Study to Determine the Biological Feasibility of a New Fish Tagging System

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A STUDY TO DETERMINE THE BIOLOGICAL FEASIBILITY OF A NEW FISH TAGGING SYSTEM

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ABSTRACT

Pacific salmon are tagged or marked as a critical part of numerous research and management studies. A new tag called the PIT (passive integrated transponder) tag measuring 7.5 mm long by 1.5 mm in diameter has a great potential for marking fish if it proves to be biologically compatible. A multi-year cooperative study between the Bonneville Power Administration and the National Marine Fisheries Service was Initiated in 1983 to evaluate the potential of the PIT tag for marking salmonids. The objectives of the first year's research were to determine: (1) the anatomical areas in which the tag could be placed, (2) tissue response to the tag, and (3) tag retention. Juvenile coho, Oncorhynchus kisutch, and chinook O. tshawytscha, salmon and adult chinook salmon held at Manchester or Big Beef Creek, Washington, were used as test animals.

Juvenile salmon were injected with sham PIT tags in the body cavity and opercular, dorsal, and caudal musculature. The fish ranged in length from 126 to 212 mm. Observations based on three tests, from 44 to 102 days long, indicated that the dorsal musculature and body cavity were the best locations to inject the tag from biological and social standpoints. Little tissue response to the tag was noted in either the dorsal musculature or body cavity, and tag retention varied from 80 to 99%.

Sham PIT tags were injected into the nose; body cavity; and opercular, dorsal, and caudal musculature of jack chinook salmon. The test was conducted for 23 days. Although all five anatomical areas were acceptable from a technical standpoint, the body cavity appeared to be the best area for tag placement.

Initial test results with the Sham PIT tag were very encouraging. Apparently the PIT tag can be successfully injected into and carried by salmon, making it a potentially useful tool for fisheries biologists.

INTRODUCTION

Pacific salmon along the west coast are tagged or marked to answer numerous fishery research and management questions. The coded wire nose tag (CWT) is the primary tool used for this purpose; however, there are inherent shortcomings with the CWT system, e.g., fish must be sacrificed to obtain the tag information, and tag recovery and decoding are time-consuming and expensive.

A new identification tag called the PIT tag (passive integrated transponder) was developed by Identification Devices Inc., Westminster, Colorado, to identify live stock. Recent size reductions make it probable that this tag could be implanted in juvenile and adult salmon. This tag would overcome many of the restrictions of present fish identification systems. The tag is unique in that each tag can be individually coded with one of about 34 billion codes; the fish does not need to be handled, restrained, or anesthetized to decode the tag; and the tag code information can be obtained electronically in vivo using a sensor placed several centimeters from the fish. Other characteristics of the PIT tag are: the tag is completely passive, the tag and decoder offer no safety hazards to the fish or operator, and the tagging system does not require special licenses or training before use.

A multi-year cooperative study between the Bonneville Power Administration and the National Marine Fisherles Service (NMFS) was initiated in 1983 to evaluate the potential of the PIT tag for salmonids. The objectives of the first year's research were to determine: (1) the anatomical areas in which the tag could be place, (2) tissue response to the tag, and (3) tag retention. Tests using functional PIT tags were scheduled to begin in April 1983, however, production delays prevented testing of the actual tag. In place of the planned tests, four tests using sham (similar external characteristics but non-functional) tags were conducted with juvenile and adult salmon. Because of -delays in obtaining functional tags, the design and construction of hand operated and automatic tag injection systems were postponed until the study's second year.

METHODS AND MATERIALS

Juvenile Coho Salmon - Seawater

Two tests using yearling coho salmon, Oncorhynchus kisutch, were conducted in seawater. Both tests took place at the NMFS', Manchester Marine Experimental Station near Manchester, Washington. The first test lasted 44 days from 30 August through 12 October 1983. The second test lasted 46 days from 31 October through 15 December 1983.

In June 1983, three thousand yearling coho salmon to be used in the test were obtained from the Washington State Department of Fisheries' Minter Creek Fish Hatchery. The fish were transported to the Manchester Marine Experimental Station and placed in four acclimation tanks with running fresh water. Salinity was adjusted by reducing the inflow of fresh water and increasing that of seawater. Acclimation to local seawater (28‰) took place over 4 davs with 2-day stops at 14‰ salinity and 21‰ salinity. On the fifth day of acclimation, the fish were transferred to a seawater net-pen measuring 4.9 x 4.9 x 3.7 m deep, where they were held until they were used in the study. During the holding and test period, the fish were maintained on an Oregon Moist Pellet diet. In early August, the fish suffered a high mortality from Vibrio anguillarum. The fish were subsequently fed medicated food (Chloramphenicol[1/]) for 7 days and the mortality decreased. Medicated food was also fed from 30 August to 3 September.

1/ Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

To begin Test I, the fish were divided into seven test groups of 202 fish each (Table 1), injected intraperitoneally with 0.2 ml of vibrio bacterin combined with Furacin and Terramycin, and then measured to the nearest 1 mm and weighed to the nearest 0.1 g. The fish in each group were placed in seawater net-pens measuring 1.2 m by 2.1 m by 1.5 m deep. The net-pens were examined daily for dead fish. Dead fish were necropsied for cause of death. All mortalities were examined for tag retention. At the termination of the study (12 October) 10 to 15 fish from each treatment were preserved in buffered formaldehyde solution for later his tological examination.

Nonfunctional sham tags, measuring 7.5 mm long by 1.5 mm In diameter, were injected into the fish using a modified hypodermic syringe and a 1 O-gauge needle. The dimensions of the tags were similar to that of functional tags as then designed. Each tag had a ferromagnetic core enabling the tag to be detected using a standard CWT detector. The tags had an outside coating of Plastrex 789 which is similar to the material which will be used on the functional tags.

