EVALUATION OF THE TX-1400ST PIT TAG USING JUVENILE AND ADULT SALMONIDS

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Report of research by

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to

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621
Project 83-319
Contract No. 307-00001

May 2003

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INTRODUCTION

Digital Angel Corp. (DA), the major supplier of passive integrated transponder (PIT) tags to the Columbia River Basin (CRB), is preparing to introduce a new, improved 134.2-kHz, FDX-B PIT tag, model TX-1400ST (ST or Super Tag) in early 2003.

The ST tag will have physical dimensions similar to the current TX-1400BE tag (BE tag): both are approximately 2.1-mm diameter by 12-mm long. Both Pacific States Marine Fisheries Commission (PSMFC) and NOAA-Fisheries (NMFS) personnel have examined pre-production samples of the tag. Because of problems that occurred in the mid 1990s when a new tag model was purchased before it was evaluated, PSMFC and NMFS recommended to Bonneville Power Administration that the ST tag be thoroughly evaluated before the agency (through PSMFC) purchases the new model for use by the entire fisheries community. In July 2002, PSMFC and NMFS designed a matrix of laboratory tests as well as field tests that would compare the two tag types using the network of PIT-tag interrogation systems presently deployed for juvenile and adult salmonids.

PSMFC contracted Peterson Engineering Services to conduct the laboratory tests (Peterson 2002). To summarize the results from these tests, the new model TX-1400ST showed significant improvement in tag-reading performance under conditions where ambient radio frequency (RF) noise, poor tag orientation in reference to antenna excitation field, or high tag velocity presented problems for the BE tag. The read range for the ST tag was better than that of the BE tag by 33 to 200%, depending on test conditions. The only negative result reported by Peterson was that under fish-grouping conditions, the signal from an ST tag might overpower the signal from a BE tag, causing the latter to go undetected. Laboratory results suggested that the performance of the ST tag in the field would be fine in the interrogation systems installed at the juvenile fish facilities and might be superior in the interrogation systems for adult salmonids installed in the fish ladders where environmental conditions are more varied and less optimal.

This report covers the field tests conducted by NMFS in which juvenile and adult salmonids were tagged with both tag models and released under similar conditions. For both juvenile and adult tests, we utilized studies that were already scheduled, as described below. Besides the main objective of comparing how well the two tags were detected by the interrogation systems, a minor objective was to determine what effects if any mixing the two tags under typical study conditions would have on data collection when large numbers of juvenile fish were released together. If the fish remained in a tight group, then code collision might become an issue. Code collision is a condition that occurs when two or more tagged fish are within the antenna tag-reading field simultaneously. When this occurs, there is a high probability that one or more of the tags will not be read.

JUVENILE SALMONID EVALUATIONS

Methods

In 2002, NMFS conducted a study for the U.S. Army Corps of Engineers at McNary Dam to determine the effects of transportation on the survival of river-run juvenile fall chinook salmon. The Corps allowed us to substitute up to 5,500 ST tags for BE tags in order to compare the performance of the two tag types. For the overall study, juvenile fall chinook salmon were tagged daily between 20 June and 15 August at McNary Dam. One treatment group was destined for transportation via barge to a release point below Bonneville Dam, while the non-transported treatment group was released into the tailrace at McNary Dam.

A paired experimental design was used to compare the two tag types with the non-transported group. With this design, approximately half of the fish released into the tailrace on two days were tagged with the ST tag. On 5 August 1,156 fish tagged with ST tags and 1,728 fish with BE tags were released. On 15 August, fish tagged with 1,889 ST tags and 1,775 BE tags were released. These juvenile salmon from the non-transported group could then be detected by the interrogation systems installed at John Day and Bonneville Dams.

A paired experimental design was also used for the transported treatment group. The transported groups released on 7 August and 15 August included 1,110 and 1,187 fish tagged with ST tags and 963 and 1,244 fish tagged with BE tags, respectively. The transported group is not part of this initial tag-comparison evaluation because these fish were released below Bonneville Dam and could not even be detected in the estuary by the PIT-tag trawl interrogation system because it was inactive in August. Consequently, the transported group can only be compared when they return as adults.

Results

All of the transportation study fish were held in the raceways at McNary Dam after tagging. The non-transported fish were then released to the tailrace through the river exit pipe. There are four interrogation antennas on this pipe; however, the study fish were crowded in the raceways before being released and thus went through this pipe quickly and en masse. For example, there were only 3 minutes between the first and last detection for the release on 5 August. Although there was an hour between the first and last detection for the release on 15 August, 98% of the fish were detected over a 4-minute period. In both cases, less than 20% of the released fish were detected. Because this low rate of detection resulted from the manner in which fish were released, we concluded that analysis of these data would not contribute anything pertinent to this tag-comparison evaluation.

