A TECHNIQUE FOR TAGGING DEEPWATER FISH

Mark-recapture data have been used extensively in fishery science to estimate population size, survival/mortality rates, growth rates, and movement parameters. Many devices and methods have been used to tag fish (reviewed extensively by Laird and Stott 1978). Virtually all tagging methods necessitate bringing the fish to the surface for marking. For fishes with physoclistic swim bladders inhabiting deeper waters, raising them to the surface subjects them to rapid changes in hydrostatic pressure and, usually, temperature. Procedures used to obtain healthy fish for marking include venting of excess gases from the swim bladder and body cavity with a hypodermic syringe (Gotshall 1964) and raising the fish gradually to the surface to allow acclimatization to changing pressure. Additionally, Phillips (1968) attempted to mark California rockfish by using detachable hooks with "Peterson type" plastic discs fastened to the hooks with wire. However, these methods are at best only moderately successful, as well as time consuming, often expensive, and simply impractical in some situations.

In 1978 we began an investigation of the life history and population dynamics of tilefish, *Lopholatilus chamaeleonticeps*, in the Mid-Atlantic Bight. Reasonable interpretation of these data requires knowledge of tilefish movements. Because tilefish are caught on longlines from depths of 73-254 m along the outer continental shelf (Grimes et al. 1980), fishing operations usually kill or severely injure the fish, thus making conventional marking at the surface pointless. This note describes the design and evaluation of a technique we developed for tagging tilefish, and potentially other deepwater fishes, with tags designed to detach from a bottom longline, thus eliminating the problems of pressure and temperature changes caused by raising fish to the surface.

Methods

We intended to design a tag that could be lightly attached to a longline, so that when a fish took a baited tag the hook would become lodged in the jaw or lip, detach, and thus mark the fish. We designed and constructed tags similar to the snoods or branch lines used on commercial longline fishing gear (see Freeman and Turner 1977 for a description of the gear). These tags consisted of a 30 cm length of 23 kg test monofilament line inserted through red vinyl tubing. We crimped an 8/0 hook to one end of the tag, and the other end was looped, crimped, and attached to the longline groundline at 4 m intervals. No addresses or serial numbers were printed on the red vinyl tubing in these preliminary experiments because our only purpose was to determine if this tagging method was functional. No reward was offered, but tags were returned because we personally alerted most fishermen. This was possible because of the small size of the fishery (i.e., about 25 vessels with most operators already cooperating with our research program by maintaining catch and effort logs) and also because of the localized nature of the tilefish ports (i.e., only two ports landed significant numbers of fish). Because we intended to evaluate only the tagging procedure, we did not request biological data on tagged fish that were caught.

To determine the optimal tag design, we tested different hook types (straight and circle) and different strengths of monofilament (0.9, 1.8, 2.7 kg test) for attaching tags to the longline. The vinyl portion of each tag was knotted to indicate the strength of monofilament (i.e., no knot for 0.9 kg, one knot for 1.8 kg, and two knots for 2.7 kg test).

We attached tags to longlines in two different sequences or "series" (one and ten) of attachment strength and hook type. To prevent a patchy distribution of tilefish from biasing the frequency of removal of tags of various hook types and attachment strengths, the "one-series" tagging consisted of one tag with a particular sequence of attachment strength and hook type (e.g., one 0.9, one 1.8, and one 2.7 kg monofilament with straight hooks; one 0.9, one 1.8, and one 2.7 kg monofilament with circle hooks, etc.). To make identification of hook type and attachment strength easier when we observed tagging longlines from a research submersible, the "ten-series" consisted of 10 tags with a particular sequence of attachment strength and hook type (e.g., ten 0.9, ten 1.8, and ten 2.7 kg monofilaments with straight hooks; ten 0.9, ten 1.8, and ten 2.7 kg monofilaments with circle hooks, etc.).

Longlines fitted with detachable tags were coiled in galvanized tubs, transported to the fishing grounds, and set voluntarily on two occasions by cooperating commercial fishermen. On one tagging operation (at east Hudson Canyon, 23 August 1979, lat. 39°38'05"N, long. 72°16'35"W, 117 m) conducted simultaneously with a gear evaluation study (Grimes et al. 1982a), an onboard observer recorded the numbers of tags of various attachment strengths and hook types remaining on the longline after retrieval. On the other tagging operation (west Hudson Canyon, 17 September 1979, lat. 39°20'30"N, long. 72°26'30"W, 137 m), the longlines were set and retrieved by commercial fishermen who returned the gear for us to count detached tags. Any tags fouled and detached on deck during setting were retained by the fishermen, returned to us, and counted. Thus our effort between tagging longline sets consisted only of counting detached tags and replacing them with new tags.