Three anatomical sites were evaluated for tag placement: opercular musculature, dorsal musculature, and body cavity. Each site was represented by a test group. Fish in three additional groups were injected with a needle only (no tag) in a manner similar to that described for tagged groups. A control group was not tagged or injected with a needle. In those fish tagged in the opercular musculature, the tag was injected into the adductor mandibulae muscle of the left opercuium by inserting the needle ventro-anteriorly at an angle of about 0° (Figure 1). For those tagged in the dorsal musculature, the needle was inserted approximately

Table 1.--Summary of sham tag test on coho salmon reared in seawater for 44 days.

Treatment	Starting number	Ending number	Overall survival (%)	Tag retention in survivors (%)	Tag retention in mortalities (%)	Overall tag retention (%)
Control	202	160	79.2	--	--	--
Needle only operculum	202	178	88.1	--	--	--
Needle only dorsal musculature	202	185	91.6	--	--	--
Needle only body cavity	202	181	89.6	--	--	--
Tag operculum	202	82	90.	8[illegible].	80.0	83.7
Tag dorsal musculature	202	6[illegible]	8[illegible].2	99.[illegible]	87.5	97.5
Tag body cavity	202	66	[illegible]2.2	79.5	86.1	80.7

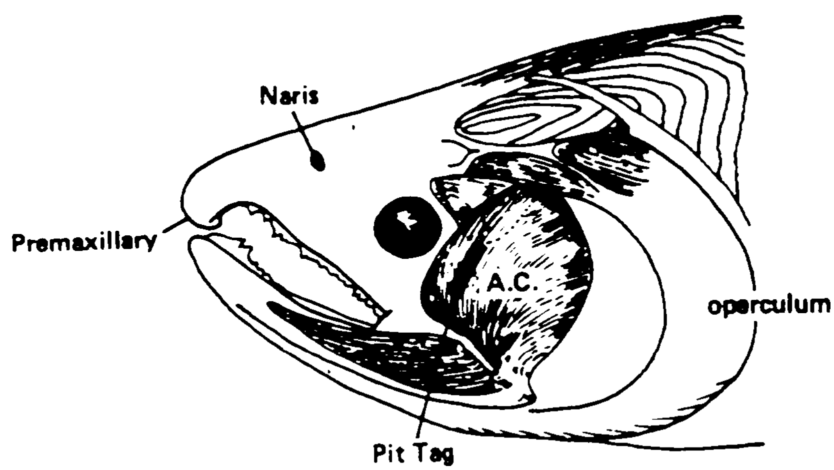

Figure 1.--Head of a salmon showing the placement of the PIT tag in the adductor mandibulae (A.C.) of the operculum (based on Greene and Greene 1913).

10 mm anterior to the dorsal fin. An attempt was made to place the tag Just ahead of the dorsal fin and between the left and right lateral epaxial muscle bundles (Figure 2). For those tagged in the body cavity, the tag was injected into the body cavity in the vicinity of the spleen and pyloric caeca. The tagging needle was inserted in an anterior direction through the hypaxial musculature about 5 to 10 mm anterior and 10 mm dorsal to the right pelvic fin (Figure 3).

In Test II, 50 of the seawater-adapted yearling coho salmon smolts were placed in each of two seawater net-pens after being tagged with sham PIT tags. PIT tag locations were evaluated in the dorsal and caudal musculature. For fish tagged in the dorsal musculature, tags were Injected into the epaxial muscle mass, perpendicular to and just under the mid-rays of the dorsal fin (Figure 4). For those tagged in the caudal musculature, the tagging needle was inserted anteriorly into the dorsal caudal flexor musculature, and we attempted to place the tag between the flexor caudalis dorsalis superioris and flexor caudalis dorsalis inferioris (Figure 5). A third group of fish was used as a control. Fish holding, maintenance, and tagging procedures were similar to those described in Test I. The fish were measured at the beginning of the test, but growth information was not obtained during the test.

Juvenile Fall Chinook Salmon--Fresh Water

This test was conducted at the University of Washington's Big Beef Creek Research Station. Fall chinook salmon, _0. tshawytscha,_ initially ranging in length from 123 to 164 mm were divided into four groups; the

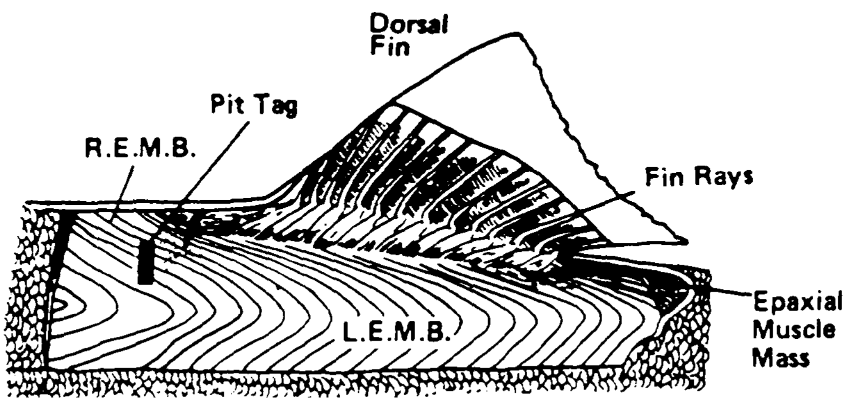

Figure 2.--Placement of the PIT tag in the dorsal musculature (left and right epaxial muscle bundle L.E.5I.B and R.E.M.B.) of a salmon; the tag is in a dorsal-ventral position just ahead of the dorsal fin (based or. Greene and Greene : 913).

