Detection of Passive Integrated Transponder (PIT) tags on piscivorous bird colonies in the Columbia River Basin, 2006

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
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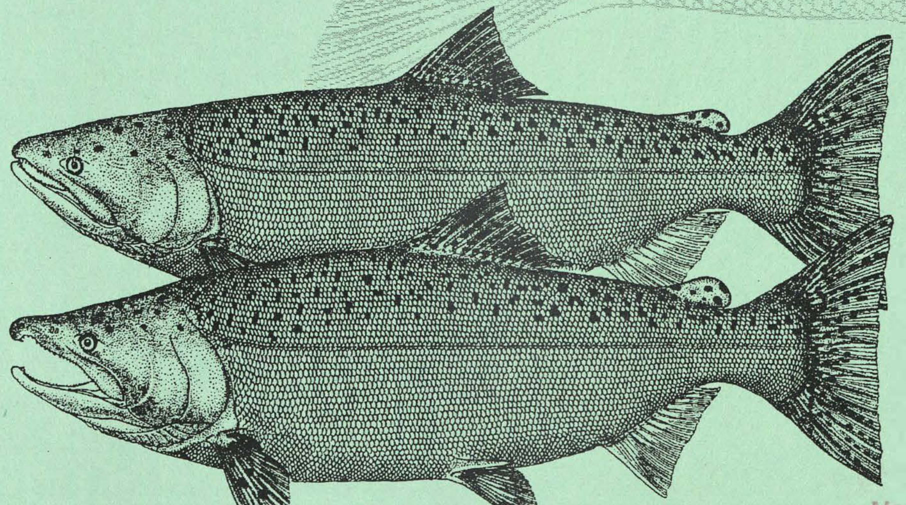

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Report of research by

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EXECUTIVE SUMMARY

In 2006, we continued the ninth year of a study to detect passive integrated transponder (PIT) tags on abandoned piscivorous bird colonies in the Columbia River Basin. Detection efforts yielded over 66,000 tags from juvenile Pacific salmon *Oncorhynchus* spp. that had not previously been detected on a piscivorous bird colony. These recoveries accounted for at least 2.6% of the tags from all salmonids PIT-tagged and released into the Columbia River Basin during the 2006 migration year. The majority of these tags were detected on Caspian tern *Sterna caspia* and double-crested cormorant *Phalacrocorax auritas* colonies.

The primary location for tag detection was the tern colony on East Sand Island in the Columbia River estuary. We calculated proportions of tags detected on colonies from steelhead that survived migration in the river and were detected at Bonneville Dam combined with those from steelhead transported and released downstream from the dam. From both groups of steelhead overall, we found an average of 7.8% of the tags detected on the East Sand Island tern colony were from fish originating in the Snake River Basin, 10.4% were from fish originating in the Upper Columbia River Basin, and 13.1% were from fish originating in the Mid-Columbia River Basin. However, of detection efficiency on this tern colony was estimated at only about 64%.

On the East Sand Island cormorant colony, detection effort was focused on specific areas. We collaborated with Oregon State University and Real Time Research, Inc. to evaluate detection efficiency and the number of tags recovered per nesting pair of cormorants. The estimated number per nesting pair was then used to estimate the total number of tags on the colony. Based on this total, we calculated the proportion of PIT-tags detected on the East Sand Island cormorant colony from all PIT-tagged salmonids detected at Bonneville Dam. Of these tags, we estimated that 9.7% were from fish originating in the Snake River Basin, 7.2% were from fish originating in the Upper Columbia River Basin, and 9.2% were from fish originating in the Mid-Columbia River Basin.

The secondary tag detection location was Lake Wallula, where the largest number of tags was detected on the Crescent Island Caspian tern colony. Detection efficiencies on colonies in Lake Wallula were low this year, ranging from 46 to 65%. The lowest detection efficiency was on the Crescent Island tern colony, where the majority of tags were detected. We are uncertain about the reason for low detection efficiencies in 2006 compared with previous years. However, we suspect that at least on East Sand Island, tag density may have played a major role in reducing detection efficiency.

In 2006, as in previous years, steelhead was found to be significantly more vulnerable to avian predation than other salmonid species. This finding was consistent in all reaches studied and for all evolutionarily significant units (ESUs) except Lower Columbia River subyearling fall Chinook.

Results from PIT-tagging lower river fall Chinook and steelhead indicated that predation rates for subyearling fall Chinook were considerably higher than those of their upper-river counterparts either detected at or released just below Bonneville Dam. For steelhead tagged and released in the lower Columbia River, predation rates were closer to those of their upper-river cohorts detected at or released below Bonneville Dam.

