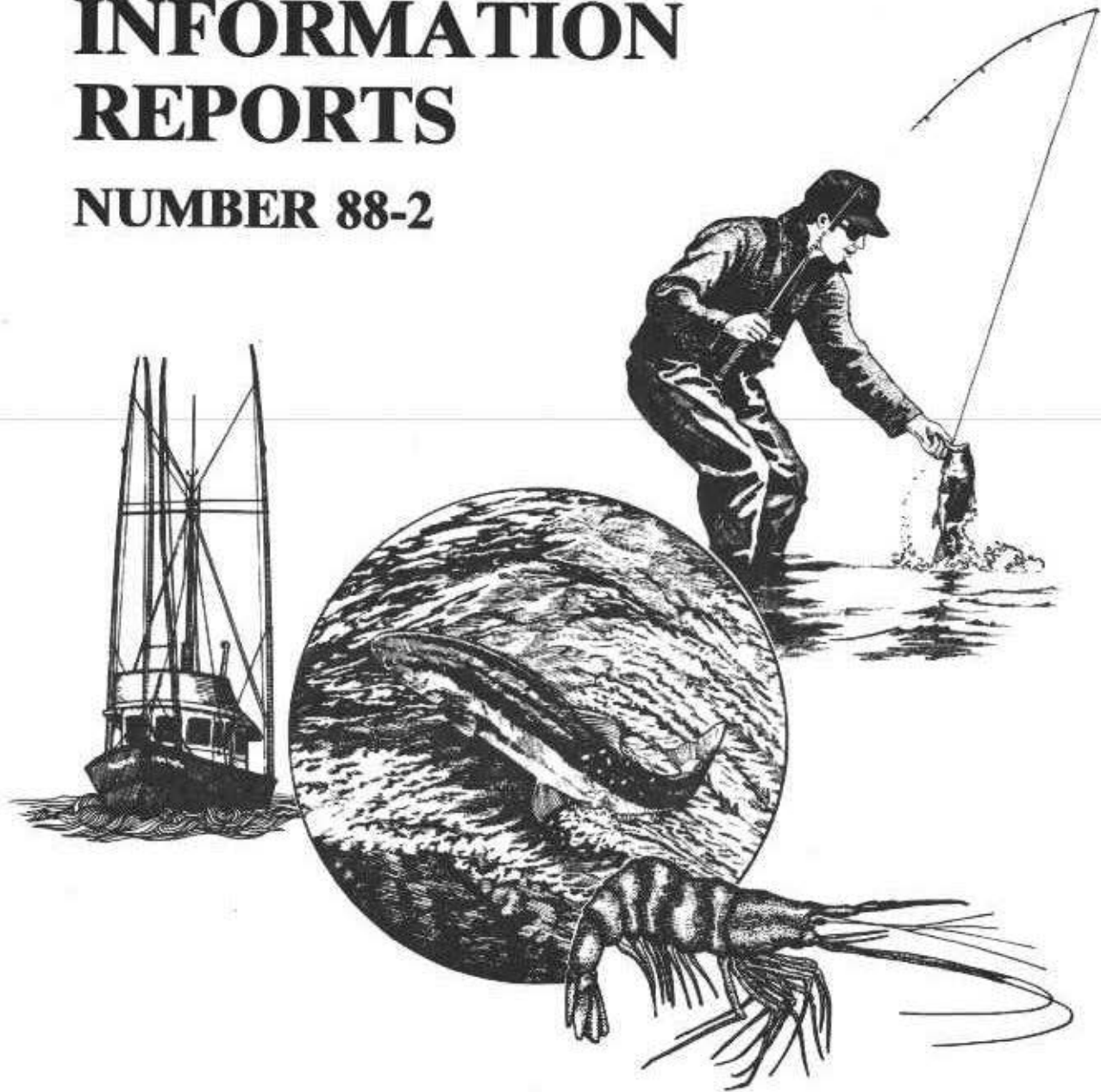


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Results of Dover Sole Tagging Projects Conducted
by The State of Oregon, 1948-75

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The State of Oregon, 1948-75

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ABSTRACT

Eight tagging experiments were conducted or assisted by the State of Oregon between 1948 and 1975 to study migration and tagging methods and to validate scale aging techniques on Dover sole Microstomus pacificus. There were 22,336 trawl-caught Dover sole tagged and released off the states of Oregon and Washington. Through February 1986, 2,194 tags (9.8%) had been recovered. Maximum time at liberty was 22 years. Only modest north-south movement was observed, and 98% of the recaptures were within 50 nautical miles of the tagging site. Fish moved inshore in the spring and returned to deep water spawning areas in the fall. Mature males were usually found deeper than 150 fm throughout the year, whereas juveniles and females were usually found in shallower depths during the summer. The Astoria Canyon and Cape Blanco may be barriers to north-south movement. Poor recovery rates were obtained from small fish, fish from deep water, fish in poor condition, and fish released while the vessel was traveling at cruising speed away from the area of catch. Instantaneous total mortality rate for Oregon Dover sole was established to be between 0.28 and 0.36.

INTRODUCTION

In 1985 a working group was established by the Technical Subcommittee of the Canada-United States Groundfish Committee to collate, on a coastwide basis, a single document that would describe the migration and stock delineation of Dover sole *Microstomus pacificus*. This report fulfills that obligation on behalf of the Oregon Department of Fish and Wildlife (ODFW).

Because Dover sole was, and still is, among the most important west coast groundfish species (16,950 metric tons (mt) were landed in 1986), numerous tagging studies were undertaken at various times to obtain information on various life history and fishery parameters. Most important of these were migration rate, fishing rate, and age and growth studies.

The eight tagging studies summarized in this report (Table 1) cover 28 years from 1948 through 1975. The tagging studies were conducted off the Oregon and southern Washington coast in Pacific Marine Fisheries Commission (PMFC) international statistical areas 2B, 2C and 3A (Figure 1), which is within the general operational area of most of the Oregon trawl fleet. A long range plan to encompass all the tagging studies did not exist. Rather, individual studies were conducted to answer specific questions pertinent to the period in which the tagging took place. Most of the studies reported here received some degree of analysis, but only two were published; the 1955 Willapa Deep study (Westrheim and Morgan 1963), and the tagging study of 1969-75 in PFMC Area 2B (Barss 1982). Numerous progress reports summarized tag returns, and Milburn (1966) produced a contract report for the tagging studies conducted in 1961-64.

In this report each tagging study is treated as a unit, even if it occurred over more than one year, in chronological order of the date of beginning. This is followed by a brief overview of tag recoveries by PMFC area and our interpretation of the seasonal changes in the depth distribution of Dover sole, particularly as these changes relate to spawning behavior.

METHODS AND MATERIALS

Tagging

The methods and materials were generally the same throughout the eight projects. Tagging occurred aboard commercial, chartered, or research trawlers. Tow duration ranged from 1 to 3 hours aboard commercial trawlers and from 0.5 to 1 hour on chartered and research trawlers. Fish that appeared healthy were held in tanks containing fresh or circulated sea water prior to tagging. Three types of tags were used: (1) 1.6 cm diameter Peterson disc tags with nickel or stainless steel pins; (2) 20.3 cm double-barb dart tags of vinyl tubing; and (3) FD-67 anchor tags (Table 1). Tags were affixed in the mid-body region approximately 2 cm below the dorsal fin. Tag number and fork length (cm) were usually recorded at tagging. Fish were graded as to their condition during the 1948-49 experiment. Scales were taken for age validation studies during the 1966-68 study and during the summer of 1971.

Table 1. Dover sole tagging projects conducted by Oregon Department of Fish and Wildlife.