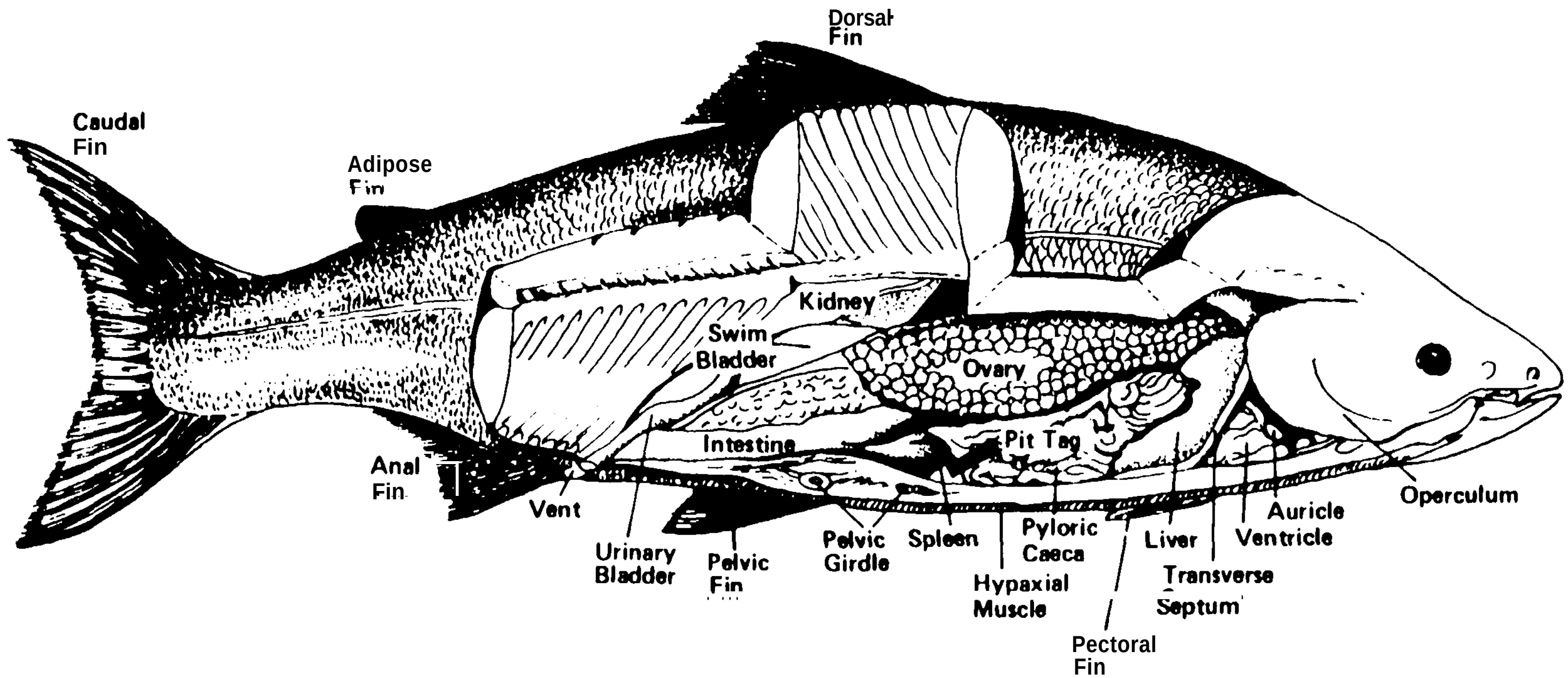

Figure 3.--Cutaway showing various external and internal features of a salmon and the general location of a PIT tag injected into the body cavity (based on Smith and Bell 1975).

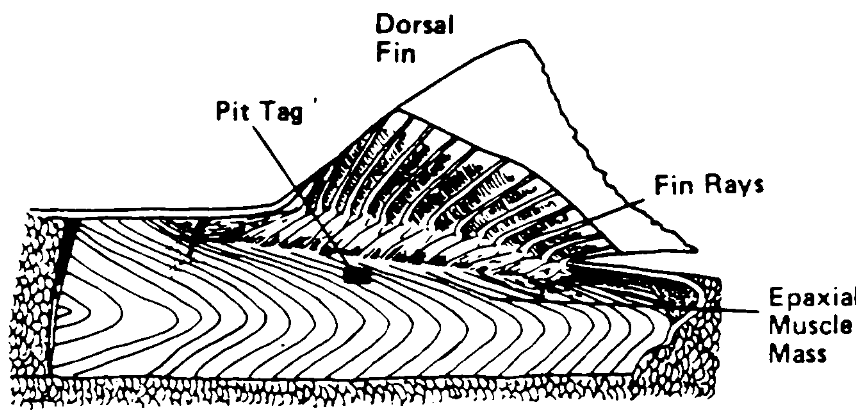

Figure 4.--Placement of the PIT tag in the dorsal musculature of a salmon; the tag is just under the dorsal fin and perpendicular to the longitudinal axis (based on Greene and Greene 1913).

