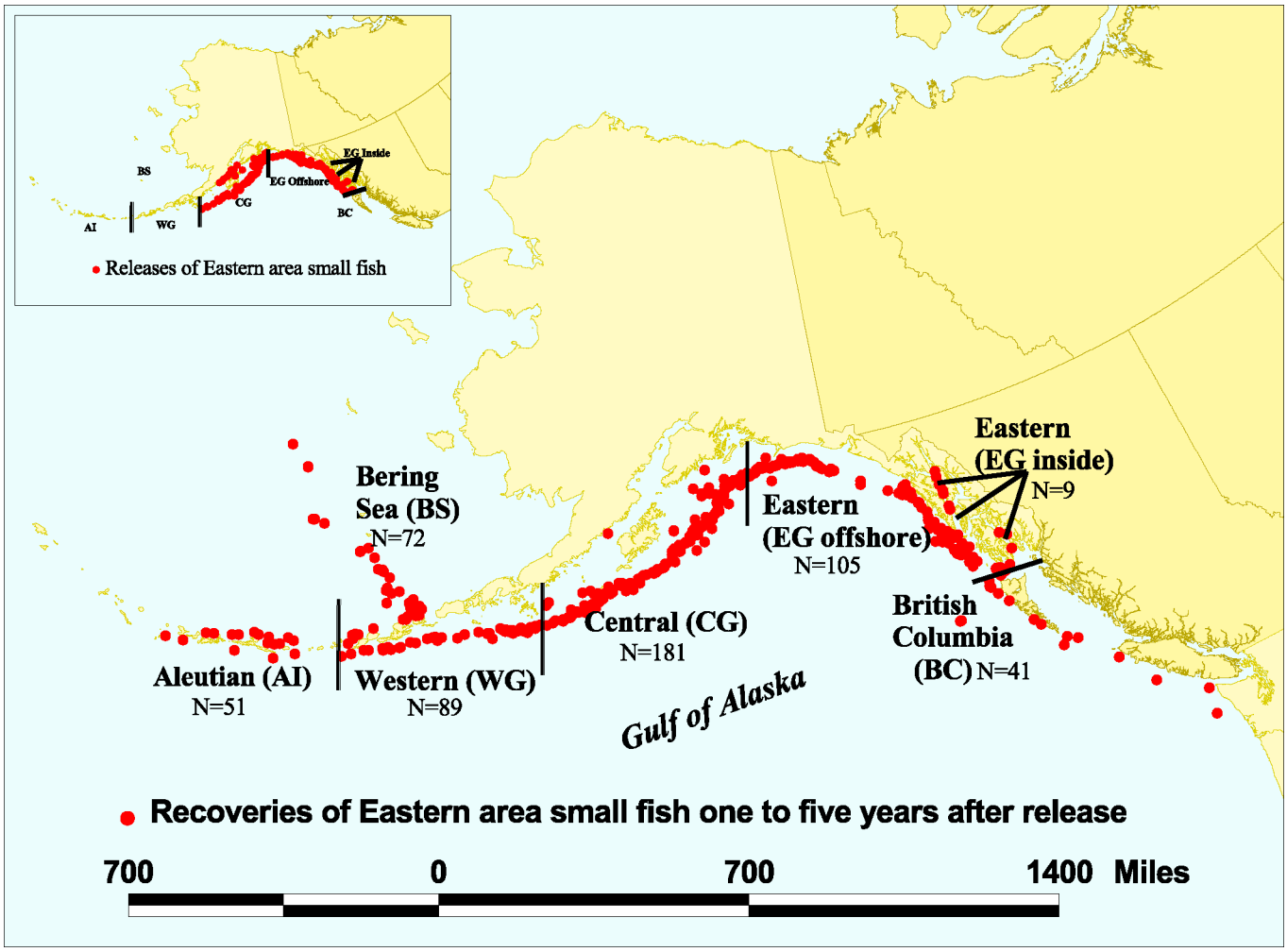

Figure 3. -- Releases and recoveries of eastern area (Eastern Gulf Offshore and Central Gulf of Alaska) small sablefish 1 to 5 years after release. N = number of recoveries for each area.

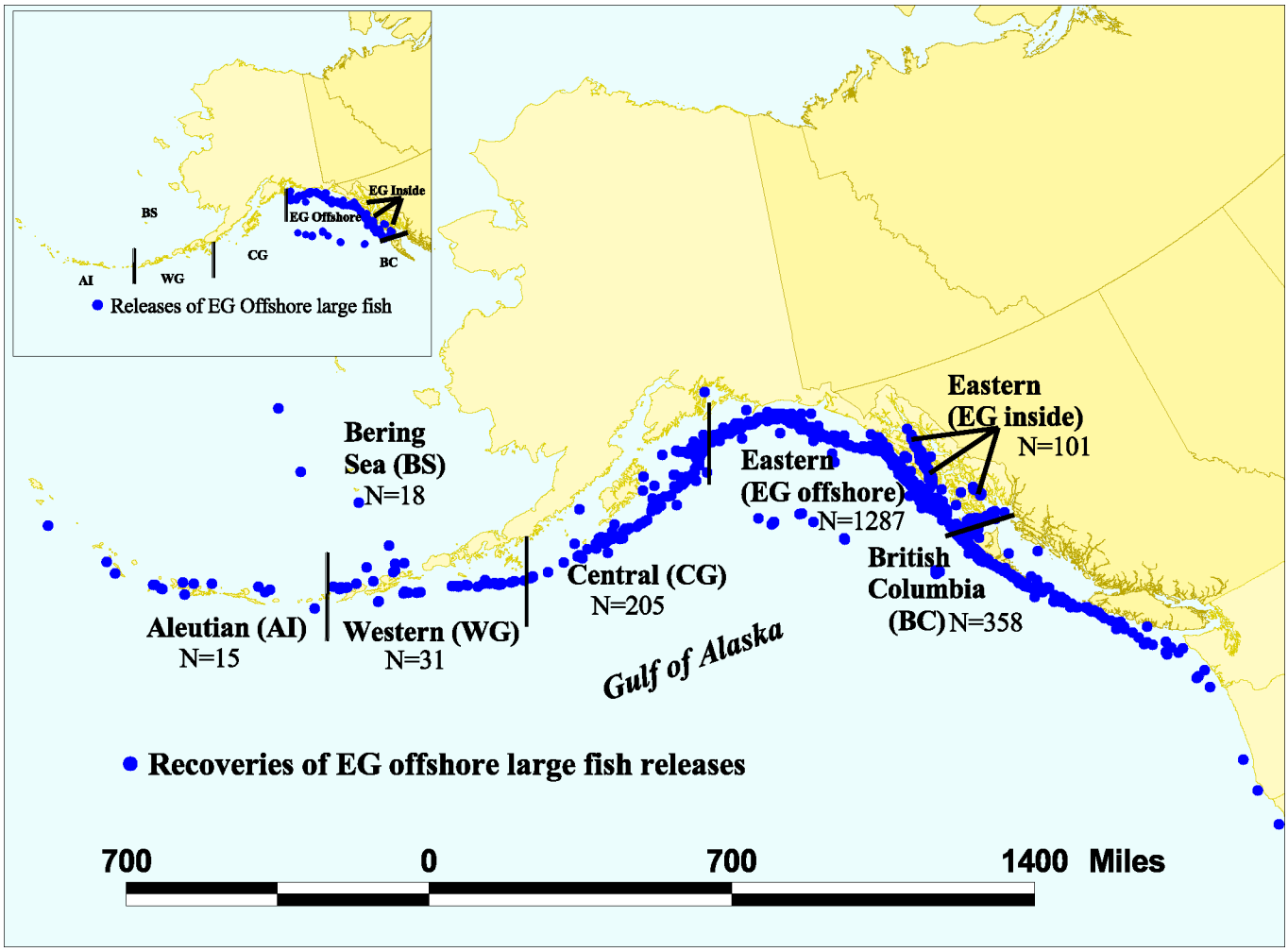

Figure 4. --Releases and recoveries of Eastern Gulf of Alaska Offshore large sablefish. N = number of recoveries for each area.

were recovered in the western areas as expected. Fish recovered in the CG may have originated in the EG and were still travelling westward or they may already have been out west and were returning when captured.

Releases and recoveries of large fish tagged in the EG Offshore are shown in Figure 4. As expected, most recoveries were made in the EG or BC. Of 2,015 recoveries, only 64 (3%) were made in the western areas and 205 (10%) in the CG.

Recoveries of EG Offshore and CG releases have been made up to 23 years after release. Almost all recoveries of EG offshore and CG releases out over 15 years have been made in areas east of the WG.

Eastern Gulf Inside Releases

Releases of small and large fish in Chatham and Clarence Straits (EG Inside) and recovery locations of these fish are shown in Figures 5 and 6. Most recoveries of both sizes were made in the EG or BC, and most EG recoveries were made in Chatham Strait rather than EG Offshore. Recoveries of EG Inside releases have been made as many as 28 years after release. Most recoveries made after 15 years at liberty were made in Chatham Strait or BC. Less than 5% of recoveries of EG Inside releases have been made in areas north and west of the EG (Table 3), and most of these recoveries were small or medium-sized fish.

