TAGGING MORTALITY EXPERIMENTS ON PACIFIC MACKEREL, *PNEUMATOPHORUS JAPONICUS*

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ABSTRACT

Two experiments were conducted to compare tagging mortality rates when Pacific mackerel are tagged using a traditional method and a modified method. Tagged and control fish in equal numbers were held in tanks on board the R/V ALASKA and observed for mortality. The experiments revealed mortality rates of 24% when the tag passes between the pterygiophores or neural spines and 1.5% when the tag is placed in the lateral musculature. Mortality from handling the fish for tagging was 4%, tank trauma was 2%, and the initial tag loss was 2.5%.

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The following Department biologists reviewed the paper and offered constructive criticism: John Fitch, Herbert Frey, Melvin Willis, and Eric Knaggs. The report was typed by Micaela Wolfe.

INTRODUCTION

Since 1970, the Department of Fish and Game has been tagging Pacific mackerel to aid in estimating the population size. The fish have been tagged with Floy anchor tags using the technique recommended by the manufacturer and Dell (1968). We have assumed that some of the released fish die from handling and accidental damage to vital tissues from the tag and applicator. This mortality reduces the number of tagged fish at liberty at an unknown rate and makes population estimates less reliable.

An experiment was conducted during September 1976 to assess this mortality rate. A group of Pacific mackerel were tagged and held with an equal number of untagged fish in tanks on the R/V ALASKA. They were observed for mortality and those that died were given a post-mortem examination to ascertain the cause of death. At the conclusion of the experiment the survivors were sacrificed and examined for comparison.

The experiment revealed an unexpectedly high mortality rate from excessive hemorrhage. I hypothesized that a change in the tagging technique would reduce the tagging mortality and not reduce tag retention. If this were true, future tagging operations would be more efficient. During 1977 a second experiment was conducted to test a modified tag insertion technique. The tagging mortality was markedly reduced during this experiment while the tag retention remained essentially the same.

METHODS AND MATERIALS

Both experiments were conducted on a 30 m (100 ft) research vessel, the Department's R/V ALASKA. The vessel has a sea water tank on each side, with volumes of approximately 280,000 L (8250 Gal or 1100 ft^3) each and pumps that replace the water every 20-30 minutes. The circulation system is open, with the intakes near the keel, about 4 m (12 ft) below the sea surface, and a screened overflow near the top of each tank.

The tags used were from the same series as those used for our general mackerel tagging program [i.e., Floy Company anchor tags FD68B which consist of a printed PVC tube 75 mm (ca. 3 inches) long with a 15 mm (ca. 0.6 inches) nylon stem and a 10 mm (ca. 0.4 inches) "T" bar molded to the stem]. The tags were applied using a Floy tagging gun FDM 68 with a heavy duty needle 3 cm (ca. 1.2 inches) long.

The fish used in the 1976 experiment were captured at Isthmus Cove on the north side of Santa Catalina Island on September 28. They were attracted to the vessel at night by the use of a variable intensity incandescent light and chum made of ground anchovies. A total of 200 fish was captured that night, 156 by blanket net and 44 by hook and line. They ranged from 300 to 378 mm fork length (FL) (11.8 to 14.9 inches) with a mean of 349 mm FL (13.8 inches), but 65% were between 350 and 370 mm FL (13.8 and 14.6 inches). The hooks were made barbless by compressing the point with pliers to reduce injury during disengagement. As the fish were removed from the blanket net, five would be tagged and placed in the starboard tank, then an equal number would be placed untagged in the port tank, as a control. In the hook and line operation, alternate fish would be tagged or consigned to the control group. The