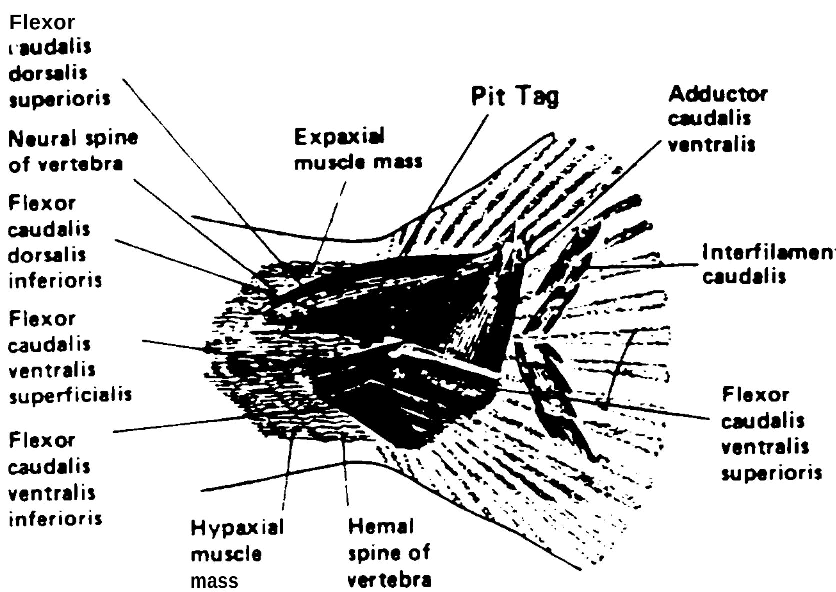

Figure 5.--Caudal musculature of a salmon showing general location of the PIT tag (based on Greene and Greene 1913).

control group contained 202 fish and the three tag groups 125 fish each. All fish were held in 4-ft diameter Fiberglass tanks which received a continuous supply of 10" C fresh water (ground water). Standard hushandry practices were used to maintain the fish. Fish in the three tag groups had sham PIT tags injected into the opercular musculature, dorsal musculature, or body cavity. Tag placement and injection techniques were similar to those described for coho salmon in Test I. Anatomical areas of tag placement are shown in Figures 1, 2, and 3. Medicated feed containing Chloramphenicol (2 mg/kg food) was fed to all fish for 9 days after the start of the test.

All fish were weighed and measured to the nearest 0.1 g and 1 mm, respectively, at the start of the test. The test began 2 September and terminated 12 December 1983 (102 days). Five fish from each test group were visually examined on Day 13 for wound healing and then returned to their rearing, tanks. To determine tissue response to the tag, five fish from each group were sacrificed and preserved on Davs 28 and 71 for later histological examination. All tagged fish were passed throught a CWT detector on Dav 71 to detenine tag presence. At the termination of the test, 4 fish from the opercular group, 19 fish from the body cavity group, and 17 fish from the dorsal musculature group were nreserved for suhsequent histological examination. Tag retention has not yet been determined in the preserved fish. ALL other fish vere examined for tag presence by dissecting the tag from the fish.

Tag retention and the effect of the tag on survival were analyzed for independence at $P < 0.05$ using the G^2 statistic (Sokal and Rohlf 1981).

Adult Chinook Salmon--Seawater

Maturing 3-vear-old (jack) fall chinook salmon were used in the test and held in five seawater net-pens 1.2 m by 2.1 m by 1.5 m deep. The test began on 31 October at the Manchester Marine Experimental Station and terminated 32 November (23 davs). Mortalities were removed and examined for tap: retention. The fish ranged In length from 321 to 480 mm. Data were not evaluated statistically because of the small number of fish tested.

Five locations were evaluated for tag placement: the nose (the tag was placed in an area similar to that used for the CWT), opercular musculature, dorsal musculature, body cavity, and caudal musculature.

In fish taeeed in the nose, the tae was injected in the cartilage below the lumen of the olfactory capsule, above the peremxiliary, and between the nares (Figures 6 and 7). For fish tagged in the opercular musculature and the bodv cavitv, the tag was iiliected in a manner similar to that described for coho salmon in Test 1 (Figures 1 and 3, respectively). For those tagged in the dorsal musculature and caudal musculature, the tag was injected in a manner similar to that described for coho salmon in Test II (Figures 4 aild 5, resnectivelv).

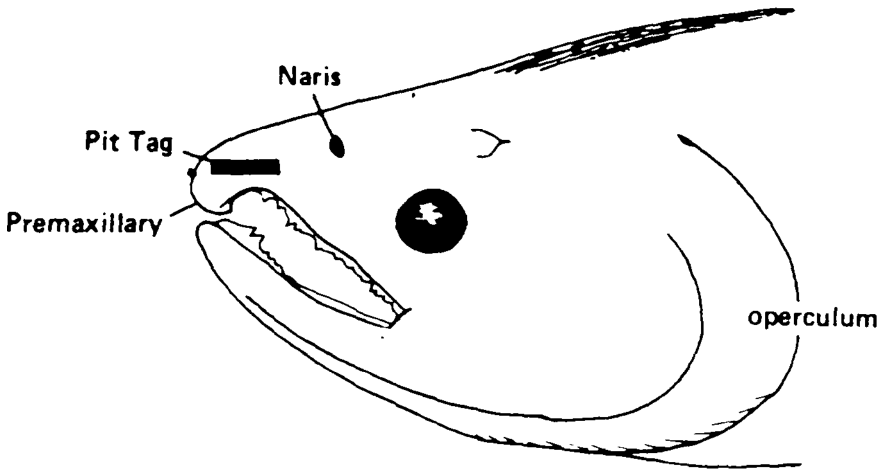

Figure 6.--General placement of the PIT tag in the nose of an adult salmon (based on Greene and Greene 1413).

a. Epidermis
b. Mesenchymal tissue
c. Cartilage of the olfactory capsule
d. Lumen of olfactory capsule
e. Portion of olfactory nerve
f. Olfactory lobe
g. Telencephalon (forebrain)
h. Diencephalon (between brain)
i. Optic nerves
j. Oral valve
k. Tongue
l. Tooth
m. Oral region

Figure 7.--Sagittal section of a salmonid showing the general placement of a PIT tag (based on Yasutake and Wales 1983).

