test groups of fall chinook salmon were transported directly from the Klickitat Hatchery.

Transporting hatchery fish by barge around the Columbia River dams to avoid mortality remains a viable management option. In spite of an impaired homing ability, barged fish in this study returned to the hatchery at a rate equal to that of the controls. Barging not only increased survival, which benefited the sports and commercial fisheries, but also provided an adequate number of fish returns to the hatchery for reproduction purposes.

Acknowledgments

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Literature Cited

EBEL, W. J.
1974. Marking fishes and invertebrates. III. Coded wire tags useful in automatic recovery of chinook salmon and steelhead trout. Mar. Fish. Rev. 36(7):10-13.

EBEL, W. J., D. L. PARK, AND R. C. JOHNSEN.
1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

ELLIS, C. H., AND R. E. NOBLE.
1960. Barging and hauling experiments with fall chinook salmon on the Klickitat River to test effects on survivals. Wash. Dep. Fish., 70th Annu. Rep., p. 57-71.

MCCABE, G. T., JR., C. W. LONG, AND D. L. PARK.
1979. Barge transportation of juvenile salmonids on the Columbia and Snake Rivers, 1977. Mar. Fish. Rev. 41(7):28-34.

SLATICK, E., D. L. PARK, AND W. J. EBEL.
1975. Further studies regarding effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 73:925-931.

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MOVEMENT OF SABLEFISH, *ANOPLOPOMA FIMBRIA*, IN THE NORTHEASTERN PACIFIC OCEAN AS DETERMINED BY TAGGING EXPERIMENTS (1971-80)

The sablefish, *Anoplopoma fimbria*, is a North Pacific species distributed along the North American coast from Mexico to the Bering Sea and on the Asian coast east to Kamchatka and south to northeastern Japan. The maximum life span of sablefish appears to be near 40 yr (Beamish and Chilton in press). At 3 yr of age, sablefish reach a weight of about 1 kg and an average length of 47 cm. By 8 yr of age, sablefish have grown to about 3 kg and average 64 cm in length (Low et al.[1]).

The sablefish fishery in the northeastern Pacific Ocean and Bering Sea developed rapidly in the past 15-20 yr, growing from small United States and Canadian fisheries to large-scale multinational fisheries by Japan, the U.S.S.R., and the Republic of Korea (ROK). The increased exploitation of sablefish was followed by declines in catch per unit effort (CPUE) in many areas (Low et al. footnote 1). Because of this decline in CPUE, a tagging program was instituted to identify management areas and determine migration patterns.

Some studies of sablefish migration had been conducted in the 1950's and 1960's (Holmberg and Jones 1954; Edson 1954; Pruter 1959; Pasquale 1962; Novikov 1968; Pattie 1970). In these studies, most of the tagged fish were recovered near the area tagged. However, some fish were recovered over 1,000 km away (Holmberg and Jones 1954; Pruter 1959). Some fish tagged in the Gulf of Alaska were recovered off the California coast (Edson 1954) while other fish, tagged off the Washington coast, were recovered in the Bering Sea (Pasquale 1962; Pattie 1970). The results of these studies provided direct evidence of the occurrence of some long-range movement. The degree of long-range movement within the population could not be evaluated, since, in most of the studies, the number of fish tagged and recovered was small and each tagging project covered only a portion of the known range of sablefish.

Methods

To tag sablefish, over as much of its range as pos-

[1]Low, L. L., G. K. Tanonaka, and H. H. Shippen. 1976. Sablefish of the northeastern Pacific Ocean and Bering Sea. Processed rep., 115 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

sible, a cooperative tagging program was established involving the National Marine Fisheries Service, California Department of Fish and Game, Oregon Department of Fish and Wildlife, and research vessels from the U.S.S.R. and the ROK. A total of 34,640 sablefish were tagged from 1971 through 1976 from off southern California to the Kodiak Island area in the Gulf of Alaska. The number of sablefish tagged varied along the coast with the greatest number released in International North Pacific Fisheries Commission (INPFC) area, Columbia (Fig. 1). No fish were tagged in the western Gulf of Alaska or British Columbia (INPFC areas, Charlotte and Vancouver, north of lat. 48°30'); only a small number were tagged in the central Gulf of Alaska.