Years	PMFC area	Location	Depth (fm)	Tag type	Number series	Number tagged	Number recovered	Percent recovered
1948-49	3A	Columbia River	5-90	Peterson disc	B, D-H, P Miscellaneous numbers	2,066	209	10.1
1955	3A	Willapa Deep	150-280	Peterson disc	JJ 0000-2415	2,406	266	11.1
1955-62	3A	Northern Oregon	57-200	Peterson disc	JJ 2416-2834 (miscellaneous)	100	16	16.1
	2C	Cape Lookout	114-150	Peterson disc	JJ 2436-2445, 2601-2616	18	0	0.0
	2B	Florence, Oregon	72-98	Peterson disc	JJ 2800-2860	37	2	5.4
1961	2C	Stonewall Bank	110-272	Peterson disc	KK 0001-1149, 1237-2164	2,073	129	6.2
				Double-barb dart	AA 0001-1147, 1215-2157	2,083	141	6.8
	2B	Heceta Bank	112-137	Peterson disc	KK 1150-1236	87	2	2.3
				Double-barb dart	AA 1148-1214	67	0	0.0
1961-66	3A	Columbia River	50-450	Peterson disc	KK 2165-10528	8,287	1,042	12.6
				Double-barb dart	AA 2158-2886	786	22	3.0
1966	3A	Columbia River	36	Peterson disc	KK 10530-10574	45	4	8.9
1966-68	3A	Columbia River and Willapa Deep	40-215	Peterson disc	KK 10847-11342	495	18	3.6
				FD-67 anchor	LL 00001-01000	723	7	1.0
				Both the above	KK 10576-10846 and miscellaneous LL00066- 00999	272	18	6.6 ^a
1969-75	2B	Reedsport to Cape Blanco: Summer	60-136	Peterson disc	KK 12140-13159	1,016	114	11.2
		Winter	120-424	Peterson disc	KK 11344-12139, JJ 2738- 2899, JJ 3200-3872 ^b	1,621	200	12.3
	1C	Port Orford	250-420	Peterson disc	JJ 3873-3998, 2700-2737	164	0	0.0

^a Percent recovered with anchor tags was only 3.7%.

^b Number series excludes 137 miscellaneous JJ tags released in the 1955-62 study.

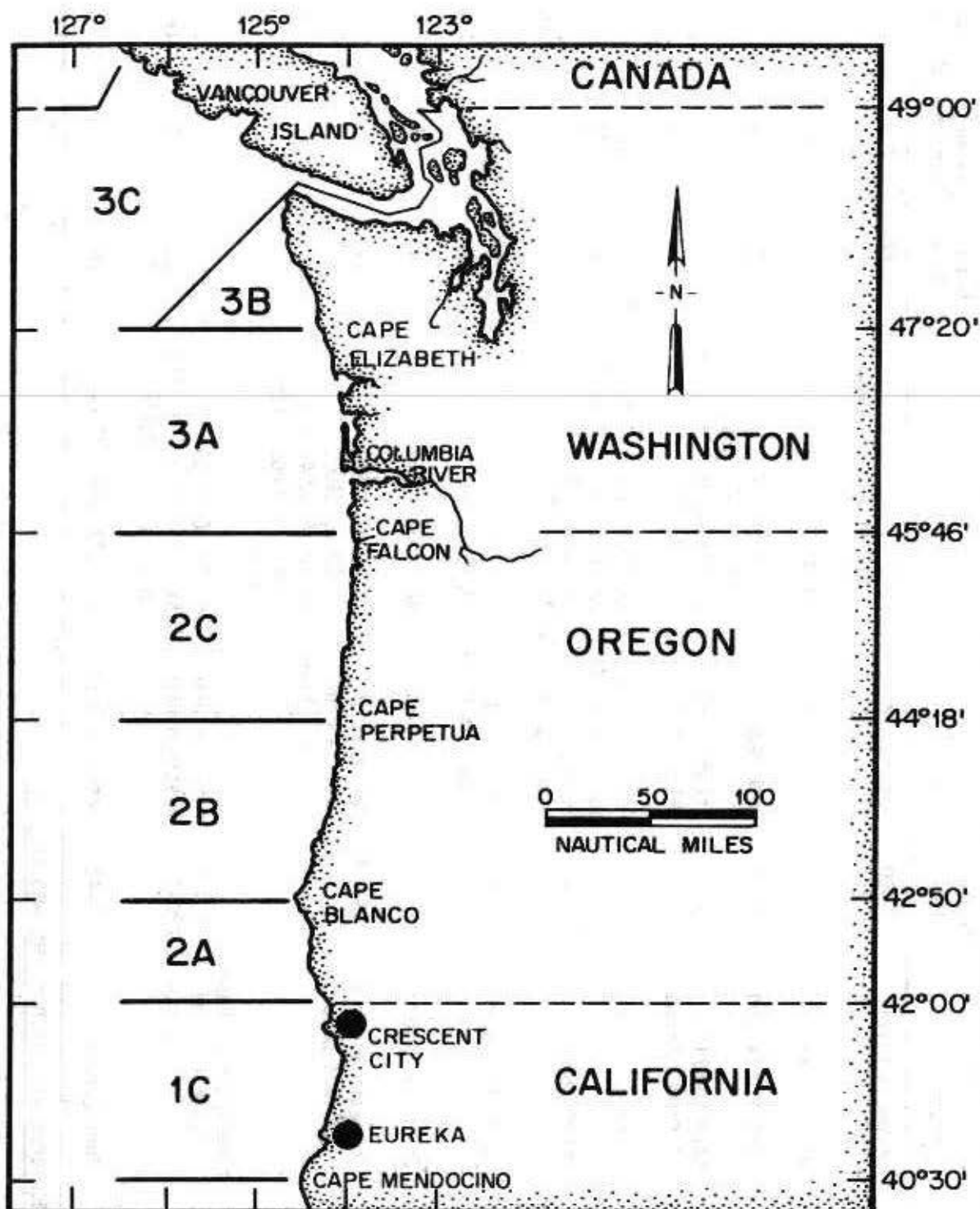


Figure 1. Pacific Coast from Vancouver Island to Cape Mendocino showing Pacific Marine Fisheries Commission International Statistical Areas 3C to 1C.

Tag Recovery

We depended on the cooperation of trawl fishermen and processing plant employees for recoveries. A modest reward (\$0.75 to \$1.00) was paid to persons returning a tag or a tagged fish. Recovery information included fork length (cm); sex; scales, otoliths, or both; time; location; depth of recovery; and the name of the trawler and the person returning the tag.

RESULTS AND DISCUSSION

The Tagging Studies of 1948 and 1949

In 1948-49 the Fish Commission of Oregon released 2,066 tagged Dover sole to study migration, stock interchange, growth, fishing intensity, and tagging techniques (Anonymous 1951; Harry 1956). Tagging occurred on trawlers fishing out of Astoria, Oregon, and fish were obtained from commercial catches. Most of the fish were released offshore between Willapa Bay, Washington, and Tillamook Head, Oregon, at depths between 5 and 90 fm (Figure 2). This area was chosen because at the time it was the primary area of fishing activity for Oregon trawlers. Peterson disc tags with nickel pins were used (Table 1). Subsequent recoveries totaled 209 (10.1%).

Results from this project indicated that Dover sole were primarily non-migratory in a north-south direction. Most fish (96%) were recovered within 25 nautical miles (nm) of the tagging site (Table 2). The longest migration was by a 40.5 cm female that was recovered about 70 nm to the north off Cape Elizabeth, Washington. The longest migration to the south was made by three fish that were recovered off Cape Lookout, about 60 nm south of where they were tagged. A definite movement of fish from the fishing grounds to deeper water, presumably to offshore spawning areas, occurred in October.

Table 2. Movement of Dover sole (in nautical miles) from the 1948-49 tagging sites. We recovered 31 tagged fish for which record of recovery location was unknown.

Movement	Tag recoveries	
	Number	Percent
<26	171	96.1
26-50	3	1.7
51-75	4	2.2

Several factors were found or expected to affect recoveries. Corrosion of the nickel pin holding the tag to the fish caused a large percentage of defective pins after one year in the ocean. These pins could be easily broken. Tagged fish were subjected to the usual physical damage and stress of commercial trawling, and this was suspected to be a source of mortality. Recovery rate was related to size and condition of the tagged fish. The recovery rate was lowest for fish under 37 cm, which are discarded at sea or have a greater chance of slipping through trawl mesh. Fish in the best condition and large enough to be fully recruited to the fishery provided the

