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Factors That Affect the Recapture of Tagged Sablefish off the West Coast of Canada

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Abstract.—Several factors affect recovery rates for sablefish *Anoplopoma fimbria* tagged off the west coast of Canada. Chief among them are tag loss, oxytetracycline injection, variation in recovery effort, and nonreporting of recovered fish. Recovery rates increased with the size of fish at release.

From 1977 to 1982, sablefish *Anoplopoma fimbria* were tagged off the west coast of Canada to determine if the Canadian stock is part of a single North American stock (Beamish and McFarlane 1983, 1988). In addition, sablefish were tagged to examine movement and patterns of recruitment, and to validate a method of age determination. Altogether, 122,715 sablefish were tagged and released. In the analyses of movements and stock identification (Beamish and McFarlane 1983, 1988) and age of validation (Beamish et. al 1983a; McFarlane and Beamish 1987), it was necessary to consider factors that affected recovery percentages.

In this paper we review factors that affected the recovery rates of sablefish, and we present new information on the relationship between fish length at tagging and recovery percentage.

Methods

Fishing and tagging methods.—Descriptions of capture and tagging methods were reported by Beamish et al. (1978, 1979, 1980, 1983b). Adult sablefish were captured with rectangular and Korean-style traps deployed from chartered fishing vessels. Traps were baited with herring and, on some cruises, with squid. The depth of each trap string was approximated by averaging depths recorded at regular intervals while the string was being set. Fishing time was recorded as the time that elapsed between setting of the last trap and retrieval of the first one.

Freshly caught fish were transferred directly to holding tanks equipped with flowing seawater. Fish were taken from tanks and placed on a measuring board, measured for fork length, and tagged with a Floy FD-68 anchor tag. We also applied a suture tag (White and Beamish 1972) to approximately 10% of the fish. Some 15,000 fish were injected with oxytetracycline (OTC) during the program to induce fluorescent marks in calcified body parts; these marks were used to validate ages of the fish.

Records were kept on the general condition of the fish, noticeable injuries, and any problems with the tag. Anaesthetic (tricaine, MS-222) was used only during the first cruise. Only fish in good condition were tagged. Tagged fish were released directly into the ocean.

To test the effect of fish length at tagging on recovery percentage, we used log-linear modeling approach to multidimensional contingency table analysis. This was carried out with a categorical modeling computer program (CATMOD) produced by SAS Institute (SAS 1985).

For analysis, we grouped releases and recaptures by 5-cm length-intervals. The program then constructed the equivalent of a two-dimensional contingency table with one row for each combination of independent variable levels. Columns consisted of the response or dependent variable values, either recovery or nonrecovery. On the basis of significance of effects indicated by the Wald statistic, we tested the hypothesis that recovery proportions are independent of length at tagging.

Results and Discussion

Length at Release

We found, for all cruises examined, that the proportion of sablefish recaptured was not independent of fish length ($P > 0.05$). Cumulative recovery percentages decreased with decreasing length of fish (Figure 1), ranging from 25 to 32% for larger fish and from 6 to 22% for small fish. Recovery of tagged smaller fish often is less than that of larger fish (McCracken 1963; Westrheim and Morgan 1963; and Wise 1963). Size-related recovery rates were attributed to size selectivity of recovery gear (McCracken 1963), size limits on commercial catches (Westrheim and Morgan

