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RETENTION, RECOGNITION, AND EFFECTS ON SURVIVAL OF SEVERAL TAGS AND MARKS FOR WHITE STURGEON

THOMAS A. RIEN, RAYMOND C. P. BEAMESDERFER, AND CRAIG A. FOSTER
Oregon Department of Fish and Wildlife
17330 Southeast Evelyn Street
Clackamas, Oregon 97015

We evaluated retention and effects on survival of tags and marks applied to 7,332 white sturgeon (*Acipenser transmontanus*) in the Columbia River between 1987 and 1991. White sturgeon were tagged and marked with combinations of spaghetti tags, Carlin tags, tattoos, barbel clips, leading pectoral fin-ray scars, and lateral scute removals. Spaghetti tag placements below the anterior and posterior portions of the dorsal fin had 96% and 88% retention during the first year at large. Removal of a combination of dorsal scutes provided a mark that lasts more than two years, whereas tattoos and fin-ray scars did not last as long. Barbel clips did not regenerate, but were subject to some misinterpretation and may have reduced survival rates. We recommend evaluating effects of scute removal on survival, and propose reserving removal of the second right lateral scute to indicate oxytetracycline injection and the second left lateral scute to indicate passive integrated transponder (PIT) tagging for white sturgeon studies in the Columbia River Basin.

INTRODUCTION

Three concerns in any marking or tagging study are: Will the mark be retained for the duration of the study? Is the mark recognizable by those expected to recapture the fish? Finally, does the mark affect survival of the fish (Wydoski and Emery 1983)? Tagging and marking of white sturgeon (*Acipenser transmontanus*) are particularly problematic because these fish are long-lived and programs to collect population information often last several years.

A variety of methods have been used to tag or mark sturgeons, but attempts to document success of these methods on wild sturgeons have been rare. Chadwick (1959) reported spaghetti and disk-dangler tags were shed over time and observed no difference in retention for placements below the dorsal fin, between dorsal scutes, and on the caudal peduncle of white sturgeon. Smith et al. (1990) evaluated retention of five externally visible tags (T-anchor, Carlin, Archer, Monel strap, and internal anchor) for captive shortnose, (*Acipenser brevirostrum*) and Atlantic sturgeon (*A. oxyrhyncus*). Carlin tags placed at the base of the dorsal fin and internal anchor tags had retention rates ≥80% after 180 days, but gill net entanglement was a problem with Carlin tags and severe tissue damage was associated with internal anchor tagged shortnose sturgeon released in brackish water.

Sequentially, numbered tattoos have been used to mark wild white sturgeon in Idaho (Cochnauer et al. 1985), but reports of tattoo retention are variable. Tattoos

were clearly visible after one year on captive white sturgeon (Bordner et al. 1990), but were barely visible on captive shortnose sturgeon after four months (Smith et al. 1990). Removal of the leading pectoral fin ray for age determination leaves a recognizable scar, but may adversely affect survival (Kohlhorst 1979). Silver nitrate marks and barbel removal have also been tried with limited success (F. Partridge, Idaho Dep. Fish and Game, Boise, R. Pipkin, Univ. California, Davis, pers. comm.). Barbel clips on captive white sturgeon did not regenerate, but Bordner et al. (1990) expressed concern that this mark may affect the fitness of wild fish.

Retention and recognition of tags and marks are interrelated and difficult to distinguish in a field study. Estimates are further confounded by natural occurrences of marks or scars and by errors in recording data. Myhre (1966) developed a regression method to differentiate shedding from non-reporting based on an assumption that recognition rate is fixed relative to shedding loss, which occurs at a uniform rate. We defined retention as the combination of true mark retention and correct recognition of marks by samplers because our concern was the net potential for bias in population assessments based on recapture of tagged or marked fish.