RESULTS AND DISCUSSION

Juvenile Coho Salmon--Seawater

Results differ from an earlier study to determine possible areas for tag placement (Prentice and Park 1983). In the earlier study, a shorter tag was used, 4.0 mm vs. 7.5 mm in the present study. The diameter of the tag remained the same. This length difference is believed to account, in part, for the different results.

Growth

If severe problems were to have resulted from the tagging operation or the actual presence of the tag within the fish, there would likely have been a noticeable growth depression in relation to the control groups. However, during the 44 days of testing in Test I, no substantial differences in either length or weight were seen between the various groups (Figure 8). A longer study would be needed to fully evaluate the effect of the tag on growth.

Survival

A series of delays and disease problems (vibriosis and myxosporean parasitosis) unrelated to the testing program materially affected survival data for these tests (Tables 1 and 2). Fish in both Tests I and 11 were in a weakened condition. Consequently, only general observations can be reported, and additional tests are needed for conclusive data.

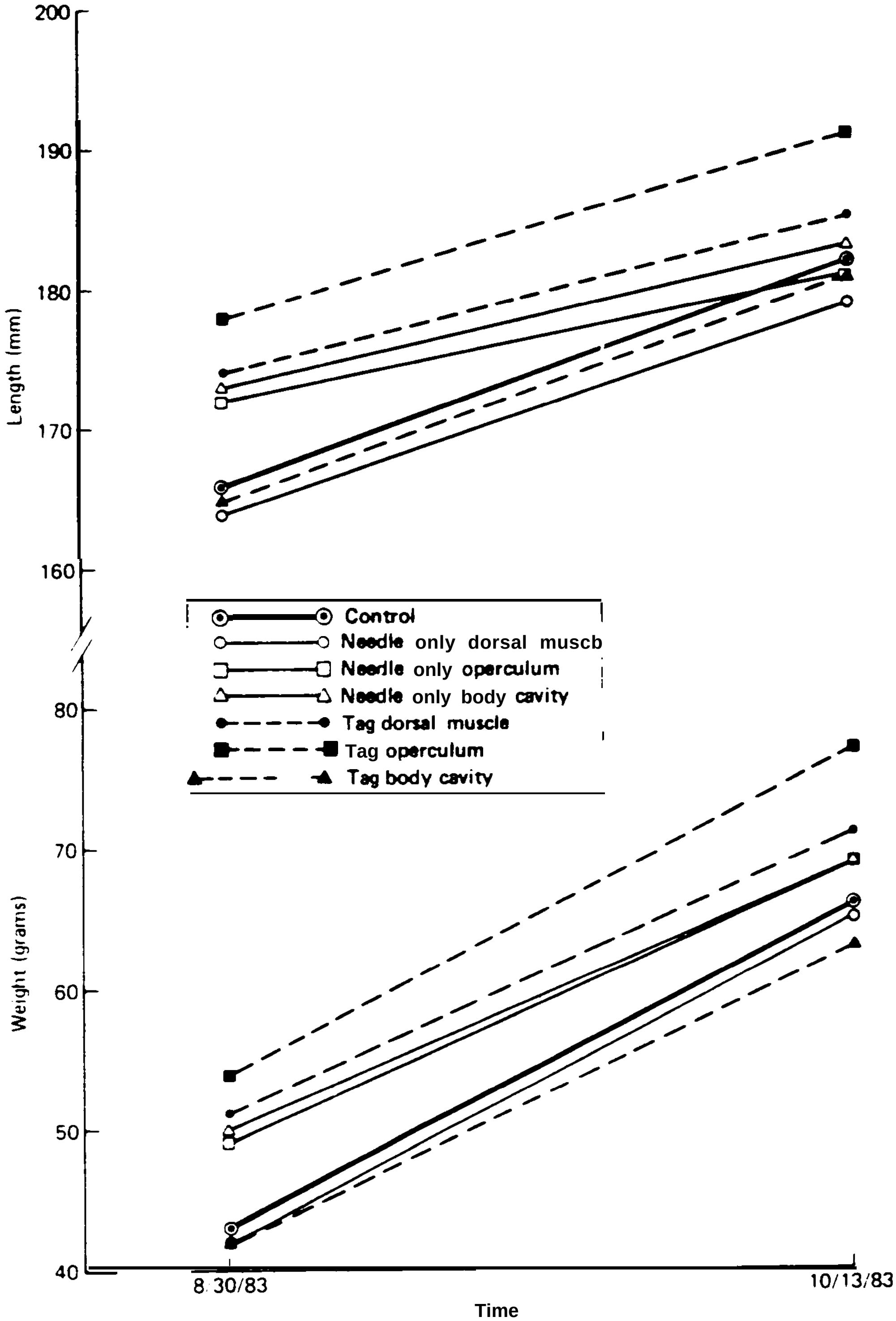

Figure 8.--Growth of coho salmon injected with PIT tags in various anatomical locations as compared to needle-injected and control fish.

Table 2.--Summary of sham PIT tag test on juvenile coho salmon reared In seawater for 46 days.

Treatment	Startlng number	Ending number	Overall survival (%)	Tag retention in survivors (%)
Con tro 1 (no tag)	50	38	76	
Dorsal musculature	50	43	86	93.0
Caudal musculature	50	19	38	84.2

In Test I, no mortality was attributed to the tag or tagging operation with the exception of fish receiving the tag or needle in the dorsal musculature. At tagging, two fish in the group receiving the tag and one in the needle-only group had difficulty swimming. The fish were removed and examined. In all three cases the needle had contacted the spinal column, causing the problem. On the second day of the test, four additional fish in the group receiving the tag in the dorsal musculature showed stress. In three of these fish, the tag was found in contact with the spinal column, and in the fourth, a severe hemorrhage of the dorsal artery was apparently caused by the tag or needle. The target area for tag placement was between the left and right lateral epaxlal muscle bundles. Because of the relatively large size of the tag and the small target area, the target was not usually achieved. By Injecting the tag into either the right or the left muscle and away from the spinal column the injuries seen in this study would be eliminated.