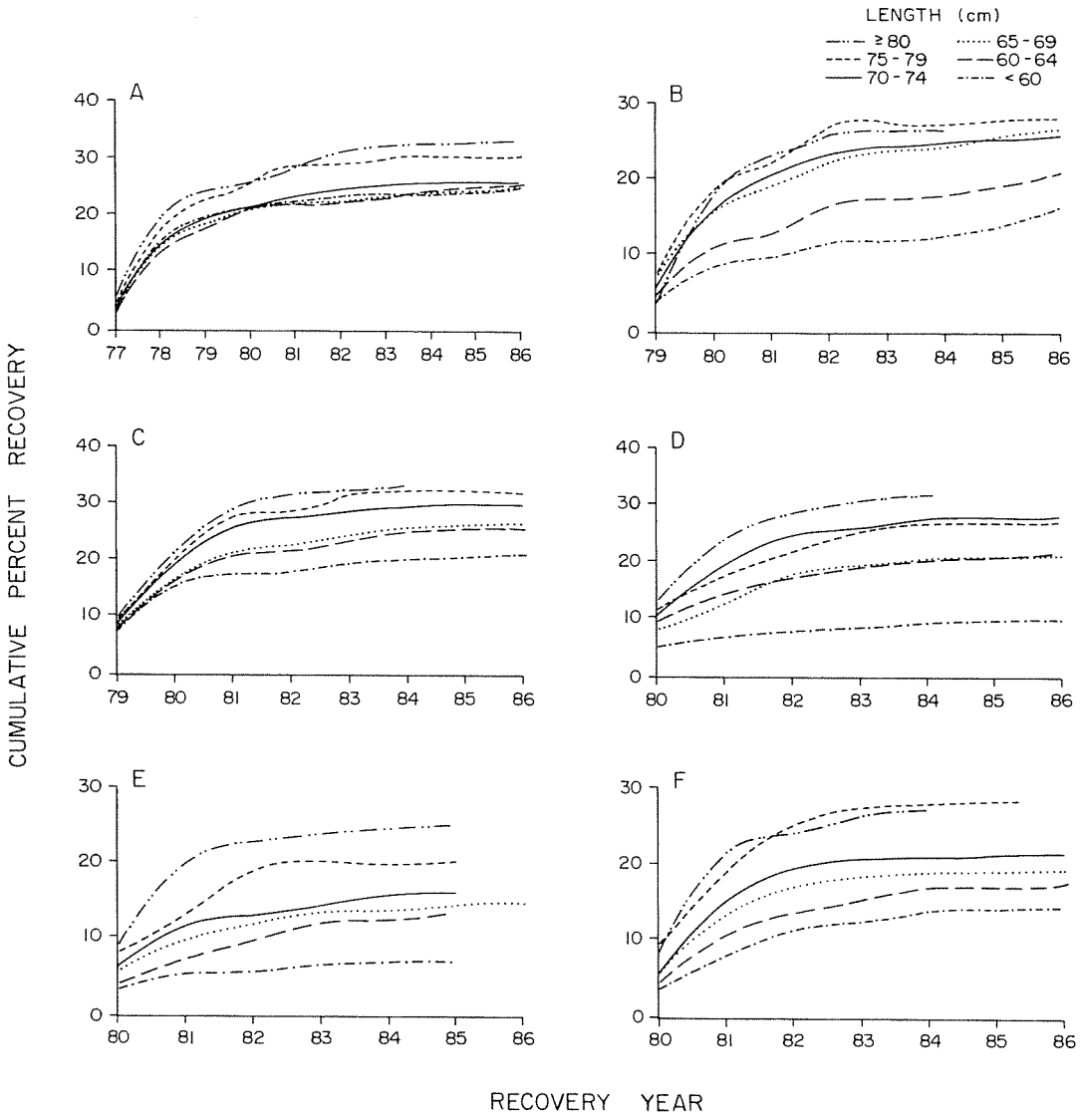

FIGURE 1.—Cumulative recovery percentages for tagged sablefish by cruise and by 5-cm length-intervals at release.

1963), and differential handling or tagging mortality (Wise 1963).

There was no difference in sex ratio for released and recaptured fish in any length category (Table 1). This indicates that differential recovery rates by length were not a result of the different growth rates of male and female sablefish (McFarlane and Beamish 1987).

Beamish and McFarlane (1988) also found no difference in mean size of males or females that moved farther than 200 km from the release area, compared with fish recaptured within 50 km of the release area. This indicates that different recovery rates by release length were not a result of size-related differences in emigration rate. In addition, the mean age of males or females that moved more than 200 km from the release area was not significantly different from that of fish that moved less than 200 km (Beamish and McFarlane 1988). Similarly, Holmberg and Jones (1954) and Wespestad et al. (1983) found no significant difference in migration distance among tagged sablefish of various lengths at release.

Juvenile sablefish recovered in the nursery area up to 2 years after release had similar recovery rates for all lengths released (our unpublished

TABLE 1.—Percentages of male sablefish released and recovered, 5-cm length-intervals.

