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National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Tagging and Tag-Recovery Experiments With Atlantic Menhaden, *Brevoortia tyrannus*

RICHARD L. KROGER and ROBERT L. DRYFOOS

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National Marine Fisheries Service, Special Scientific Report--Fisheries Series

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Tagging and Tag-Recovery Experiments With Atlantic Menhaden, *Brevoortia tyrannus*

RICHARD L. KROGER and ROBERT L. DRYFOOS

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Tagging and Tag-Recovery Experiments With Atlantic Menhaden, *Brevoortia tyrannus*

By

RICHARD L. KROGER[1] and ROBERT L. DRYFOOS[2]

ABSTRACT

Laboratory tagging experiments with adult and juvenile Atlantic menhaden were conducted at Beaufort, N.C., in 1965 and 1969. Tag-recovery experiments were done at menhaden processing plants at Beaufort, N.C. Internal ferromagnetic body tags of appropriate sizes are suitable for tagging adults and juveniles, and the tags can be recovered effectively on magnets in the processing plants.

INTRODUCTION

Information on the movements, mortality, and recruitment of Atlantic menhaden are available from catch, effort, and length-frequency data; but more direct, independent estimates of these parameters, derived from mark-recapture studies, are desirable. We conducted a series of laboratory experiments in 1965 to determine the best techniques for tagging and handling adult menhaden. These experiments were designed to estimate the amount of tag shedding and fish mortality that could be expected for fish exposed to different techniques of tagging and handling. Our tag-recovery experiments were designed to estimate the recovery rates for tags which entered each menhaden reduction plant. In 1969 we conducted similar experiments with juvenile menhaden using smaller tags. This paper reports the methods we used and the conclusions we reached and includes a brief review of former tagging experiments.

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REVIEW OF MENHADEN TAGGING

Since menhaden are mass-processed into meal, oil, and solubles, the fish must be marked with tags that can be recovered mechanically or electronically from the reduction plants. Internal metallic tags were experimented with initially since they had been found satisfactory to mark clupeids by other workers (Rounsefell and Dahlgren, 1933; Dahlgren, 1936; California Division of Fish and Game, 1945; Fridriksson and Aasen, 1950; Bayliff and Klima, 1962; and Newman, 1970).

The results from the first attempt, in 1959, to mark juvenile menhaden with internal ferromagnetic tags were unsuccessful (Reintjes, 1963). This tag, a nickel-plated iron toroid, 19.0 by 4.0 by 1.5 mm, with rough edges, caused internal damage to the small menhaden.

A photoelectric device to detect fish marked with biological stains and dyes was designed, constructed, and tested during 1959-62 (Reintjes, 1963). He reported that the naturally occurring fluorescence in menhaden and other marine organisms made discrimination of marked menhaden impractical without modification of the photoelectric device.

In 1961 Carlson and Reintjes (1972) tested four internal ferromagnetic tags on captive menhaden 115-168 mm long (fork length). They found that the most suitable type was a smooth-edged stainless steel (Type 420) torus tag, 14.0 by 2.5 by 0.5 mm, similar to one that had been used successfully with small Atlantic herring in Norway (Dragesund and Hognestad, 1960). When they tagged 75-90 mm menhaden, however, most of the fish, including the handled controls, died. Carlson and Reintjes also tested the recovery of tags by magnets in a menhaden reduction plant and found that about 60% of the tags entering the plant in fish were recovered. They believed the tag recovery efficiency could be increased by installation of additional magnets.

METHODS OF HANDLING EXPERIMENTAL FISH AND RECOVERING TAGS

Menhaden were conditioned to the holding facilities so the results of the experiments could be attributed to the procedures tested (Bayliff and Klima, 1962). Most were captured with a haul seine. They were held in rectangular concrete tanks, 5 by 2 by 0.7 m, with rounded corners or in circular fiberglass tanks, 2 by 0.8 m, continuously supplied with aerated seawater. Within 2 days after being captured fish began feeding on a mixture of menhaden meal and homogenized clams or on commercial trout food.

Two sizes of tags were tested — one for adults and one for juveniles. Juvenile menhaden are those in their first year of life and adults are those in their second or later years of life. Tags measuring 14.0 by 3.0 by 0.5 mm for adult menhaden were ground and filed to 6.9 by 1.8 by 0.5 mm for juveniles. The corners were rounded and the edges smoothed to remove the burrs. Throughout this paper, larger tags are referred to as adult tags and smaller tags as juvenile tags.