Western Area Releases

According to the general movement pattern shown in Figure 2, fish tagged as small in the WG are probably migrating westward and would be expected to move into the BS and/or AI before turning back toward the east. Medium-sized fish tagged in the WG might still be moving

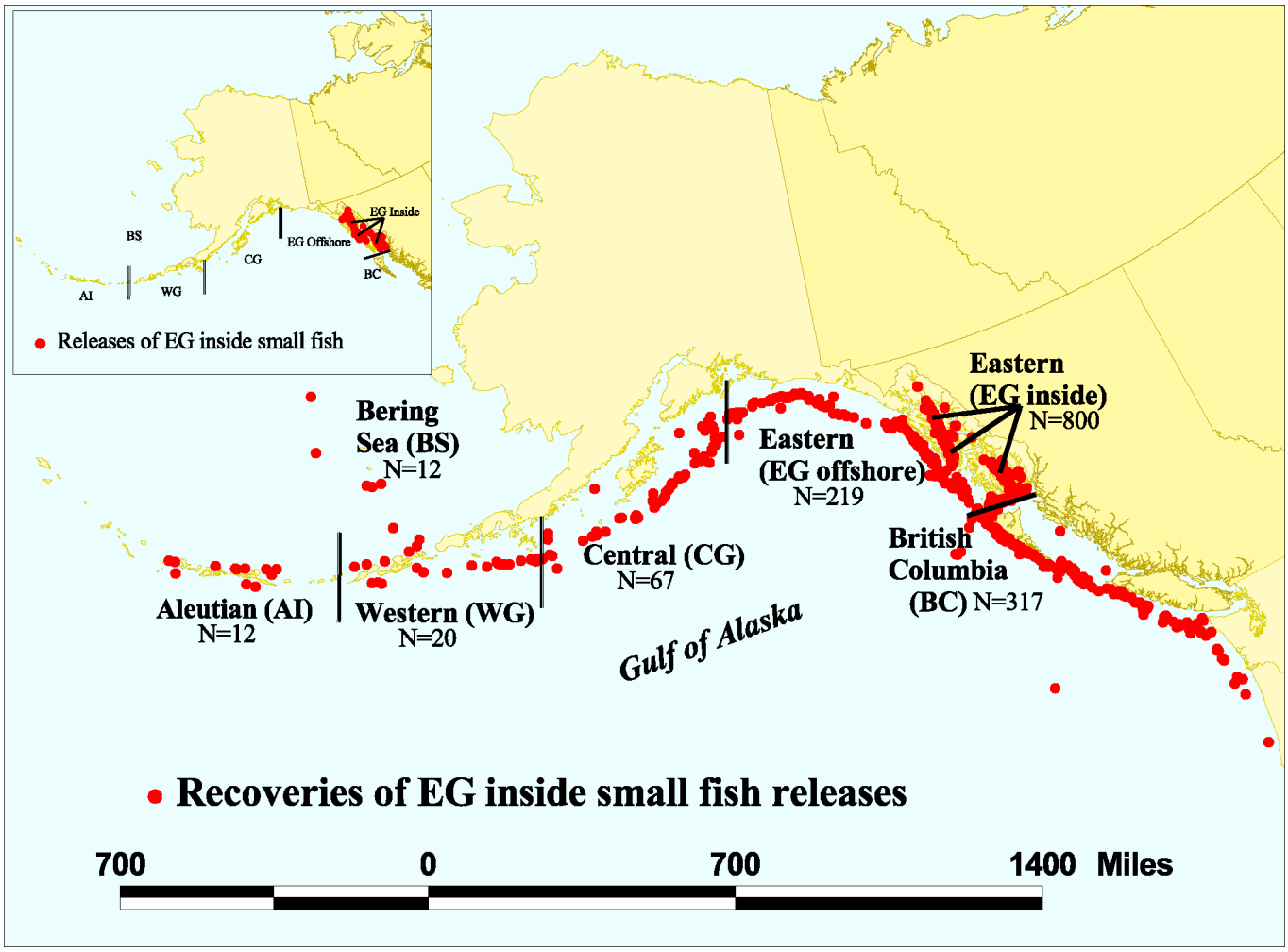

Figure 5. -- Releases and recoveries of Chatham and Clarence Straits (EG Inside) small sablefish 1 to 5 years after release. N = number of recoveries for each area.

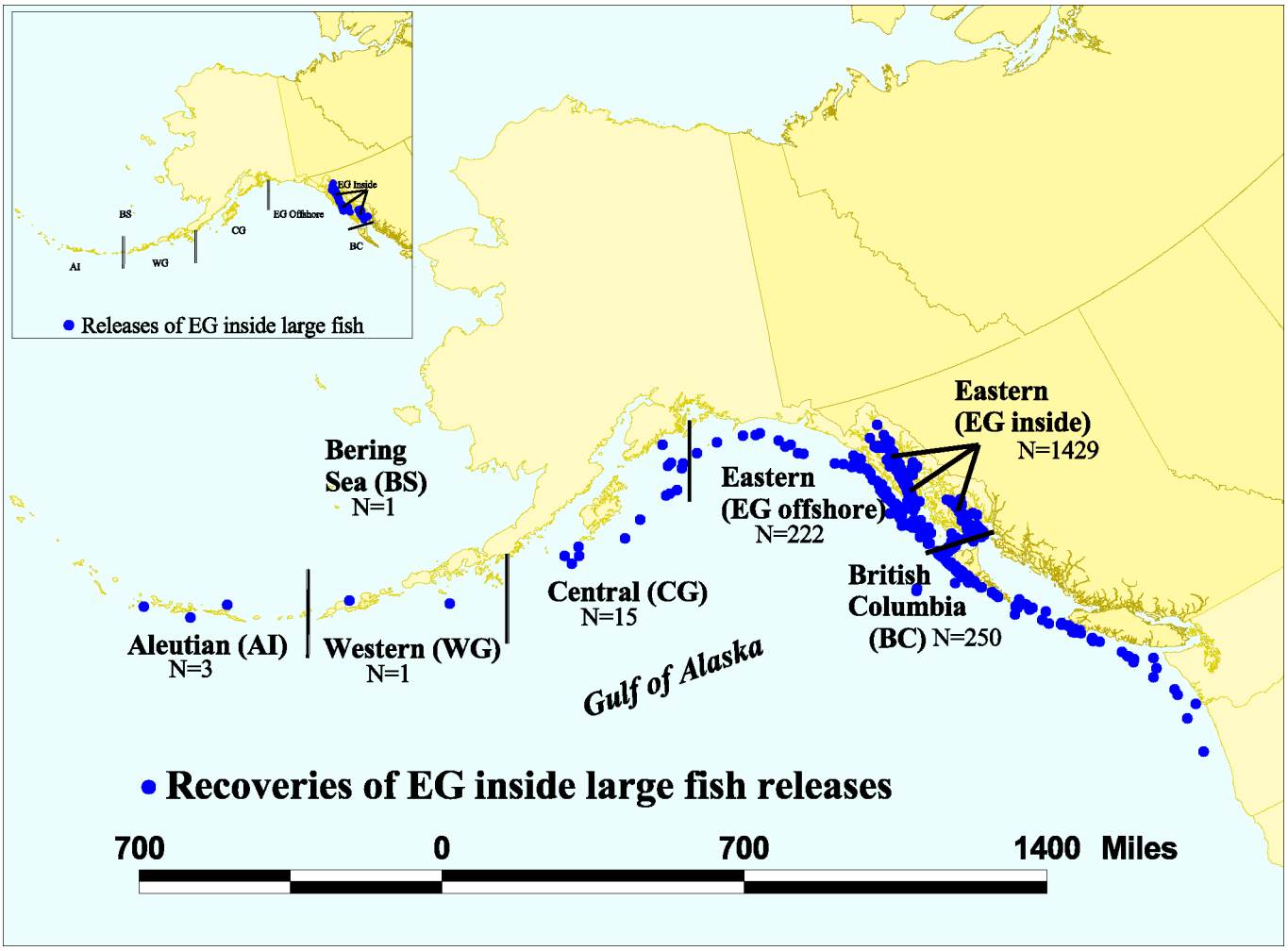

Figure 6. -- Releases and recoveries of Chatham and Clarence Straits (EG Inside) large sablefish. N = number of recoveries for each area.

westward or might be returning eastward back through the WG after having been out west. Large fish tagged in the WG would most likely be travelling eastward.

Sablefish caught in the BS could have arrived directly from the WG or by way of the AI. They may travel on to the AI before heading eastward or they may return south and eastward through the WG. Sablefish tagged in the AI probably reached the westernmost area of their migration and will likely return eastward through either the BS or the WG.

Most western area recoveries of WG releases were made in the first 4 or 5 years after release, and almost all recoveries were of small or medium-sized fish. This would be expected since large fish in the WG mostly travel eastward. Only four large fish tagged in the WG have ever been recovered in the BS and only six in the AI.

Recoveries in areas east of the WG showed quite a different pattern, with large fish from the western areas dominating recoveries in the EG and BC for the first 5 or 6 years after release. Examination of tag recovery data shows that fish tagged at a small size in the western areas tend to remain in the western areas longer than large fish. Figures 7 and 8 show releases and recovery locations in the third year after release of small and large fish tagged in the western areas. Over 75% of small fish recoveries were made in the western areas (Fig.7), and over 80% of large fish recoveries were made in the eastern areas (Fig. 8).

Tag data also indicates that most fish, having reached the Aleutians, do not return eastward by way of the BS. Only 4% of the recoveries of AI releases were made in the BS (Table 3), and only four fish, all small, have been recovered in the BS more than 8 years after release in the AI.