Fork length (cm)	Percent males	
	Release samples	Recovery
<60	52.9	60.8
60–64	56.4	60.6
65–69	36.2	36.0
70–74	10.3	9.4
75–79	1.6	2.7
>79	2.7	2.1

data). However, when these juveniles moved offshore, fish that were longer at time of release showed a higher rate of recapture. The relatively high survival of smaller fish in the nursery area indicates that tag loss or physiological stress were not affecting smaller fish more than larger fish. The relatively higher survival of larger juvenile fish in outside waters suggest that they are less subject to predation. The possibility that possession of a tag contributed to increased predation was examined in the evaluation of the standardization procedure of Beamish and McFarlane (1988). After returns were standardized and corrections were made for tag loss and tagging mortality, the expected number of returns expected given a total mortality rate of 0.2 was only 10% higher than the standardized returns. Thus, if tags do attract predators, the selection for tagged fish appears to be minor.

Tag Loss

As reported by Beamish and McFarlane (1988), tag loss has a great effect on the recovery percentage for tagged sablefish. Of the 5,076 fish that received two tags, 822 (16.2%) were recovered. There was no significant difference in tag loss between the two tag types (t-test, $p \leq 0.01$). This indicates that the loss of either tag can be considered as a loss for an individual fish, provided that the rate of loss of either tag is not a result of interaction between the two tags. Tag loss in the first year after tagging was approximately 10% and approximately 2% per year afterwards (Figure 2).

Tag loss resulted in a significant reduction in marked fish over a 10-year period. Natural (M) and fishing (F) mortality rates of 0.1 for sablefish (Saunders et al. 1987) cause the most losses of marked fish. Even though many fish were tagged and released, tag loss and annual mortality limited the length of this study to about 10 years. After this period, recoveries were too few to be interpreted.

Standardization

In few studies have attempts been made to standardize recovery percentages. It seems to be generally accepted that standardization is important, but results often are interpreted with the disclaimer that no standardization was undertaken. Standardization can be difficult because catch and effort statistics may not be available for all potential recovery areas throughout the duration of study. For estimates of movement, abundance, and mortality, some form of standardization is necessary.

In this study, we compared rates and direction of movement of adult sablefish by using recaptures standardized for variation in recovery effort

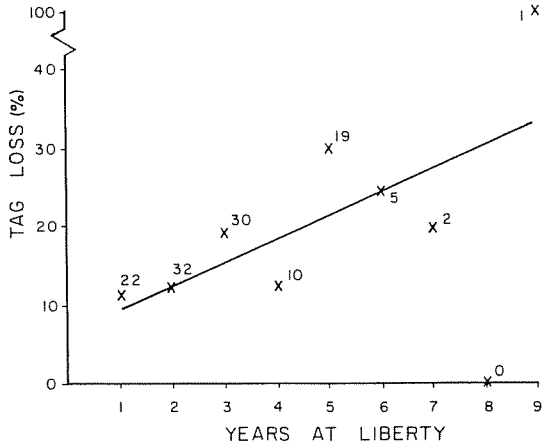

FIGURE 2.—Percentage of sablefish recaptured annually with one tag missing. Numbers of fish recaptured that had lost a tag are indicated for each year at liberty. The line was fitted by eye. (From Beamish and McFarlane 1988.)

TABLE 2.—Actual (Act) and standardized (Stand) recoveries of tagged sablefish released off Vancouver Island (VI), in Queen Charlotte Sound (QCS), off the Queen Charlotte Islands (QCI), and in mainland inlets, by years at liberty.

Years at liberty	Total recaptures							
	VI		QCI		QCS		Inlets	
	Act	Stand	Act	Stand	Act	Stand	Act	Stand
1	973	1,241	1,475	2,556	165	258	472	745
2	1,211	1,452	2,065	3,426	265	395	271	424
3	585	663	1,009	1,557	145	228	236	366
4	410	447	463	711	82	123	143	217
5	175	200	268	406	41	54	169	221
6	103	114	155	253	14	23	30	42
7	120	120	73	117	8	10		
8	14	14	30	40	3	3		
9	6	7	20	32				

and for unreported recaptures (Table 2; Beamish and McFarlane 1988). We tagged and released 72,735 adult sablefish off the west coast of Canada from 1977 to 1982. As of December 31, 1985, 11,121 (15%) of these fish were recaptured. If all fish receiving oxytetracycline (OTC) injections of 100 and 75 mg/kg are excluded, the nominal release was 54,916 adult fish, of which 10,152 (18.5%) were recovered. When we standardized all recaptures (including OTC-injected fish), 16,539 fish (23%) were considered as recoveries.