Basically the same percentage of both tag types was detected by the interrogation system at John Day Dam; 13.9% (n = 424) of the 3,045 fish tagged with the ST tag and 14.0% (n = 491) of the 3,503 fish tagged with the BE tag. The Corps was still spilling water at John Day Dam until 1 September, so we assume that many of the undetected study fish went through the spillway. In this initial evaluation, the two tag types from fish released at McNary Dam were statistically compared for the number of antennas that detected each tag at John Day Dam.

At the juvenile fish facility at John Day Dam, most PIT-tagged fish go through only two monitors (Separation-by-Code (SbyC) Separator and the River Exit monitors), which together contain eight antennas (A1-A4 and 81-84; Fig. 1). Because so few study fish were diverted into the Sample Room (outer pathway in Figure 1), these detections were omitted from the analysis, and only fish that used the primary pathway were analyzed (466 fish tagged with the BE tags and 407 fish tagged with the ST tags).

For each study fish, we determined how many of the eight antennas detected its tag (Table 1). The majority of the fish were detected on all eight antennas. Overall, there were 12 different detection histories for the eight antennas at John Day Dam for the fish PIT tagged with either the BE or ST tag. The 12 detection histories for Antennas A1-A4 (Separator monitor) and 81-84 (River Exit monitor) are presented as a series of ones and zeros in Table 1, where one denotes detection and zero non-detection. For example, a detection history of 11010111 would be interpreted as a fish being detected at Antennas A1, A2, A4, 82, 83, and 84 and not being detected at Antennas A3 or 81. Note that for both tag types, no fish was missed by more than two antennas and only four fish were missed by two antennas. Because detection rates appear to be excellent, we assumed that no tagged fish of either tag type was missed entirely.

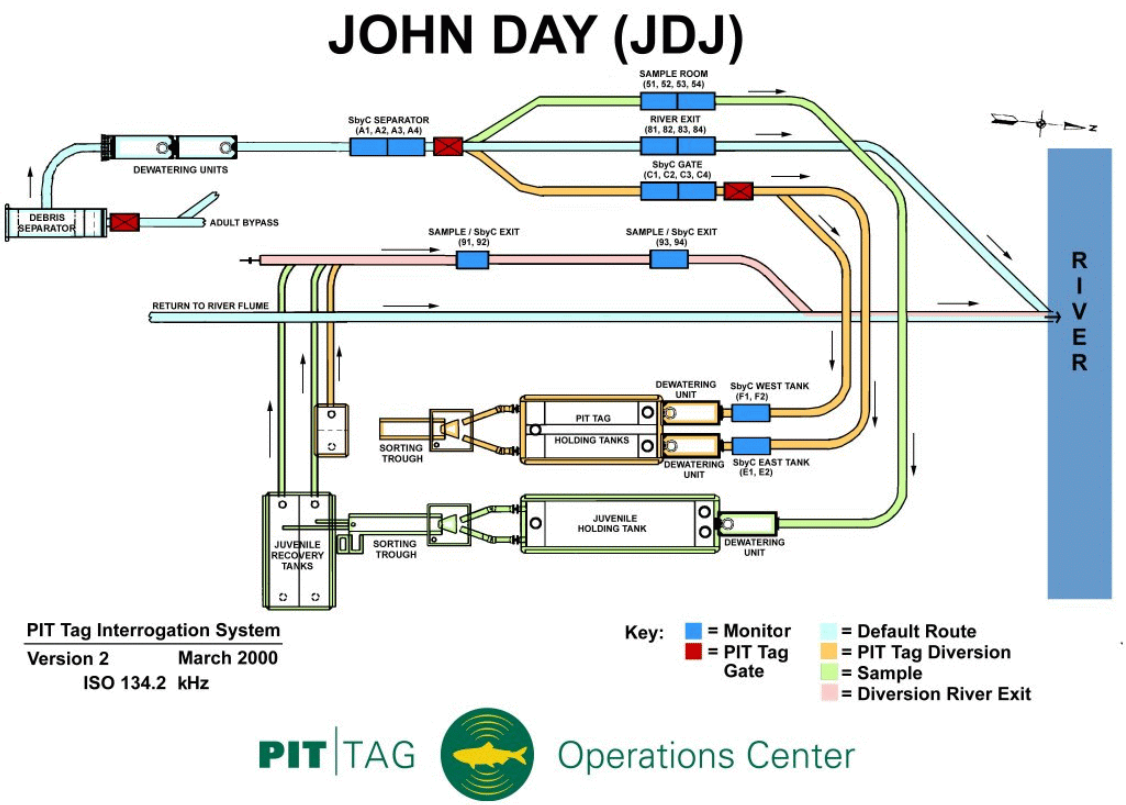

Figure 1. Overview of the PIT-tag interrogation system at the juvenile fish facility at John Day Dam (figure courtesy of PSMFC).