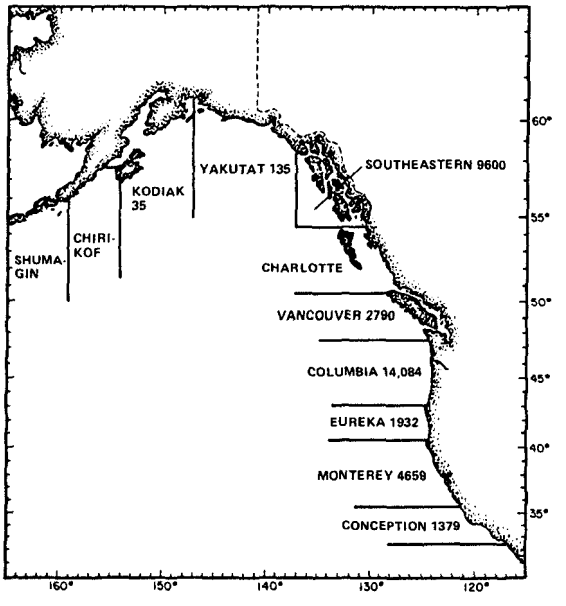

FIGURE 1.—Number of sablefish tagged in each International North Pacific Fisheries Commission area, 1971-76.

Five types of gear were used to capture sablefish in the cooperative research program: Trawl, trap, longline, rod and reel, and troll. Trawl, trap, and longline were the predominant gear types accounting for almost 99% of the captures. After capture, the sablefish were placed in tanks continuously supplied with seawater. The fish to be tagged were dipped from the tank, placed in a padded tagging cradle, and measured for fork length to the nearest centimeter. Those fish not seriously injured at capture were tagged and released. Most of the trawl-caught fish tagged during the study were taken in 400-mesh Eastern trawls equipped with 3.8 cm mesh liner. The traps used had either one or two tunnels and were 0.86 m wide by 0.86 m high by 2.44 m long (Hipkins 1974).

Three types of tags were used in the cooperative research program: Anchor, spaghetti, and an experimental tag. Spaghetti tags (yellow-colored, size #20 vinyl tubing) were applied to 636 fish in 1971 and another 100 by 1972 to provide a standard for evaluating the recovery rate of the anchor tags. Some experimental tags similar to standard spaghetti tags, but applied with a hollow needle and secured by interlocking plastic terminals, were tested in 1973. Only 76 fish were tagged with this method, which proved to be too time consuming for general use. The primary tag, a Floy FD68[2] anchor tag, was used on the remainder of the fish. Tagging information recorded included the tagging agency, vessel name, cruise number, fishing set, gear used, fishing depth, position in degrees and minutes, date, fish length, and the relative condition of the fish.

Tag recovery data were recorded in the same way as the release data, although the information reported was more variable. The most consistent recovery data reported were tag number, recovery date, fish length, and recovery location. Other data occasionally reported for recoveries include the capture gear, depth of capture, sex, weight, and state of maturity.

In some instances, the tag recovery information was treated as more detailed than actually reported. For example, the recovery location, recorded in degrees and minutes, may have been derived from other information, such as a recovery location lying between two reported loran base lines in a given depth strata or a location reported as lying at a given bearing and distance from a prominent landmark. The dates may represent the midpoint of periods ranging from 3 to 30 d, or may also be the day of delivery of a sablefish catch which contained the tagged sablefish. However, the errors introduced by such interpolation were very small in terms of the distances traveled or time the tagged fish were at large.

Distance traveled between release and recovery locations was the shortest distance between the two points calculated by great circle distance.

Sablefish tagging and recovery data were transformed into SPSS (Statistical Package for the Social Sciences) files. SPSS programs (Nie et al. 1975) were used to produce both the descriptive and analytical statistics presented in this report.

[2]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Results

As of 31 December 1980, there were 1,362 tag recoveries for an overall recovery rate of 3.9%. The INPFC area of recovery was known for 1,334 of the 1,362 recoveries. Recoveries by INPFC area are shown in Figure 2 where it can be seen that most sablefish were recovered in the same area as tagged and that only a limited amount of long-range movement occurred.