During 1987-1991 we used spaghetti and Carlin tags, tattoos, barbel clips, fin-ray scars, and lateral scute removal marks on white sturgeon to estimate population characteristics in Bonneville, The Dalles, and John Day reservoirs on the Columbia River (Beamesderfer and Rien 1992). This study was not originally designed to compare mark and tag retention, but recapture data presented for the marks and tags we applied are useful for future mark-recapture experiments involving sturgeons. This paper summarizes the information on retention, recognition (including the ability of samplers to recognize the presence or absence of marks, how well marks conveyed specific information, and the incidence of 'natural' marks), and the effects of these tags and marks on survival.

METHODS

From 1987 through 1991 we tagged and marked 7,332 white sturgeon (Table 1). Combinations of marks changed over time as new information became available. White sturgeon were captured using setlines, gill nets, angling gear, and a creel survey (Elliott and Beamesderfer 1990).

All untagged white sturgeon over 84 cm fork length were double-tagged. One spaghetti tag was inserted below the anterior portion of the dorsal fin. A second tag was inserted below the posterior portion of the dorsal fin. From 1987 to 1989 the second tag was a spaghetti tag. From late 1989 to 1991 it was a Carlin tag (Table 1). White sturgeon 65-84 cm were single-tagged with a spaghetti tag in the anterior position; we believed double tagging would substantially stress these smaller fish. Spaghetti tags were made of extruded vinyl with a hollow core and were tied with an overhand knot 1 cm behind the dorsal fin. Carlin tags consisted of a circular plastic disk (1.4 cm diameter) secured by 0.5 mm diameter stainless steel wire using methods described by Wydoski and Emery (1983). Spaghetti tags and Carlin tags were sequentially numbered.

Table 1. Tags and marks applied to white sturgeon in three reservoirs of the Columbia River from 1987 through 1991.

Tags Marks[a]	87	88	89	90	91	Total
Anterior spaghetti tag only						
B	121	0	0	0	0	121
B T	2	0	0	0	0	2
B F	83	0	0	0	0	83
B S	0	202	0	0	0	202
F	0	0	0	0	19	19
F S	0	91	302	112	746	1,251
S	0	277	1,426	197	265	2,165
Anterior and posterior spaghetti tags						
None	0	1	0	0	0	1
B	115	3	0	0	0	118
B T	251	0	0	0	0	251
B T F	235	0	0	0	0	235
B F	22	1	0	0	0	23
B F S	0	50	0	0	0	50
B S	0	433	0	0	0	433
T	1	0	0	0	0	1
F S	0	174	270	0	0	444
S	0	466	676	0	0	1,142
Anterior spaghetti tag and Carlin tag						
F	0	0	0	0	17	17
F S	0	0	3	141	428	572
S	0	0	6	66	130	202
Total	830	1,698	2,683	516	1,605	7,332

[a]Marks are: B = barbel clip, T = tattoo, F = fin-ray scar, S = scute removal.

Except for one fish in 1988, all tagged fish were also marked using one or more of the following procedures: tattoos, barbel clips, removal of fin-ray sections, and removal of scutes (Table 1). We applied sequentially numbered tattoos to the pectoral girdle of 489 white sturgeon longer than 75 cm in 1987. The skin was rubbed with black tattoo ink and physical pressure was used to puncture the flesh with the needles of a 1-cm rotary tattoo. We removed a single barbel from specific positions on 1,518 fish during 1987 and 1988 to identify year of tagging. On 2,694 fish we removed right or left pectoral fin-ray sections from white sturgeon to determine age. A small hacksaw blade or coping saw was used to make two cuts through the leading pectoral fin ray. The first cut was made about 5 mm distal of the fin articulation and the second cut was made about 10 mm distal of the first. The fin-ray piece was then removed using a knife inserted between the rays as needed. Done correctly, little bleeding was associated with this procedure, but it left a recognizable scar on the leading edge of

the fin. We removed one or two scutes in various combinations from the first four lateral scutes on the right and left sides on 6,461 white sturgeon beginning in 1988. Scute removal patterns corresponded to the year the fish was tagged and whether or not the fish had been injected with oxytetracycline (used to validate our aging technique). Scutes were removed by shaving them off close to the skin surface using a knife. The site of scute removal heals darker and smoother than the surrounding skin.