tag was applied in a manner which has been traditionally used and recommended by the manufacturer. The tagging needle was inserted on either side of the upper back in an anterior direction at an angle of approximately 45^{o} to the saggital plane of the fish and ventrally at about 10^{o} to the lateral plane. This method directs the needle beyond the dorso ventral midline and hence between the pterygiophores or the neural spines. The tag was driven into the fish and the needle removed with a twisting action so that the anchor was lodged against the bony structure. The placement of the tag was seldom perfect because of the excited nature of the fish, its strong musculature, and slippery skin. The tagging operation took two persons to effect, with one holding the fish with two hands and the other administering the tag. Care was taken to control the fish with a minimum amount of restraint, but especially strong or excited fish surely suffered from excess compression and vital tissues were likely to have been damaged from misdirected needle insertions. When the fish were placed in the well, some of them would swim away at maximum acceleration until they struck the side of the well. Occasionally fish would be dropped onto the deck and recovered, but none of these was used for the experiment or control if it was visually damaged. Damage from the above hazards was subsequently recognized during autopsy. The total tagging operation took 5½ hours ending at 0330 hours on September 29. The fish were observed after tagging and thence at least twice daily for 15 days. Observations were most often made during night hours so that visibility was not hampered by daylight reflection off the surface of the water. When fish were observed in a moribund state or dead on the bottom they were removed for autopsy. After three days, an unexpectedly high number of fish had

died from hemorrhage near the spine, so I decided to supplement the experiment with some fish tagged in a different way and compare the results. At that time an additional 25 fish were caught by blanket net and tagged by installing the tag in the lateral musculature on the same side as the point of entry. The additional fish were smaller than the first group with a size range of 295-365 mm FL (ca. 11.6 to 14.4 inches) and a mean of 324 mm FL (ca. 12.8 inches). After the addition of the supplementary fish, the live fish count was 98 control and 107 experimental; a difference which should have little effect on the experiment outcome with low fish densities in the tanks. The vessel stayed at Isthmus Cove until October 2, when it came into port and tied up at Berth 56 in Los Angeles Harbor. The water quality at Catalina was excellent (clear and clean) and in Los Angeles Harbor was good (clean and clear enough to see the fish and tank bottom) for the first few days. On October 4 the fish were fed for the first time. They eagerly ate anchovies cut into thirds. Twice daily, both tanks of fish were fed until they rejected the anchovy heads, the portion least desired by the mackerel. The fish were not fed heavily during the experiment to avoid an accumulation of excrement and uneaten food, which would add to the biochemical oxygen demand. On the afternoon of October 6, tugboat activity in the area roiled the water to such an extent that the fish could not be seen or fed. This condition lasted for about 24 hours and reoccurred on October 9 for the same reason. On October 12 the last observation was made and the remaining live fish were sacrificed and examined for pathological conditions. This examination was conducted with the help of Melvin Willis, Associate Fish Pathologist, Calif. Dept. of Fish and Game.

The fish used in the 1977 experiment were captured in Catalina Harbor on the south side of Santa Catalina Island on February 28. They also were attracted to the vessel at night to a light and anchovy chum. More than 400 fish were caught that night on barbless hooks. They were smaller than the 1976 fish ranging from 220 to 297 mm FL (8.7 to 11.7 inches) with a mean of 254 mm FL (10 inches). I tagged two hundred fish and added 200 fish to the tank as a control. All of the fish were placed into the starboard tank. Tagged and control fish were added to the tank at approximately the same rate. There was a difference in handling between the groups because many of the control were not held in the hands but just released from the hooks into the tank. The tagging technique used was to insert the tag near the dorsal midline and place the anchor anterior-laterally in the musculature. This was sometimes difficult to accomplish because of poor light conditions and slippery fish. The total tagging operation took 6 hours, ending at 0200 hours on March 1. The fish were first fed on the fourth day of captivity. The vessel stayed at Santa Catalina Island until the second day of the experiment, when it traveled to Los Angeles Harbor and tied up at the same place as in the previous experiment. The water at this locality was clear enough to see the bottom of the tanks and was not roiled during the experiment. These fish were observed at least twice daily until March 7 when the survivors were sacrificed and autopsied.