More precise analysis of movement was possible for 969 sablefish for which recovery was reported by position rather than general geographic area. Grouping these recoveries by distance from release site revealed that 65% of all recoveries occurred within 100 km of the release site, 24% were recovered within

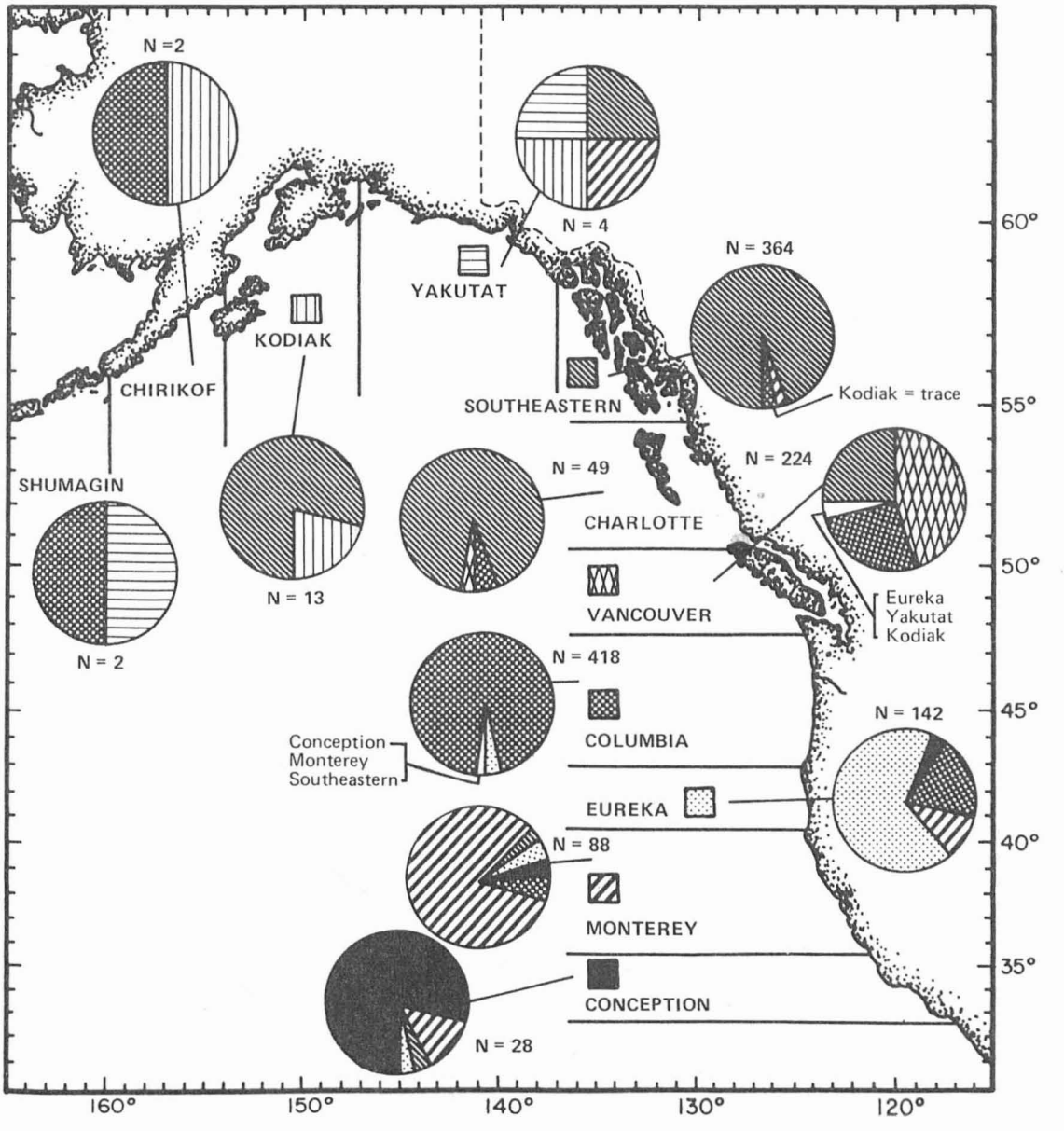

FIGURE 2.—Number of sablefish recovered in each International North Pacific Fisheries Commission (INPFC) area and the percentage of recoveries by INPFC area of tagging.