Table 1. A summary of the 12 detection histories for the eight antennas at John Day Dam using fish PIT tagged with either the current TX-1400BE tag or the new TX-1400ST tag. Detection histories for Antennas A1-A4 (Separator) and 81-84 (River Exit) are presented as a series of ones and zeros, where ones denote detection and zeros, non-detection.

Detection histories	5 August 2002		15 August 2002	
	TX-1400BE	TX-1400ST	TX-1400BE	TX-1400ST
01111111	2	1	5	
10011111	1			
10111111	3		1	
11001111		1	1	
11011111	10		6	3
11101111	1		3	2
11110111	2	1	1	1
11111011		1	2	
11111100		1		
11111101	9	1	1	2
11111110	2	1	1	1
11111111	212	131	203	260
Total	242	138	224	269

Since no fish was missed by more than two antennas, we compared the percentage of tags of each type that was detected on eight antennas versus the percentage detected on only six or seven antennas. For both release groups, higher percentages of fish tagged with the ST tag were detected on all eight antennas than fish tagged with the BE tag (Table 2). Although the differences in percentages of detections on eight antennas was larger than 5%, all fish tagged with the BE tag were detected by at least two antennas at each monitor; therefore, given the current number of antennas, the improved detection rate displayed by the ST tag was not particularly significant. However, one possible advantage of this improved detection rate might be that it would allow the number of antennas in a monitor to be reduced in the future.

Table 2. Percentages of fish with each tag type from two release groups detected on all eight antennas versus on only six or seven antennas at John Day Dam and the differences between the two tag types for detections on eight antennas.

	5 August 2002		15 August 2002	
Number of antenna detections	TX-1400BE (%)	TX-1400ST (%)	TX-1400BE (%)	TX-1400ST (%)
6 or 7	12.4	5.1	9.4	3.3
8	87.6	94.9	90.6	96.7
Difference	7.3		6.1	

Because fish are more apt to be in less than optimal orientations as they pass through the SbyC Separator monitor at John Day Dam, we also compared the percentages of fish detected on all four antennas versus on only two or three antennas for the SbyC Separator and River Exit monitors individually (Tables 3 and 4). These results show that there does appear to be a larger difference for detections on four antennas between the two tag types at the SbyC Separator monitor (~5%) than at the River Exit monitor (~1-2%).

Table 3. Percentages of fish with each tag type from the two release groups that were detected on all four antennas versus on only two or three antennas for the SbyC Separator monitor at John Day Dam. Differences shown are between the two tag types for detections on four antennas.

	5 August 2002		15 August 2002	
Number of antenna detections	TX-1400BE (%)	TX-1400ST (%)	TX-1400BE (%)	TX-1400ST (%)
2 or 3	7.0	1.4	7.1	1.9
4	93.0	98.6	92.9	98.1
Difference	5.6		5.2	

Table 4. The percentages of fish for each tag type from the two release groups that were detected on all four antennas versus on only two or three antennas for the River Exit monitor at John Day Dam. Differences shown between the two tag types are for detections on four antennas.

	5 August 2002		15 August 2002	
Number of antenna detections	TX-1400BE (%)	TX-1400ST (%)	TX-1400BE (%)	TX-1400ST (%)
2 or 3	5.4	3.6	2.2	1.5
4	94.6	96.4	97.8	98.5
Difference	1.8		0.7	

Another objective of this field test was to determine under typical study conditions whether tagged fish released as a group at one dam remain closely grouped together when they reached the next dam. If so, then some fish might not be detected because of code collisions, which occur when two or more fish are within the antenna tag-reading field simultaneously. The results do not suggest that either group of fish remained tightly grouped.

For fish released on 5 August, the first fish was detected at John Day Dam on 8 August at 22:17:26 and the last fish on 12 September at 04:31:21 (Fig. 2). For the fish released on 15 August, the first fish was detected at John Day Dam on 17 August at 20:15:10 and the last fish on 14 September at 22:39:55. For all four groups of fish, 60-70% of the fish were detected at John Day Dam over a 3-day period; however, no two fish passed the first antenna, A1, within the same second, and only twice did two fish pass within 2 seconds of each other. At John Day Dam, fish that are separated by a minimum of 1 second would be at least 8 feet apart physically, and thus quite easily detected. These results do not raise the concern that tags were missed because of code collisions caused by grouping.