In early experiments tags were inserted into the fish with a scalpel and forceps, following the methods of Carlson and Reintjes (1972). An incision was made about 15 mm above the origin of the right pelvic fin depending on the size of the fish, with a scalpel, and the tag was pushed anteriorly through the incision with forceps. In later experiments the tags were inserted with a Bergen-Nautik tagging gun (Fig. 1). The tag protruding from the barrel of the tagging gun punctured the body wall before being pushed into the body cavity with the thumb plunger. An adult tagging gun was modified to facilitate injecting the juvenile tags. Unless stated otherwise, these tags were also inserted about 15 mm above the origin of the right pelvic fin and pushed forward into the body cavity.

Standardized procedures were followed for the experiments. Fish were seined from the tanks, placed in 30-liter plastic tubs of seawater, tagged, and returned to a tank. In most experiments untagged menhaden, taken from the same group as the tagged fish, were used as controls. The sequence of tagging the fish was selected randomly. In the first three experiments fish were anesthetized in the tubs with tricaine methanesulfonate (MS-222) at a concentration of 1:26,000, but in later experiments they were not.

Tagging loss, as used in the text, represents a combination of the total loss of tags from fish that died or shed their tags during the experi-

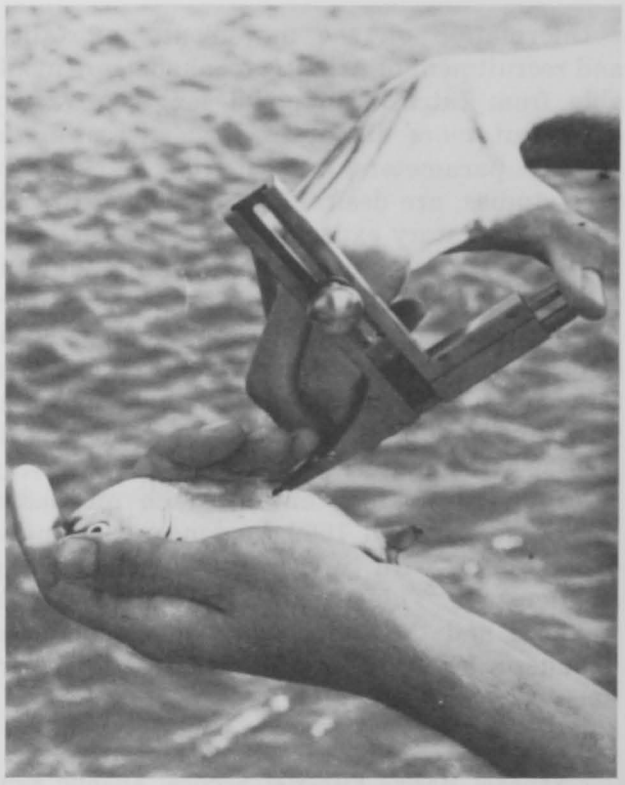

Figure 1.—Adult tag about to be inserted with the tagging gun into the body cavity of a yearling menhaden.

ments. Dead fish were removed daily, and shed tags were recovered weekly from the tanks. The experiments were terminated after 4 to 16 weeks when Type-1 tagging mortality and tag shedding had ceased. Type-2 tagging mortality and tag shedding, which occurs throughout the life of a tagged fish, were not investigated in these experiments.

The tag-recovery methods were also investigated. Electronic detectors and several types of magnets were installed at different locations in menhaden reduction plants (Fig. 2). Primary magnets and electronic detectors recover tags early enough in the processing to identify the time of capture of the fish. Secondary magnets recover tags too late in the handling of the fish scrap to determine the time of capture.

The type of magnet installed was dependent on the conveyor system of each plant because magnets could be placed only in locations which did not impede the flow of scrap and which were accessible for cleaning. Two- and four-pole plate magnets were placed in primary and secondary locations in chutes with steep slopes, and grate magnets, rotating at 12 rpm to prevent clogging, were mounted in locations where fish scrap dropped through the bars of the magnets (Fig. 3). Stationary grates and hump magnets were unsatisfactory because they clogged.

Tag-recovery test consisted of putting one tag in each of 100 whole fish that were to be processed with the catches. To compare the recovery efficiency of adult tags with that of juvenile tags, one of each was placed in each of 100 fish. The tag-recovery rate for each plant was determined as the mean percentage of test tags recovered on the magnets from several tests.