We compared retention of tags and marks among fish at large <1 year, 1 year, and 2+ years. Tag retention was estimated as the percent of recaptured fish with secondary marks that also had a tag:

$$\text{Tag retention} = 100 \times R_{t+m} / (R_{t+m} + R_m)$$

Where: R_{t+m} = the number of recaptured fish having a tag and secondary mark.
R_m = the number of recaptured fish having only a secondary mark.

Mark retention was estimated as the percent of recaptured fish with tags that also had the appropriate secondary mark:

$$\text{Mark retention} = 100 \times R_{t+m} / (R_{t+m} + R_t)$$

Where: R_t = the number of recaptured fish having only a tag.

This method will provide unbiased estimates of retention rates when tag\mark losses are independent of each other, even though fish losing all tags\marks may not be recognized. Evaluation of tag and mark retention was restricted to observations by our sampling crews or creel interviewers. Although use of voluntary angler recoveries would increase our sample size, anglers were not aware of the secondary marks we applied, thus they could not recognize fish that lost tags or marks. Year of tagging was determined from the tag number, or from secondary marks. We used chi-square tests of independence to compare retention of tags or marks over years at large unless half or more of the expected cell frequencies were small (<5), in which case we used Fisher's exact test (FET; Sokal and Rohlf 1981). We also used a chi-square test of independence to compare retention of spaghetti tags in anterior and posterior positions for fish at large less than one year were compared using a chi-square test of independence. Statistical comparisons were performed with the SAS "FREQ" procedure (SAS Institute 1988).

Mark recognition (presence or absence) was compared for two groups of samplers with different experience in recognizing marks. Samplers who applied marks and tags as part of their routine duties were considered to have greater expertise in mark recognition than creel samplers who were trained in the recognition of marks, but did not apply marks as part of their regular duties. We compared the rate at which mark types were identified as present on recaptures of previously marked fish between the groups, which provided insight into the importance of experience in mark identification.

The utility of marks for conveying specific information was examined by comparing recorded mark combinations when fish were tagged and when recaptured between sampler groups. Misinterpretation of marks at recapture may reflect inadequate mark application, misreading of the marks at recapture, or partial loss of marks. Regardless of the reason for the differences, the level of recording error indicates the utility of a mark to convey specific information. For example, removal of the second and fourth right lateral scutes indicates a fish was marked and injected with oxytetracycline in 1990.

The rate of natural occurrence for barbel clips, fin-ray scars, and scute removals was estimated as the percent of recaptured fish with tags that had "acquired" a mark while at large. This rate reflects loss of structures during the period at large, as well as recording errors at marking or recapture.

We examined the effect of barbel removal and fin-ray scarring on survival by comparing recapture rates between groups of fish with and without these marks. In 1988 we removed a barbel from about half the white sturgeon we tagged and released in The Dalles Reservoir each day; fish tagged in Bonneville Reservoir were excluded from this analysis because most fish were not barbel marked. In 1988 and the early part of 1989 we took fin-ray samples from about half the white sturgeon $\leq$124 cm that were tagged in Bonneville Reservoir each day; fish tagged in The Dalles Reservoir were excluded from this analysis because the rate of fin-ray sampling changed as our sample size needs were met. Other than the mark being tested, fish were treated similarly among groups — fish were single- or double-tagged depending on size. Recapture rates were not comparable between the barbel-clip analysis and the fin-ray sample analysis, because the test groups were from different reservoirs, sizes, and recapture efforts.

RESULTS

Samplers recovered 645 white sturgeon that had previously been tagged. Of these, all had been spaghetti tagged in the anterior position (anterior tag), 319 had been spaghetti tagged in the posterior position (posterior tag), and 30 had been tagged with a Carlin tag. Of all previously-tagged fish, 593 (92%) had retained at least one tag at recapture. Among recaptures of tagged fish, 64 had been tattooed, 204 had been barbel clipped, 174 had fin-ray sections removed (fin scarred), and 448 had lateral scutes removed (scute marks) at the time of marking.