The purpose of the autopsies was to determine the most probable cause of death in the hopes of reducing future tagging mortalities. Each fish was examined and the following observations were noted: tag number; fork length; condition of the gills, skin, and fins; presence

of injuries; tag site location; condition of tissue surrounding the tag; remarks; and probable cause of death. The probable cause of death was determined by evaluating all of the diagnostic observations and comparing them with observations from other fish. Some determinations were obvious while others were more subjective. Untagged fish were examined similarly except that in the second experiment, each was examined for possible tag wounds which would indicate that it had been a tagged fish and not a control. Color photographs were taken to document commonly observed and unusual conditions. Data derived from the autopsies were analyzed by grouping the probable causes of death and comparing them to the chronology of each experiment. Also, the extent of tagging trauma was compared between groups and between experiments.

RESULTS

1976 Experiment

Pacific mackerel normally swim constantly, and when confined in a tank they circle as a school. One of the first signs of distress is any behavior other than normal. Advanced distress was revealed by fish swimming aimlessly, swimming in a "head up" attitude, gaping at the surface, or foundering at the bottom. At the end of 24 hours in captivity, one control and one tagged fish were lethargic and two tagged fish were listing. None had died. The first mortalities were observed during the second day when seven tagged and two control fish died (Tables 1 and 2). By the end of the third day 16 tagged fish had died from tagging trauma. This trauma was recognized by hemorrhages from 1 cm (ca. .5 inch) in diameter in some fish to 2 x 8 cm (ca. 1 x 3 inches) in others. Each extravasation radiated from the neural spines

TABLE 1. The Fate of 100 Pacific Mackerel Tagged Using a Conventional Technique During the September-October 1976 Tagging Mortality Experiment.

Date observed	Days after tagging	Probable Cause of Death						Total mort.	Survivors
		Tag trauma	Handling	Hook trauma	Tank trauma	Tank stress	Unknown		
Sept 29	1								
30	2	6			1			7	
Oct 1	3	10	2					12	
2	4	5	1		1		1	8	
3	5	1						1	
4	6	2	1			1		4	
5	7					2		2	
6	8								
7	9								
8	10					1		1	
9	11					11		11	
10	12					2		2	
11	13					2		2	
12	14								
13	15					1		1	
Unknown							4	4	45
TOTALS		24	4		2	20	5	55	45/100

TABLE 2. The Fate of 100 Pacific Mackerel in the Control Group from the September-October 1976 Tagging Mortality Experiment.

Date observed	Days after tagging	Probable Cause of Death						Total mort.	Survivors
		Tag trauma	Handling	Hook trauma	Tank trauma	Tank stress	Unknown		
Sept 29	1								
30	2		1	1				2	
Oct 1	3								
2	4		2					2	
3	5		1	1	1			3	
4	6					4		4	
5	7					1		1	
6	8					6		6	
7	9					9		9	
8	10					6		6	
9	11					8		8	
10	12					5		5	
11	13								
12	14					2		2	
13	15								42
Unknown							10	10	
TOTALS			4	2	1	41	10	58	42/100

at the tag site and progressed anteriorally, some reaching the cranium. This condition prompted the hypothesis that an unexpectedly high number of tagged fish were dying from needle damage to blood vessels which are associated with each neural spine. Eventually 20 conventionally tagged fish died from hemorrhages larger than 1 cm in diameter (Table 3). This problem may be peculiar to Pacific mackerel because I have tagged many juvenile striped bass, *Roccus saxatilis*, with the same guns and tags without high mortalities and Carline and Brynildson (1972) state that trout greater than 150 mm (ca. 5.9 inches) could be tagged with little mortality using a similar Floy tag and gun. Perhaps the necessity to swim constantly prevents healing, or the space between neural spines and blood vessels may be proportionately smaller than in other fish. This high mortality prompted the accessory experiment of tagging 25 additional fish in the lateral musculature.