100-500 km, 8% within 500-1,000 km, and only 3% were recovered at distances >1,000 km from the release site (Table 1). Regression analysis (Table 2) revealed a slight, but significant increase in distance traveled in relation to the number of days at liberty.

Analysis of variance tests of movement relative to area released was significant, indicating that the amount of movement differed between areas (Table 3). Least significant range tests (Sokal and Rohlf 1969) showed fish recovered from Yakutat releases were significantly different ($P = 0.05$) from other recoveries. Only two tagged fish were recovered from releases made in the Yakutat area, both at long distance from the release site.

TABLE 1.—Distance traveled between release and recovery sites by tagged sablefish in the northeastern Pacific Ocean.

Distance (km)	Percent
<100	65.3
100-500	23.9
501-1,000	7.6
1,001-2,000	2.8
>2,000	0.3
$N = 969$	

TABLE 2.—Regression analysis of kilometers traveled by tagged sablefish on the number of days at liberty.

$\beta = 0.0876$ SE = 0.0131
$\alpha = 97.63$ $R^2 = 0.04$

ANOVA

Source	df	Mean squares	F
Regression	1	4,079,421.425	44.653**
Residual	967	91,358.267	

**$P<0.05$.

An analysis was performed to determine if there was any seasonal variation in movement such as movement between spawning and feeding grounds or winter and summer grounds. Releases and recoveries were fairly evenly distributed throughout the year, although more were recovered during the spring and summer months when the fisheries were more active. It was assumed that if seasonal movement occurred, fish would be recovered near the release site in the same season and in other areas in other seasons; however, for fish tagged in January-March and October-December the opposite occurred (Table 4). Recoveries tagged in the spring (April-June) and winter (October-December) months exhibited the greatest amount of movement, which suggests that fish may be more active in these months. Using chi-square statistics, significant differences were detected between seasons ($\chi^2 = 42.42$,9 df), but not in any discernible pattern.

TABLE 3.—Movement of sablefish in relation to INPFC area of release.

Area of release	N	Mean	SD	95% C.I.	Min.	Max.
Conception	23	150.8	289.1	25.8-275.8	5	1,010
Monterey	94	240.3	415.6	155.2-325.4	0	2,172
Eureka	92	60.2	102.5	39.0- 81.4	0	576
Columbia	315	108.5	246.5	81.2-135.8	0	2,373
Vancouver	85	75.5	88.7	56.3- 94.6	0	531
Southeast	352	249.8	352.9	212.8-286.8	0	1,866
Yakutat	2	1,510.3	281.1	0-4035.6	1,311	1,709
Kodiak	6	375.5	285.0	76.4-674.6	30	779
Total	969	170.7	293.5	152.2-189.2	0	2,373

ANOVA

Source	df	Mean squares	F
Between areas	7	1,373,994.5	15.946**
Within areas	961	86,165.4	

**$P<0.05$.

TABLE 4.—Seasonal variation in sablefish movement in the northeastern Pacific Ocean.

Release	Time of recovery				
	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Total
Jan.-Mar.					
Mean (km)	196.33	67.09	54.83	78.51	78.44
Sample size	24	106	69	28	227
SD	392.58	166.95	64.05	142.97	184.44
Apr.-June					
Mean (km)	317.37	380.12	175.87	228.71	254.29
Sample size	29	89	141	77	336
SD	314.48	431.75	267.96	329.30	345.16
July-Sept.					
Mean (km)	92.04	117.98	74.19	128.23	95.64
Sample size	21	48	89	28	186
SD	126.68	188.08	239.45	265.66	220.92
Oct.-Dec.					
Mean (km)	196.68	159.56	131.20	293.08	175.57
Sample size	28	61	84	35	208
Total					
Mean (km)	209.37	185.32	120.64	200.34	164.63
Sample size	102	304	383	168	957
SD	292.43	328.62	233.40	376.89	301.98

It was hypothesized that movement was related to size-at-tagging. To test this, recoveries were grouped into three divisions: <40 cm, 40-60 cm, and >60 cm. These divisions were derived from data presented by Low et al. (footnote 1), and correspond to juvenile, juvenile-maturing, and mature fish, respectively. No significant differences were found among the three groups (Table 5).