Recoveries of western area (WG, BS, and AI) releases have been made as many as 22

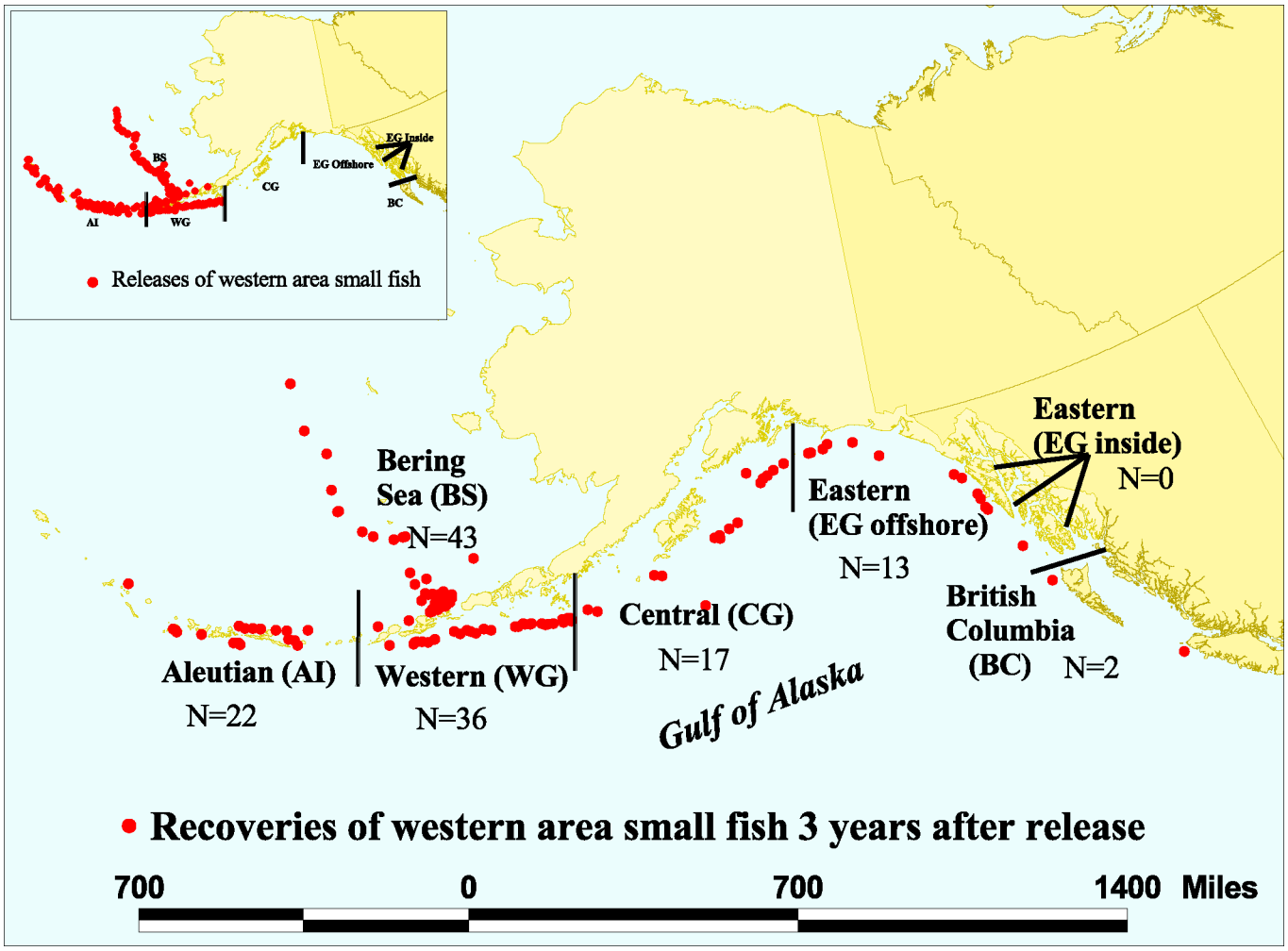

Figure 7. -- Releases and recoveries of western area (Western Gulf of Alaska, Aleutian Islands, and Bering Sea) small sablefish 3 years after release. N = number of recoveries for each area.

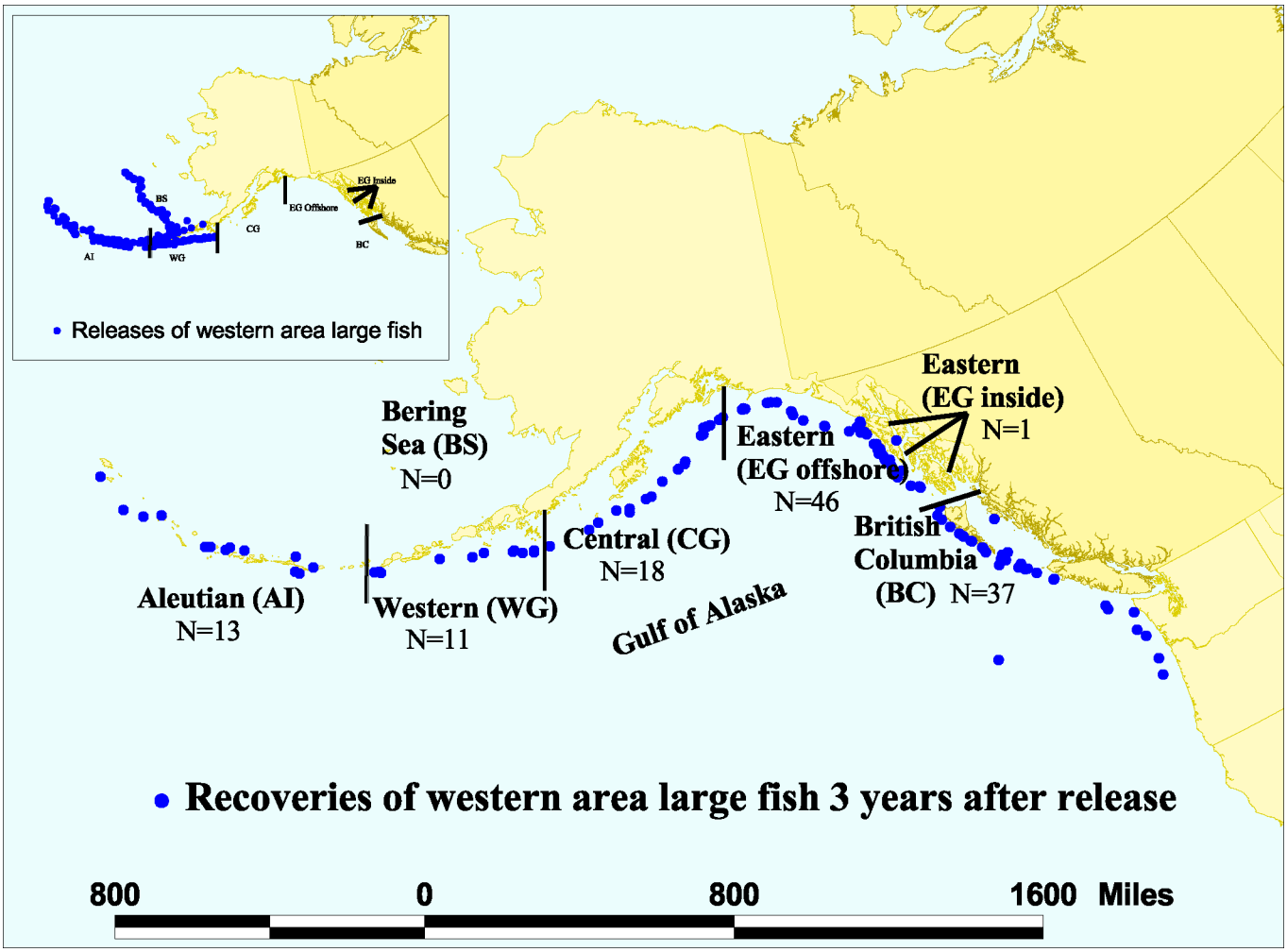

Figure 8. --Releases and recoveries of western area (Western Gulf of Alaska), Aleutian Islands, and Bering Sea) large sablefish 3 years after release. N = number of recoveries for each area.

years after release. Almost all recoveries of fish out over 15 years were made in areas east of the WG.

Summary of All Area Releases

Tag recovery data from each of the release areas agrees well with the movement pattern illustrated in Figure 2. The two EG areas show a net loss of small fish and the western areas show a net loss of large fish, as expected (Table 4). EG Inside, however, seems to have a different migration pattern than the other areas. Most of the fish tagged there were recovered near their point of release or south in BC; less than 5% were recovered in areas west of the EG (Table 3). Although some small and medium-sized fish do make the typical migration to the north and west, more fish of all sizes from EG Inside are recovered in BC than in all other areas combined, except for EG Inside itself. Chatham and Clarence Straits seem to have a higher proportion of resident or non-migrating fish than the other areas, and fish which do migrate are more likely to move south than north.

Movement Rates

Rates of movement from one area to another are affected by a wide range of environmental and biological factors and may vary greatly between years, areas, and individual fish. Also, tagging data has two inherent problems: 1) the length of time a fish was in an area before being captured and tagged is unknown, and 2) the length of time a fish was in an area before being recovered is unknown. If fish are recovered more than one area distant from the release area the problem is compounded because it is impossible to know how much time was spent in each of the areas between release and recovery. In general, the longer a fish is at liberty

and the farther it has traveled, the more uncertain estimates of between-area movement rates become.