In addition to needle trauma, four of the tagged fish and four of the control died from handling during the experiment. This diagnosis was indicated by the presence of skin lesions beginning at a point of abrasion or scale removal and progressing by fungal infection until up to 75% of the epidermis on a side had sloughed away and the musculature was partially exposed. Death by tank trauma was evidenced by broken and hemorrhagic facial bones and pale pink to yellow gills suggesting fatal hypovolemia. A similar syndrome indicated hook mortality where the maxilla would be torn and hemorrhagic, or a gill arch would be torn free at one end. Fish that had been in distress for a day or more commonly had frayed caudal fins from contact with the tank bottom.

Starting on the sixth day, a condition developed which I call tank stress. Autopsies of fish with this condition showed minimal

TABLE 3. A Comparison of Tag Site Conditions and Type of Fate Within Experimental Tagging Groups and Between Them. Totals of Actual Counts are Followed by Percent of Observations in Each Group in Parentheses.

Test group	Tag Site Condition				Total
	Minimum trauma	Slight hemorrhage	1 cm. diam. hemorrhage	Larger hemorrhage	
1976 Conventional technique					
Survivors	36	6	3	0	45
Mortalities					
Tag induced		1	3	20	24
Handling	2	1	1	0	4
Hook induced				0	0
Tank trauma	2			0	2
Tank stress	13	2	4	1	20
Unknown	1	0	0	0	1
TOTALS	54(56.3%)	10(10.4%)	11(11.5%)	21(21.8%)	96
1976 Modified technique					
Survivors	1	0	1	0	2
Mortalities					
Tag induced	0	2	1	6	9
Handling	0	0	0	0	0
Hook induced	0	0	0	0	0
Tank trauma	2	0	0	0	2
Tank stress	5	2	2	1	10
Unknown	0	0	0	0	0
TOTALS	8(34.8%)	4(17.4%)	4(17.4%)	7(30.4%)	23
1977 Modified technique					
Survivors	37	1	1	0	39
Mortalities					
Tag induced	0	0	3	0	3
Handling	7	1	1	0	9
Hook induced	0	0	0	0	0
Tank trauma	0	0	0	0	0
Tank stress	127	14	2	0	143
Unknown	1	0	0	0	1
TOTALS	172(88.2%)	16(8.2%)	7(3.6%)	0(0%)	195

visible evidence of injury to the integument, musculature, skeleton or blood vessels. However, many did have various quantities of lysed blood in the coelom. At first I thought that they had starved but the symptom was observed in fish that died after the onset of regular feeding and the amount of subdermal fat had not diminished noticeably. In addition, after the water was roiled on October 4, some fish began swimming with their mouth constantly open and died with the mouth agape in rigor. This condition generally indicates respiratory distress which may have been caused by mechanical obstruction of gas exchange in the gills. Fish that died in this condition were included in the tank stress group.

As the experiment progressed some fish with tagging trauma were diagnosed as dying from tank stress. The justification for this was that the tank stress symptoms were predominant and the tag wounds were healing.

In general, no tagged or untagged fish died of trauma after the fifth day following handling and/or tagging. Both the control and conventional tag site groups suffered heavy tank stress mortalities after that. The conventional tag site group had 24 (or 24%) mortalities directly attributable to tagging and 7% attributed to other trauma, an amount equal to the control group. Had there not been tagging mortality, the tagged fish probably would have died of stress at the same rate as the control since stress is often density dependent.

The fish tagged in the lateral musculature (modified technique), had a discouragingly high tagging mortality, nine fish out of 25 (36%) (Table 4). However, autopsies revealed that six (24%) of the fish in this group had died from extensive hemorraging originating near the

TABLE 4. The Fate of 25 Pacific Mackerel Tagged Using a Modified Technique During the September-October 1976 Tagging Mortality Experiment. Actual Counts are Followed by Percent of the Group in Parentheses.