One difficulty in evaluating the recovery information is the lack of area specific catch and effort data with which to weight recoveries. For example, in 1973 the sablefish fisheries off Oregon and Washington were at a low level, while those off California were active. Releases made off Oregon in 1972 were recovered off California in 1973. In 1974, fisheries off Oregon became active and most of the fish tagged off Oregon were recovered at or near release locations, and many sablefish tagged off California were recovered off Oregon as well.

Catch data are available by INPFC area for all nations harvesting sablefish. These data can be utilized to provide a rough weighting to tag returns if it is assumed that catch is proportional to effort. Table 6 contains the percent of total catch, recoveries, and tagged sablefish for each INPFC area. It can be seen that recoveries for each area were generally proportional to releases except for the Monterey, Eureka, and Vancouver areas in which higher or lower recoveries occurred due to movement between adjacent areas. Neither the releases nor recoveries of tagged sablefish was proportional to area sablefish catches. A high percentage of the catch came from the Yakutat and Kodiak areas (30%) while only 0.5% of the tagged fish and 1.3% of the recoveries occurred in these areas. Conversely, the Columbia and Vancouver areas accounted for 13% of the catch, but 49% of releases and 48% of the recoveries. The Chirikof and Shumagin regions accounted for 15% of the catch (nearly equal to Columbia-Vancouver), but no fish were released in these areas, and only 0.2% of the recoveries occurred in these areas. While general catch data is not a substitute for more detailed catch and effort data, it does indicate that on a gross level estimates of movement did not appear to be influenced by the level of fishing as measured by catch.

TABLE 5.—Analysis of variance of distance traveled (km) by sablefish in relation to size at tagging.

Size Group (cm)	Mean	SD	*n*
<40	134.9	298.8	106
40-60	118.7	273.4	687
>60	117.2	260.3	560
All sizes	119.3	270.0	1,353

ANOVA

Source	df	Mean squares	*F*
Between groups	2	9,259.95	0.098
Within groups	957	94,493.38	

Discussion

The results of this study indicate that for the study period, sablefish are primarily nonmigratory and that most movement is limited to relatively short distances. Long-distance movement was found to occur in only a small portion of the population. These results suggest that the amount of interchange decreases with distance and movement has little effect on abundance over long distances. Beamish et al. (1980) reported similar results for sablefish tagging studies performed in the waters of British Columbia.

The results also provide indications that the northeastern Pacific sablefish population can be subdivided into "stocks" or management units. It does appear that sablefish off southern California are independent of those off Oregon and Washington and these are independent of stocks in the eastern Gulf of Alaska, since very little movement occurs over long distances. Finer divisions are suggested by the data,

TABLE 6.—Total sablefish catch for 1971-79, the number of sablefish released and recovered (1971-80), and the percentage of total catch, releases, and recoveries with each INPFC area.

INPFC area	Total *catch (t)* (1971-79)	Number of		Percent of total in area		
		Releases	Recoveries	Catch	Releases	Recoveries
Conception	7,886	1,379	28	3	4.0	2
Monterey	30,563	4,659	88	10	13.0	7
Eureka	12,557	1,938	142	4	6.0	11
Columbia	28,067	14,084	418	9	41.0	31
Vancouver	12,273	2,790	224	4	8.0	17
Charlotte	20,386	0	49	7	0.0	4
Southeastern	54,628	9,600	364	18	28.0	27
Yakutat	53,060	155	4	18	0.4	0.3
Kodiak	37,240	35	13	12	0.1	1.0
Chirikof	18,223	0	2	6	0.0	0.1
Shumagin	25,866	0	2	9	0.0	0.1
Total	300,749	34,640	1,334			

but definite conclusions cannot be reached in the absence of fisheries data to weight the results.