The results of experimentally setting tagged longlines (i.e., the variation in proportions of detached tags in relation to various attachment strengths, hook types, tagging locations, and series) were tested by analysis of variance (ANOVA) using the Statistical Analysis System (Barr et al. 1976).

Results and Discussion

A total of 1,156 detachable tags (687 of one-series and 469 of ten-series) were set with various hook types and attachment strengths on two separate occasions near Hudson Canyon (Table 1). Following retrieval of the longlines we determined that 384 detachable tags had been lost, 96 at the east Hudson location and 288 at the west Hudson site (Table 1).

ANOVA of the proportions of tags detached showed significant variations in detachment rate (Table 2). Significant or near-significant probability levels were calculated for variations in proportions of detached tags in relation to the following sources of variation: Tagging location (east or west Hudson); series (one or ten); tagging location-series interaction; attachment strength; hook type; and hook type-tagging location interaction (Table 2).

We know that some accidental tag loss occurred due to fouling, which was observed at the east Hudson site as the gear was being set. However, we believe that detachment rate data actually reflect the relative abundance of tilefish tagged. This is supported by observations made from a submersible at the same time and location (Grimes et al. 1982a); in a transect of commercial longline gear, tilefish were hooked on 42 of 227 hooks (0.19 hooking rate). This hooking rate was nearly identical to the 0.19 loss rate for all tags set at the east Hudson location (Table 3). Evidently, tag loss from fouling was a random event that occurred irrespective of hook type or attachment strength and thus did not affect the analysis, although it could be logically reasoned that weaker attachment strengths and curved hooks would foul most readily.

We know no obvious reason why 1) higher proportions of one-series than ten-series tags were detached, or 2) higher proportions of ten-series than one-series tags were detached at the east Hudson site (Table 3), causing the significance in the ANOVA of the series and tagging location-series interaction (Table 2). If tilefish were contagiously distributed, one might expect these results from the ANOVA and also expect overall tag loss to be contagiously distributed along longlines. A runs test (Sokal and Rohlf 1969) failed to demonstrate contagion in tag loss, and Grimes et al. (1982a) failed to demonstrate contagion for longline catches using the same statistical procedure. The significantly greater tag loss at the west Hudson site (Tables 2, 3) presumably reflects greater tilefish abundance there.

Attachment strength was deemed significant by the ANOVA because increasing proportions of tags were lost with decreasing attachment strength (Table 3). Apparently tilefish were able to detach most easily those tags with 0.9 kg monofilament, followed by 1.8 and 2.7 kg. Among tags returned, four were attached with 1.8 kg and two with 2.7 kg monofilament (Table

TABLE 1.—Numbers of detachable tags of various hook types and attachment strengths set, detached, and returned at east and west Hudson Canyon tagging locations, August and September 1979.

Attachment strength (kg)	Hook type	Set East	Set West	Detached East	Detached West	Returned East	Returned West
0.9	Straight	81	82	22	43	—	—
1.8		80	81	12	39	—	—
2.7		81	80	12	30	—	—
		242	243	46	112		
Total no.		485		158			
0.9	Circle	78	147	19	67	—	—
1.8		81	140	14	55	—	4
2.7		81	144	17	54	—	2
		240	431	50	176		6
Total no.		671		226			[1]7
Total no. tags set and detached		1,156		384			
Total no. tags set, detached and returned		482	574	96	288		

[1]Includes one hook of unknown attachment strength.

TABLE 2.—Analysis of variance of the proportions of tags detached at east and west Hudson Canyon locations, August and September 1979.

Source of variation	df	Sum of squares	Mean square	F value	P>F
Tagging location	1	0.2724	0.2724	61.53	<0.01
Series	1	0.0486	0.0486	10.98	0.01
Tagging location-series	1	0.1059	0.1059	23.91	<0.01
Attachment strength	2	0.0379	0.0190	4.28	0.05
Attachment strength-tagging location	2	0.0039	0.0019	0.44	0.66
Attachment strength-series	2	0.0016	0.0008	0.18	0.83
Hook type	1	0.0154	0.0154	3.47	0.10
Hook type-tagging location	1	0.0212	0.0212	4.80	0.06
Hook type-series	1	0.0002	0.0002	0.04	0.84
Hook type-attachment strength	2	0.0123	0.0062	1.39	0.30
Standard error	9	0.0399	0.0044		
Total	23	0.5593			

1). Evidently 0.9 kg monofilament attachment did not offer sufficient resistance for the hook to pierce the jaw and tag the fish. Furthermore, it did not take an exceptionally large fish to detach a tag because the returned tag with 2.7 kg monofilament was removed from a 3.2 kg fish.