Table 5 lists the individual sablefish with the fastest rate of travel between each release and recovery area, as determined by tag recovery data. These data give an idea of the maximum rate of travel between adjoining areas. Analysis using all available tag data is more useful for providing overall patterns of movement and, until sonic tagging of large numbers of individual fish becomes economically feasible, it will remain the best tool for estimating rates of migration.

Heifetz and Fujioka (1991) estimated annual movement rates of tagged sablefish among regulatory areas using all available tag recovery data from 1979 to1987. The study was undertaken so that migration of sablefish could be taken into account in evaluation of various harvest strategies for sablefish. Their quantitative analysis included factors for natural mortality, tag shedding, tag reporting rate, and area-specific fishing effort. The analysis showed that movement patterns for all areas depended on fish size. Table 6 shows the annual percentage of small, medium-sized, and large sablefish from each regulatory area which moved into another area or remained in the same regulatory area. The Total Movement column is the sum of percentages for each size group and release area of fish which did not remain in the release area. Over half of all small fish released in the EG, CG, and WG moved out of their release area each year. Over half or nearly half of all medium-sized and large fish released in the CG, WG, and BS moved out of their release area annually. The highest percentages of movement were from WG for small (69.2%) and medium-sized (71.5%) fish and from BS for large fish (71.4%). They concluded that sablefish movement among regulatory areas is an important factor in determining the amount of fish available for harvest in an area.

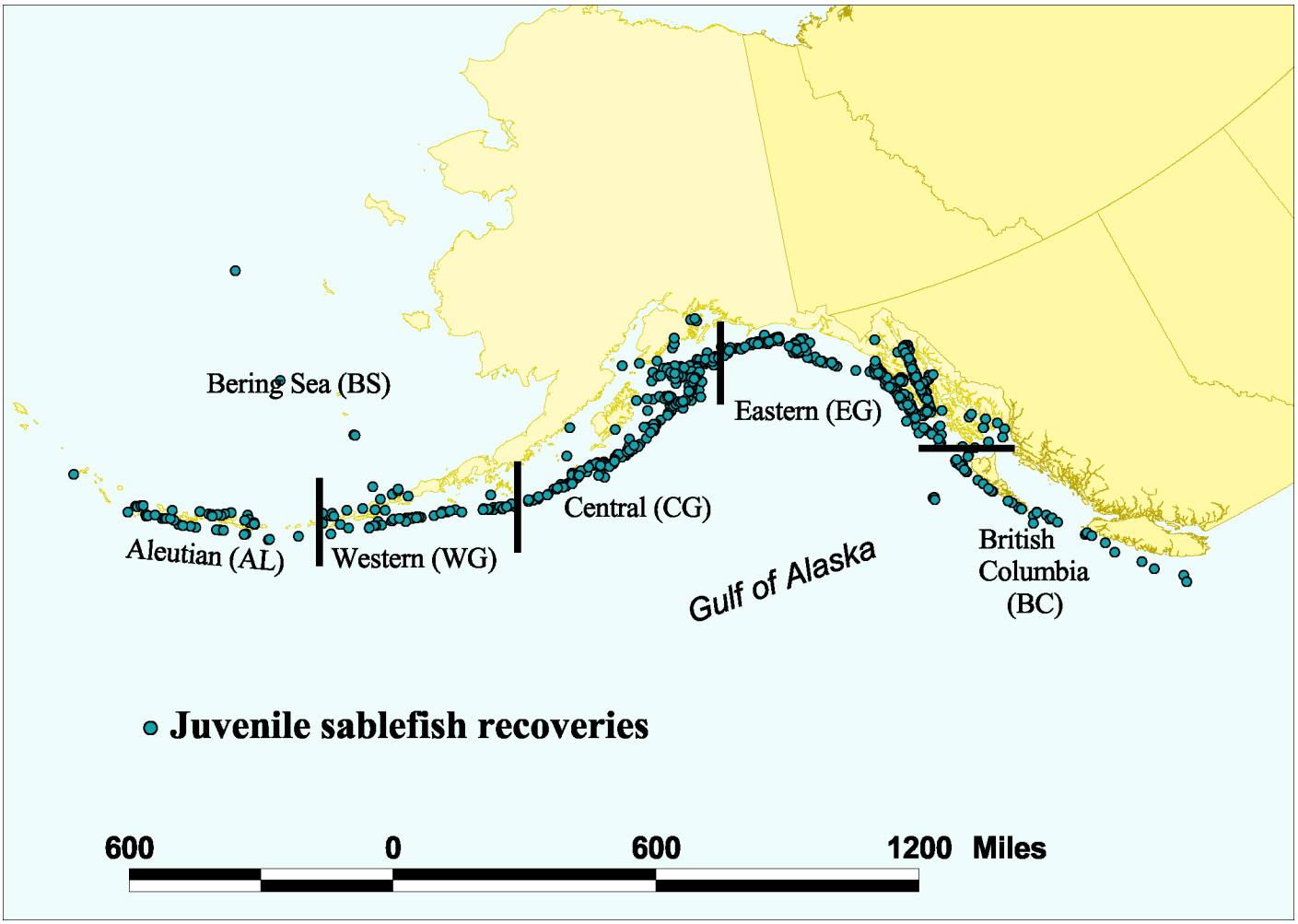

Figure 9. --Recovery locations of tagged juvenile sablefish at liberty more than 120 days after release in southeast Alaska.

Juvenile Sablefish

A number of researchers (Beamish and McFarlane 1988, Bracken 1982, Kodolov 1968, and Sasaki 1985) have suggested that most sablefish recruitment takes place in the northeastern Pacific in the coastal waters of British Columbia and the eastern Gulf of Alaska. They believe that sablefish populations in the northwestern Pacific and Bering Sea are maintained by migration from the eastern areas rather than by local reproduction. Kodolov (1968) noted that juvenile sablefish less than 1 year of age were seldom found in the Bering Sea and Aleutians. Umeda et al. (1983) described the occurrence of juveniles of the exceptionally strong 1977 year class in the southeastern Bering Sea in 1978 and noted that they were the only juveniles found there in a 12-year period. More recently, Sigler et al. (2001) fished small mesh gillnets at night during the annual longline surveys of 1995-99. Most young of the year sablefish were caught east of Kodiak Island. None were caught in the western areas.

Off southeast Alaska, adults spawn offshore in deep water in late winter or early spring. Larvae rise to the surface and develop rapidly as they drift inshore and juveniles are found in coastal bays and inlets by late summer. These 0-age fish ("young of the year") usually remain in the bays and inlets until early fall of the year following entrance (about a year), although some fish remained there for 2 years (Rutecki and Varosi 1997). Average lengths of 0-age, 1-, and 2- year-old fish in the late summer or early fall were about 22 cm (8.7 inches), 32 cm (12.6 inches), and 45 cm (17.7 inches), respectively.

A total of 32,221 juvenile sablefish were tagged and released in the EG by NMFS between 1985 and 2001 (Table 1). Most of these fish were 1 year old; a small percentage were zero or 2 years old. Most of the recoveries of fish at liberty less than 120 days were made by sport

