North American Journal of Fisheries Management 6:69–76, 1986

A Tag Suitable for Assessing Long-Term Movements of Spiny Dogfish and Preliminary Results from Use of This Tag

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Abstract.—A tag was developed and tested for the long-term marking of spiny dogfish (*Squalus acanthias*). The tag is retained without corrosion and with minor skin abrasion. They have not been lost from fish held in captivity for up to 3 years. Most recoveries were in the immediate release area, but some fish were recovered 250 to 7,000 km from the release area. The greatest distance travelled (7,000 km) was by a fish tagged in June 1980 in Queen Charlotte Sound and recovered in November 1982 off the northeast coast of Japan. The recovery rate for fish tagged and released in the Strait of Georgia and standardized for catch suggested that movement of spiny dogfish throughout their range is an important aspect of their biology. Less movement was exhibited by fish tagged in the Hecate Strait region. However, of the fish that did move, the majority were recaptured off Washington and the west coast of Vancouver Island and not in the Strait of Georgia.

Spiny dogfish (*Squalus acanthias*) have been an important commercial species off the west coast of Canada and are perceived by fishermen to be a serious predator of other commercially important species. They are a long-lived species, attaining ages in excess of 60 years (Ketchen 1975; Wood et al. 1979). They mature at ages of approximately 23 and 14 years for females and males, respectively (Ketchen 1975), but recent studies indicate that age at maturity may be considerably higher (McFarlane, unpublished data).

The development of an effective management strategy for the maintenance of a commercial fishery and control of the abundance of spiny dogfish requires a knowledge of the importance of short- and long-term movements. Because of the long life span and late age at maturity, it is possible that spiny dogfish may move extensively as juveniles or adults or both. To examine this possibility, it was necessary to develop a tag that would be retained with a minimum of loss and mortality and would not impair mobility. This report describes the design of a tag that we feel is suitable for a study of short- and long-term movements. Preliminary tagging results are presented to indicate the relative success of the tag.

Methods

The tag consists of two elongated plastic discs with rounded ends (Figure 1). Each disc measures 19.3 × 6.5 mm and is 1.1 mm thick. The disc is attached to the fish by two pins, which are inserted through holes drilled in each disc 2.5 mm from each end. The application of the tag is similar to that of a Petersen disc tag (Wydoski and Emery 1983). To avoid sharp cutting edges or the necessity of smoothing edges, each disc is "punched" during manufacture so that the edge of the surface adjacent to the fish is bevelled outwards. A message is printed on each side of each disc. The size of the tag allows for a considerable amount of information. The discs are fastened to the fish with titanium pins made specifically for this study from Grade 4, commercially pure (Ti70A) titanium wire. Each pin is 7.6 cm long and 0.99 mm in diameter.

The applicator (Figure 2) consists of a pair of hypodermic needles attached to a plexiglass handle in a way that allows for the insertion of the pins with the exact spacing required. The discs, one on each side of the fish, are attached just below the anterior base of the first dorsal fin. During the tagging operation, the hypodermic needles are pushed through the base of the fin, the two pins are inserted through one disc and into the hypodermic needles, and the applicator is withdrawn, leaving the pins and disc attached to the fish. The second disc is placed over the pins and secured by bending the end of each pin 180° to form a small circle, with the free end of the pin resting under the bent portion of the pin that projected from the hole in the disc (Figure 3). The discs are loosely affixed and bent outwards to follow the contour of the fish.

The suitability of this tag in the laboratory and in the ocean was compared to that of the Petersen disc tag and a Floy anchor tag. The suitability of pins manufactured from other metals was examined. Nickel and stainless steel pins were rejected

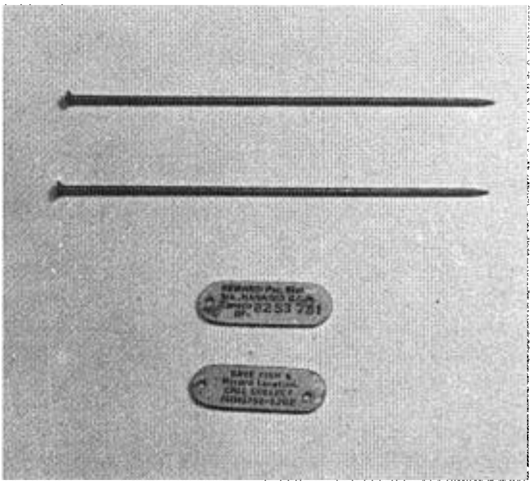

FIGURE 1.—Modified tag for spiny dogfish developed for this study.