The standardization procedure resulted in more recaptures. To evaluate this procedure, Beamish and McFarlane (1988) compared expected and standardized returns for one release each year off Vancouver Island in 1979 and in 1980, and also for one release each year off the Queen Charlotte Islands in 1977 and 1980. The total number of

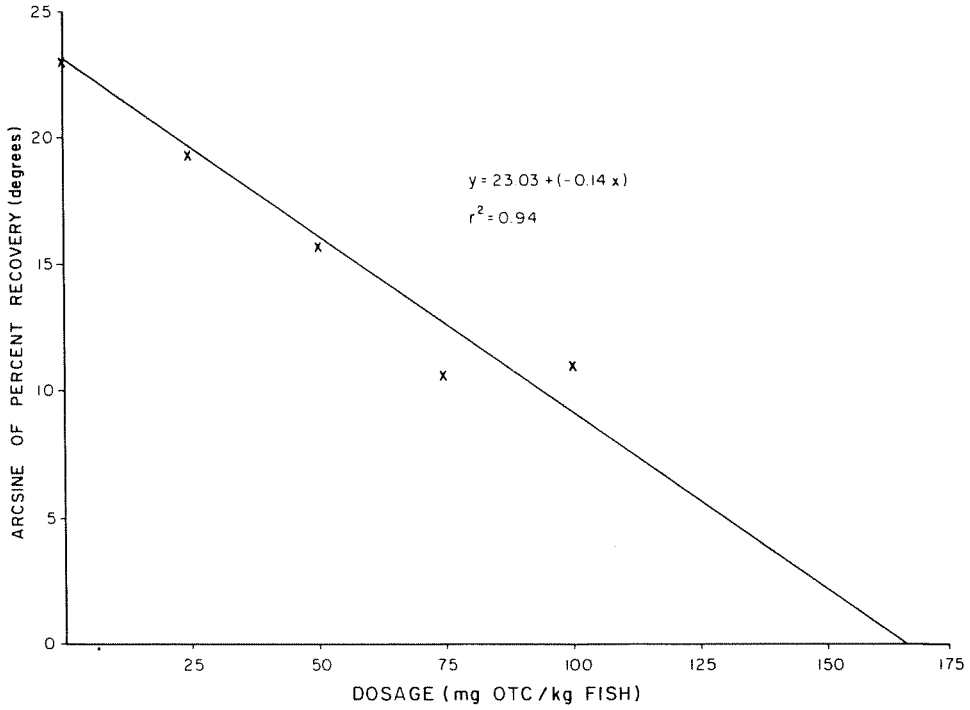

FIGURE 3.—Relationship between dosage rate of oxytetracycline (OTC, x) and recovery (an index of survival, y) for tagged and injected sablefish. (From McFarlane and Beamish 1987.)