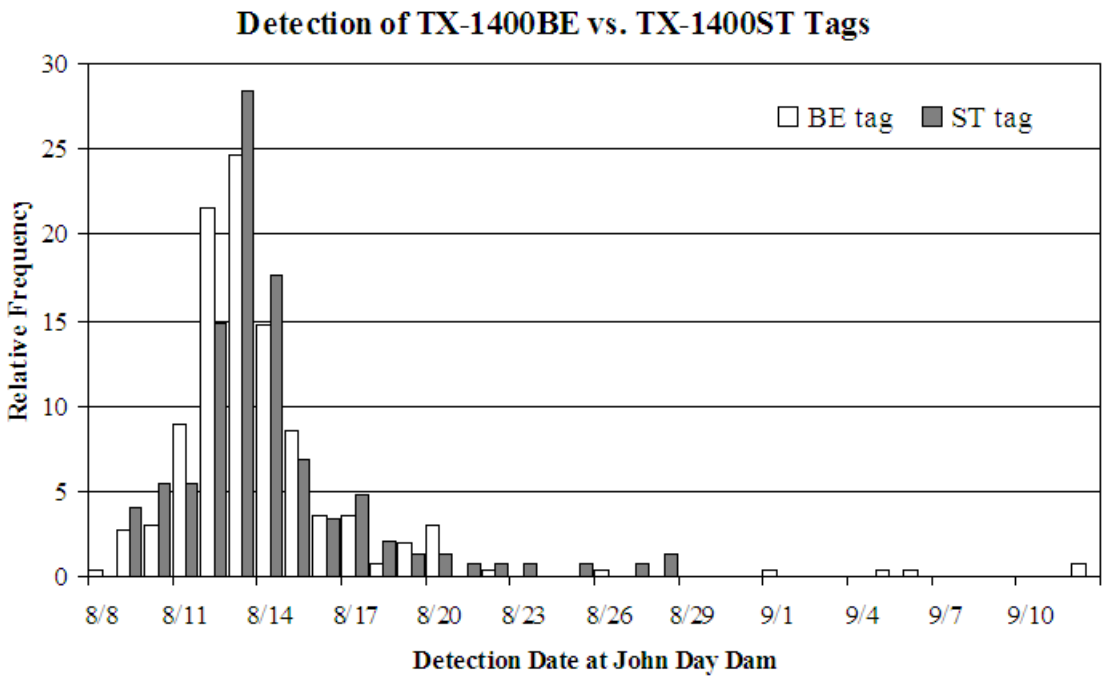

Figure 2. Relative frequency distribution for the detection of study fish tagged with TX-1400BE and TX-1400ST PIT-tags at John Day Dam. Fish were released on 5 August 2002 at McNary Dam.

Some of these fish were also detected at the juvenile fish facility at Bonneville Dam Second Powerhouse. Spill at Bonneville Dam was also discontinued on 1 September and so once more we assume that the undetected study fish went through the spillway. Again, similar percentages of both tag types were detected, with a detection rate of 1.6% (n = 50) for the 3,045 fish tagged with the ST tag and 1.3% (n = 46) for the 3,503 fish tagged with the BE tag. Similar to the juvenile fish facility at John Day Dam, most PIT-tagged fish at Bonneville Dam only go through two monitors (SbyC Separator and the River Exit monitors). At this site, the River Exit monitor only has two antennas, so the fish pass through six antennas. Since the numbers of fish were so low, this was the only pathway analyzed. Of the 96 fish detected overall, 36 tagged with ST tags and 35 tagged with BE tags used this pathway. Except for one fish tagged with a BE tag, all of these fish were detected on all six antennas. Therefore, at this facility we did not find any difference in detection rates between the two tag types.

ADULT SALMONID EVALUATIONS

Methods

During the fall 2002, both NMFS and the University of Idaho (UI) tagged some adult salmonids at the Adult Fish Facility at Bonneville Dam using the ST tag. NMFS tagged 49 fall chinook salmon, 33 coho, and 18 steelhead during September as part of its effort to determine reading efficiencies for the salmonid populations ascending the orifice-based interrogation system in Bonneville Washington Shore Ladder. All of the study fish were released into the Adult Fish Facility. Biologists from the UI also tagged adult salmonids with the ST tag in addition to radio tags as part of their ongoing Corps-funded study on fish migration behavior. The UI biologists tagged 151 fall chinook salmon and 48 steelhead with the ST tag between 31 August and 6 September. Both projects also tagged adult salmonids with the BE tag over the same time period so the tags could be compared with fish tagged under identical conditions. The UI released most of their tagged fish at locations below Bonneville Dam. Therefore, the released fish passed through the interrogations systems installed at Bonneville and McNary Dams, and some also passed Lower Granite Dam.