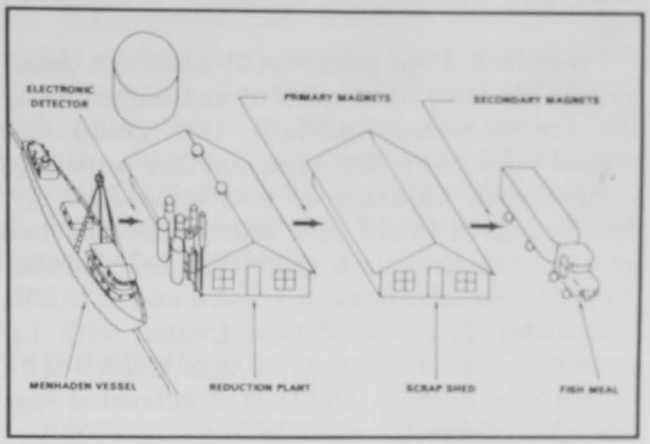

Figure 2.—Tag recovery locations in a typical menhaden reduction plant.

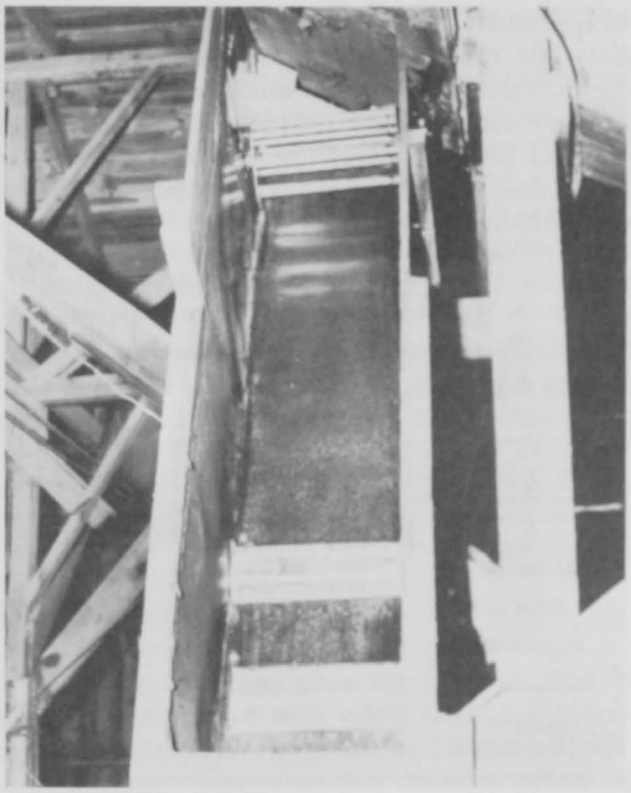

Figure 3.—Rotating grate and two 2-pole magnets installed in a transfer chute of a menhaden reduction plant.

EXPERIMENTAL TAGGING

The object of the experiments was to develop methods of internally tagging adult and juvenile menhaden with ferromagnetic tags that could be recovered on magnets. The prerequisites were that the tagging methods would not cause high mortality or tag-shedding rates and that they would be simple enough to permit us to tag large numbers of fish in a short period of time. We were interested not only in developing an efficient tagging method, but also in determining the amount of tag loss that we might expect in the field from both mortality and tag shedding.

Experiment 1

Objective: To determine if the loss of tags treated with antibiotics or disinfectants from

adult fish was different from that of untreated tags.

Procedure: Four groups of 50 adult fish (mean length 122 mm) were selected and tagged using the scalpel-forceps method. One group was tagged with clean dry tags, another with tags treated with Liquamycin (oxytetracycline hydrochloride, a broad base antibiotic), and two groups with Roccal (a germicide and disinfectant) at concentrations of 1:1,000 and 1:10,000.

Results: The loss of tags treated with Liquamycin was 40%, that of tags treated with Roccal was 22-26%, and that of untreated tags was 22% (Table 1).

Discussion: The higher shedding rate of treated tags may have resulted because incision healing was slowed by the antibiotics. Bayliff and Klima (1962) mention that antibiotics can slow the rate of healing, although they found no increased shedding of antibiotic-treated tags in their study. Since untreated clean dry tags had the lowest rate of tag loss and were more easily handled, they were selected for future experiments.

Table 1.--Experiment 1; effects of an antibiotic and a disinfectant on the mortality and shedding in groups of 50 adult fish.