In Test II, fish tagged in the caudal musculature had much poorer survival than fish in the dorsal-musculature or control groups. Six of the mortalities and five of the survivors showed erosion of the caudal areas due to a myxobacteria infection. A number of fish had varying degrees of hemorrhaging In the area of the tag by the end of the test. Movement of the tag by the continuous flexing and contracting of the caudal muscles may have caused repeated rupture of the segmental veins and arteries in the caudal area. The hemorrhaging, even though not severe, may have compromised the fish.

Tag Retention and Tissue Response

Tag retention in surviving fish varied with the area in which the tag was implanted (Tables 1 and 2). The dorsal ❑uscula ture area had the highest retention (99.4%-Test I, 93.0%-Test II), followed by the caudal musculature (84.2%), opercular musculature (84.1X), and the body cavity (79.5%).

The highest tag retention (99X-Test I, 93X-Test II)) *in* surviving fish was in the group tagged in the dorsal musculature (Tabl1). These tags were placed dorso-ventrally between the left and right expoxfal muscle bundles just anterior to the dorsal fin. In all cases the wound was healed at the termination of the test. There was little sign of tag irritation in the muscle tissue or of any attempt by the fish to encapsulate the foreign body. In Test I, tag retention In the mortalities was 88%. The reduced tag retention in mortalities compared to living fish probably resulted from the tag working out of the open wound in the first few days when the tissue may not have healed in the sick fish. Further study is required to explain this tag loss.

Tag retention among surviving fish tagged in the caudal musculature was 84X. Two tags were found in the recovery tanks immediately after tagging. The tags had not been retained by the caudal musculature and were immediately expelled from the longitudinal wound created by the 14-gauge tagging: needle. Other tags were probably lost in a similar manner, until the wounds partially healed. At the end of the test, open or partially healed wounds were evident on several fish. One tag was found protruding from an open tag wound: it would have been lost within a few days. The non-healing wound contributed to low tag retention, bacterial infection, and poor survival.

Tag retention was 84% among the surviving fish in the onerculum-tagged group (Table 1). In the living fish in which the tag was lost, 14% showed erosion of the skin and muscle, 10% showed an open wound where the needle entered the skin, and 76% showed complete healing. During examination of the fish, several more tags were seen protruding from wounds created by the tag. These tags would also have been lost in time. In the mortalities, only 80% of the tags were present. The tag loss was attributed to rapid deterioration of the fish after death.

The poorest tag retention (80%) was among those fish tagged in the body cavitv (Table 1). The majority of the tags in surviving fish at the termination of the test were found in the peritoneum of the pyloric caeca and spleen (Table 3). Two tags were found embedded in the spleen with no apparent ill effects to the fish. One tag was found in the vent. Two mortalities were also seen with tags protruding from the vent. The number of tags lost in this fashion is unknown. About 10% of the body cavity tags were found embedded in the hvpaxial muscle mass anterior to the right pelvic fin. These tags had not been injected through the muscle mass and into the hody cavity. At the tfme of injection, the needle apparently was held at too shallow an angle and did not penetrate through the muscle mass. other areas in which tags were located are shown in Tahle 3. Tag retention within the 36 mortalities was 86% (Table 1). The higher tag retention in the mortalities compared to living fish was probably due to the decreased time the tag had to migrate from the body cavity.

The time to closure for the wound created by the tag insertion needle and tissue response related to the tag are important for two reasons. First, an open wound increases the possibilitv of disease or infection, compromising the fish and/or Increasing the likelihood that the tag could he rejected.

Table 3.--Location of sham tag in coho salmon 44 days after injection of the tag into the body cavity.

Tag location	Number	%
In peritoneum near pylotic caeca and spleen	52	39.4
In pyloric caeca	30	22.7
Near spleen	23	17.4
In spleen	2	1.5
Near mid-gut	11	8.3
In gut	1	0.8
In hypaxial muscle mass	12	9.1
In vent	1	0.8

Second, the likelihood of the tag being expelled from an open wound is much higher than in a healing or healed wound.

A subsample of five fish from each treatment group in Test. I was examined for wound healing 15 days after injecting the tags. In all cases 75 to 100% of the wound had closed. Dorsal-musculature test fish showed the most complete healing. One of the five fish in the operculum-tagged group had the skin stretched very taut. Fish in other groups often showed some darkening, probably melanin, in the area of needle insertion. If the fish had been non-stressed at the start of the test, wound healing may have occurred more rapidly. In future tests, the period in which complete wound healing take6 place will be evaluated.

Tissue response to the tag or needle was normally very limited. The greatest response to the tag was seen in the opercular musculature. When the tag was placed just under the skin and not embedded In the muscle tissue, erosion (skin and/or muscle) was noted in the vicinity of the tag. So encapsulation of the tag by tissue was noted among the treatment groups. Fish tagged In the body cavity showed no hemorrhaging. Most tags in the body cavity were found surrounded by connective tissue.