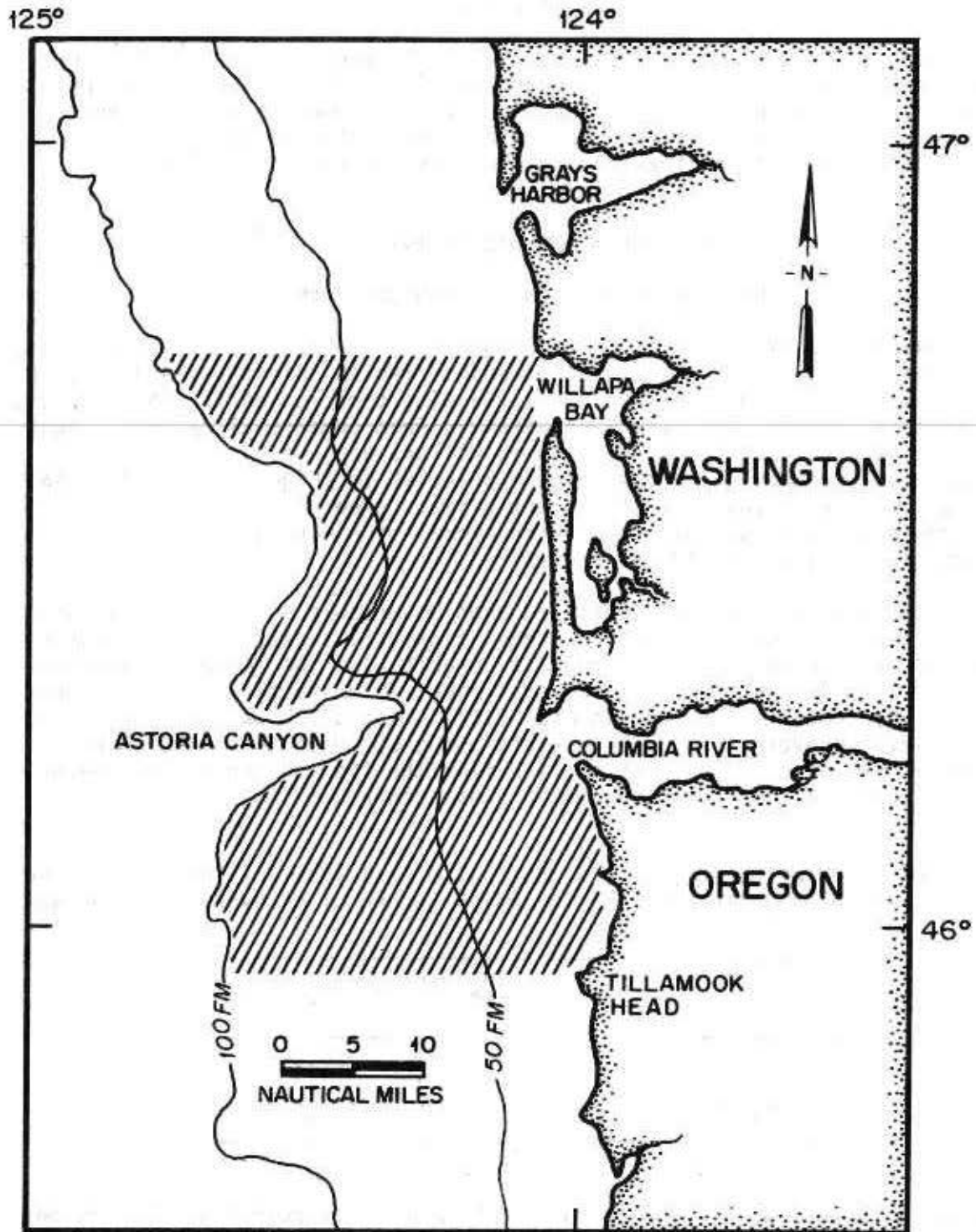


Figure 2. Area of tagging for Dover sole tagging studies conducted off southern Washington and northern Oregon, 1948-49. Crosshatched area denotes tagging sites.

highest returns. Market conditions for trawl caught fish were poor in 1948 and 1949 resulting in sporadic fleet activity. Trawling was not usually attempted during winter months, and no tag recoveries were made in the months of December through March.

The Tagging Study of 1955 (Westrheim and Morgan 1963)

In 1955 a tagging study was undertaken to determine if Dover sole caught on a winter, deep water spawning ground discovered in 1954 were the same fish that were available on traditional inshore fishing grounds during the summer months. This project was undertaken because of a controversy within the fishing industry over the merits of harvesting Dover sole while they were concentrated in deep water for spawning. Peterson disc tags were affixed to the fish with stainless steel pins.

The Astoria based commercial trawler Marian F was chartered to catch fish for tagging. Only fish in good condition were tagged. Most of the fish tagged were males because tagging took place near the end of the spawning season when most females had left the area. Of the 2,406 fish tagged and released in two adjacent offshore fishing grounds in the Willapa Deep area off Washington in 150 to 280 fm (Figure 3), 266 (11.1%) were recovered. Migration was not extensive with only seven fish recaptured more than 30 nm from the tagging area. Maximum migrations were 110 nm north to the southwest coast of Vancouver Island and 360 nm south to off Humboldt Bay, California. Only two fish were recaptured that had traveled south of the Astoria Canyon. Seasonal offshore-inshore migration was indicated. During the summer months principal recovery depths were 30 to 60 fm. Recoveries were primarily between 180 and 300 fm during winter months.

Two factors apparently adversely affected recoveries. Low recovery rate (2.0%) resulted from releasing tagged fish while cruising away from the tagging area at a speed of 8-9 knots. Recovery rate was higher (12.5%) when fish were released as the vessel drifted or was trawling at 2-3 knots. Returns were also poor (0-2%) for fish shorter than 36 cm at tagging.

The Tagging Study by Art Anderson, 1955-1962

In 1955, Art Anderson of Astoria, Oregon, owner-captain of the commercial trawler Betty, was provided Peterson disc tags to tag Dover sole caught in new or little fished deep water trawling areas south of the Astoria Canyon. Through 1962 he tagged 155 fish, most of which were released during the spring months. One hundred were released from just south of the Astoria Canyon southwest to off Cape Falcon in 57 to 200 fm (Figure 4). Eighteen fish were released off Cape Lookout in 114 to 150 fms and 37 fish were released off Florence, Oregon, in 72 to 98 fms. Eighteen tags (11.6%) were subsequently recovered.

All 14 recaptured Dover sole tagged in "deep" water (96-200 fm) were caught 22 to 35 nm inshore or northeast of the tagging area. All but one were recaptured during the summer months. The four recoveries from tagging in "shallow" water (57-64 fm) were recovered near the release location. Only two fish were recovered from the area off Florence, one of which moved inshore and north 23 nm. No Dover sole tagged off Cape Lookout were recovered.