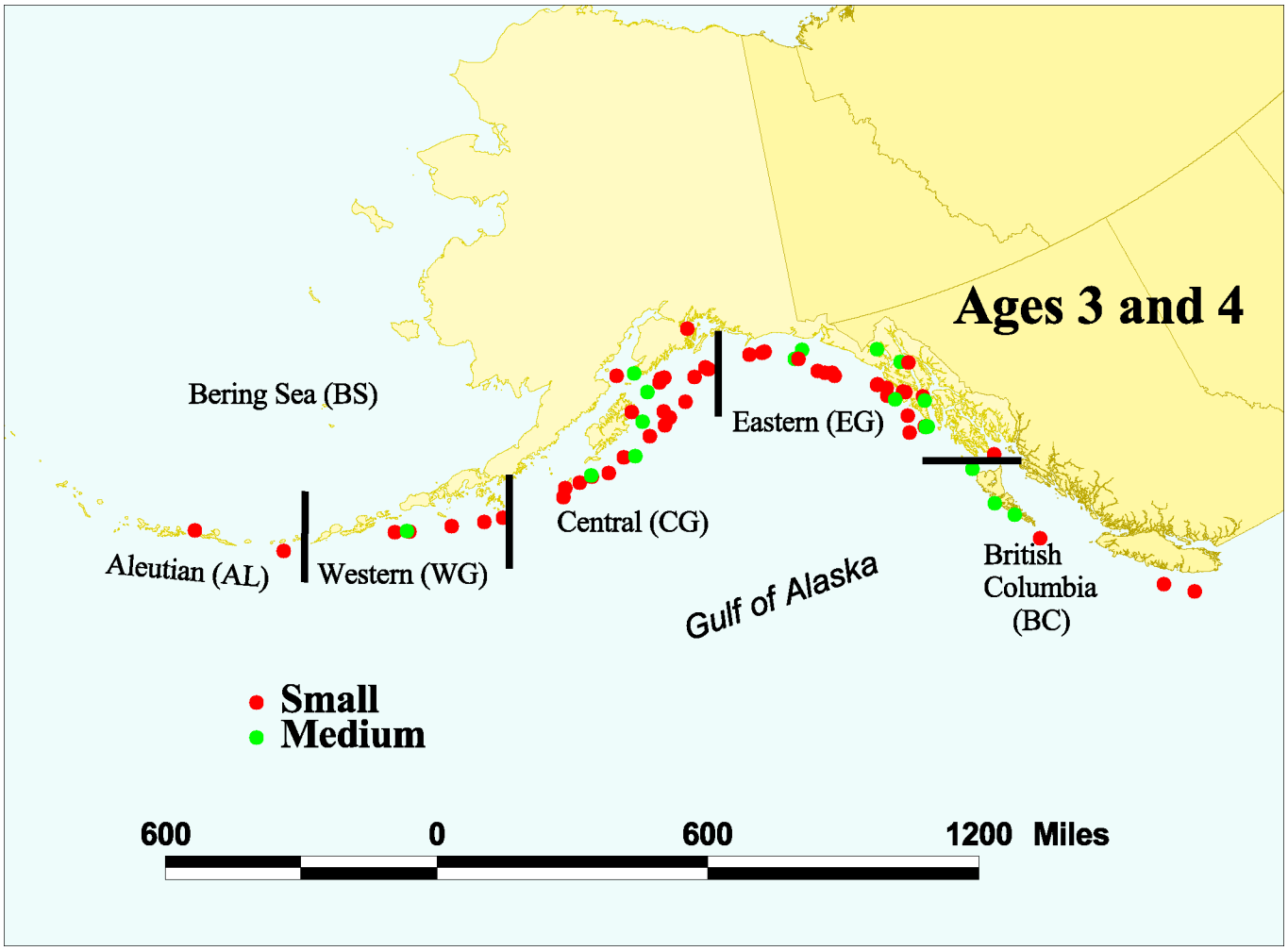

Figure 10. -- Movement by size and age of sablefish (ages 3 and 4) tagged and released as juveniles in southeast Alaska.

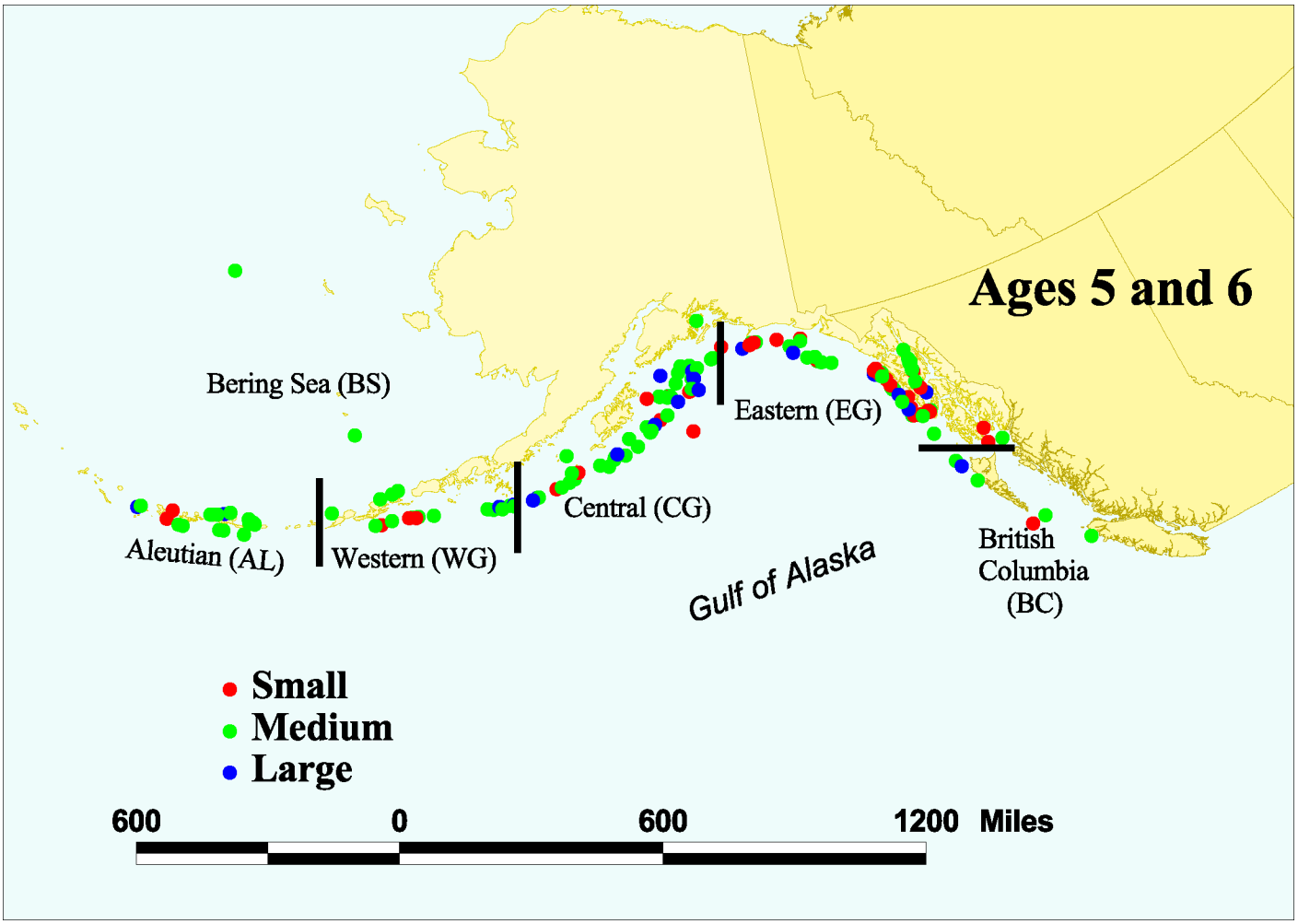

Figure 11. -- Movement by size and age of sablefish (ages 5 and 6) tagged and released as juveniles in southeast Alaska.

fishermen in the immediate area of release and did not provide any information on rates or direction of movement. Figure 9 shows the locations of the 1,004 tagged juvenile sablefish recoveries made by commercial fishermen or fish processors more than 120 days after release. Since the age of these fish is known at release, analysis of their recoveries provides a generalized picture of sablefish movements by age, although these same data demonstrate that there is great variability between fish.

Figures10 through 14 illustrate movement by age and size of the 548 juvenile sablefish tagged in southeast Alaska for which recovery size was available. By ages 3 and 4, most fish were moving out of the shallow inshore bays into offshore waters where they became vulnerable to commercial fishing gear (Fig. 10). A few fish headed south into Canadian waters, but most tag recoveries of 3- and 4-year-old fish were made north of release sites in the EG or CG. Some fish moved only a few miles from their release sites while others traveled as far as the WG or AL.

At ages 3 and 4, most fish still fell into the small size category (i.e., <57 cm) but by ages 5 and 6 many (especially the faster growing females) had grown to medium size (57-66 cm) and a few even reached large size (> 66 cm) (Fig. -11). The highest numbers of tag recoveries of juvenile tag releases were made at ages 5 and 6 when most fish were at least medium-sized and fully vulnerable to the fishery. More recoveries of tagged juveniles were made in the western areas (WG, BS, AI) at age 6 than at any other age. This was also the only age at which western recoveries exceeded EG and BC recoveries.

Most age-6 fish were medium-sized, but by ages 7 and 8 (Fig.12) and 9 and 10 (Fig. 13), numbers of medium-sized and large fish were nearly equal and only a few fish still fell into the small category. At age 10 and older the majority of recoveries with recovery size available were