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INTRODUCTION

Since 1987, juvenile Pacific salmon *Oncorhynchus* spp. have been tagged with passive integrated transponders (PIT) to evaluate measures implemented to improve their survival through dams of the Federal Columbia River Power System. Information from PIT-tag detections has aided in identifying causes of decline for salmonids at different life history stages (NMFS 2000). The total number of PIT-tagged juvenile salmonids released in the Columbia River Basin varies each year, but has increased from less than 50,000 in 1987 to over two million in 2003 (PSMFC 1996).

At the time of tagging, individual PIT-tag codes and other information, such as species, type, and origin, are recorded in a regional database, the Columbia Basin PIT Tag Information System (PTAGIS; PSMFC 1996). Codes in this database can be matched with records of subsequent detection and used to determine the migration history and often the ultimate fate of an individual fish.

Since the mid-1960s, colonies of Caspian tern *Sterna caspia* have shifted northward from California, and by the 1980s, had begun to concentrate on small islands in the Columbia River estuary (Gill and Mewladt 1983). By 2001, over 12,000 terns were reported along the North Pacific Coast (USACE 2001). Colonies of double-crested cormorants *Phalacrocorax auritas* have also expanded rapidly in the Columbia River estuary, from initial sightings in the 1980s (Carter et al. 1995) to over 13,700 breeding pairs in 2006 (Jessica Atkins, Oregon State University, personal communication). Both the tern and cormorant colonies in the estuary now have the distinction of being the largest in the world. Smaller colonies of double-crested cormorants were also found on Miller Sands and Rice Island in 2006 during studies by Oregon State University.

In addition to terns and cormorants nesting in the estuary, there are at least eight islands in upstream areas of the Columbia River that host colonies of piscivorous birds. These include terns, cormorants, gulls *Larus* spp., American white pelicans *Pelecanus erythrorhynchos*, and three species of herons *Ardea alba, A. herodias, and Nycticorax nycticorax*. Detections on colonies to date have indicated that of all these avian predators, terns and cormorants are the major predators affecting salmonids (Ryan et al. 2002, 2003). Therefore, in 2006 we focused detection effort on colonies of Caspian terns and double-crested cormorants in the Columbia River estuary and Lake Wallula, along with a small number of other locations with large colonies of these species.

We began detecting PIT tags on abandoned nesting colonies in the Columbia River Basin in 1998 (Ryan et al. 2001), and data from these detections have been used to analyze bird feeding behavior, prey selectivity, and the relative vulnerability of various groups of juvenile salmonids to avian predation (Collis et al. 2001a; Ryan et al. 2003). To detect tags from nesting colonies on dry land, we modified PIT-tag detection equipment designed for use in freshwater (Prentice et al. 1990a,b).

Two types of PIT tag have been detected using the land-based detection equipment: the Standard or BE Tag (TX1400BE) and the Super Tag (TX1400ST; Ryan et al. 2006). Recently an additional improved model was introduced, the SST tag (TX1400SST). The SST tag has a greater reading range than either the BE or ST tag. This tag is now in limited use throughout the basin, and will eventually replace the ST tag.

In the Columbia River Basin, PIT-tagged salmonids have been released at sites upstream from Bonneville Dam since 1987. However, prior to 2001, very few PIT-tagged salmonids were released from the lower river streams and rivers that discharge directly into the estuary (PSMFC 1996). Lower-river stocks may be more vulnerable to avian predators nesting in the estuary than their upper-river counterparts, as the life history strategy of these stocks may rely more heavily on estuarine habitat.

Variation in life history characteristics of the Chinook salmon has led to categorization of the species into two types: stream-type and ocean-type (Narum et al. 2004). These differ in timing of the adult spawning migration, utilization of freshwater habitat, and characteristic juvenile morphology and behavior (Narum et al 2004). For example, stream-type Chinook spends one or more years in the natal river before migrating to the sea, and is typically found in headwater streams. Ocean-type Chinook migrates from its natal stream more rapidly, frequently in less than 3 months. It may subsequently spend an extended time rearing in the estuary before continuing on to the ocean, and tends to inhabit coastal streams at lower elevations.

We began a project in 2002 to tag fall Chinook salmon in the estuary in order to compare the effect of estuarine residency time on vulnerability to avian predation. Subyearling fall Chinook are the primary focus, as these lower river stocks appear to behave like ocean-types, while the upper river stocks seem to behave similarly to stream-type Chinook in their use of the estuary. Estuary residence time may have an important impact on vulnerability to predation, considering the large number of avian predators nesting in the estuary. We tagged river stocks for these comparisons each year except 2004.

Here we report the results of continuing PIT-tag detection efforts on piscivorous bird colonies in the Columbia River Basin in 2006, along with the results of our estuary PIT-tagging effort. These data will be added to a growing database that continues to be used to evaluate the relative vulnerabilities of juvenile salmonids to bird predation based on species, run, rear-type, and migration history.