Date observed	Days after tagging	Probable Cause of Death						Total mort.	Survivors
		Tag trauma	Handling	Hook trauma	Tank trauma	Tank stress	Unknown		
Oct. 2	1								
3	2	2(8%)						2(8%)	
4	3	5(20%)			2(8%)	4(16%)		11(44%)	
5	4	1(4%)				2(8%)		3(12%)	
6	5	1(4%)					1(4%)	2(8%)	
7	6					2(8%)		2(8%)	
8	7								
9	8								
10	9					1(4%)		1(4%)	
11	10								
12	11								
13	12								2(8%)
Unknown						1(4%)	1(4%)	2(8%)	
TOTALS		9(36%)			2(8%)	10(40%)	2(8%)	23(92%)	2(8%)

spine (Table 3) and the location of the anchor indicated that during the tag insertion, the needle had been misdirected and ruptured a blood vessel associated with the spine. The modified tagging technique study in 1976 was thought to be inconclusive so the technique was tested again in 1977.

Tags were known to be shed from three (3%) of the fish. The rest of the tags were firmly implanted.

1977 Experiment

The tag induced losses in this experiment were substantially reduced from the 1976 experiment (1.5% and 24% respectively, Tables 1 and 5). However, since the fish were smaller and they were all caught on hook and line, there was a slight increase in handling mortality over 1976 (4.5% and 4% respectively, Tables 1 and 5). The first four fish to

die exhibited paralysis in the posterior third of the body which was evidenced by swimming disability and lack of muscle tone. This was probably caused by damage to the spinal cord from excess compression when the fish were removed from the hook and restrained during tagging.

On March 4, which was the first day in Los Angeles Harbor, the fish were fed for the first time. They seemed indifferent to the cut anchovies and some were swimming listlessly. This was a marked difference from the 1976 experiment when the fish ate actively. At this time I had some apprehension about the water quality because I could smell an organic chemical in the air that reminded me of fiber-glass resin, and industrial pollution was not unknown in that area. The first observation on March 5 revealed 43 dead fish (21 tagged, 20 control). Many fish were swimming lethargically and aimlessly. Some were gasping at the surface. That evening there were 102 more dead (52 tagged and 50 control). The next day 80 dead fish were removed (40 tagged and 40 control). The daily mortalities diminished after March 7, but the rates for tagged and control remained similar (Tables 5 and 6). This undifferentiated mortality could have resulted from one or more causes. Most suspect is that there was a lethal amount of dissolved petroleum distillate in the water. As noted before, detectable vapors were present and the fish swam in a drugged manner. The fish did not die with their mouths agape in rigor as in the 1976 experiment. Other possibilities were: overcrowding, low dissolved oxygen, high metabolic waste concentrations, and chemicals associated with the bottom of the harbor. To minimize the influence of these factors, future tests should be conducted in oceanic waters such as found near Santa Catalina Island.

TABLE 5. The Fate of 200 Pacific Mackerel Tagged Using a Modified Technique During the March 1977 Tagging Mortality Experiment. Actual counts are Followed by Percent of the Group in Parentheses.

Date observed	Days after tagging	Probable Cause of Death						Total mortality	Survivors
		Tag trauma	Hand-ling	Hook trauma	Tank trauma	Tank stress	Unknown		
March 1	0		3(1.5%)					3(1.5%)	
2	1		1(.5%)					1(.5%)	
3	2		1(.5%)				1(.5%)	2(1%)	
4	3	1(.5%)	1(.5%)			1(.5%)		3(1.5%)	
5	4		1(.5%)			72(36%)		73(36.5%)	
6	5	2(1%)				38(19%)		40(20%)	
7	6		2(1%)			18(9%)		20(10%)	
8	7					14(7%)		14(7%)	39(19.5%)
Unknown							5(2.5%)	5(2.5%)	
TOTALS		3(1.5%)	9(4.5%)			143 (71.5%)	6(3%)	161(80.5%)	39(19.5%)

TABLE 6. The Fate of 200 Pacific Mackerel in the Control Group from the March 1977 Tagging Mortality Experiment. Actual Counts are Followed by Percent of the Group in Parentheses.