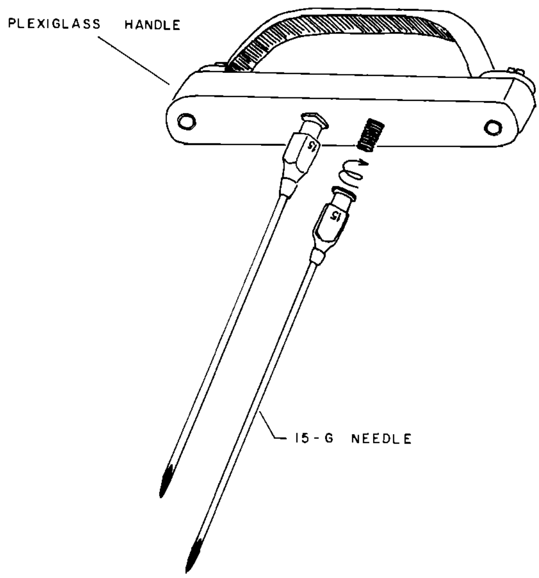

FIGURE 2.—Diagram of tag applicator.

as previous studies (Calhoun et al. 1951; Forrester and Ketchen 1955) showed them to be less resistant to corrosion than other metals. Tantalum pins were tested but they were more expensive and malleable than titanium. Both titanium and tantalum pins recovered from fish that had been at liberty for 1, 2, and 3 years were submitted to the Department of National Defence, Defence Research Establishment Pacific, Victoria, British Columbia, to compare the amount of corrosion of used pins with unused ones.

Barbless hooks were used to capture most fish. Barbed hooks and bottom trawls also were used. In most cases, fish were held in tanks on the vessel and only fish that appeared healthy were tagged. Fish were anaesthetized with MS 222 (tricaine) prior to tagging and were measured for total length to the nearest millimeter (tip of the snout to the tip of the upper lobe of the caudal fin when held in a horizontal position). Most tagged fish also were held in shipboard tanks to ensure recovery prior to release. Measurement to the nearest millimeter ensured that attention was paid to the measurement process and reduced error. Sex was determined for all fish and their condition was noted before and after tagging.

Spiny dogfish also were held in captivity and tagged with both the new tag and a conventional Petersen disc. These tagged fish were maintained for up to 3 years in a 62,000-L tank which contained flowing salt water. Growth and condition of these fish were examined every 3 months.

A reward was paid for recaptured fish. Capture locations were recorded. All returned fish were measured for length and sexed; the second dorsal spines were collected for age determination. The tag wounds from all fish that were recovered were assessed as follows: no wound, slight wound, or severe wound, according to the criteria described in Table 1.

Results

Suitability of Tag

The modified tag has been used for over 3 years in both the laboratory and the ocean. In the laboratory, 31 fish, ranging in size from 54 to 113 cm, received this tag. There was no mortality for up to 3 months. Although fish died over the 3-year period, in general they have survived longer than spiny dogfish normally survive in captivity (Vancouver Aquarium staff, personal communication). No tags were lost. There was some wounding after 1 year (40%), but the severity was much less (7% penetrated deeply into the flesh) than observed for the Petersen disc tag. The 37 fish that were tagged with the Petersen disc tag also had no immediate mortality and there was no tag loss. However, after 1 year, most fish (82%) developed wounds and many wounds (73%) penetrated deeply into the flesh and showed no signs of healing (Figure 4). Because of the severity of these wounds, the Petersen disc tags were removed after 1 year and the tag described in this paper was developed and applied. Wounds did heal 1 year after the removal of the Petersen tag.

FIGURE 3.—Modified tag attached to spiny dogfish showing portion of label and wire pin holding label in position.

FIGURE 4.—Severe wound caused by Petersen disc tag.

In the ocean, 31,498 spiny dogfish have received the new tag as of December 31, 1982, and 468 fish have been recaptured. In 1980, 6,080 of these fish were tagged with a prototype label that was not bevelled during manufacture to ensure smooth edges and, when applied, the pins were not bent so that the label was parallel to the body.