Tag treatment	Dead	Shed	Total loss	
	----Number----		Number	Percent
Liquamycin	4	16	20	40
1:1,000 Roccal	2	9	11	22
1:10,000 Roccal	1	12	13	26
Untreated	7	4	11	22
Control (not tagged)	1	--	1	2

Experiment 2

Objective: To determine whether injecting the tags posteriorly, rather than anteriorly, into the adult fish by the scapel-forceps method would reduce tag loss.

Procedure: Two groups of 50 fish (mean length 150 mm) were selected. In Group 1 the tag was inserted into the fish anteriorly as in Experiment 1. In Group 2 the tag was inserted posteriorly through an incision 15 mm above the pectoral fin tip.

Table 2.--Experiment 2; effects of tagging location and direction of insertion on the mortality and shedding in groups of 50 adult fish.

Tagging method	Dead	Shed	Total loss	
	----Number----		Number	Percent
Anterior	2	1	3	6
Posterior	0	7	7	14

Results: Insertion of tags anteriorly resulted in less tag loss (Table 2).

Discussion: Since Bayliff and Klima (1962) also had similar results, we decided to insert tags anteriorly.

Experiment 3

Objective: To determine which method of inserting the tags — scalpel-forceps, tagging gun, or gun-forceps — causes the least tag loss in adult fish.

Procedure: Fish in groups of 50 (mean length 131 mm) were tagged using three methods: (1) scalpel and forceps, (2) a long-barreled tagging gun, and (3) tagging gun and forceps. In method 3 the tag was pushed deeper into the body cavity with forceps because the tag, when inserted with the long-barreled tagging gun, did not appear to penetrate deeply enough to prevent shedding.

Results: The mortality from all methods was low, but shedding of tags inserted with the gun was high (Table 3).

Discussion: Since the tagging-gun method was much faster and is not as dangerous to the taggers as the other two methods which involve an open scalpel blade and since most of the tags were probably shed because of poor tag penetration with the long-barreled gun, we decided to conduct all further tests with recently purchased short-barreled guns. Short-barreled guns, which had about one-half of the tag protruding from the barrel, injected tags farther into the body cavity of fish than did long-barreled guns, which had only about one-eighth of the tag protruding from the barrel.

Table 3.--Experiment 3; effects on the mortality and shedding of tagging with scalpel and forceps, tagging gun, and tagging gun and forceps in groups of 50 adult fish.

Tagging methods	Dead	Shed	Total loss	
	----Number----		Number	Percent
Scalpel and forceps	2	1	3	6
Tagging gun	2	10	12	24
Gun and forceps	1	0	1	2
Control (not tagged)	2	--	2	4

Experiment 4

Objectives: (1) To determine if tags coated with four types of tag lubricants which facilitated loading the guns affected the tag loss or speed of incision healing in adult fish; (2) to determine the rate of tag shedding with the short-barreled tagging guns.

Procedure: We tagged five groups of about 50 fish (mean length 160 mm) using short-barreled tagging guns. The tags were uncoated or were coated with Vaseline, Bacitracin, Bacitracin and Vaseline, or Tetracycline and Vaseline.

Results: Untreated tags had the lowest loss (Table 4). The incision healing portion of the experiment was conclusive.

Table 4.--Experiment 4; effects of tag coatings on the mortality and shedding from adult fish.

Type tag coating	Number of fish in experiment	Dead	Shed	Total loss	
		---Number---		Number	Percent
Vaseline	50	7	8	15	30
Bacitracin	50	9	3	12	24
Bacitracin and Vaseline	49	11	4	15	31
Tetracycline and Vaseline	50	6	0	6	12
Untreated	50	3	2	5	10
Control (not tagged)	52	7	--	7	13

Discussion: Since the loss of tags coated with the Tetracycline and Vaseline mixture was slight, we decided to test both the mixture and Vaseline again. The low shedding rate obtained with untreated tags injected with the short-barreled guns in this experiment substantiated our belief that the high rate of tag shedding with the long-barreled gun in Experiment 3 resulted from poor tag penetration.

Experiment 5

Objective: To determine if the tag loss from adult fish is affected by sticky tag coatings which facilitate loading the guns, and if the tag loss, as found by Janssen and Aplin (1945), Aasen et al. (1961), and Bayliff and Klima (1962), is affected by different taggers.