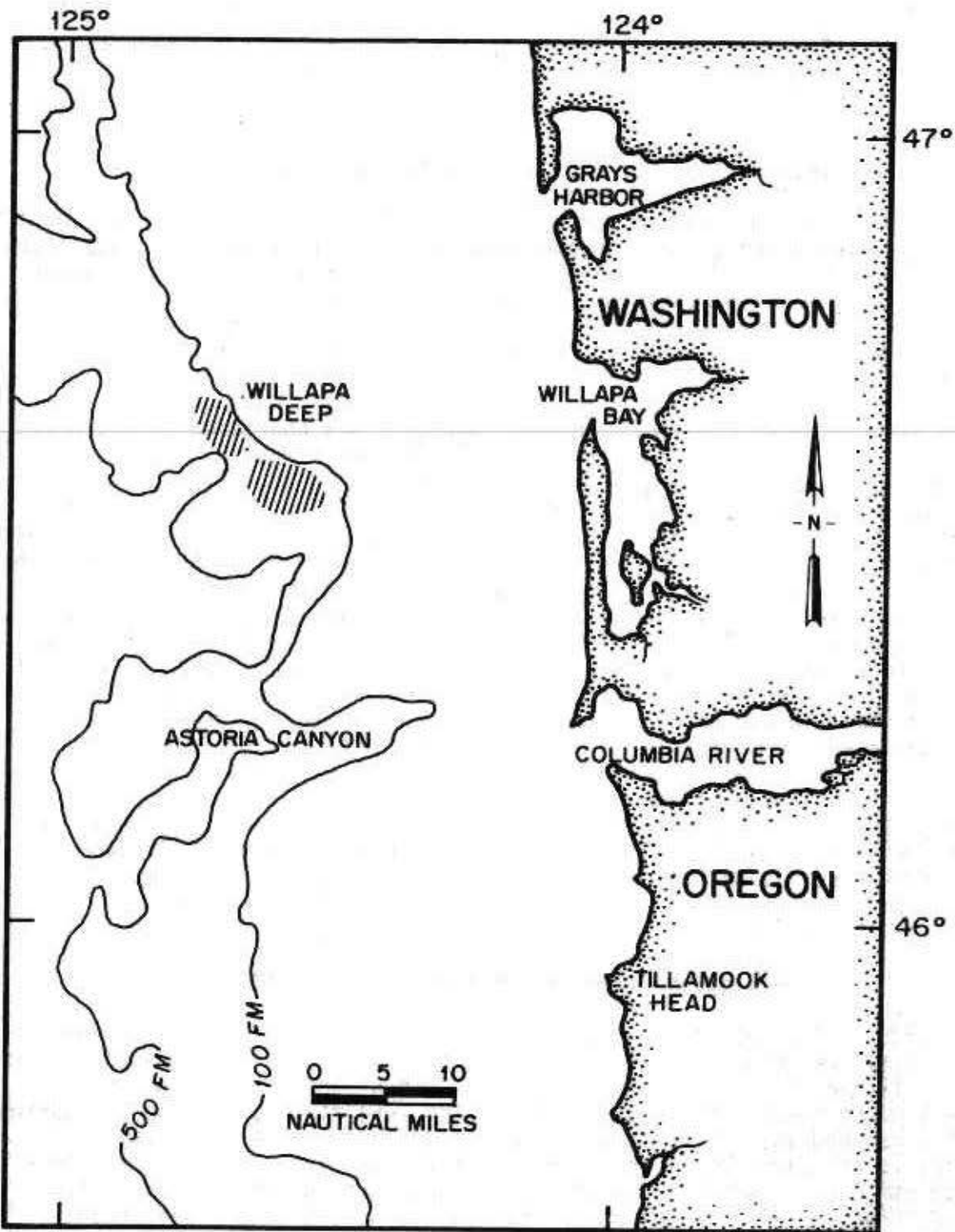


Figure 3. Area of tagging for the Dover sole tagging study conducted in Willapa Deep off Willapa Bay, Washington, 1955. Crosshatched areas denote tagging sites.

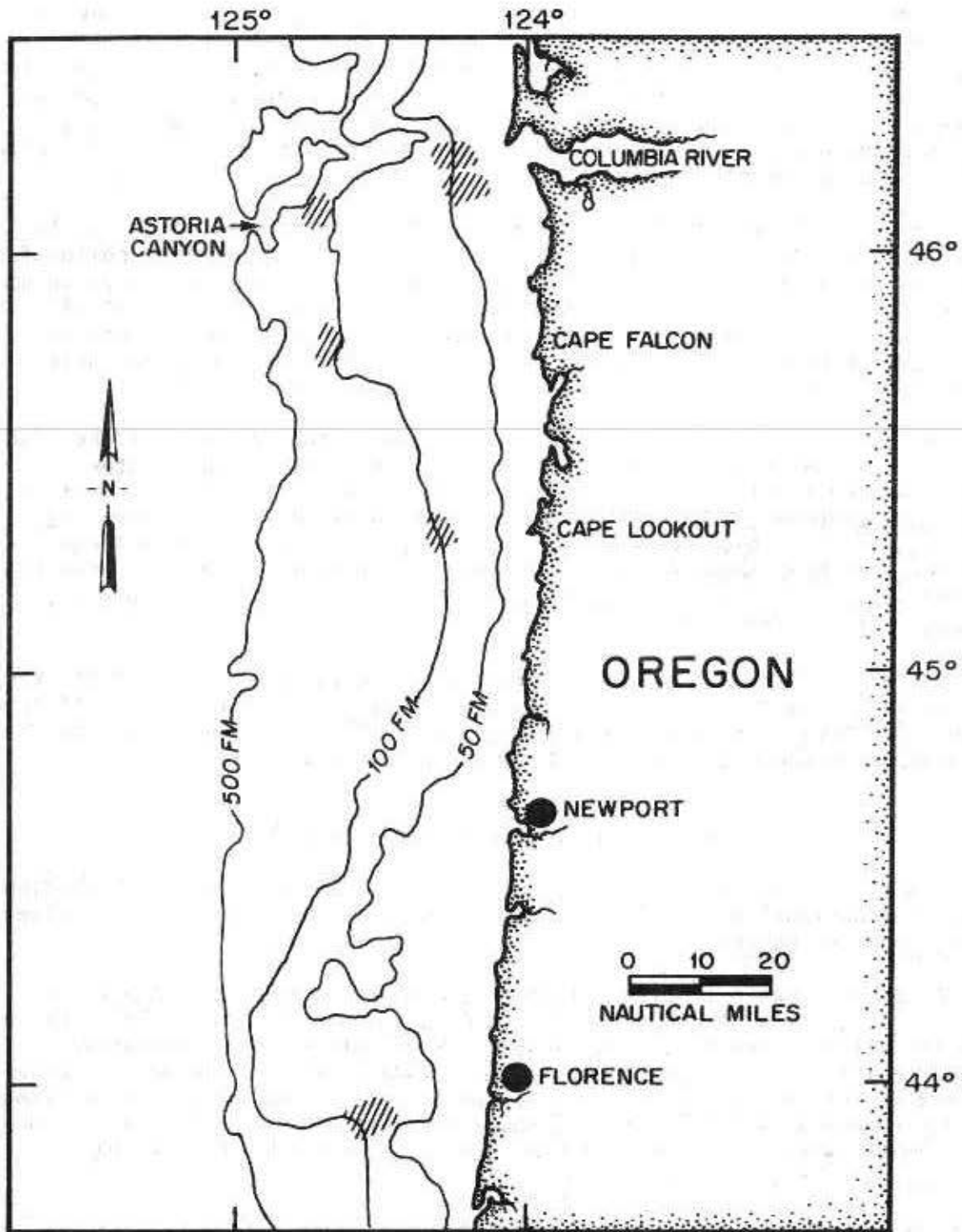


Figure 4. Area of tagging for the Dover sole tagging study conducted by Captain Art Anderson off northern and central Oregon, 1955-62. Crosshatched areas denote tagging sites.

The Tagging Study of 1961

In 1961, 4,311 tagged Dover sole were released near Stonewall Bank in PMFC Area 2C, and on Heceta Bank in PMFC Area 2B in 109-272 fm (Figure 5). This project was conducted to determine the migration patterns of Dover sole off the central Oregon coast and to evaluate the recovery rates of Petersen disc tags and 8-inch, double-barb, vinyl tube dart tags. Fish were tagged during exploratory fishing cruise Number 50 from the National Marine Fisheries Service research vessel, John N. Cobb.

There were 272 tagged fish recovered (6.3%). No general northerly or southerly migration pattern was found, with most of the recoveries coming from the general area of tagging. Seven tagged fish (2.7%) moved more than 50 nm south of the tagging area, one tagged fish was recovered 200 nm south off Eureka, California. Only 12 fish moved over 50 nm north, and only one of those traveled north of the Astoria Canyon. This fish was recovered near Destruction Island, Washington, (Area 3B) and had moved 178 nm.

The low recovery rate may be due to seasonal catch patterns of the fishing fleet and the usual low recovery rate of fish tagged in deep water. Greatly reduced fishing effort for Dover sole in the winter months, whether due to poor weather or choice of fishermen not to trawl in deep water, may explain the lack of Dover production during that period. Little information on inshore-offshore movement was gained by this project, since only nine tag recoveries were obtained from depths greater than 150 fm. These recoveries occurred in the winter and spring.

Rate of recovery did not depend upon depth released, since over 95% were released at depths between 110 and 130 fm. There was only a slight difference between the recovery rate of the two tag types; 140 recoveries from 2,083 dart tags and 132 recoveries from 2,073 Peterson disc tags.

The AEC Tagging Studies of 1961-66

From 1961-66 a tagging study was funded by the Atomic Energy Commission (AEC). The National Marine Fisheries Service provided the research trawlers John N. Cobb and Commando.

The project was established in part to determine possible effects on domestic fisheries of the dumping of radioactive waste in deep water (100 to 1,000 fm) off northern Oregon and southern Washington. The cooperative tagging project was designed to study the offshore-inshore movement of Dover sole and sablefish Anoplopoma fimbria, two important commercial species known to inhabit deep water. If returns showed movement of fish from proposed deep water dumping sites to inshore fishing grounds, then such areas would be unsuitable as sites for radioactive waste disposal.

From June 1961 to May 1966, we tagged 9,013 Dover sole with Petersen discs and double-barb vinyl tube tags. Fish were released in PMFC Area 3A between 50 and 450 fm in an area southwest of the Columbia River (Figure 6). A total of 1,064 (11.8%) were subsequently recovered.