Of the 645 recaptured white sturgeon that had been anterior tagged, 99 lost their tag prior to recapture (Table 2). Retention rates of anterior tags were significantly different among years and declined with years at large. The first-year tag retention rate for anterior spaghetti tags was significantly greater than for posterior tags (chi-square test: df = 1, $X^2 = 7.39$, $P = 0.007$). Posterior tags were lost on 42 of the 319 recaptures. Posterior tag retention also was significantly different among years and declined with years at large (Table 2). Of 30 Carlin-tagged fish recaptured, 4 had lost the tag.

First year retention did not vary significantly among marks (FET: df = 1, $P = 0.429$), but subsequently there were some distinct differences. Tattoos were

Table 2. Retention/recognition rates for various tags and marks applied to white sturgeon, Columbia River, 1987-1991.

Tag or mark	Years at large			Chi-square results		
	<1	1	2+	df	X^2	P[a]
Anterior spaghetti tag						
retained	244	167	135			
lost	11	35	53			
retention rate	96%	83%	72%	2	48.37	<0.001
Posterior spaghetti tag						
retained	113	111	53			
lost	6	15	29			
retention rate	88%	88%	65%	2	36.27	<0.001
Posterior Carlin tag						
retained	19	7	—			
lost	2	2	—			
retention rate	90%	78%	—	—	—	—
Tattoo[b]						
retained	9	0	0			
lost	1	33	4			
retention rate	90%	0%	0%	2	—	<0.001[c]
Barbel clip[b]						
retained	60	83	35			
lost	4	5	4			
retention rate	94%	94%	88%	2	—	0.653[c]
Fin-ray scar[b]						
retained	81	31	28			
lost	4	17	2			
retention rate	95%	64%	93%	2	25.55	<0.001
Scute removal[b]						
retained	206	96	111			
lost	8	4	1			
retention rate	96%	96%	99%	2	2.41	0.300

[a] Retention rates among 'years-at-large' groups are considered significantly different if $P \leq 0.05$.

[b] Numbers reflect fish examined for a particular mark, not all previously marked fish recaptured.

[c] Fisher's exact test results.

retained only during the first year after application (Table 2). Barbel clips were retained by 93% of recaptures and retention rate did not vary significantly among years at large. Fin scars were retained by 86% of recaptures. The trend in long term retention of fin scars retention was not clear, but retention varied significantly among years and was greatest during the first year at large. Scute marks were retained by 97% of recaptures and retention rate did not vary significantly among years.

Table 3. Recaptures of tagged white sturgeon by mark type, similarity of mark combinations and positions recorded at recapture to those recorded at marking (recognition), and experience of personnel, Columbia River, 1987-1991. Personnel with modest experience were creel clerks who were trained in mark recognition but did not apply marks; expert personnel tagged and recaptured fish as part of their regular duties. Fish were examined without knowledge of the original marks applied.

Mark type applied	Recognition at recapture	Experience of personnel: Modest *n*	Modest Percent	Expert *n*	Expert Percent
Tattoo	Identical	2	17%	3	9%
	Present [a]	0	0%	4	11%
	Absent	10	83%	28	80%
Barbel clip	Identical	31	68%	129	89%
	Present [a]	9	20%	9	6%
	Absent	6	13%	7	5%
Fin-ray scar	Identical	6	38%	111	75%
	Present [a]	3	18%	20	14%
	Absent	7	44%	16	11%
Scute removal	Identical	37	74%	349	93%
	Present [a]	4	8%	23	6%
	Absent	9	18%	4	1%

[a] The correct type of mark was seen but the exact position or combination of marks recorded at recapture was different from that recorded at marking, or the tattoo number did not match.

Tattoo recognition was low among all samplers due to the low retention after one year (Table 3). Tagging crews saw and correctly recorded barbel clips, fin scars, and scute marks more often than creel samplers. Of these marks, fin scars were the most difficult to recognize by both groups of samplers. Fin-scar recognition increased with experience; they were recognized twice as often by tagging crews as by creel samplers.