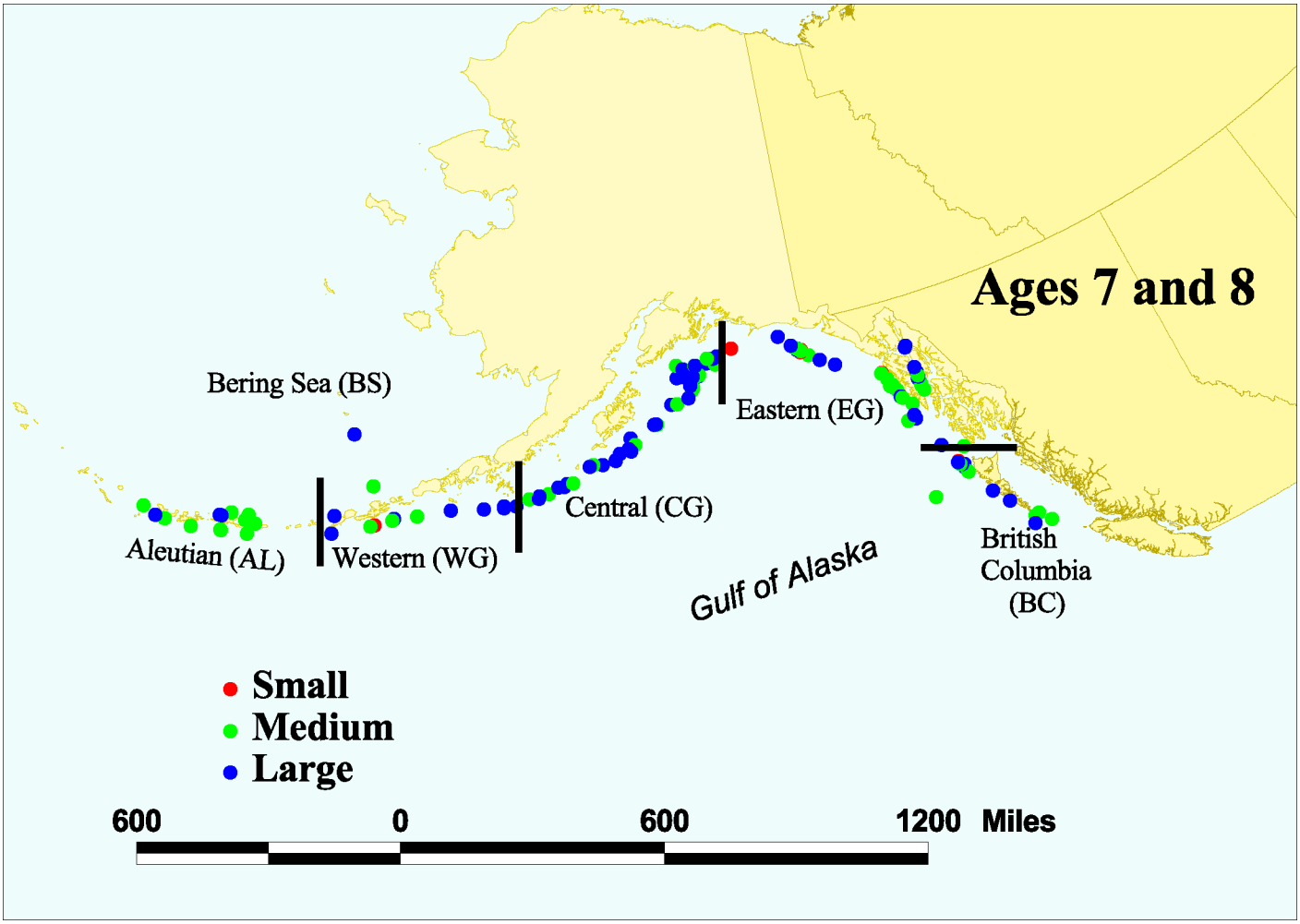

Figure 12. -- Movement by size and age of sablefish (ages 7 and 8) tagged and released as juveniles in southeast Alaska.

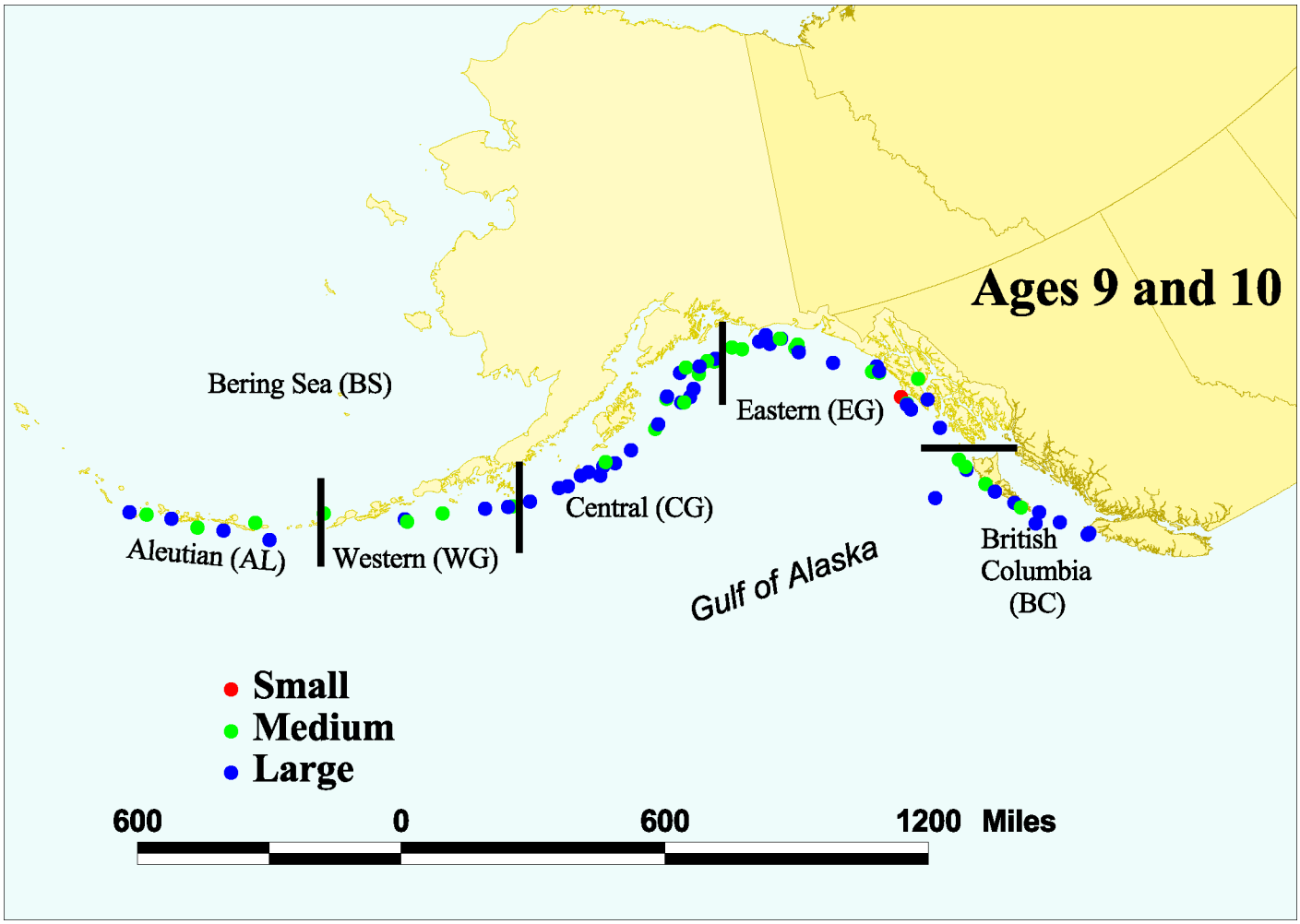

Figure 13. -- Movement by size and age of sablefish (ages 9 and 10) tagged and released as juveniles in southeast Alaska.

large fish (Fig. 14). Most migrants returning from the western areas were ages 7 - 9 when they entered the CG, and ages 7 - 10 when they reached the EG or BC.

Recruitment

Recruitment of sablefish is characterized by great variation in year class strength. Often a single strong year class dominates fishery catches for 5 or more years. This variability is thought to be due mostly to differences in survival of eggs and larvae from year to year (Kendall and Matarese 1987). Causes of variability may be biological (food availability, predation on larvae) or environmental (rate and direction of drift between spawning and nursery areas, extreme temperatures, etc.) For example, recruitment success appears related to winter current direction; above average recruitment was more common for years with a northerly drift (59%) than a southerly or easterly drift (25%) (Sigler et al. 2001).

Favorable conditions during critical periods of development may result in exceptionally strong year classes. Historically, strong year classes have been signalled by the presence of large numbers of juvenile sablefish in many parts of the migration range. This was true for the 1959, 1977, 1980, and 1984 year classes, all of which proved to be exceptionally strong. More recently, the 1995, 1997, and 1998 year classes have shown signs of being above average in size. Using the age schedule described above, it is possible to predict where and when these three year classes will be most abundant. The 1995 year class was strong in the western areas in 2000 and 2001. It is predicted to be abundant in the CG from 2002 to 2004, and in the EG and BC in 2002 to 2005. The 1997 year class was strong in the WG in 2001 and should remain abundant there through 2003. It is predicted to be abundant in the CG from 2004 to 2006 and in the EG and BC from