In general, recoveries of tagged Dover sole showed an inshore, northerly movement during the late spring and early summer with an opposite movement to

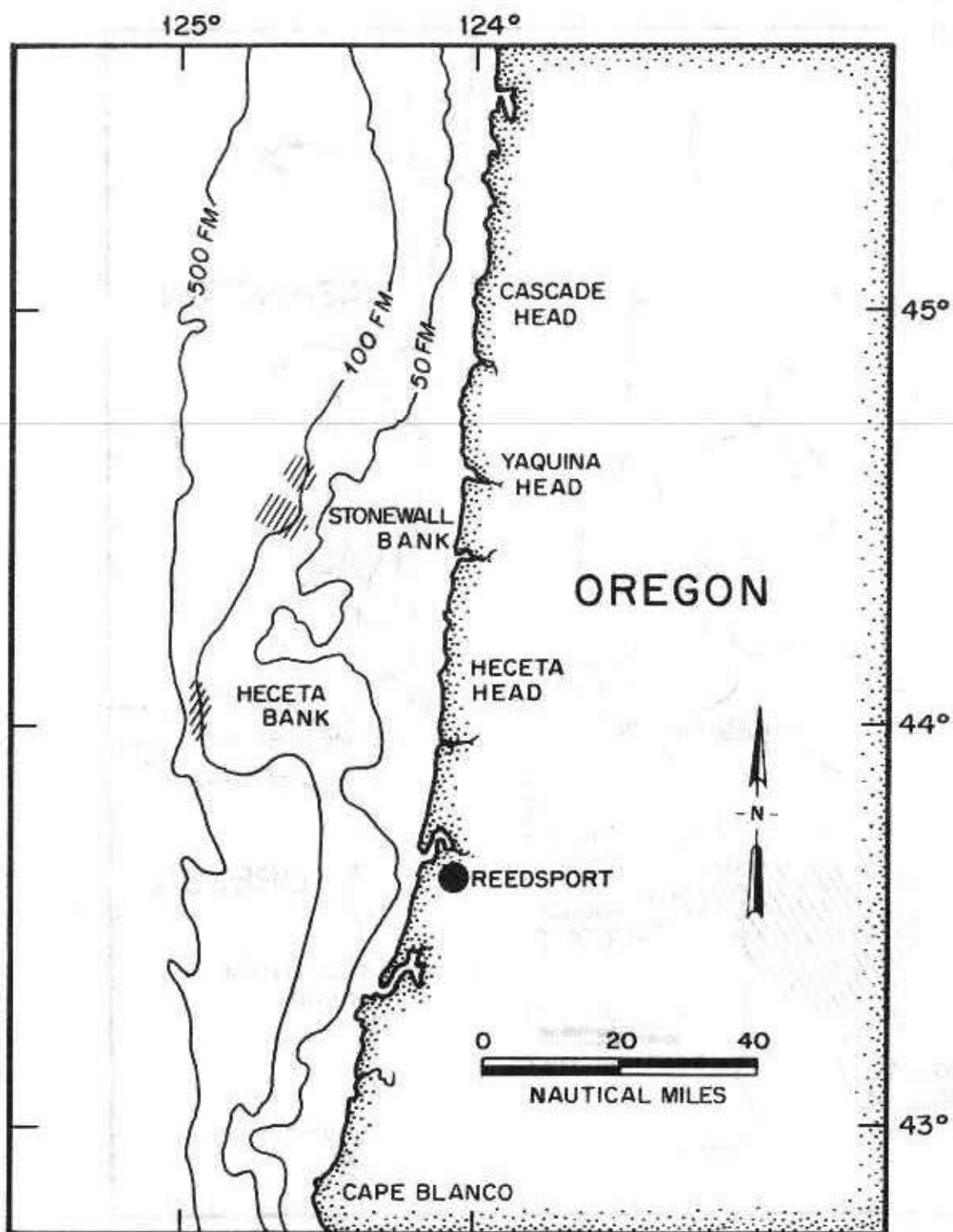


Figure 5. Area of tagging for the Dover sole tagging study conducted near Stonewall Bank and Heceta Bank off central Oregon, 1961. Crosshatched areas denote tagging sites.

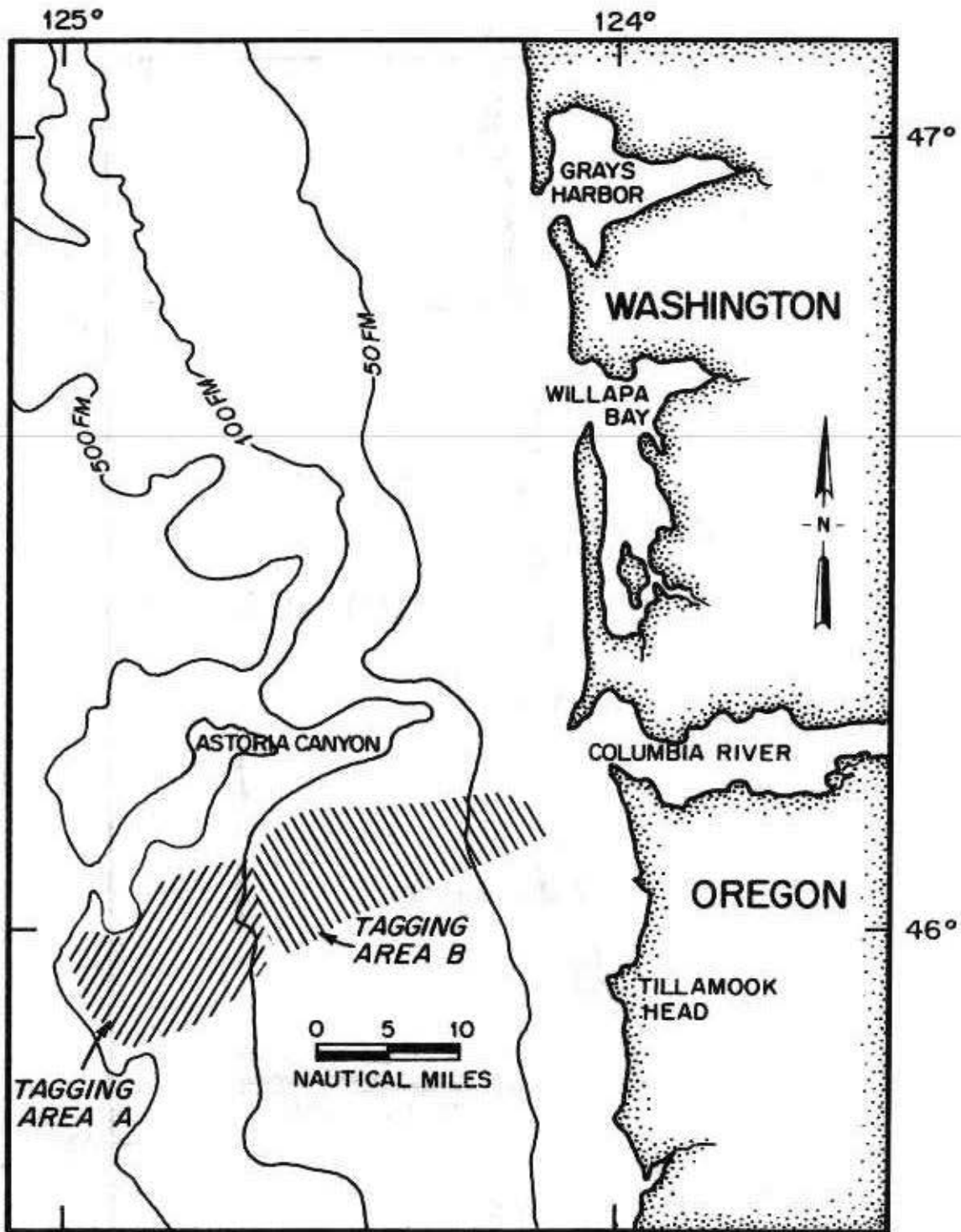


Figure 6. Area of tagging for the Dover sole tagging study conducted off northern Oregon and southern Washington, 1961-66. Crosshatched areas denote tagging sites.

offshore areas in the late fall and early winter (Milburn 1966). Most tagged fish were recovered near the tagging site. Only 10 fish were recovered outside the PMFC area of tagging, all to the south. The most southerly recovery, 250 nm south, occurred off Crescent City, California, in PMFC area 1C. The greatest movement north was of a fish recaptured off Willapa Bay, Washington, 40 nm from the tagging site.