STUDY SITE

Our study sites for 2006 ranged from East Sand Island, at river kilometer (rkm) 8, in the Columbia River estuary, to Goose Island in the Potholes Reservoir, located 40 km from the Columbia River (rkm 665; Figure 1). The sampling locations consisted of 12 distinct bird colonies on 9 islands (Table 1).

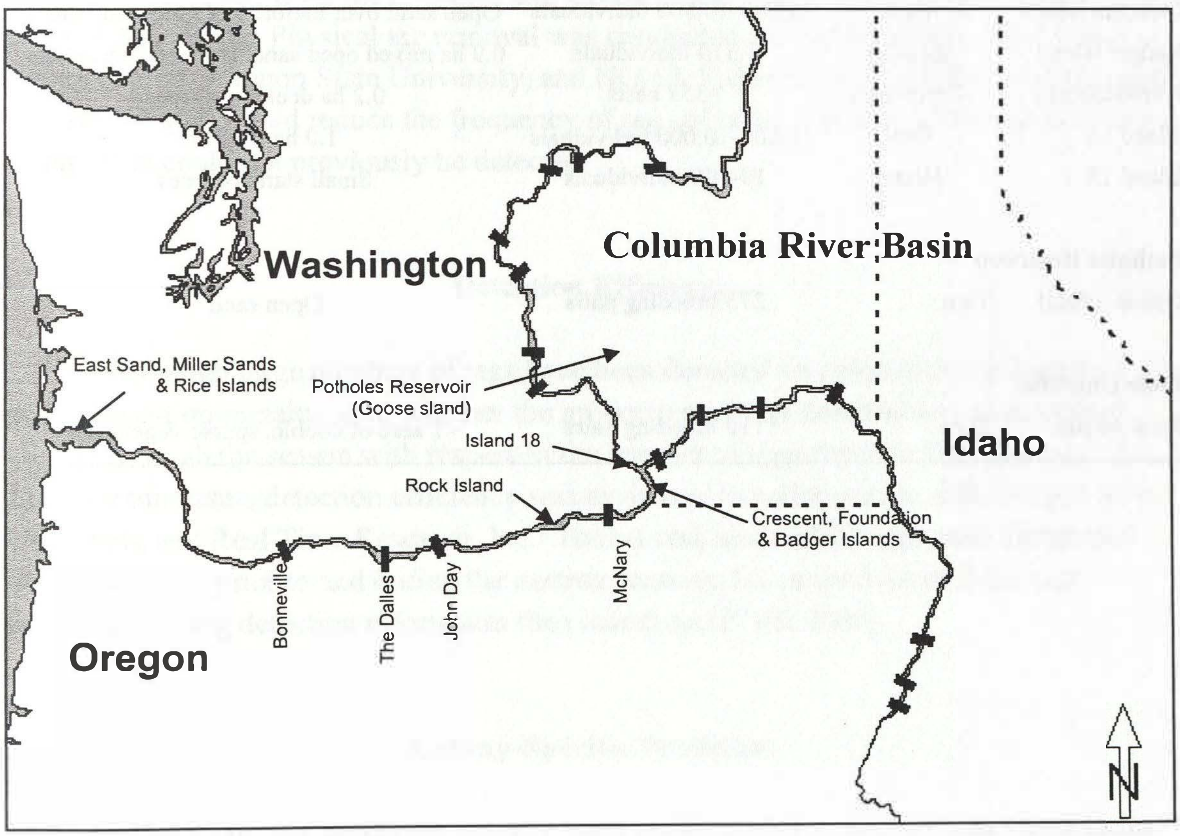

Figure 1. Islands sampled in the Columbia River Basin in 2006.

Table 1. Sampling locations in the Columbia River Basin that had a considerable impact on migrating PIT tagged juvenile salmonids. Colony size and description courtesy of Oregon State University (personal communication, Jessica Adkins, Oregon State University).

Location	Bird species	Colony size	Colony description
Columbia River Estuary			
East Sand Island	Tern	9,201 breeding pairs	1.6 ha open sand
East Sand Island	Cormorant	13,738 breeding pairs	1.2 ha rock jetty with adjacent sands
Miller Sands	Cormorant	41 breeding pairs	Social attraction study (OSU), tires/sand
Rice Island	Cormorant	35 breeding pairs	Social attraction study (OSU), tires/sand
LakeWallula			
Crescent Island	Tern	448 breeding pairs	0.1 ha open sand
Crescent Island	Gull	1,000-10,000 individuals	Open sand over majority of Crescent Island
Badger Island	Pelican	1,310 individuals	0.9 ha mixed open sand, trees and shrubbery
Foundation Isl	Cormorant	>359 nests	0.2 ha deciduous trees
Island 18	Gull	1,000-10,000 individuals	1.0 ha cobble
Island 18	Heron	10-100 individuals	Small stand of trees
Potholes Reservoir			
Goose Island	Tern	273 breeding pairs	Open sand
Lake Umatilla			
Rock Island	Tern	110 breeding pairs	<1 acre of cobble, sparse vegetation