Examination of 454 tags that had been In fish for 44 days in Test I revealed some tags with a visible reaction. A blackening was noted on 73 tags (16%). The outer coating of the tag seemed permeable to body fluids, causing oxidation of the metal core. Oxidation, in the form of a rust color, was noted on an additional 74 tags (16%). No reaction was noted on the remaining 307 tags. A sample of the affected tags was sent to Identification Devices Inc. for examination. In spite of some visual alteration to the tag, no adverse effects could be seen In the fish. No tissue response to the tag was noted; however, final conclusions must await histological examination of tissue samples.

Juvenile Fall Chinook Salmon--Fresh Water

Growth

So growth information was obtained on this test group.

Survival

Overall survival ranged from 91 to 100% (Table 3). So signif lcant difference was seen in survival between tagged groups (G^2=0.610, df=3). Control fish had a significantly lower survival (G^2=9.667, df=1) than operculum-tagged fish, but not in comparison to fish tagged in the body cavity (G^2=1.454, df=1) or dorsal musculature (G^2=2.070, df=1). Long-term tests (holding fish to maturity) need to be conducted to verify these findings. Mortality among control fish was from a myxobacteria infection. This infection, which caused severe erosion of the caudal fin and msculatzre, was seer. only among control fish. All test groups were treated with m.:lachite green (1 ppm for 1 h) on Days 43 and 46 to combat and the spread of the infect ion. Other than a higher rearing density in the controls (9.5 g/l vs 5.9 g/l), all groups were treated the same. Although the higher rearing density among control fish may have caused s tress, the density was within acceptable limits.

Tag Retention and Tissue Response

Due to a malfunction of the CWT detection equipment, tag retention was based solely on the presence or absence of tags in surviving fish at the termination of the study. Tag retention was 93, 87, and 73% for fish tagged in the body cavity, dorsal musculature, and opercular musculature, respectively (Table 4). So significant difference in tag retention was seen between fish tagged in the dorsal musculature and body cavity (G^2=2.187, df=!). Fish tagged in the operculum showed a significantly higher tag loss in coapari son to those fish tagged in the dorsal musculature or body cavity (G^2=6.011, df=l; G^2=15.323, df=l). The trend toward a higher tag retention in the body-cavity group is important from a biological, social, and economic standpoint .

Tag retention in the body cavity was 93%. In the fish examined, tags injected into the bodv cavity were found near the area of injection in all but the 5% where the tag had migrated toward the hind gut (Table 5). Tag movement probably occur red soon after tagging since the tags were surrounded by peri toneal tissue when examined at the end of the test. This tissue would 1 have prevented the tag from migrating or moving within the body cavity. So tissue response to the tag was noted (visual examination only). Tag loss probably occurred during the first few days after tagging since there was no evidence of tags being expelled at 102 days. Initially tags may have migrated through the tagging wound, or they nay have been injected into the gut of the fish and subsequently expelled.

Tag retention among dorsal-musculature tagged fish was 87%. The majority of the tag loss probably occurred within the first week when the tagging wound had not completely healed. Only i fish out of the 9i fish examined showed an open wound at the end of the test. There was hemorrhaging and inflamed muscle tissue in the area of the tag in 4% of the dorsally-tagged fish examined. Tag loss probably would have occurred

Table 4.--Summary of sham tag tests on juvenile fall chinook salmon reared in fresh water for 102 days.

Treatment	Starting number	Sacrificed number	Ending number	Overall[a] survival (%)	Number of fish examined for tags	Number of tags present	Tag retention in fish examined (%)
Control	202	10	174	90.6	--	--	--
Tag-operculum	125	10	115	100.0	111	81	73.0
Tag-body cavity	125	10	109	94.8	90	84	93.3
Tag-dorsal musculature	125	10	108	93.9	91	79	86.8

a/ % survival adjusted for sacrificed fish (10 fish per treatment).

Table 5.--Location of PIT tags injected into the body cavity of juvenile fall chinook salmon after 102 days.

General tag location	Number in location	%
Near spleen	27	32.1
In spleen	1	1.2
In pyloric caeca	7	7.3
Near spleen and pyloric caeca	42	50.0
Sear hind gut	4	4.8
Sear kidney (mid)	1	1.2
Adjacent to body wall in area of injection	2	2.4

among these fish from the eventual decay of the muscle tissue surrounding the tag. The reason for the reaction to the tag among a few fish is unknown.

Fish tagged in the operculum had the poorest tag retention (73%) and the greatest tissue response. On Day 13, no tissue reaction to the tag was noted nor were any tag wounds open. On Day 102, termination of the test, 40% of the operculum-tagged fish had open tagging wounds. Sixty percent of those fish had developed a lesion in the tissue overlying the tag at both ends of the tag. The large size of the tag in relation to the muscle mass in which the tag was injected apparently caused irritation. This in turn caused hemorrhaging, inflammation, tissue decay, and the ultimate loss of the tag.

On Day 13, five fish from each test group were visually examined for wound repair. All fish tagged 'in the dorsal musculature showed slight inflammation near the tagging wound, however, the wounds were closed. Fish tagged in the body cavity and operculum showed no inflammation, and the taqginn wound appeared healed. The area where the tagging needle penetrated the skin was evident on all fish. Future studies should determine the period reauired for wound closure, since open wounds increase the likelihood of tag loss and infection.

Adult Chinook Salmon--Seawater

Growth

So growth information was collected on the fish because of their advanced state of maturity.

Survival

The test was terminated after 23 days because of high mortality in all groups. The fish died of natural causes due to their advanced state of maturity.

Tag Retention and Tissue Response

Tag retention was highest (100%) for tags placed in the body cavity, caudal musculature, and operacular musculature followed by the nose (93%), and the dorsal musculature (92%). Tag retention data are included in Table 6 for each of the test groups. However, because of the few fish tagged and the short duration of testing, the tag retention data are of limited value. The results did allow an evaluation of tagging techniques and wound repair as related to the specific anatomical areas in which the tags were injected.