Of the 6,070 tagged fish released at depths greater than 100 fms, 106 were recovered from depths greater than 100 fms and 212 were recovered from depths less than 100 fms. Of the 2,942 tagged fish released at depths of less than 100 fms, 676 were recovered at depths less than 100 fms and 29 were recovered at depths greater than 100 fms.

Milburn (1966) noted that fish tagged in water deeper than 100 fms were mostly mature males and that the low recovery rate suggested that most males do not migrate to inshore areas of high fishing intensity. Recovery data analysis also suggested that two major concentrations of Dover sole exist during the summer months, at least in the tagging area--an inshore concentration that consists mostly of females and small males, and an offshore concentration that consists mostly of large males.

Recoveries from this study strongly suggested that the Astoria Canyon may be a barrier to North-South movement of Dover sole. Tagged fish apparently did not cross the deep part of the canyon. Any northerly movement appeared to occur shoreward at the head of the canyon.

The Tagging Study of 1966

In April 1966, Dover sole were tagged with Petersen discs and released just north of the Columbia River in 36 fm. (Figure 7). The purpose of this tagging was to validate the scale aging method. Fish were tagged on the chartered commercial trawler Columbia. Tagging was discontinued after only one tow because the vessel skipper decided not to continue with the study. Forty-five tagged fish were released and four (8.9%) were recovered. All recoveries were at the tagging site and within 13 months of release.

The Tagging Studies of 1966-68

In 1966-68 tagged Dover sole were released just south of the Columbia River in 40 to 58 fm and in Willapa Deep in 170 to 215 fm (Figure 8). The purpose of this experiment was to validate the scale aging method and evaluate the use of FD-67 anchor tags for juvenile fish. Fish were tagged on the chartered commercial trawler Sunrise. Tow duration was usually 30 minutes or less.

A total of 1,539 tagged fish were released. Only 47 (3.1%) tagged fish were recovered. The low recovery rate was expected because most of the tagged fish released were under market size and such fish are usually discarded at sea or escape from commercial trawls.

No extensive movement was found, but seven of the nine recoveries from the Willapa Deep tagging in 1968 occurred in shallow water near the Long Beach Peninsula and the Columbia River. The greatest movement from Willapa Deep was a fish recovered 38 nm southeast of the tagging site in 28 fm off the Columbia

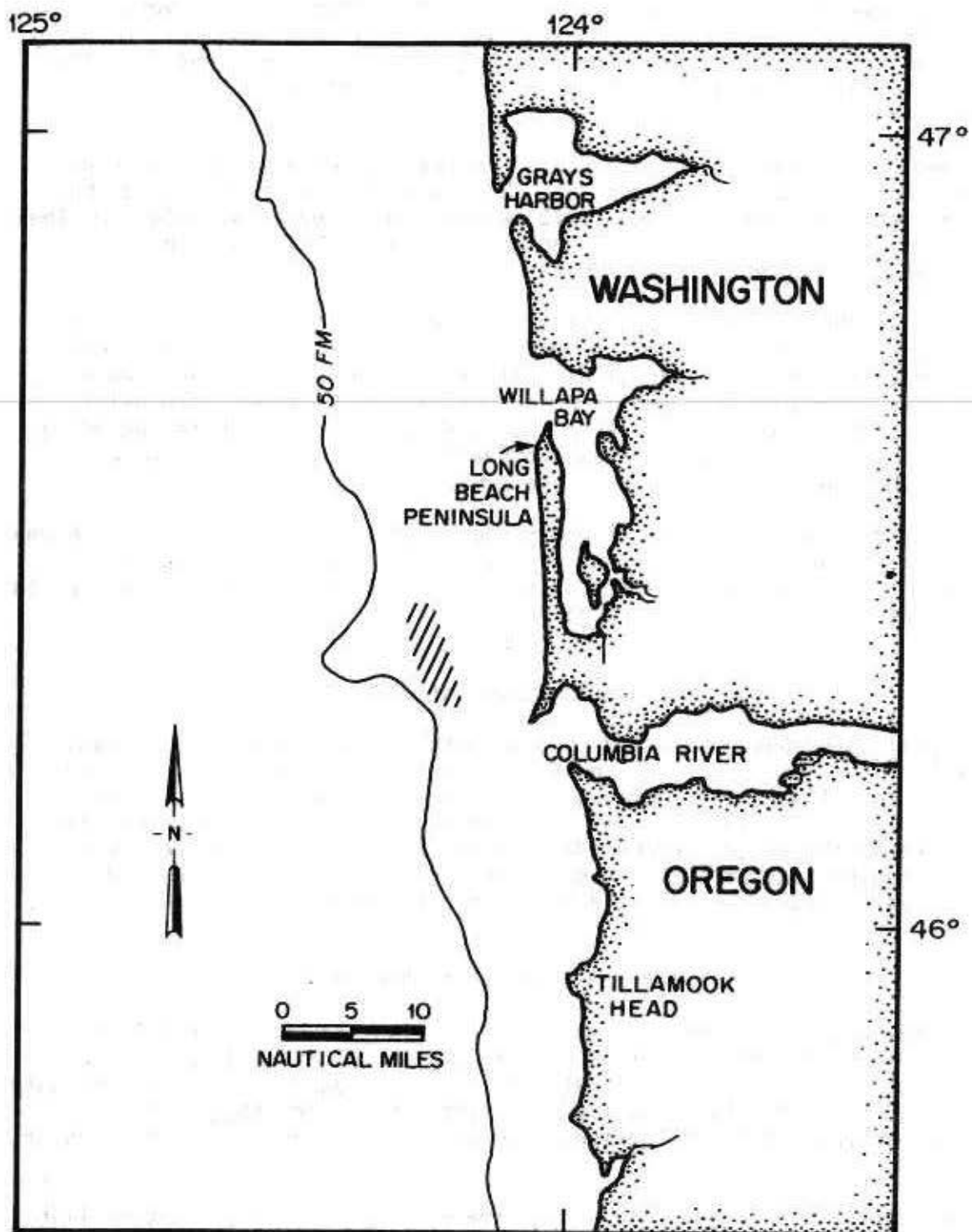


Figure 7. Area of tagging for the Dover sole tagging study conducted off the Columbia River, 1966. Crosshatched areas denote tagging sites.