Procedure: Three taggers each tagged three groups of 20 fish (mean length 114 mm). One group was tagged with clean dry tags, another with tags coated with Vaseline, and a third with tags coated with Tetracycline and Vaseline.

Results: The differences among taggers were as great as those among tag treatments (Table 5).

Discussion: A mechanical means of loading tags into the guns eliminated the need to coat the tags, and no further experiments on tag coatings were conducted. We planned to reduce tagger differences in field tagging studies by further standardizing the tagging techniques.

Experiment 6

Objective: To determine the survival rate of juvenile fish tagged with adult tags and microwire tags (Jefferts, Bergman, and Fiscus, 1963).

Procedure: Sixty-five fish from a group of juveniles (mean length 90 mm) were tagged with adult tags. An equal number of fish from the same group were tagged with microwire tags (1.02 by 0.25 mm) in the head, which is the standard location for inserting them.

Results: Only two fish with adult tags and three with microwire tags survived.

Discussion: Since microwire tags were too small to be efficiently recovered with magnets and since we also found that they could not be recovered with electronic detector systems, we discontinued experiments with them. Instead we decided to conduct a series of experiments to

Table 5.--Experiment 5; effects of tag coating and different taggers on the mortality and shedding in groups of 20 adult fish.

Tag coating	Tagger 1			Tagger 2			Tagger 3			Total			
	Dead	Shed	Total loss	Dead	Shed	Total loss	Dead	Shed	Total loss	Dead	Shed	Total loss	
	Number			Number			Number			Number			Percent
Vaseline	7	4	11	8	3	11	4	0	4	19	7	26	43
Tetracycline-vaseline	2	1	3	5	1	6	1	1	2	8	3	11	18
Untreated	10	4	14	4	0	4	2	0	2	16	4	20	33
Total	19	9	28	17	4	21	7	1	8	43	14	57	32

determine if a smaller version of the adult tag would be successful.

Experiment 7

Objective: To determine the survival rate of juvenile fish tagged with adult and juvenile tags.

Procedure: Thirty-five fish (mean length 77 mm) were tagged with adult tags and 41 fish of similar size were tagged with juvenile tags.

Results: The tag loss was 100% for adult tags and 59% for juvenile tags (Table 6).

Discussion: Death caused 97% of the adult tag loss, but only 7% of the juvenile tag loss. We thought the high rate of juvenile tag shedding (51%) resulted because construction of the gun prevented the small tag from being injected far enough into the body cavity. The gun was modified to give deeper tag penetration in the remaining experiments. Most of the mortalities occurred within 3 days, as found by Bayliff and Klima (1962), suggesting that tagging injuries caused death. The tag shedding was 95% complete within 2 weeks.

Table 6.--Experiment 7; effects of adult and juvenile tags on the mortality and shedding in juvenile fish.

Type tag used	Number of fish in experiment	Dead	Shed	Total loss	
		Number		Number	Percent
Adult tag	35	34	1	35	100
Juvenile tag	41	3	21	24	59
Control (not tagged)	66	1	--	1	2

Experiments 8, 9, and 10

Objective: To compare the losses of adult and juvenile tags from juvenile fish and to substantiate the results obtained in Experiment 7.

Procedure: In each experiment, 50 fish (mean length 77 mm) were tagged with adult tags and 50 with juvenile tags, and both groups were put into a tank with equal numbers of control fish.

Results: Nearly 95% of the tagged fish in each experiment died, as did 12 to 50% of the control fish.

Discussion: Since many control fish died, we assumed some of the mortality resulted because of the poor condition of the fish. The most noticeable difference, however, between the fish in Experiment 7 and those in Experiments 8-10 was the fullness of their intestines. The fish in Experiment 7 had very little food in their intestines, but those in Experiments 8-10 had consumed much food and had distended intestines. In the well-fed fish, tags probably punctured the distended intestines, but in the starved fish, tags evidently slipped past the flaccid intestines without damaging them. Fry and Roedel (1949), after finding that the guts of gorged mackerel were likely to be pierced when making tag incisions, allowed the fish about an hour to digest the food before tagging them. We decided to further test the effects of intestinal contents on juvenile tagging mortality.

Experiment 11

Objective: To validate the mortality and tag-shedding rates obtained with juvenile tags in Experiment 7.

Procedure: Thirty-five starved fish (mean length 82 mm) from the same group used in Experiment 7 were tagged with juvenile tags.

Results: Two fish died and four shed their tags.