During the first week of September, PSMFC set up all of the interrogation systems in the fish ladders so that their transceivers reported all redundant reads for individual fish (i.e., the unique read feature was turned off). Therefore, the two tag types could be statistically compared for the number of antennas that detected each tag and for the number of reads per tag by each antenna as fish ascended the ladder.

Results

For adult salmonids tagged at Bonneville Dam by NMFS and UI, the two tag types were compared statistically for the number of antennas that detected each tag as the fish ascended a ladder and the number of reads per fish at each antenna. These comparisons were done for the data collected at Bonneville and McNary Dams.

The interrogation system for adult salmonids at Lower Granite Dam is different from the systems at Bonneville and McNary Dams. It consists of two parallel pipes, which both contain two antennas that detect 134.2-kHz tags. Furthermore, the transceivers for these four antennas are set up with the unique read feature turned on. Therefore, data from redundant reads by an antenna cannot be collected, and the only comparison that can be done at this site is to compute the percentages for each tag type of fish that were detected on two antennas vs. those detected on one antenna.

Adult salmonid fish ladder usage varies among ladders at Bonneville and McNary Dams. Since relatively few adult salmonids were tagged with the ST tag (n = 300), detection in some ladders was below 20 fish. For that reason, only detections from the Bonneville Washington Shore Ladder and McNary Oregon Ladder, which had the highest numbers of fish ascending, were analyzed for the number of antennas that detected each tag type.

The two tag types were compared for the numbers of antennas that detected fish as they ascended Bonneville Washington Shore Ladder using 88 and 86 adult salmonids tagged with BE and ST tags, respectively. At this ladder, there are eight weirs with orifice-based antennas above the exit to the Adult Fish Facility, and thus a fish ascending through an orifice at each of these weirs would have transited eight antennas. Although most fish go through the orifices, fish can use the weir overflows. When fish use these overflows, the orifice-based antennas do not detect them, regardless of tag type. In our previous analysis of inriver salmonid populations ascending the different fish ladders at Bonneville and McNary Dams, we observed that fish ascending the Bonneville Washington Shore Ladder used the weir overflows more frequently than in the other ladders (Downing and Prentice 2003). In this ladder, around 75% of the study fish went through seven or eight orifices; consequently, the average number of antennas that detected a fish ascending the ladder was 7.1 and 6.6 for the BE tag and ST tag, respectively. A *t*-test comparing the numbers of antennas that detected a tag as fish ascended a ladder showed no significant difference between the two tag types (P = 0.15).

The two tag types were compared for the numbers of antennas that detected fish ascending McNary Oregon Ladder using 32 and 28 adult salmonids tagged with the BE tag and ST tag, respectively. At this ladder, there are eight weirs with orifice-based antennas and then two antennas at the counting window area. Thus, a fish ascending through an orifice at each of these weirs and then through the 2 antennas at the counting window would have gone through 10 antennas. In this ladder, 93% of the study fish went through 9 or 10 antennas and so the averages were closer to the maximum number of antennas than in the Bonneville Washington Shore Ladder. The average number of antennas that detected a fish ascending the ladder was 9.7 for the BE tag and 9.5 for the ST tag. A *t*-test comparing the numbers of antennas that detected a tag as fish ascended a ladder was not significantly different between the two tag types (P = 0.75).

The other variable analyzed was the number of reads per fish at an individual antenna. This was done for adult salmonids tagged with the BE and ST tags for every antenna at Bonneville and McNary Dams. Although the percent improvement of the ST tag relative to the BE tag was small in several cases, the median value for the number of reads per fish was higher for the ST tag than the BE tag at every antenna (Table 5 and Fig. 3).

We expected that for each antenna there would be more reads per fish tagged with the TX-1400ST tag because it is activated by less excitation power, and therefore its antenna tag-reading field is larger. By plotting percent improvement of the ST tag over the median value for number of reads per fish for the BE tag, one sees the general pattern that the largest improvements occurred when the BE tag was not being read well by an individual antenna (Fig. 3). Another way of viewing this trend is that when an antenna was reading BE tags well, there was less room for improvement and therefore the percent improvement was lower.