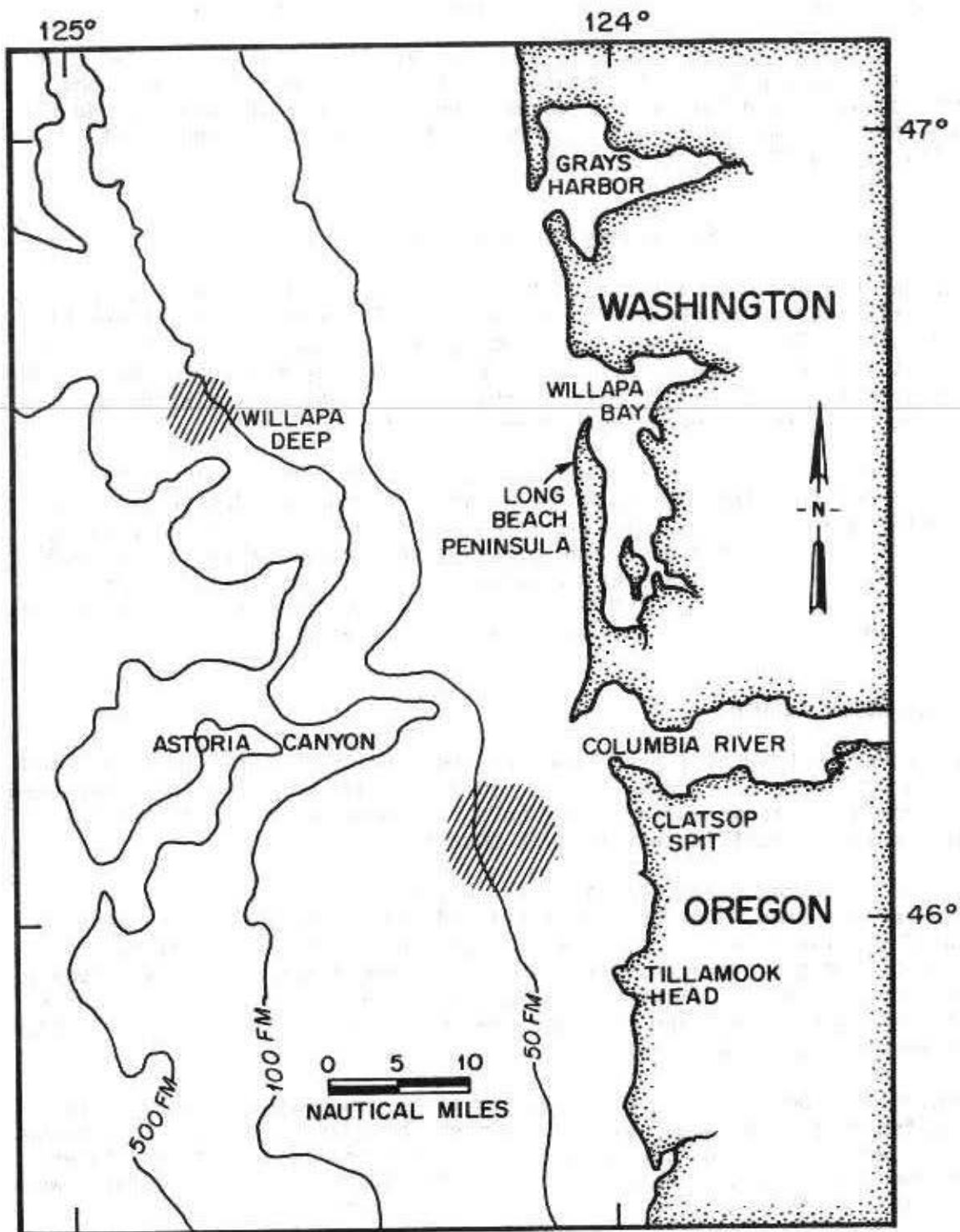


Figure 8. Area of tagging for the Dover sole tagging study conducted off the Columbia River and in Willapa Deep, 1966-68. Crosshatched areas denote tagging sites.

River mouth. Only one fish, a female, was recovered in deep water. She was caught after 2 years at liberty near the tagging site at Willapa Deep.

About half of the fish tagged in shallow water off Clatsop Spit were recovered at shallow depths off the mouth of the Columbia River and off Long Beach Peninsula. The others were recovered near the area of tagging. Nearly all recoveries were made during the summer months. One fish tagged off Clatsop Spit moved 22 nm to the north.

The Tagging Study of 1969-1975

Between 1969 and 1975 a series of Dover sole tagging cruises took place in PMFC statistical areas 2B and 2A off the central Oregon coast (Figure 9) to obtain data on Dover sole movement from largely unstudied portions of the Oregon coast. We were especially interested in studying movement around Cape Blanco because it is associated with extensive reefs and strong winds and currents that may affect north-south movement of fish.

This study consisted of two parts. The first was to determine the dispersal of tagged fish from the spawning areas. Tagging was done during the winter months when Dover sole fishing takes place in deep water on spawning concentrations. The second part took place in the summer of 1971 to provide further validation of the scale aging method. Scales were collected from tagged fish. Females were sought because of a suspicion that scales might not be reliable indicators of age for male Dover sole (Demory 1972).

Winter Deep Water Tagging

No recoveries have ever been reported from the 164 Dover sole tagged and released in PMFC Area 2A in 250-420 fm. This may have been due to an expected increased mortality from tagging Dover sole from deep water and to the low level of trawling effort in this area at that time.

Of 1,621 fish tagged in PMFC Area 2B in 120-424 fm, a total of 200 (12.3%) were recovered. One hundred fifty (84.3%) of the recoveries were in the area of tagging, and 26 (14.6%) were recovered south of Cape Blanco in PMFC Areas 2A and 1C. The greatest southerly movement was 160 nm by a female recovered off Eureka, California, from 300 fm. Only two tags were recovered north of the tagging area, and both were recovered from PMFC Area 2C. Twenty-two tags were recovered with no information on area of recovery.

Recoveries from fish tagged during the winter suggest that Dover sole migrate offshore to deep water by early winter and move inshore in the spring. Tagged fish were recovered at a depth greater than 150 fm during the winter. Few males were recovered in water shallower than 100 fm, and most females were recovered at a depth less than 150 fm during the summer.

Summer Tagging

In the summer of 1971, 1,016 Dover sole were tagged in PMFC Area 2B between 60 and 150 fm. One hundred fourteen (11.2%) tagged fish were

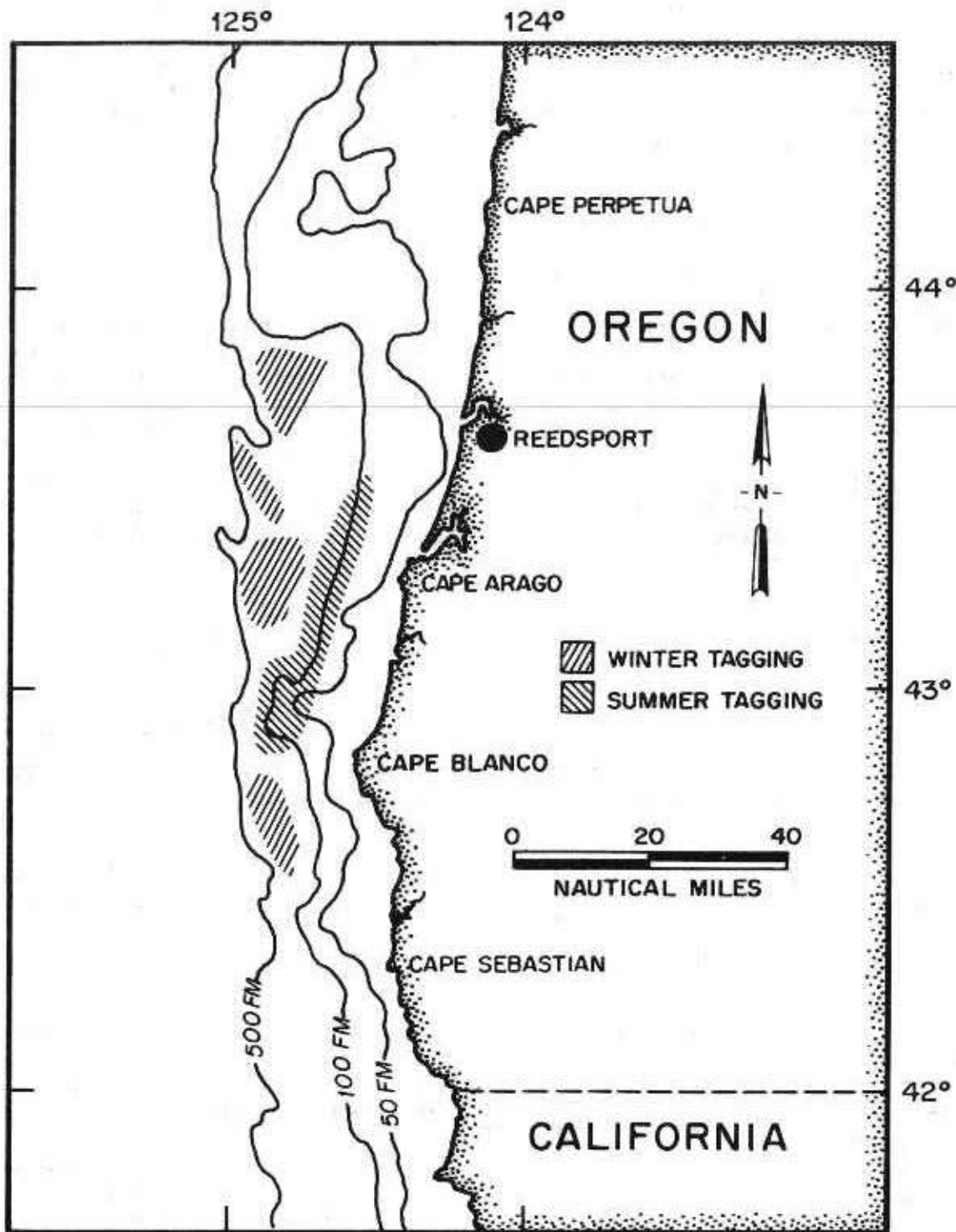


Figure 9. Area of tagging for the Dover sole tagging study conducted off the central Oregon coast, 1969-75. Crosshatched areas denote tagging sites.

recovered with 103 being recaptured in the area of tagging. The greatest northerly movement was about 20 nm for a fish captured off Reedsport, Oregon. Only three fish were known to have migrated south into PMFC Area 2A.