Discussion: These starved fish did not suffer high tagging mortality rates when tagged with juvenile tags. The rate of tag shedding probably decreased in this experiment as a result of tagging gun modifications.

Experiment 12

Objective: To further substantiate the effects of intestinal fullness on mortality of juvenile fish tagged with adult and juvenile tags.

Procedure: Fifty fish (mean length 83 mm) from a group that had been fed a light diet for the preceding 5 days were tagged with adult tags, and 49 fish from the same group were tagged with juvenile tags. Fifty-one fish were used as controls.

Results: The tag loss was 54% for adult tags and 37% for juvenile tags (Table 7). Death accounted for 48% and 6%, respectively.

Discussion: Since only 48% and 6% of the fish died, as opposed to 95% in Experiments 8-10, we concluded that fish similar in size to those in Experiment 12 have a good chance of surviving if tagged with juvenile tags and not overfed. As in previous experiments, most of the mortality occurred within 3 days and tag shedding within 2 weeks.

Table 7.--Experiment 12; effects of adult and juvenile tags on the mortality and shedding in juvenile fish without distended intestines.

Type tag used	Number of fish in experiment	Dead	Shed	Total loss	
		---Number---		Number	Percent
Adult tag	50	24	3	27	54
Juvenile tag	49	3	15	18	37
Control (not tagged)	51	0	--	0	0

Experiment 13

Objective: To gain a better understanding of the tag-loss rate from juvenile fish under field conditions.

Procedures: We tagged 50 juvenile fish (mean length 101 mm) with adult tags and 50 with juvenile tags in an estuary and then transported them with control fish to the laboratory.

Results: Eighty-six percent of the adult tags were lost, mostly from mortality; 64% of the juvenile tags were lost, mostly from shedding (Table 8).

Discussion: No handled controls died, indicating that mortality, which occurred within 3 days, was caused by tagging. The fish in this experiment contained more food material than the well-fed fish used in Experiments 8-10. The first fish to die had punctured intestines, suggesting that mortality of field-tagged juveniles may be directly related to the fullness of the intestines. Since most previous tag losses had resulted from juvenile tags being shed and from mortality in fish with excess intestinal contents, we devised experiments to test further tag shedding and to determine further the effects of intestinal contents on tagging mortality.

Table 8.--Experiment 13; effects of adult and juvenile tags on the mortality and shedding in groups of 50 juvenile fish tagged in the field and transported to a laboratory tank.

Type tag used	Dead	Shed	Total loss	
	----Number-----		Number	Percent
Adult	41	2	43	86
Juvenile tag	11	21	32	64
Control (not tagged)	0	--	0	0

Experiment 14

Objectives: (1) To determine if different amounts of intestinal contents affect tagging mortality of juvenile fish; (2) to determine if inserting the tag at a different angle than previously affects the tag-shedding rate.

Procedures: Fish (mean length 101 mm) were kept in two tanks. Five times as much food was given to fish in one tank as was given to

those in the other for 1 week prior to tagging. From each group 70 fish were tagged with adult tags and 70 were tagged with juvenile tags as in Experiments 7-13. Another 70 fish from each group were tagged by pushing the tag through the body wall at a 45° angle, instead of a 30° angle as in previous experiments, and then rotating it to a 10° angle before injecting it into the body cavity.

Results: The new method of insertion had only slightly less juvenile tag-shedding loss than the old method (Table 9). The effect of intestinal contents on tagging mortality was inconclusive.

Discussion: The fish reduced their food intake as the water temperature declined during October. The intestines in both groups were flaccid and not distended. Since no effect of overfeeding on tagging mortality could be assessed, the data were combined (Table 9). Tag shedding, tagging mortality, and incision healing took place over a much longer period of time in this experiment than in previous summer experiments and were evidently prolonged because of the lower water temperature.

Experiment 15

Objective: To determine if applying tags either higher in the body cavity than in previous experiments or posteriorly reduces tag loss, especially shedding, of juvenile tags from juvenile fish.

Procedures: Five groups of about 40 fish each (mean length 101 mm) were tagged with juvenile tags. In one group the tag was inserted anteriorly at an angle of 30° (as in experiments 7-13). In the second it was inserted at an angle of 45° and rotated to 10° before being injected (as in Experiment 14). In the third and fourth groups the tag also was inserted anteriorly, but the point of insertion was high on the body wall above the origin of the right pelvic fin, to position the tag above the stomach. In Group 3 the tag was inserted and injected at a 30° angle; in Group 4 it was inserted at 45° and injected at 10°. In Group 5 the tag was inserted at the origin of the left pectoral fin and injected posteriorly into the body cavity. Five other groups were tagged by identical methods with adult tags.