Recoveries of tagged fish were standardized for catch because commercial catches of spiny dogfish in the Strait of Georgia ranged from 763 to 4,320 tonnes from 1978 to 1982 in response to market demands (Table 2). Only fish that were at liberty for more than 6 months and less than 3 years were compared. This was necessary because some fish with the Petersen tag had been at liberty 5 years as of December 31, 1982, while fish receiving the new tag were at liberty only 3 years. The 3-year period for each tag was not the same. The 1980–1982 recovery percentage of the modified tag was standardized to the 1978–1980 recovery percentage of the Petersen disc tag. The standardized recovery percentage (3.9%) for the modified tag compared to the Petersen tag (2.4%) was significantly higher. We tested the ratios of the numbers put out to the numbers returned with a chi-square test and selected a significance level of $P = 0.01$. Because the materials used in the tags were similar and none of the modified tags were returned with one pin missing, the decrease in percentage of recoveries of Petersen tags probably was due to mortality caused by tag wounds and not to disc or pin loss.

In none of the recoveries was the label damaged. It was common for algae to be attached to the tag after a few years but, when the algae was removed, there was no damage to the label and the message was clearly visible.

The modified tag caused much less wounding than the Petersen tag (Table 1). After 3 years, almost all of the fish that had a Petersen disc had wounds and more than one-half of these were considered to be severe (Table 1). The modified tag did show an increase in wounding, but the percentage was much less than for the Petersen, and the percentage of severe wounds was less. Because the modified tag was smaller than the Petersen tag,

TABLE 1.—Comparison of the number and percentage (in parentheses) of spiny dogfish tag wounds by tag types.

Years at liberty	Modified tag			Petersen disc tag		
	No wound	Slight[a]	Extreme[b]	No wound	Slight[a]	Extreme[b]
1	107 (80.5)	24 (18.0)	2 (1.5)	13 (30.2)	14 (32.6)	16 (37.2)
2	53 (46.9)	42 (37.2)	18 (15.9)	2 (4.9)	18 (43.9)	21 (51.2)
3	1 (11.1)	6 (66.7)	2 (22.2)	1 (6.2)	7 (43.7)	8 (50.0)
4					8 (44.4)	10 (55.6)
5				1 (10.0)	2 (20.0)	7 (70.0)
Total	161 (63.1)	72 (28.2)	22 (8.6)	17 (13.3)	49 (38.3)	62 (48.4)

[a] Slight wounding, abraded, or just penetrated the skin.
[b] Severe wounding penetrated the flesh to a depth of at least 2 mm and a distance at least one-half the circumference of the tag.

TABLE 2.—Recovery percentages for Petersen disc tags and modified tags on spiny dogfish released in the Strait of Georgia, 1978–1982 (releases to July 1, 1982; recoveries to December 31, 1982), standardized for catch.

		Number of releases		Number of recoveries (all tagging years)		Standardized[a] recovery percentage	
Year	Catch (tonnes)	Petersen disc tag	Modified tag	Petersen disc tag	Modified tag	Petersen disc tag	Modified tag
1978	≈1,200	1,688	0	15	0		
1979	4,320	3,172	1,329	47	0	2.4	
1980	2,104	0	7,474	56	90		
1981	763	0	6,970	36	93		3.9
1982	1,257	0	6,527	33	285		

[a] Petersen disc tag recovery percentage calculated for 1978–1980; modified tag recovery percentage calculated for 1980–1982.

the size of a severe wound was smaller for the new tag.

Both titanium pins remained in the tag in all recovered fish. Pins removed from 24 fish that had been at liberty for up to 3 years were structurally similar to unused pins. There was no corrosion at the flesh, metal, sea-water interface, or at any of the bends in the pins. A metallurgical stress test indicated that there was no difference between unused pins and pins that had been in fish for 3 years. The absence of corrosion indicated that the pins were durable in salt water and might be expected to last more than 20 years (J. Moores, Department of National Defence Pacific, personal communication). The tantalum pins were equally acceptable; however, because of the increased cost of tantalum, the titanium pins were preferred.

In a previous unpublished and unrelated study, Floy anchor tags (FD-68) were applied to 5,692 spiny dogfish between 1975 and 1979. Of these fish, only 21 (0.37%) have been recovered and 17 (81%) of these were recaptured within the first

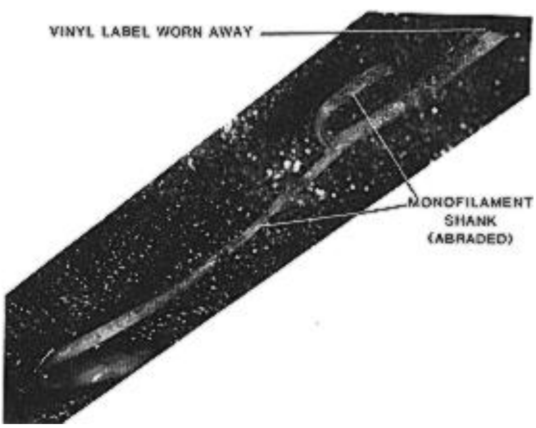

FIGURE 5.—Floy anchor tag which has been abraded by placoid scales of spiny dogfish.