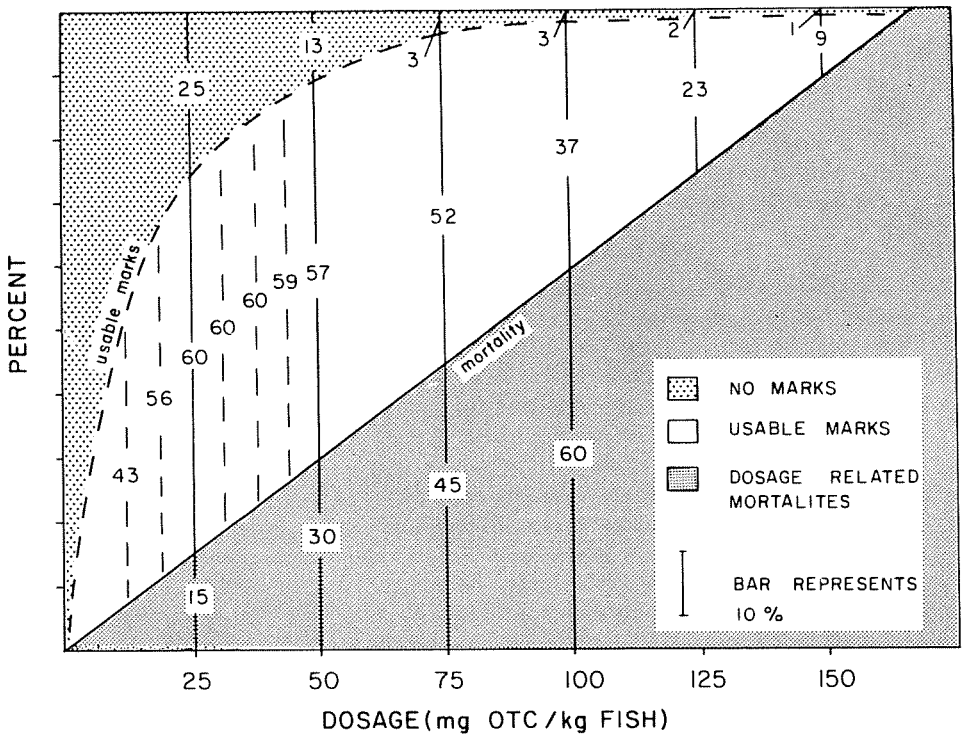

FIGURE 4.—Nomograph of optimal dosage. For example, a dosage of 25 mg OTC/kg fish kills 15% of the fish, imparts usable marks to 60%, and does not mark 25%.

released fish was 23,060 and the expected number of returns was 6,972. The standardized number of returns was 5,576—20% fewer than expected. If only the release group that had been at liberty longest was used from each area, the expected return was 4,510 fish and the standardized number was 4,041 fish—10% fewer than expected. This agreement confirmed the reliability of the standardization procedure.

Chemical Injections

In a previous study, McFarlane and Beamish (1987) reported on the effect of OTC dosage rate on mortality of fish released into the ocean. They tagged 15,183 fish, injected the fish with OTC at varying dosage rates, and released them. The relationship between dosage and survival of injected fish was positive and strongly linear (Figure 3). Even the smallest dosage rates had some level of mortality associated with them, and a dosage rate of 165 mg OTC/kg was the theoretical rate at which 100% mortality occurred (Figure 4).

Although this study specifically examined one chemical, it is clear that there can be a trade-off between recovery percentage and mortality when a tagging program attempts to carry out several objectives. In the OTC study, even the lowest dosage caused 15% mortality. Although this mortality was acceptable in relation to the importance of developing a method for age determination, it would not be acceptable for studies of mortality rates and abundance.

Other Factors

Factors such as density of fish in the holding tank, depth of capture, fishing time, and tagging procedures were examined and in some cases were found to affect recovery percentages. These factors frequently are associated with other conditions, such as weather, and can be difficult to interpret. Often, investigators are more interested in examining the response of the population than in maximizing the number of recoveries. It is important, however, to appreciate that these other factors can affect recovery percentages and, depending on the objectives of the study, may need to be examined.

Investigators commonly attempt through laboratory study to examine factors that affect mortality. For example, laboratory studies conducted

on English sole *Parophrys vetulus* by Manzer (1952) and on Pacific halibut *Hippoglossus stenolepis* by Peltone (1969) showed no differences in mortality of tagged fish by length. We found no effect of OTC in the laboratory but, as previously shown, the response in the natural environment was quite different.

Conclusions

Tag loss, OTC injection, variation in recovery effort, and nonreporting had the greatest effects on recovery rates of tagged sablefish.

There is a strong positive relationship between length at release and recovery rate for tagged sablefish. Investigators attempting to tag specific size components of a stock, to analyze growth over the entire size spectrum, or to validate aging criteria over all ages must take into account the differences in effective releases among sizes tagged.

As indicated by the OTC study, laboratory studies may not accurately mimic the ocean environment. Experimental design should include control releases to evaluate the effects of varying conditions at release.

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