Results: Total loss of juvenile tags applied posteriorly from the origin of the pectoral fin was less than for all other methods (Table 10). With adult tags, the two-angle, low method caused the lowest loss. Juvenile tags applied by the two-angle methods again caused lower tag-shedding rates than those injected at one angle.

Discussion: Juvenile tag-shedding and mortality rates were reduced to about 5% each when the tags were inserted by the pectoral method (Fig. 4). The tags did not penetrate the viscera, but slid between them and the body wall, whereas tags applied by anterior methods penetrated the viscera. The total loss of tags applied posteriorly from the origin of the pectoral fin, therefore, should not be affected by the fullness of the intestines. Bayliff and Klima (1962) said tags should not penetrate the viscera, and they tried to place the tags next to the body wall. Evidently the one-angle, low

Table 9.--Experiment 14; effects of adult and juvenile tags inserted into juvenile fish at one angle (30°) and two angles (45° and 10°) on the mortality and shedding in groups of 70 juvenile fish.

Type tag	Method	Dead	Shed	Total loss	
		----Number-----		Number	Percent
Juvenile	1 angle	4	36	40	57
	2 angles	5	28	33	47
Adult	1 angle	35	3	38	54
	2 angles	33	3	36	51
Control (not tagged)		0	--	0	0

Table 10.--Experiment 15; effects of adult and juvenile tags on the mortality and shedding in juvenile fish when tags were inserted anteriorly at one angle (30°) and two angles (45° and 10°) either high or low on the body cavity wall and when applied posteriorly from the base of the pectoral fin.

Type tag	Method	Number of fish in experiment	Dead	Shed	Total loss	
			----Number----		Number	Percent
Juvenile	1 angle-high	40	3	11	14	35
	2 angle-high	40	11	6	17	43
	1 angle-low	39	9	20	29	74
	2 angle-low	40	10	10	20	50
	Pectoral	41	2	2	4	10
Adult	1 angle-high	45	21	1	22	49
	2 angle-high	45	18	0	18	40
	1 angle-low	40	28	0	28	70
	2 angle-low	30	8	1	9	30
	Pectoral	40	12	4	16	40
Control (not tagged)		20	2	--	2	10

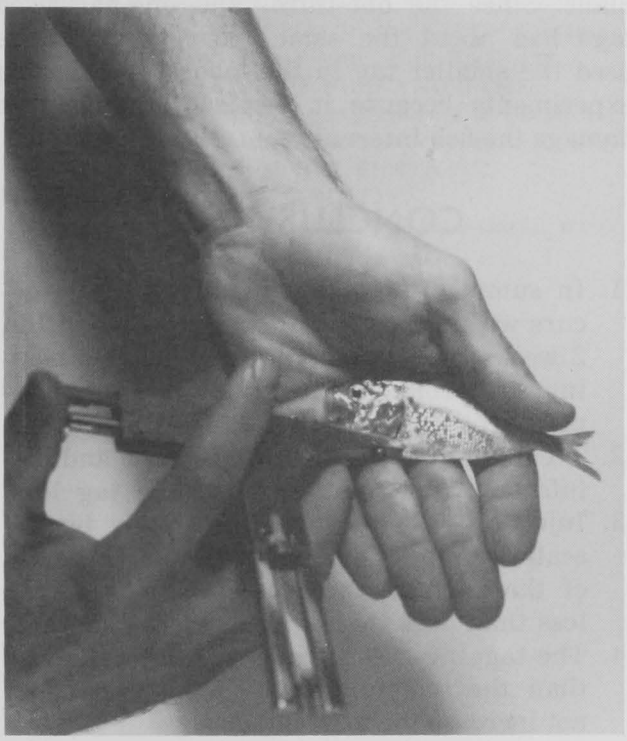

Figure 4.—Juvenile tag being inserted with the modified tagging gun in the pectoral position. The tag is injected posteriorly from the origin of the left pectoral fin.

method used in experiments 7-13 is the poorest of the tested methods for applying both adult and juvenile tags in small menhaden. Tag shedding, tagging mortality, and incision healing were prolonged as in Experiment 14, suggesting again that these factors are slowed in cool water.