Date observed	Days after tagging	Probable Cause of Death						Total mortality	Survivors
		Tag trauma	Hand-ling	Hook trauma	Tank trauma	Tank stress	Unknown		
March 1	0								
2	1								
3	2			1(.5%)				1(.5%)	
4	3			1(.5%)			1(.5%)	2(1%)	
5	4			8(4%)		62(31%)		70(35%)	
6	5			2(1%)	2(1%)	36(18%)		40(20%)	
7	6					26(13%)		26(13%)	
8	7					12(6%)		12(6%)	43(21.5%)
Unknown							6(3%)	6(6%)	
TOTALS				12(6%)	2(1%)	136(68%)	7(3.5%)	157(78.5%)	43(21.5%)

Autopsies of the tagged fish revealed that 88.2% had minimal tagging trauma, and none had ecchymoses larger than 1 cm in diameter (Table 3). This indicates that careful administration of the tag into the musculature can greatly reduce the risk of lethal tissue damage.

Tags were known to have been shed from two (1%) of the fish and probably would have been lost from three (1.5%) others. A fish that had been double tagged in October 1976, was captured while fishing for test animals. It had been tagged with the modified technique. Both tags were firmly implanted in the lateral musculature and the surrounding tissue was completely healed.

DISCUSSION

Successful tagging of fish usually involves such variables as the size of the fish, method of capture, holding vessel, type of tag, technique of application, and location of release. Each variable affects the mortality rate as a unit and the combined effects equal the tagging mortality. An ideal study would include one experiment for each variable which, in the case of the mackerel tagging operation conducted by the Department, would have required about 12 experiments. However, it is hoped that by carefully analyzing these two experiments along with other observations of relative tag return rates we will be able to estimate tagging mortality for any combination of variables in a routine tagging operation. From these experiments we have learned to expect the following mortalities: (i) holding the fish for tagging = ca. 4%, (ii) conventional tagging = ca. 24%, (iii) modified tagging = ca. 1.5%, (iv) capture by hook = up to 6%, (v) tank trauma = ca. 2% and (vi) tank stress in oceanic waters = ca. 0% (Tables 1, 2, 4, 5, and 6).

Tag returns from routine tagging operations have revealed dramatic differences in tagging mortality. In the spring of 1977 on two separate days 4,000 Pacific mackerel were tagged. Our procedures were essentially the same with one exception: in the first operation the fish were removed from a roundhaul net with a normal brail, and in the other with a brail that had a waterproof liner which kept the fish in water during transfer to the holding tanks. To date, we have had 14 returns from the first operation and 266 returns from the second. This indicates that perhaps the first group suffered unobserved trauma, such as scale removal, which jeopardized their survival after tagging and release.

Based on present knowledge, the operation which would produce the lowest tagging mortality for about 4,000 released fish would be: (i) fish taken in one set of a roundhaul net, (ii) removed from net by water brail or gravity flow, (iii) placed in live well in moderate numbers (about 2,000 per commercial live bait boat well), (iv) about 20 fish at a time kept at the surface by a crowder, (v) each fish to be handled by only one person wearing wet cotton gloves, (vi) tagging to be done by a second individual using the modified technique described above, (vii) release tagged fish immediately into ocean waters, while (viii) the vessel is slowly underway to avoid predators and effect dispersion, and (ix) there should be five or six people in the tagging crew so that the operation takes place in less than 8 hours. This method would produce an expected tagging mortality of 7.5% (1.5% for tagging trauma, plus 4% for handling, plus 2% for tank trauma).

In addition to the above tagging mortality, 2.5% for initial tag shedding should be subtracted from the number of fish released to compute the initial number of fish at liberty.

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