Hook type and the hook type-tagging location interaction approached the 0.05 significance level as sources of variation in the ANOVA (Table 2) because higher proportions of straight hooks were detached, except for tagging longlines set at the east Hudson site where slightly higher proportions of circle hooks were lost (Table 3). These results suggest that fish are more easily hooked by straight hooks. However, all tags returned had circle hooks (Table 1); thus, although straight hooks tagged more fish, they apparently did not remain in the jaws as well.

The returned tags (7) represent about 2% of the maximum number theoretically deployed (384). However, because an unknown number of tags were observed to be lost due to fouling during setting and retrieval, the true rate of return is >2%. This return rate is comparable with that reported for marine tagging studies on relatively deep-dwelling reef fishes using conventional tags applied at the surface (Grimes et al. 1982b). Our tagging technique appears to be useful over relatively long periods. Tagged fish were at liberty from 115 d (0.32 yr) to 577 d (1.6 yr) (Table 4). Similarly, Phillip's (1968) only detachable tag return was from a marked kelp bass at liberty about 2 yr. All of our returns suggest that tilefish in the vicinity of Hudson Canyon are relatively sedentary, which might be expected given that tilefish inhabit (and presumably construct) extensive burrows (Able et al. 1982).

This tagging procedure may represent one of the few workable procedures presently available for investigating deep-dwelling fish. Optimal tag design could be determined by a preliminary study, as we have demonstrated (e.g., the optimal detachable tag for tilefish is constructed with a circle hook, serially numbered and addressed, and attached with 1.8 kg test monofilament). Studies using this procedure could be relatively inexpensive because the major expense in most marine fish-tagging studies—vessel time—would be eliminated. However, problems with the detachable tagging technique may make its use questionable for determining population parameters other than movement. As with other tagging procedures, mortality of tagged animals may be increased, especially since tags are placed in the mouth and could impair feeding. However, all recaptured animals in our study were reported in good condition with no obvious scars, wounds, or other signs of stress. Gut hooking (swallowed hooks) may also cause additional tagging mortality. In a longline assessment study (Grimes et al. 1982a) about 4% of all hooked fish seen (42) from a submersible were gut-hooked.

Unlike conventional tagging procedures, the researcher using detachable tags does not know what species (and their relative numbers) were marked, other than the target species. This was not a problem in our tilefish study because this fishery is virtually monospecific; if detachable tags are administered via a fishery, as in the case we described, tagging data can be adjusted according to the relative abundance of species in the catch.

It may also be possible to use detachable tags to estimate other population parameters, such as total mortality, if sufficient return data are available and assuming that tags are not lost from fish over the experimental period. For example, mortality could be estimated either from the ratio of numbers of tagged

TABLE 3.—Weighted mean proportions of tags detached according to hook type, tagging location, series (see Methods section) and attachment strength.

	Hook type		Tagging location		Series		Overall mean
	Straight	Circle	East	West	One	Ten	
Attachment strength (kg)							
0.9	0.40	0.32	0.24	0.47	0.39	0.32	0.36
1.8	0.32	0.24	0.16	0.39	0.33	0.23	0.28
2.7	0.26	0.27	0.18	0.36	0.32	0.22	0.27
Tagging location (all attachment strengths)							
East Hudson Canyon	0.19	0.20			0.17	0.22	0.19
West Hudson Canyon	0.46	0.35			0.52	0.30	0.41

TABLE 4.—Returns from tilefish tagged in the west Hudson Canyon, 1979. n.a. = not available.

Tag	No. days at liberty	Retrieval site	Fish weight and condition
1	115	tagging site	5.5 kg (good)
2	256	tagging site	n.a.
3	256	tagging site	n.a.
4	257	tagging site	n.a.
5	257	tagging site	n.a.
6	365	tagging site	2.3 kg
7	577	1.9 km west of tagging site	3.2 kg (good)

individuals to total individuals caught over time, or from the number of tagged individuals caught per unit of fishing effort over a specified period of time (Jones 1976).

In conclusion, we believe this procedure can be of value to fishery biologists desiring to investigate migration and movement (and perhaps mortality) of deep-dwelling fishes not markable by more conventional methods.

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