On the basis of results from Experiments 1-5, we developed field tagging techniques for adult menhaden. With tagging guns we injected clean dry tags anteriorly at a point about 15 mm above the origin of the right pelvic fin. Personnel were instructed to use the same method of tag application to minimize tag loss differences among taggers. Experimental results indicated the Type-1 tag loss for laboratory-tagged fish (114 to 160 mm) ranged between 10 and 20%. This is also our only indication of tag loss in field-released tagged menhaden of this size.

Experiments 6-15 were conducted to establish tagging techniques for juvenile menhaden. Tags smaller than those used for adults, but identical in other respects, were injected posteriorly into the fish from the origin of the left pectoral fin with tagging guns which were mod-

ified to give good tag penetration. To compensate for the effect of tagging mortality, which may be greater in the field than in laboratory experiments, we planned to tag sufficient numbers of juveniles so that we would have an adequate number of recoveries on which to test our hypotheses concerning movement and population structure.

EXPERIMENTAL TAG RECOVERY

Tags can be recovered at processing plants by two methods. Tagged fish can be located by passing the catch through an electronic detector system, or tags can be recovered with magnets from the processed fish scrap. The detector system gives more useful recovery data, but construction, maintenance, and operation are too costly for operation at all the plants (Parker, 1972). Permanent magnets were used for tag recovery at all plants. These included magnets already installed in the plants to collect tramp metal and additional magnets installed specifically for tag recovery.

In 1965 experiments were conducted to calculate the recovery rate of adult tags at different processing plants. The recovery efficiency at five plants ranged from 55 to 90% (Table 11). Differences in rates of tag recovery resulted from a combination of factors such as type and location of magnets and plant conveyor systems.

In 1968 and 1969, experiments were conducted to determine the recovery rate of juvenile tags at different processing plants. Two sizes of juvenile tags and the adult tag were tested to determine whether recovery efficiency varied greatly with tag size. The recovery efficiency of the small tags, which were one-third or one-half the mass of the adult tag, was about 70% of the recovery rate of adult tags at most plants (Table 12). Plant G had about equal returns for the three types of tags, but it is a small-capacity plant. Since the one-third- and one-half-sized tags had about the same recovery rates, we used the smaller tag in the laboratory tagging experiments because it seemed less likely to damage the fish internally.

Table 11.--Estimated tag-recovery efficiency rates at five menhaden reduction plants.

Plant	Number of test tags	Percentage of test tags recovered within 4 months
A	200	56
B	400	89
C	96	90
D	196	75
E	198	55

Table 12.--A comparison of tag-recovery efficiency rates for three sizes of tags.

Plant	Number and type tags used in each experiment			Percentage of tags recovered from each experiment		
	1/3	1/2	Adult	1/3	1/2	Adult
A	200	--	200	37	--	36
B	100	--	100	45	--	80
C	100	--	100	33	--	59
D	--	100	99	--	58	69
E	--	88	100	--	39	68
F	105	105	100	49	53	77
G	200	200	200	92	94	94
Totals 1/3 vs. adult	705		700	55		68
1/2 vs. adult		493	499		68	80

CONCLUSIONS

1. In summer, tagging mortality usually occurs within 3 days and tag shedding within 2 weeks; but both, as well as incision healing, are prolonged at the lower water temperatures encountered in the fall.
2. Treatment of tags with antibiotics and disinfectants does not decrease the tag loss.
3. Injection of adult tags posteriorly by the scalpel-forceps method from above the tip of the pectoral fin causes more total tag loss than does the regular anterior method.
4. The tagging-gun method is faster and safer than the scalpel-forceps method and does not increase the total tag loss.
5. The total tag loss varies among taggers.
6. Menhaden as small as 114 mm can be successfully tagged using tagging guns and adult tags.

7. When tagged anteriorly, juvenile menhaden with distended intestines suffer higher rates of mortality than do those with flaccid intestines.
8. By most methods of anterior insertion of tags in juveniles, mean length about 100 mm, adult and juvenile tags cause about the same total tag loss; however, adult tags cause high rates of tagging mortality, and juvenile tags cause high rates of tag shedding.
9. Juvenile menhaden can be successfully tagged using juvenile tags and the pectoral method, which eliminates the high rate of tag shedding.
10. Adult and juvenile tags can be efficiently and economically recovered on magnets from dried fish scrap at menhaden processing plants.

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