Although only five fish were tagged in the body cavity, results suggest that this may be a preferred area for tag placement. Tag retention was 100%. There was no tissue response to the tag. This agrees with previous findings with juvenile fish. The tags were found near the spleen and/or in the pyloric caeca. In all cases the tag was in contact with connective tissue, preventing it from changing position within the body cavity. The tagging wounds had closed but were not completely healed. No infection was observed. Further work on tagging technique is needed.

Tag retention was 100 in the caudal musculature group. So effect was noted on the swimming behavior of the test fish. At the end of the test, varying amounts of hemorrhaging were seen around three tags, but no tissue deterioration was noted. With the continuous flexing and contracting of the caudal tmscles, the tags probabiy repeatedly ruptured the numerous

Table 6.--PIT tag loss in adult (jack) salmon in relation to anatomical area of tag placement.

Anatomical area	Number of fish	Number of tags lost	Tag retention(Z)
Body cavity	5	0	100
Caudal musculature	16	0	100
Opercular musculature	15	0	100
Dorsal musculature	13	1	92
Sose	15	1	93

segmental veins and arterioles near the tag. This potential problem warrants further tests to include a series of swimming chamber tests to determine if tag retention is affected over time and if there are adverse effects on swimming performance under controlled conditions.

Tag retention was 100% in fish tagged in the opercular musculature. However, the puncture wound of the tagging needle remained open in 10 of the 15 fish. If the test had continued, the tags would probably have been lost through the open wound. Since the muscles of the operculum are continuously flexing and contracting, a foreign body such as a tag in this area can aggravate a wound and retard healing. This is especially true in adult fish where tissue regeneration is suppressed. An open wound, of the type seen on the test fish, is also very susceptible to infection. If infection occurs, tissue decay would increase the likelihood of tag loss. Overall, the risk of tag loss appears high in adult fish tagged in the opercular musculature; however, additional tests are warranted.

Tag retention for adult fish tagged in the nose was 93%. An open puncture wound was evident on the fish immediately after tagging; the wound closed by the end of the test. If a tag was not placed deeply into the nose cartilage, it could be lost during the first few days. One of the 15 fish tagged in the nose showed tissue decay and erosion in the area of tag penetration. The tag was lost from that fish. Nose erosion is common in net-pen cultured fish, thus the erosion seen may not be related to the tag. So other fish showed any reaction to the tag or to the initial wound.

Even though tag retention was relatively high for tags placed in the fish's nose, this procedure is not recommended using the present tag or tagging equipment. Because of its size and variable resistance, it was difficult to insert the needle and control its depth of penetration. Accurate tag placement was difficult to achieve within a realistic tagging time. Upon dissection of the tags from fish at the end of the test, a number of tags were found in or near the diencephalon. An object, such as a needle or tag, penetrating this region could alter behavior or physiological functions; no such effects were noted in this test.

In those fish tagged in the dorsal musculature, tag retention was 922. The wounds on all but two fish had closed by the end of the test (23 days), and no infection was noted. No changes in swimming activity were noted among the fish tagged in the dorsal musculature. One fish showed some hemorrhaging in the area of the tag when it was dissected from the fish. The primary criticism of the dorsal musculature as an area for tag placement is that the tag is in a potentially edible portion of the fish. The risk of accidental tag consumption is reduced, however, by placing the tag near the base of the dorsal fin. If the fin is removed from the fish, there is a high probability that the tag will also be removed. This area for tag placement warrants further tests including refinement of the tagging technique.

CONCLUSIONS AND RECOMMENDATIONS

1. Based on survival, tag retention, and tissue response data collected during the study, the PIT tag can be Injected successfully and retained in the dorsal musculature and body cavity, but not in the operculum or caudal musculature of juvenile coho and fall chinook salmon 126 mm to 212 mm in length. Placement of the tag in the body cavity rather than in the dorsal musculature is recommended since the tag would then be in a non-edible portion of the fish and would be removed upon evisceration. This does not preclude the use of the tag in the dorsal musculature for applications where tag consumption is not considered a problem.

2. The tag did not affect survival in juvenile fish tagged in the operculum, dorsal musculature, or body cavity, but did affect those tagged in the caudal musculature.

3. Growth of the fish was not affected in any of the groups tested, however, long term tests are suggested.

4. Tag retention varied not only between the different anatomical areas of placement, but between similar areas. Slight variations in tagging technique and tag placement may have accounted for these differences. Further tests are required to refine our tagging technique to ensure consistent results.

5. The effect of the tagging on iuvenile fish, in part, depended upon where the tag was injected. Tissue response was most severe in the operculum tagged group, followed by fish tagged in the caudal and dorsal musculature. The tissue response was normally not seen until after the tagging wound appeared to be closed for a short period. The time required for the tagging wound to heal (closed was fairly consistent in all groups

at about 13 days. Wound healing should be evaluated further since it can affect tag retention and fish health.

6. Based on limited tests with jack chinook salmon, the PIT tag can be successfuly placed and carried in a number of anatomical areas. However, the body cavitv and the dorsal musculature appear to be better areas for tag palcement than the nose, opercular musculature, or caudal musculature. For the same reasons stated for juvinile fish, the body cavity is presently the recommended site. Further testing will be required to fully evaluate the effects of the tag on adult fish.

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APPENDIX

Budget Information

A. Summary of expenditures

1.	Labor	s31,500
2.	Travel	2,800
3.	Supplies and eauipment	2,800
4.	SLUC	2,000
5.	NOAA and DOC overhead	13,000
	TOTAL	s77,300

B. Major property items

1. None.