The percent improvement in the number of reads per fish of the ST tag relative to the BE tag ranged from 6 to 300% with a median of 50% (Table 5). Six out of the seven antennas where the percent improvement was above 125% were antennas that detected the BE tag at less than five reads per fish. As indicated above, these would be antennas that had the most room for improvement. Based on laboratory results released by Peterson (2002) this may indicate that RF noise was a problem at these antennas (there is no supporting evidence to suggest that orientation or fish velocity would be significantly different among the orifices). Peterson's tests showed that the ST tag performs significantly better than the BE tag as the level of radio-frequency noise increased.

There were three antennas that had median values of about five reads per fish, even with the ST tag (these are three of the four outliers circled in Figure 3). One of these antennas in the left branch of the Bradford Island Ladder (ID = 0E) at Bonneville Dam was examined by PSMFC on 10 September, after study fish had already ascended it, and was found to be seriously detuned. The second of these antennas (03 at McNary Washington Ladder) was found to have an equalizer circuit in the transceiver out of tolerance by PSMFC and Digital Angel, but again, this problem was not repaired until mid-September after the study fish had ascended. The third antenna (0A at McNary Washington Ladder), whose median was 4.5 reads per fish with the ST tag, had been reading BE tags poorly all year long. We did not find any record of problems or repairs in its event log.

Table 5. The median number of reads per fish for all antennas in fish ladders at Bonneville and McNary Dams for TX-1400BE and TX-1400ST tags. The percent increase in the number of reads per fish for the ST tag relative to the BE tag is given for each antenna as well as its natural log transformation. The four outliers are designated with asterisks at the bottom of their columns.

	Coil ID																Median
	Bonneville Washington Shore Ladder (BWL)																
	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	
BE tag	11	13	12	12	12	14	11	12.5	10	10	12	13	13	12	10	3	12.0
ST tag	14.5	16	17	17	16	16	14	15	15	15	15	17	16	17.5	14	8	15.5
Increase(%)	32	23	42	42	33	14	27	20	50	50	25	31	23	46	40	**167**	32.6
Ln	3.46	3.14	3.73	3.73	3.51	2.66	3.31	3.00	3.91	3.91	3.22	3.43	3.14	3.83	3.69	5.12	
	Bonneville Bradford Left Branch (BBA)																
	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01	
BE tag	9	6	2	9	11	11	6.5	8	9.5	11	8	11	10	10.5	9	4.5	9.0
ST tag	14	15	5	13.5	15	16.5	12.5	12	15.5	16	16	13	16	19.5	15	11	15.0
Increase(%)	56	**150**	**150**	50	36	50	92	50	63	52	100	18	60	86	67	**144**	61.6
Ln	4.02	5.01	5.01 *	3.91	3.59	3.91	4.53	3.91	4.15	3.96	4.61	2.90	4.09	4.45	4.20	4.97	
	Bonneville Bradford Right Branch (BBB)																
	20	1F	1E	1D	1C	1B	1A	19	18	17	16	15	14	13	12	11	
BE tag	7	8.5	10	10	10	10	10	8	9	6	5	10.5	11.5	8	13	8	9.5
ST tag	13	16	16.5	15	14	15	14	16	18	13	10	15	18	17	17	14	15.0
Increase(%)	86	88	65	50	40	50	40	100	100	117	100	43	57	113	31	75	70.0
Ln	4.45	4.48	4.17	3.91	3.69	3.91	3.69	4.61	4.61	4.76	4.61	3.76	4.03	4.72	3.43	4.32	
	Bonneville Cascades Island (BO2)																
	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01	
BE tag	9	8	8	9.5	12	12	11	13	11	11	12	11	12	16	9	9	11.0
ST tag	13	12	12	13.5	18	15	14.5	20	17.5	16	17.5	17	15	23	14	16.5	15.5
Increase(%)	44	50	50	42	50	25	32	54	59	45	52	55	25	44	56	83	50.0
Ln	3.79	3.91	3.91	3.74	3.91	3.22	3.46	3.99	4.08	3.82	3.95	4.00	3.22	3.78	4.02	4.42	
	McNary Washington (MC2)																
	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01	
BE	11	8	12	12	13	2	4	13	12.5	9	15	9	11	3.5	8.5	12	11.0
ST	15	15	18.5	14	18	8	4.5	18	18	16	19	13	16	5	15	13	15.0
Increase (%)	36	88	54	17	44	**300**	13	38	44	78	31	44	45	43	76	8	44.0
Ln	3.59	4.47	3.99	2.81	3.78	5.70	2.53 *	3.65	3.78	4.35	3.44	3.79	3.82	3.76 *	4.34	2.12	
	McNary Oregon (MC1)																
	12	11	10	0F	0E	0D	0C	0B	0A	09	08	07	06	05	04	03	02	01	
BE tag	3	8	7	8	12	12	9.5	7	10	10	9	5	8	10	7	3	16	25	8.0
ST tag	10.5	14	15	14	18	17	19	14	17	15.5	14	11	16	15	10	9	17	10.5	14.5
Increase (%)	**250**	75	114	75	50	48	100	100	70	55	56	120	100	50	43	**200**	6	110	75.0
Ln	5.52	4.32	4.74	4.32	3.91	3.87	4.61	4.61	4.25	4.01	4.02	4.79	4.61	3.91	3.76	5.30	1.83 *	4.70	