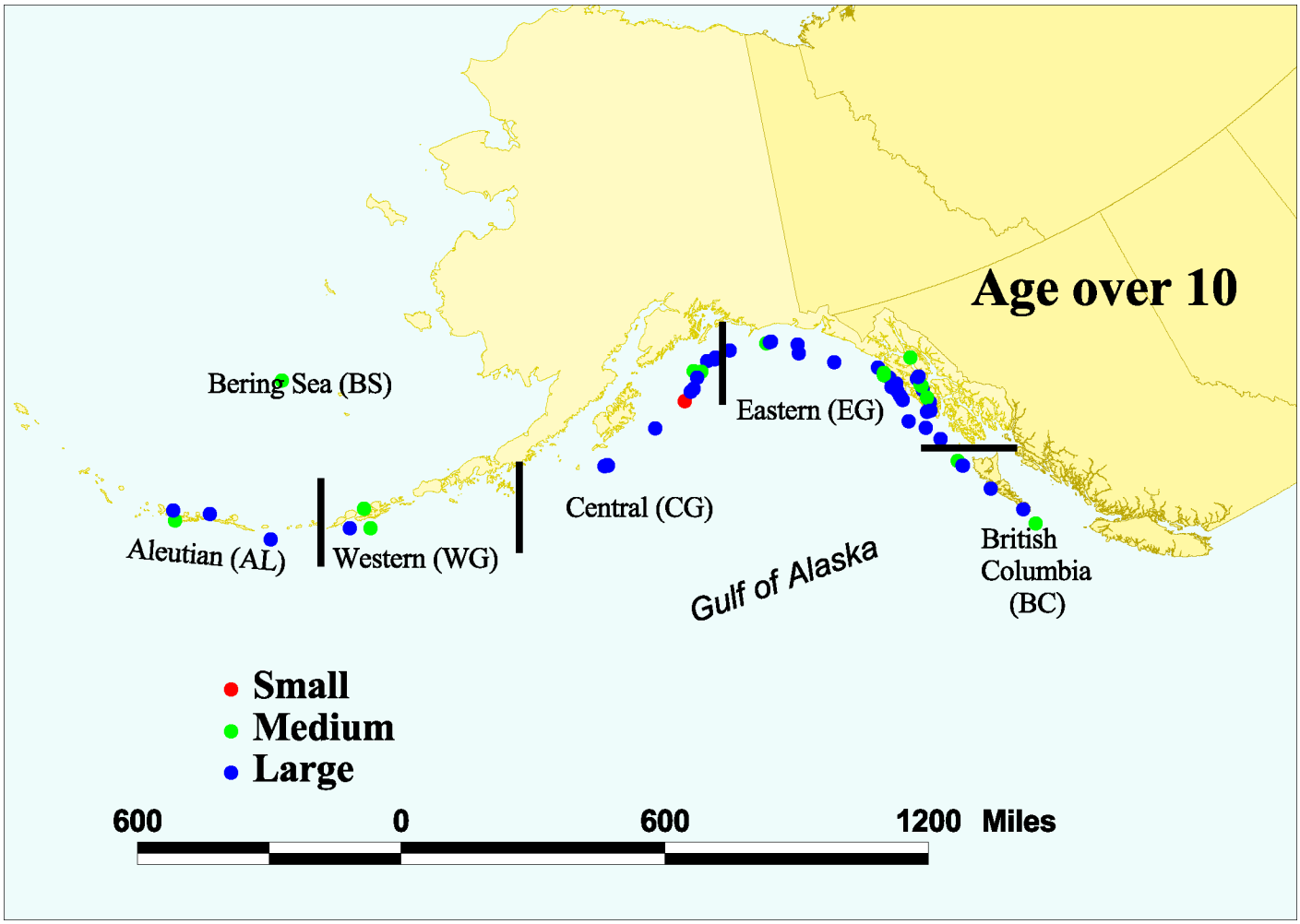

Figure 14. -- Movement by size and age of sablefish (age over 10) tagged and released as juveniles in southeast Alaska.

2004 to 2007. The 1998 year class is expected to be abundant in the WG from 2002 to 2004, in the CG from 2005 to 2007, and in the EG and BC from 2005 to 2008.

RELATED STUDIES

Tag-reporting Rate

Heifetz and Maloney (2001) compared tag returns from the commercial fishery to tag returns from the annual sablefish longline survey to obtain an estimate of the percentage of tags which are actually returned. This number, known as the tag-reporting rate, is an important part of any study used to estimate abundance, exploitation rates, or migration rates. Unreturned tags include those which are caught but not seen as well as those recovered but not turned in. The tag-reporting rate was found to be highest in the CG (38.5%) and EG (31.5%), intermediate in the WG (26.9%), and lowest in the AI (17.4%) and BS (16.9%). Pooled over all areas, the reporting rate has increased gradually and has fluctuated between 37.6% and 45% since 1995.

Electronic Tags

In 1998, NMFS began releasing a small number of sablefish with surgically implanted electronic tags. The tags store depth and temperature readings taken at preset time intervals and can store up to 2 years worth of data, depending on the frequency of observations. Data from these tags provide information about inshore-offshore migration, daily depth movements, and habitat temperature. Two or three fish with these electronic tags were released at each station of the annual longline survey in 1998, 2000, and 2001.

Seamounts

Exploratory fishing by NMFS on 9 Gulf of Alaska seamounts in June and July of 1979 found that sablefish were the dominant finfish caught on each of the seamounts (Hughes 1981, Alton 1986). Only older and larger fish were caught, indicating that seamount populations are maintained by the migration of mature fish from the continental slope rather than by local recruitment. Tagged fish released in the AI, BS, WG, and CG have been recovered on GOA seamounts, verifying that slope to seamount migration does occur (Parks and Shaw 1997). No tagged fish from the EG have been recovered on GOA seamounts, although many tags from the EG have been recovered on Bowie Seamount off British Columbia.

Only 99 sablefish had been tagged and released on GOA seamounts prior to 1999. Of these fish, 5 were recovered on the seamount where they were released and none were recovered elsewhere. In 1999, scientists from Auke Bay Laboratory began sampling sablefish populations and releasing tagged fish on GOA seamounts, using a longline survey vessel during a transit between survey areas from WG to EG. The purpose of releasing more tags on the seamounts was to determine the extent, if any, of emigration from and exchange between seamounts.

About 2800 sablefish were tagged and released on 5 seamounts from 1999 to 2001 (Table 1). Seven tagged fish were recovered in 2000 and 21 in 2001, all from the same seamounts where they were released in 1999 or 2000. In addition, 7 fish released on seamounts in 1999 and 2 fish released in 2000 were recovered on the continental slope in 2000 and 2001, proving that emigration from the seamounts does occur. Time at liberty for the 7 fish with recovery data ranged from 283 to 699 days. Figure 11 shows the origins and recovery locations of 8 of the slope recoveries; recovery data for the ninth fish, which was released on Giacomini Seamount,

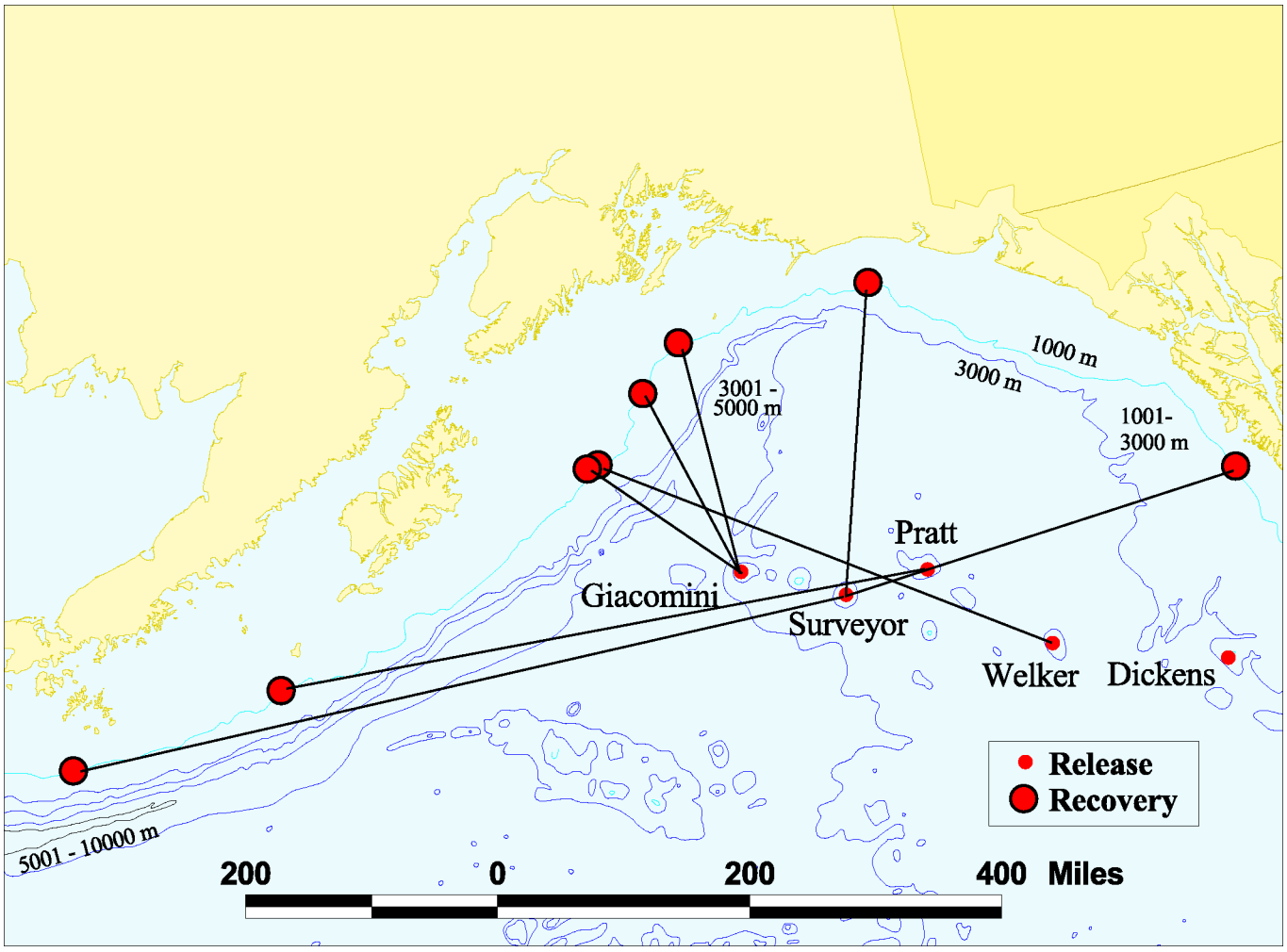

Figure 15.-- Release and recovery locations of 8 sablefish tagged on Gulf of Alaska seamounts and recovered in the U.S. commercial fishery on the continental slope. Lines are intended only to connect release and recovery positions and not to indicate routes of travel.

was unavailable. The lines on Figure 11 are intended only to connect release and recovery positions and not to indicate routes of travel.

The GOA seamounts are all separated from the continental slope by water which is 3,000-5,000 m deep. Sablefish have been caught in traps as deep as 2,740m (Beamish et al.1979), so it is not impossible that they make the journey between seamounts and continental slope on the bottom. It is also possible that part of the route is traversed at midwater depths, or that other seamounts are used as "stepping stones" on the journey. Seamount tagging will continue for the next few years in an effort to determine migration routes and the rate of emigration from the seamounts to the slope.

FUTURE STUDIES

Sablefish abundance in Alaska has varied two-fold since the early 1980s, with abundance changes related to the presence or absence of exceptionally strong year classes. Persistance of the basic migration pattern through wide fluctuations in abundance indicates that the pattern is unaffected by density. Regardless of population levels, migrating sablefish follow a counter-clockwise path through the Gulf of Alaska with younger, smaller fish travelling westward along the contintental shelf, and older, larger fish moving offshore and travelling eastward along the continental slope.