All marks had low natural occurrence rates: 3% of 362 for barbel loss, 6% of 380 for fin scars, and 5% of 104 for scute loss.

We tagged and released 635 barbel-clipped and 548 unclipped white sturgeon in The Dalles Reservoir in 1988. Respective recapture rates were 16% and 22%. The recaptures were significantly different (chi square test: df = 1, X^2 4.993, P = 0.025).

During 1988 and early 1989 in Bonneville Reservoir we tagged and released 578 fin-scarred fish and 549 that were not fin scarred. We recaptured 13% and 11% of these, respectively. The recaptures were not significantly different (chi square test: df = 1, X^2 0.903, P = 0.342).

DISCUSSION

Double-tagging white sturgeon remains the most satisfactory method of ensuring high tag retention rates over a period of several years. Posterior spaghetti tag retention was lower in the first year than anterior tags or Carlin tags, and retention rates for all tags declined over time. Small samples of Carlin tags precluded statistical comparisons of retention with spaghetti tags, but both were retained at high rates in the first year after tagging. Unless Carlin tags are retained at significantly higher rates, we would recommend spaghetti tags, because of easier application and because Carlin tags may increase catchability with gill nets (Smith et al. 1990).

Although spaghetti tags were the most effective of the tags that we examined, the style of spaghetti tag we used is still unsatisfactory. Spaghetti tags left a wound that we occasionally saw on fish at large more than one year, and tag numbers became difficult to read over time. Legibility of tags is particularly important in studies that depend on voluntary tag returns from anglers. Anglers must be able to recognize the tag to report harvest of tagged fish. Evaluation of tag types that may be less irritating to the fish and remain more legible is recommended. Passive integrated transponder (PIT) tags and visible implant tags may be less irritating (Duke et al. 1990, Haw et al. 1990, Smith et al. 1990); however, PIT tags cannot be read without special equipment and visible implant tags become difficult to read in white sturgeon due to pigment and scarring over the tag (L. Beckman, National Biological Survey, Cook, Washington, pers. comm.). Latex-coated spaghetti tags with a stainless steel wire core may improve legibility and retention over vinyl hollow core spaghetti tags (J. DeVore, Washington Department of Fish and Wildlife, Battle Ground, Washington, pers. comm.). We are now evaluating a molded nylon dart tag similar to that described by Gutherz et al. (1990) on wild white sturgeon. The dart head is designed to encourage muscle tissue adhesion and may improve long-term tag retention.

Scute marks appear to be an ideal secondary mark. Scute removal provided a long-term mark that is recognizable by samplers with varying levels of experience and combinations of scute marks may be used to convey much information about fish at tagging. However, further work is needed to evaluate the effect of scute marks on survival. We removed the second right lateral scute to identify fish that had been injected with oxytetracycline (OTC). We propose that this mark be reserved region-wide to indicate OTC treatment and further propose reserving removal of the second left lateral scute as a standard to indicate a white sturgeon that has been PIT tagged. The PIT tag has shown promise as a long-term tagging technique for sturgeons, but one problem is the lack of a readily identifiable external mark (Smith et al. 1990).

Retention of tattoos, barbel clips, fin scars, and scute marks was similar in the year of tagging, but retention declined for tattoos and fin scars in subsequent years. Barbel clips were retained over long periods, but reduced recapture rates of barbel-clipped fish suggest reduced survival. In contrast, removing a section of the leading pectoral fin ray did not reduce recapture rates, suggesting survival was not affected. Kohlhorst (1979) observed that removal of the first pectoral fin ray resulted in "substantial" (36% higher) mortality of white sturgeon during the first year following removal. The

difference in mortality rate may be due to the difference in technique: Kohlhorst removed the entire fin ray starting just distal to the area forming the articulation, whereas we removed a small (10 mm) section of the fin ray.

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