year. Our evaluation of the Floy anchor tag compared to the Petersen disc tag indicated the Floy anchor tag was quickly abraded and lost (Figure 5). Of the 1,688 fish receiving both tags, 49 (0.06%) have been recovered over the 1978–1982 period. All those recovered had a Petersen disc tag. However, only 11 fish had both tags, and nine of those were recaptured during the first 18 months (Table 3). There was no doubt that the monofilament nylon used in the Floy anchor tag was easily abraded by the placoid scales, making this tag of little value for long-term tagging studies of spiny dogfish.

Fish Recoveries

Twenty-eight spiny dogfish (6% of those recaptured) were recovered 250 to 500 km away from the release site; seven fish (1.5%) were recovered 500 to 1,000 km away (Figure 6). In one case, a fish tagged in Queen Charlotte Sound on June 19, 1980, was recovered off Hokkaido, Japan, on November 24, 1982. This fish, which travelled a straight-line distance of 7,000 km, averaged 7 km/d during its time at liberty. While the revovery pe-

TABLE 3.—Comparison of retention of Petersen disc tags and Floy anchor tags on spiny dogfish receiving both tags during April–June 1978 and recovered as of December 31, 1982 (number tagged = 1,688; number recovered = 48).

	Number recovered			
Recovery year	Petersen disc tag only	Floy anchor tag only	Both tags	Total
1978	6	0	9	15
1979	14	0	2	16
1980	7	0	2	9
1981	3	0	1	4
1982	4	0	0	4
Total	34	0	14	48

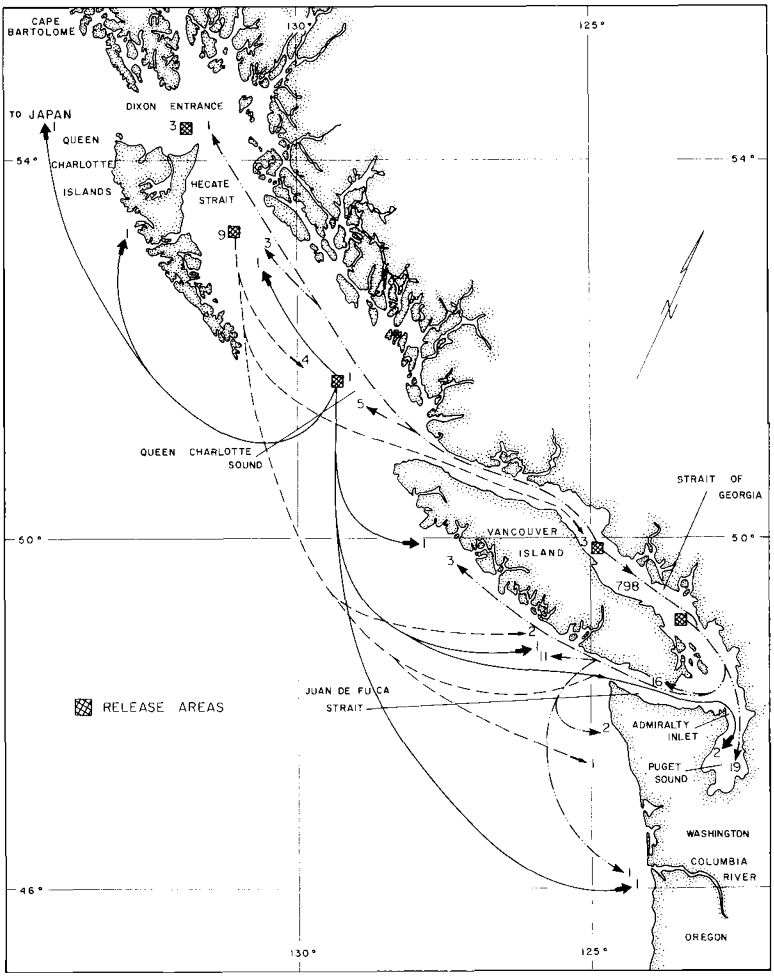

FIGURE 6.—Patterns of spiny dogfish movements determined from recoveries (1978–1982) made during the present study. Cross hatching represents release areas; numbers indicate the nonstandardized numbers of fish recovered at each location.

riod to date has been short relative to the life span of spiny dogfish, the recovery of some individuals at extensive distances from the release sites indicates the tag probably does not interfere with movement.