Tagged fish were usually recovered in offshore waters throughout the winter months beginning in October and generally recovered inshore during the spring and summer. All the males were recovered outside of 100 fm whereas females were usually caught between 50 and 150 fm during the summer months.

An Overview of Dover Sole Movement

Tag returns from a number of experiments conducted over many years show that Dover sole move little in a north or south direction. About 98% of the recaptured fish were recovered within a radius of 50 nm of their respective tagging sites (Table 3). Regardless of the area of tagging, the pattern was consistent. This does not mean, however, that no movement occurs within a PMFC area, but little movement was observed between statistical areas. More dispersal was found in the studies conducted in PMFC areas 2B and 2C than in area 3A (Table 4). Fish tagged in Area 2C dispersed slightly to both the north and south whereas dispersal of fish tagged in Area 2B was to the south. Reasons for these differences in dispersal are not entirely clear, but the area adjacent to Stonewall Bank is characterized by irregular and often hard terrain that apparently is not good Dover sole habitat.

Table 3. Direction and distance (nm) of movement of tagged Dover sole recovered from all Oregon studies combined.

	South					North				
	>100	76-100	51-75	26-50	0-25 ^a	26-50	51-75	76-100	>100	
Number	8	2	17	51	1,934	56	7	9	4	
Percent	0.4	0.1	0.8	2.4	92.6	2.7	0.3	0.4	0.2	

^a North or south from tagging site.

Table 4. Recoveries (percentage) of Dover sole by PMFC area of tagging listed from north to south.

PMFC area of recovery	PMFC area of tagging		
	2B	2C	3A
3C	--	--	0.1
3B	--	0.4	0.3
3A	--	4.9	98.6
2C	0.7	87.9	0.6
2B	89.2	6.0	0.1
2A	8.7	0.4	0.1
1C	1.4	0.4	0.1
Number of recoveries	288	265	1,548

In general we conclude from our analysis that discrete subpopulations of adult Dover sole exist off the Oregon and Washington coast with only minor exchanges of adults between subpopulations. Our view of these exchanges may be flawed, however, because during the time of most of the tagging studies a deep water winter fishery was not developed to the extent that it is now. A deep water fishery, particularly off the Columbia River during the AEC tagging study, may have yielded different results.

Dover sole show strong seasonal inshore and offshore movement. From May through October tagged fish were usually recovered inside of 150 fm and during the rest of the year were generally recovered in deeper water (Table 5). Tag returns and commercial trawl activity indicate that Dover sole move into deep water in the fall and concentrate for spawning in November through March. Spawning usually peaks in January. They subsequently move inshore during the summer months where they disperse over feeding grounds.

We conclude from our analysis of tag returns that the Astoria Canyon and conditions near Cape Blanco may be physical barriers to movement of Dover sole. Tag returns indicate that north and south movement near the Columbia River probably occurs on the broad shallow shelf inshore of the Astoria Canyon rather than across the deep part of the canyon. Cape Blanco, the most westerly headland on the Oregon coast, is associated with extensive reefs that, combined with strong winds and currents, may inhibit north-south movement of fish.

Our tagging studies support the opinion that Dover sole are longlived. Chilton and Beamish (1982) reported Dover sole to be at least 45 years of age. We recently determined from an otolith section that a female Dover sole was 46 years of age. We have records for 13 fish that were at liberty for 10 or more years (Table 6), the longest being 22 years. This fish was caught within 1 nm of where it was released.

Table 6. Oregon Dover sole tag returns for fish at liberty for over 10 years. nm = nautical miles; F = female; M = male.

Tag number	Date tagged	Time at liberty		Movement		Sex
		Years	Months	Distance (nm)	Direction	
AA 880	27 May 1961	22	2	<1	--	--
KK 8318	16 May 1964	19	0	6	SW	F
KK 9546	18 May 1964	18	2	22	SW	--
KK 8481	16 May 1964	18	1	<1	--	M
KK 3989	22 May 1964	17	1	<1	--	F
KK 6883	9 May 1963	16	1	12	NW	F
KK 6772	9 May 1963	16	0	23	NW	M
KK 5982	7 May 1963	16	--	8	E	F
KK 9172	18 May 1964	14	10	14	W	F
JJ 363	21 May 1955	14	2	<10	N	M
KK 12841	3 August 1971	13	4	<1	--	--
JJ 3854	29 March 1973	10	7	--	--	F
KK 11398	31 December 1969	10	2	16	S	--

Table 5. Seasonal depth distribution at recovery for tagged Dover sole, all studies combined, 1948-75. Values are percent of total recoveries by sex and month.

Depth (fm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Males:												
0-49	0	0	0	2	7	8	32	26	17	16	0	0
50-99	0	0	0	3	32	66	47	56	54	43	0	17
100-149	0	0	0	13	42	23	21	14	17	22	0	0
150-199	0	0	13	8	5	1	0	1	9	8	13	0
200-249	57	50	52	36	7	1	0	1	3	8	81	67
250-299	14	33	29	36	7	0	0	0	0	0	6	17
>299	29	17	6	3	0	1	0	1	0	3	0	0
Number	7	6	31	64	57	79	104	77	70	37	31	6
Females:												
0-49	0	0	0	6	17	17	26	32	23	25	0	0
50-99	0	0	5	25	48	57	56	54	62	51	32	0
100-149	0	0	11	25	33	25	17	14	14	21	18	0
150-199	0	0	53	10	0	tr	tr	1	0	1	23	0
200-249	25	67	11	10	0	tr	0	0	1	1	23	100
250-299	75	0	21	16	2	0	tr	1	1	0	5	0
>299	0	33	0	8	0	tr	0	0	0	0	0	0
Number	4	3	19	51	120	273	212	155	186	76	22	1
Unknown sex:												
0-49	0	0	0	0	15	20	25	35	25	44	7	0
50-99	0	0	0	13	26	39	47	48	39	8	13	0
100-149	0	0	14	38	37	30	24	13	36	20	0	0
150-199	0	0	14	6	11	11	4	4	0	4	13	50
200-249	0	0	14	44	4	0	0	0	0	4	40	50
250-299	0	0	14	0	4	0	0	0	0	16	27	0
>299	100	100	43	0	4	0	0	0	0	4	0	0
Number	1	1	7	16	27	61	51	23	28	25	15	2

Estimates of Total Instantaneous Mortality Rate (Z)

Estimates of instantaneous total mortality rate were obtained for each Dover sole tagging experiment by using the method of Ricker, that is, calculating the regression of the natural log (ln) of the returns against year (Table 7). Estimates of Z ranged from 0.23 to 0.69. The high estimate for Z in the 1948-49 project was probably an artifact that resulted from the large tag loss caused by the defective pins. Likewise the high estimate of Z in the 1966-68 study was due to the large number of tagged juveniles not vulnerable to capture. The low estimate of Z in 1961 was probably the result of the low level of fishing effort directed towards Dover sole and the resulting low catch of that species in PMFC Area 2C prior to 1979.

Table 7. Estimates of total instantaneous mortality (Z) based on regression of the natural log of recoveries of year i to year $i+n$.

Study	PMFC area	Number of tags		Number of recovery years	Z	R^2
		Released	Recovered			
1948-49	3A	2,066	209	1-8	0.69	0.96
1955	3A	2,406	266	2-15	0.34	0.87
1955-62	3A	155	18	1-6	0.38	0.59
1961	2C	4,311	272	1-23	0.23	0.50
1961-66	3A	9,013	1,064	1-20	0.29	0.88
1966-68	3A	1,539	47	1-7	0.56	0.93
1969-75	2B	2,801	314	1-14	0.32	0.71
All studies combined		22,291	2,190	1-23	0.31	0.90

Estimates of Z were also made by qualifying recoveries by the fishing effort in the tagging area (PMFC area). This method was used where effort was known and when a sufficient number of tags was released over a short period of time. The regression of ln of tags/fishing hour on significant Dover sole trips against time (year) was calculated for annual recoveries. This method was used for PMFC Area 3A studies in 1962 and 1964 and Area 2B studies in 1970, 1971, and 1972. Estimates of Z ranged from 0.30 to 0.36 with the exception of the 1972 study which resulted in an estimate of 0.51.

We obtained a much higher R^2 value for our estimate of Z for the 1961 study in Area 2C by using the catch in the tagging area as a reflection of fishing effort. By calculating the regression of ln of tags/catch against time (year) for annual recoveries, we calculated Z at 0.28.

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