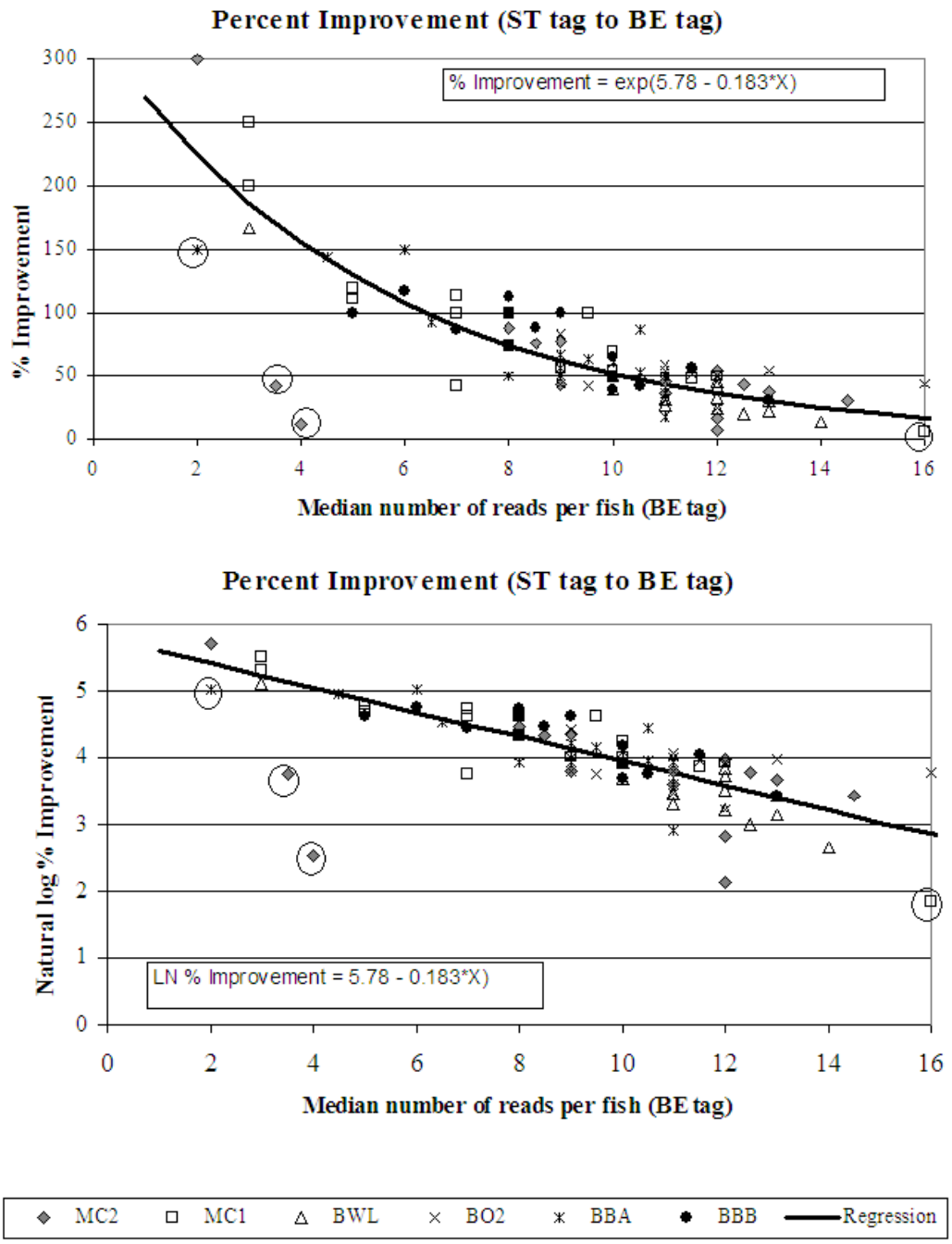

Figure 3. Top graph depicts the percent improvement in the number of reads per fish of the TX-1400ST tag relative to the TX-1400BE tag for each coil in the five fish ladders at Bonneville and McNary Dams. The bottom graph depicts the natural log values for the percent improvement of the ST tag relative to the BE tag for each coil. The regression analysis was conducted without the four outliers circled in the two graphs.