Recoveries of fish tagged and released in the Strait of Georgia have been summarized by four major areas: the Strait of Georgia including U.S. portion; Puget Sound; other United States waters including Admiralty Inlet, Juan de Fuca Strait, and the west coast of Washington and Oregon; and other Canadian waters including west coast Vancouver Island, Hecate Strait, and Dixon Entrance (Table 4). Most recoveries were made in the area of release; however, some fish moved south into Puget Sound, west to the west coast of Washington, Oregon, and Vancouver Island, and north into Hecate Strait and Dixon Entrance.

In order to assess the long-term movements of spiny dogfish, it is necessary to standardize recovery percentage to effort. Accurate effort data is unavailable for these areas, but we have attempted to estimate relative effort using average annual catch estimated for the years 1978–1980 (Leaman 1982; Pedersen and DiDonato 1982). Catches in the Strait of Georgia (Canada and United States combined) are approximately five times larger than catches in other areas (Table 4). Catches in the other areas were approximately equal. We have assumed that catches fluctuate in response to market demand. Use of a standardized recovery percentage does not alter the conclusion that most

TABLE 4.—Strait of Georgia releases and recoveries of spiny dogfish by tag type and area 1978–1983. (Recoveries, standardized to Strait of Georgia catch, are in parentheses.) Catches were estimated for 1978–1980.

		Number recovered				
Tag type and catch	Number released	Strait of Georgia (Canada and U.S.)	Puget Sound	Other U.S.	Other Canada	Total
Tag type						
Modified	27,889	605	15	19[a]	16[b]	655
Petersen disc	5,029	193	4		7[c]	204
Total	32,981	798	19 (116)	19 (67)	23 (100)	859
Average annual catch (tonnes)		4,595	755	1,298	1,053	

[a] 16—Juan de Fuca; 1—Oregon; 2—west coast of Washington.
[b] 10—SW Vancouver Island; 3—NW Vancouver Island; 2—Queen Charlotte Sound; 1—Hecate Strait.
[c] 1—SW Vancouver Island; 3—Queen Charlotte Sound; 2—Hecate Strait; 1—Dixon Entrance.

fish are recaptured in the release area. However, one-quarter of these recoveries were made outside the Strait of Georgia. Although it is too early to comment on long-term movements, this relatively high percentage of recoveries outside the release area indicates that movements throughout the range appear to be an important aspect of the biology of spiny dogfish.

Recoveries of fish tagged and released in the Hecate Strait region (Hecate Strait, Queen Charlotte Sound, Dixon Entrance) were summarized as follows: Hecate Strait region; Strait of Georgia; "other" Canada; and United States (Table 5). Standardized recoveries indicated little movement outside the Hecate Strait region. For example, the commercial catches in the Strait of Georgia were 16 times larger than commercial catches in the Hecate Strait region, yet only 3 fish were recovered in the Strait of Georgia. Movement that does occur is primarily to offshore areas.

Discussion

Spiny dogfish are long-lived (attaining ages in excess of 60 years) and it is important to find a tag that can be used to monitor the long-term movements of this species. Previous tagging studies have been done with Petersen disc tags (Foerster 1942; Bonham 1949; Holden 1965; Jensen 1969). When recovery percentages could be determined by years at liberty for these studies, most recoveries were made within 3 years of tagging (Table 6). Some of these studies were conducted during periods of extensive commercial fisheries operations, and the natural mortality rate of spiny dogfish is considered to be low, so a greater long-term percentage recovery could have been expected. For example, in the northeast Atlantic Ocean, large numbers of spiny dogfish were tagged between 1958 and 1968 by British and Norwegian scientists (Holden 1965; Jensen 1969). The ma-

TABLE 5.—Hecate Strait releases and recoveries of spiny dogfish by tag type and area 1980–1982. (Recoveries, standardized to Strait of Georgia catch, are in parentheses.) Catches were estimated for 1980–1982.