Still incompletely understood, however, are what factors may influence variability in migration rates from year to year or between individuals. Density (or abundance) may be one of those factors. For example, in years with exceptionally strong recruitment, a higher proportion of the year class may migrate and young fish may move farther and faster on the migration route in order to reach less crowded conditions. This would help explain why large numbers of young

fish sometimes appear in areas like the Bering Sea where usual recruitment is light (Umeda et al., 1983). Other factors contributing to variability in migration rate between years might include oceanographic conditions such as temperature or current strength, food availability, and differences in migration behavior of males and females.

Also interesting and not fully understood are the great differences in migration rates of individual fish. Several pairs of sablefish, tagged and released at the same time and place, have been recovered together at a new location several years later, indicating that their respective migration rates were very similar. Other fish starting out from the same area at the same time have been recovered at approximately the same time hundreds of miles apart, indicating vastly different migration rates. Still other fish seem to migrate westward in the typical pattern and then, rather than returning to the EG or BC as most fish do, apparently become resident, in the AI or CG, for example, and are recovered there many years later.

Answers to these and other questions, including what motivates sablefish to migrate in the first place, are still being sought, and tag recovery analysis remains one of the best tools available for finding these answers.

ACKNOWLEDGMENTS

Many individuals and groups have contributed to the Alaska Sablefish Tag Program in the 30 years since it began. Crews of Japanese and U.S. research vessels and chartered commercial fishing vessels have spent many hours and days helping biologists in the tedious business of measuring, tagging, recording information, and releasing fish. Dozens of NMFS biologists have been involved with the tagging effort over the years.

On the recovery side, hundreds of commercial fishermen have taken the time and made the effort to take measurements and to write down and mail in information about tagged fish they have caught. Many tags are also recovered by fish processing workers, and special thanks goes to plant managers who encourage and assist their workers to turn in tags.

Constructive reviews by Mike Sigler, Jeff Fujioka, and Phil Rigby were much appreciated and added greatly to the quality of this report.

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TABLES

Table 1.--Sablefish tags released by the National Marine Fisheries Service in the Aleutian Islands, Bering Sea, and Gulf of Alaska, 1972-2001.

	Adults		Juveniles		
Year	Survey	Non-survey	Seamount		Total
1972		2396			2396
1973		6981			6981
1975		261			261
1976		162			162
1978	6964	718			7682
1979	16062	8310	99		24471
1980	13488	3370			16858
1981	20226	7139			27365
1982	25116	1182			26298
1983	19848	5990			25838
1984	8279	5874		1	14154
1985	7752	4558		6175	18485
1986	8879	8256		1178	18313
1987	8451	8059		7920	24430
1988	7089	5799		3906	16794
1989	6273	8821		531	15625
1990	4316	1676			5992
1991	4295	5734		3370	13399
1992	4075			1659	5734
1993	4055	1		613	4669
1994	3488			1199	4687
1995		2		987	989
1996				1737	1737
1997	3871			58	3929
1998	3482			1174	4656
1999	3832		783	866	5481
2000	3229		930	737	4896
2001	4170		983	110	5263
Total	187240	85289	2795	32221	307545

Table 2.--Sablefish tagged and released in inside waters of the Eastern Gulf of Alaska (Chatham and Clarence Straits), 1972-1995.

Year	Chatham	Clarence	Total
1972	677	1719	2396
1973	6981		6981
1976		91	91
1979	35	6347	6382
1980	5	1243	1248
1981	2760	2938	5698
1983	1403	2800	4203
1984	4040	250	4290
1985	1850	137	1987
1986	7010		7010
1987	1967	308	2275
1988	5799		5799
1989	8821		8821
1990		1676	1676
1991	5734		5734
1993	1		1
1995	2		2
Total	47085	17509	64594

Table 3.--Recovery area and percent of recoveries for sablefish release areas AI(Aleutian Islands), BS(Bering Sea), WG(Western Gulf of Alaska), CG(Central Gulf of Alaska), EG offshore (offshore waters of the Eastern Gulf of Alaska), EG inside(Chatham and Clarence Straits), BC (British Columbia and the U.S.West Coast).

	Recovery Area							
Release Area	AI	BS	WG	CG	EG offshore	EG inside	BC	Total
AI	26	4	5	13	28	2	22	100
BS	5	19	7	22	30	3	14	100
WG	3	5	25	22	25	2	18	100
CG	2	3	5	45	26	2	17	100
EG offshore	2	2	4	16	56	5	15	100
EG inside	<1	<1	1	2	13	64	19	100

Table 4.--Size composition (%) of sablefish releases and recoveries by release area for areas AI (Aleutian Islands), BS (Bering Sea), WG (Western Gulf of Alaska), CG (Central Gulf of Alaska, EG offshore (offshore waters of the Eastern Gulf of Alaska), and EG inside (Chatham and Clarence Straits).

		Release Size					
	Total	Small (41-56 cm)		Medium (57-66cm)		Large (>66cm)	
Release Area	Releases	Release	Recovery	Release	Recovery	Release	Recovery
AI	17817	34	33	49	52	17	15
BS	24750	35	40	58	57	7	4
WG	21093	33	39	53	36	14	3
CG	50845	30	36	50	37	20	27
EG offshore	90993	27	22	46	37	28	41
EG inside	64594	30	20	42	46	28	34

Table 5.--Individual sablefish with the fastest rate of travel between release and recovery areas, for areas AI (Aleutian Islands), BS (Bering Sea), WG (Western Gulf of Alaska), CG (Central Gulf of Alaska), EG Offshore (offshore waters of the Eastern Gulf of Alaska), EG Inside (Chatham and Clarence Straits), BC (British Columbia and the U.S. West Coast). Size is length at release: S = Small (41-56 cm), M = Medium (57-66 cm), L = Large (>66 cm).

	Release Area AI					Release Area BS			
Recovery Area	Miles	Days	Miles/Day	Size	Recovery Area	Miles	Days	Miles/Day	Size
BS	521	17	30.68	S	AI	445	338	1.32	M
WG	675	135	5.00	M	WG	556	379	1.47	L
CG	750	114	6.58	M	CG	714	76	9.40	S
EG offshore	1317	88	14.96	S	EG offshore	999	309	3.23	M
EG inside	1477	90	16.41	L	EG inside	1041	431	2.42	L
BC	1473	274	5.37	L	BC	1880	378	4.98	M

	Release Area WG					Release Area CG			
Recovery Area	Miles	Days	Miles/Day	Size	Recovery Area	Miles	Days	Miles/Day	Size
AI	480	79	6.08	M	AI	1039	260	4.00	M
BS	234	156	1.50	M	BS	703	244	2.88	M
CG	267	50	5.34	M	WG	281	66	4.27	M
EG offshore	1065	303	3.51	L	EG offshore	376	20	18.78	M
EG inside	1170	422	2.77	M	EG inside	821	372	2.21	L
BC	1280	171	7.49	L	BC	744	152	4.90	L

	Release Area EG offshore					Release Area EG inside			
Recovery Area	Miles	Days	Miles/Day	Size	Recovery Area	Miles	Days	Miles/Day	Size
AI	1133	46	24.63	M	AI	1566	410	3.82	S
BS	836	80	10.45	M	BS	1210	758	1.60	S
WG	1089	101	10.78	S	WG	1246	281	4.43	S
CG	116	6	19.35	S	CG	693	269	2.58	S
EG inside	162	36	4.50	S	EG offshore	472	148	3.19	S
BC	601	60	10.02	M	BC	260	71	3.66	M

Table 6.--Estimated annual movement rates of tagged sablefish, (percent by size), between regulatory areas. EG, Eastern Gulf of Alaska; CG, Central Gulf of Alaska; WG, Western Gulf of Alaska; BS, Bering Sea; AI, Aleutian Islands; BC, British Columbia and the U.S. West Coast. Adapted from Heifetz and Fujioka, 1991.

From Area		To Area BC	EG	CG	WG	BS	AI	Total Movement
EG	Small	0.8	48.5	37.5	10.7	1.2	1.2	51.5
	Medium	1.7	69.9	22.3	5.3	0.3	0.4	30.1
	Large	2.6	73.1	19.5	4.3	0.2	0.3	26.9
CG	Small	0.1	19.4	48.4	22.8	4.6	4.6	51.6
	Medium	0.3	27.2	47.4	19.8	2.3	2.9	52.6
	Large	0.8	46.8	42.3	7.3	1.1	1.7	57.7
WG	Small	>0.1	7.8	32.1	30.8	14.5	14.7	69.2
	Medium	0.1	13.3	40.9	28.5	7.2	10	71.5
	Large	0.4	26.1	11.5	51.5	4.6	5.9	48.5
BS	Small	<.1	1.0	7.3	16.1	71.0	4.7	29.0
	Medium	<.1	2.9	16.5	24.6	49.4	6.6	50.6
	Large	0.1	9.5	18.1	25.9	28.6	17.8	71.4
AI	Small	<.1	0.5	4.0	9.3	4.9	81.3	18.7
	Medium	<.1	1.3	7.7	12.8	3.4	74.8	25.2
	Large	<.1	4.7	10.3	15.5	1.8	67.6	32.4

Small: 41-56 cm
Medium: 57-66 cm
Large: > 66 cm