The fourth outlier in Figure 3 is Antenna 02 at McNary Oregon Ladder. This antenna had a higher than expected median value for detecting the BE tag because of fish behavior. Fish tend to hesitate at this location before they go through the narrow counting window section and thus remained in the antenna tag-reading field longer than usual.

Antenna 0E in the Bradford Island Ladder, which was seriously detuned during this comparison, constituted the only instance wherein fish with BE tags apparently went undetected while fish with ST tags were mostly detected (it is impossible to know if all were detected that transited the orifice because fish do not have to use the orifices; Table 6). This antenna only detected 1 BE tag, and its adjacent antenna detected 11 out of a possible 23 BE tags. In contrast, it detected 10 ST tags and its adjacent antenna also detected 10 out of a possible 22 ST tags.

Table 6. Weir counts (the two coil IDs that make up an individual weir are bracketed together) for the orifice-based interrogation system in the left branch of the Bradford Island Fish Ladder at Bonneville Dam. The weir counts combine the fish counts for the two adjacent orifices in each weir. There were 23 adult fish tagged with BE tags and 22 tagged with ST tags for the groups analyzed.

	Coil ID							
	10 0F	0E 0D	0C 0B	0A 09	08 07	06 05	04 03	02 01
BE tag	25	**12**	24	22	24	23	22	23
ST tag	23	20	20	20	22	22	21	20

At Lower Granite Dam, 100% of the adult salmonids tagged with ST tags (n = 31) were detected by two antennas. Of the adult salmonids tagged with BE tags (n = 54) by the University of Idaho, 52 or 96.2% of them were detected by two antennas. Of all other adults tagged with BE tags that transited the site between 26 September and 12 October (n = 636), 98% of them were detected by two antennas. These results suggest that any difference in detection rates between the two tag types is negligible at this site.

CONCLUSIONS

In general, the field tests found that the ST tag was read more times in the interrogation systems for adult salmonids and read on more antennas in the interrogation systems for juvenile salmonids; however, this improvement did not translate into more fish being detected. In the juvenile systems, improvement was not possible because 100% of fish tagged with the BE tag were detected (thus there was no room for improvement). For adult salmonids, the one antenna that seemed to favor the ST tag was badly detuned during the test. Since this is an atypical and correctable situation, we have to conclude that there was no statistical support that using the improved tag will translate into more adults being detected in the systems currently deployed.

The results also suggested that although juvenile fish were released together at McNary Dam, they had time to disperse before reaching John Day Dam so that they did not pass through the interrogation systems in such tight groupings that fish were missed. Thus, concerns that the signal from a ST tag might overpower the tag signal from a BE tag or code collisions in general might occur were apparently unfounded. Of course, the fish densities were low because of spill at the dams until 1 September. However, analysis of tag data collected over several years at Lower Granite Dam during the spring juvenile migration (when tag densities are at their highest) has shown that it is rare for two fish to be detected at any antenna within a separator monitor within the same second.

Although not observed in these field tests, there are certainly situations where the ST tag will make a significant improvement in tag detection. For example, the ST tag will be critical to the success of both in-stream interrogation systems and the interrogation system for the corner collector at Bonneville Dam. These are situations where marginal detection conditions (e.g., high RF noise, poor fish orientation, and high flow velocities) will likely occur.

ACKNOWLEDGMENTS

We thank Digital Angel for providing us with the TX-1400ST tags. We also thank Christopher Peery and Steve Lee from the University of Idaho for agreeing to tag some of their study fish with ST tags. Support for this research came from the region's electrical ratepayers through the Bonneville Power Administration. We are also grateful to the U.S. Army Corps of Engineers for allowing us to add a new variable to the study to determine the effects of transportation on the survival of river-run juvenile fall chinook salmon.

REFERENCES

Downing, S.L., and E.F. Prentice. 2003. Overview of the performance of PIT-tag interrogation systems for adult salmonids in fish ladders at Bonneville and McNary Dams, 2002. Report by the National Marine Fisheries Service to the Bonneville Power Administration, Portland, Oregon.

Peterson, B.W. 2002. Super Tag and Standard Tag Comparison Test. Report by Peterson Engineering Services to Pacific States Marine Fisheries Commission, Gladstone, Oregon.