The net distance traveled was not related to size, time at liberty, or season. During the period of this study, the abundance of sablefish was believed to have been decreasing from overfishing (International North Pacific Fisheries Commission 1980). It is possible that behavior and migration tendencies could be different when the population is stable or increasing. Recently, a relatively strong year class of sablefish has been noted in most areas (International North Pacific Fisheries Commission 1980). Some of these fish had been tagged in 1979 and 1980 (Hughes 1980[3]). It will be interesting to see if movement patterns of adults alter in response to the presence of a large year class.

Acknowledgments

The sablefish tagging program was a cooperative effort involving several agencies which included the California Department of Fish and Game, Oregon Department of Fish and Wildlife, Fisheries Research and Development Agency of Korea, and the Pacific Institute of Fisheries and Oceanography (U.S.S.R.). Assistance in tag recovery and data transmittal were provided by the above agencies and the Alaska Department of Fish and Game, Canadian Department of Fisheries and Oceans, Japan Fisheries Agency, as well as individual fishermen. Dwayne Rodman, current tagging program coordinator, administered the program and his diligence in recording and maintaining the tag data files is appreciated. Acknowledgment is also made of the critical review and helpful suggestions provided by Richard Beamish of the Pacific Biological Station, Nanaimo, B.C.

Literature Cited

BEAMISH, R. J., AND D. E. CHILTON.
In press. A preliminary evaluation of a method to determine the age of sablefish (*Anoplopoma fimbria*). Can. J. Fish. Aquat. Sci.

BEAMISH, R. J., C. HOULE, AND R. SCARSBROOK.
1980. A summary of sablefish tagging and biological studies conducted during 1979 by the Pacific Biological Station. Can. Manuscr. Rep. Fish. Aquat. Sci. 1588, 194 p.

EDSON, Q. A.
1954. Premilinary report on the Alaska sablefish fishery. Pac. Mar. Fish. Comm., Bull. 3:73-85.

HIPKINS, F. W.
1974. A trapping system for harvesting sablefish *Anoplopoma fimbria*. U.S. Dep. Commer., Natl. Mar. Fish. Serv., Fish. Facts 7, 20 p.

HOLMBERG, E. K., AND W. G. JONES.
1954. Results of sablefish tagging experiments in Washington, Oregon, and California. Pac. Mar. Fish. Comm., Bull. 3:103-119.

INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION.
1980. Proceedings of the 27th Annual Meeting—1980, Anchorage, Alaska, November 4 to 7, 1980. Int. North Pac. Fish. Comm., Vancouver, B.C., Canada, 352 p.

NIE, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BRENT.
1975. SPSS - Statistical Package for the Social Sciences. 2d ed. McGraw-Hill, N.Y., 675 p.

NOVIKOV, N. P.
1968. Tagging of the coalfish (*Anoplopoma fimbria* Pall.) in the Bering Sea and on the Pacific coast of Kamchatka. [In Russ.] Vopr. Ikhtiol. 8(5):955-957. (Transl. *In* Probl. Ichthyol. 8:762-764.)

PASQUALE, N.
1962. Notable migration of sablefish tagged in Puget Sound. Wash. Dep. Fish., Fish. Res. Pap. 2(3):68.

PATTIE, B.
1970. Two additional long-range migrations of sablefish tagged in Puget Sound. Wash. Dep. Fish., Tech. Rep. 5:22-23.

PRUTER, A. T.
1959. Tagging experiments on sablefish at Holmes Harbor, Wash. Wash. Dep. Fish., Fish. Res. Pap. 2(2):66-70.

SOKAL, R. R., AND F. J. ROHLF.
1969. Biometry. The principles and practice of statistics in biological research. W. H. Freeman and Co., San Franc., Calif., 776 p.

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[3]Hughes, S. 1980. Pacific west coast and Alaska research plan on sablefish, 1980-84. Unpubl. manuscr., 17 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

WINTER AND ALTERED SPRING MOVEMENTS OF STRIPED BASS IN THE SAVANNAH RIVER, GEORGIA

The striped bass, *Morone saxatilis*, population of the Savannah River supports a small sport fishery and provides all the brood fish for the Richmond Hill, Ga., striped bass hatchery. Information on the biology and management of Savannah River striped bass also has application for management of similar populations in coastal rivers of Georgia, South Carolina, and Florida.

Previous studies of striped bass in the Savannah River have shown that the population is primarily