		Number recovered					
Tag type and catch	Number released	Hecate Strait region[a]	Strait of Georgia	Other Canada	United States	Other	Total
Tag type							
Modified	5,233	16	3	2[b]	2[c]	1[d]	24
Petersen disc	508	2		3[e]	2[f]		7
Total	5,741	18 (291)	3	5 (7)	4 (3)	1	31
Average annual catch (tonnes)		110	1,776	1,309	2,528		

[a] Includes Queen Charlotte Sound, Hecate Strait, and Dixon Entrance.
[b] 2—SW Vancouver Island.
[c] 1—Puget Sound; 1—west coast of Washington.
[d] 1—Japan.
[e] 1—NW Vancouver Island; 1—SW Vancouver Island; 1—west coast of Queen Charlotte Islands.
[f] 1—Puget Sound; 1—Oregon.

TABLE 6.—Summary of results of previous spiny dogfish tagging studies in the northeast Pacific Ocean and the northwest and northeast Atlantic Ocean, 1940 to present.

Year	Area	Tag type	Number of releases	Percent recoveries (1 year)	Percent recoveries (3 years)	Percent recoveries (total)	Reference
			Northeast Pacific Ocean				
1940–1946	Puget Sound, Strait of Georgia	Petersen disc	9,705			6.7	Bonham et al. (1949) Holland (1957)
1941	Strait of Georgia	Petersen disc	564	6		6	Foerster (1942)
1969–1972	Puget Sound, Strait of Georgia, west coast of Washington	Anchor	24,079	2.4	3.9	4.9	Fujioka et al. (1974) and unpublished documents of the technical subcommittee of the U.S.–Canada Groundfish Committee
			Northwest Atlantic Ocean				
1942	Newfoundland	Atkins	279	3.3	3.9	5.4	Templeman (1954)
1942–1965	Newfoundland	Atkins	2,576			8.5	Templeman (1976)
1956–1964	New England	Petersen disc and anchor	907			2.9	Jensen (1969)
1966	New England	Rototag	111			1.8	Jensen (1969)
			Northeast Atlantic Ocean				
1958	North of Scotland	Lea	8,122	4.4	10.5	10.8	Aasen (1962); Jensen (1969)
1960	North of Scotland	Petersen disc and plastic flag	1,438	1.0	2.3	2.3	Holden (1965); Jensen (1969)
1960–1962	North of Scotland	Petersen disc and plastic flag	9,115	6.0	10.0	10.0	Holden (1965)

jority of recaptures were made within 1–3 years even though catches during those and following years remained high. Estimated catches for that area (Holden 1977) ranged from 31,000 to 42,000 tonnes in 1958–1962, and 27,000 to 42,000 tonnes until the mid-1970s. Assuming that natural and fishing mortality remained unchanged, recoveries of tagged fish could have been expected at least until the early 1970s.

The modified tag used in this study is suitable for monitoring long-term fish movements but, in order to reduce the amount of wounding that still occurs, it will be necessary to develop a softer label. It was clear that the Floy anchor tag was unacceptable as a tag for spiny dogfish because it was lost within months of application. The metallurgical analyses of the pins used with our tags indicated that corrosion had not occurred and that the pins would have a life expectancy in the ocean in excess of 20 years.

The modified tag was a better tag than the Petersen tag or the Floy anchor tag. The modified tag did cause some wounding; however, the wounding was less frequent and less severe than that caused by the Petersen tag. The two pins used in the modified tag may be advantageous in the long term. Certainly there was no indication that the use of two pins resulted in increased wounding or decreased recovery.

It was evident from recoveries in this study that movements of spiny dogfish are more extensive than previously thought, particularly those from the Strait of Georgia (Foerster 1942; Holland 1957). Standardizing recovery percentages indicated that one-quarter of the fish tagged in the Strait were recovered in other areas. Although we were unable to demonstrate compensating movement into the Strait of Georgia from Hecate Strait, tagging studies have continued in Hecate Strait and have been initiated off the southwest coast of Vancouver Island to determine if there is a compensating movement from these areas into the Strait of Georgia.

A biased rate of reporting among areas may exist. The nonreporting rate in the set-line fishery in the Strait of Georgia (in which fish are individually handled) would be expected to be lower than that in the trawl fishery in other areas. It is probable, therefore, that if reporting rates were equal, more movement would be detected. In any event, it is apparent that movements are important and must be considered when developing management strategies for this species.

The applicability of this tag to other sharks and bony fishes seems possible but was not tested in this study. Some recent studies on sharks (Casey et al. 1983; Gruber and Stout 1983; Pratt and Casey 1983) have indicated that individuals of some species are older than previously thought; thus, the long-term movements of these sharks also may be of interest.

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