METHODS

On-Colony PIT Tag Recovery

In 2006, we continued to monitor bird colonies in Lake Wallula and the Columbia River estuary, as well as additional areas where Caspian tern colonies may be having a significant impact on migrating juvenile salmonids. This year additional colonies were located on Goose Island in the Potholes Reservoir, where we had recovered tags previously, and on Rock Island in Lake Umatilla, which was a new location for significant numbers of Caspian terns.

Electronic detection of PIT tags in 2006 was conducted using the same techniques reported by Ryan et al. (2006), except that the flat-plate antenna was powered by a Digital Angel MUX box (multiplexing transceiver system). In addition, PIT tags were physically removed from the Crescent and Goose Island tern colonies using magnets and rakes (CBR 2006). Physical tag removal was conducted in a joint effort by Real Time Research, Inc., Oregon State University, and NOAA Fisheries. We believed that physical removal of tags would reduce the frequency of tag collision, and thus allow the recovery of tags that could not previously be detected.

Detection Efficiency

Although large numbers of tags have been detected on colonies in each study year, a question remains as to whether the proportion of tags detected on colonies may change through the season with respect to the number of tags deposited on colonies. To examine this issue, detection efficiency was evaluated in collaboration with Oregon State University and Real Time Research, Inc. To this end, known PIT tags were distributed on the colonies prior to and during the nesting seasons; the proportion of these tags recovered during detection efforts was then calculated (CBR 2006).

Colony-Specific Predation

Colony-specific predation impacts were estimated for avian predator populations posing the greatest risk to salmon survival. For this evaluation, we used PIT-tagged inriver migrant fish detected at Bonneville Dam and PIT-tagged transported fish released just below the dam. Previous detections of tags from these fish provided evidence that fish were alive at locations near the predator colonies. Therefore, these fish were used as a measure of the general population of PIT-tagged salmonids known to be available to birds nesting in the estuary. The proportions of PIT-tags from these fish that were subsequently detected on tern and cormorant colonies in the estuary provided minimum estimates of predation on different groups of PIT-tagged juvenile salmonids.

Similarly, the PIT tags of juvenile salmonids detected at Rock Island and Lower Monumental Dam, respectively, were used as a measure of PIT-tagged fish from the upper Columbia and Snake Rivers that were available to avian predators nesting in Lake Wallula. Again, the proportions of these PIT-tagged fish that were subsequently detected on a colony in Lake Wallula were used as minimum estimates of avian predation.

To account for varying detection efficiencies between colonies, the proportion of PIT tags detected on a colony was adjusted using a detection efficiency factor. We used the detection efficiency measured for a specific colony and divided it by the proportion of PIT tags detected on that colony to estimate the overall proportion. For example, on the East Sand Island cormorant colony we obtained a detection efficiency rate for only a subset of the entire colony. We used this rate to extrapolate detection efficiency over the entire colony based on PIT tags recovered per nesting pair (CBR 2006). Since none of the detection efficiencies were 100%, and since the estimates do not account for tags deposited by birds at locations other than colonies, these methods also provide only minimum estimates of predation.

Estuary Tagging

In spring 2006, we PIT tagged both fall Chinook and steelhead using the methods outlined by Ryan et al. (2006). Fish were released into rivers that discharged directly into the Columbia River estuary to evaluate disparities in predation rates between lower and upper river stocks, particularly fall Chinook salmon. To examine the data for trends in different predation rates, we summarized release and detection numbers both monthly and yearly.

Predation rates of PIT-tagged lower river juveniles were compared with those of juveniles of the same species detected at Bonneville Dam or released from barges downstream from the dam when there was a corresponding lower river release date. For these comparisons, we used detections from tern and cormorant colonies on East Sand Island, Miller Sands, and Rice Island. Although the East Sand Island cormorant and tern colonies had the greatest impact on fall Chinook and steelhead, respectively, we summarized data from all three estuarine colonies to estimate the overall impact of avian predation in the estuary.

RESULTS

In 2006, we detected over 61,000 juvenile salmonid PIT tags on piscivorous bird colonies in the Columbia River Basin utilizing electronic detection techniques. In addition, approximately 5,000 PIT tags that had not been previously detected were physically recovered by researchers from Oregon State University and Real Time Research, Inc. The approximately 66,000 juvenile salmonid PIT tags detected on piscivorous bird colonies accounted for 2.6% of all the migration year 2006 PIT tagged juvenile salmonids released into the Columbia River Basin (Table 2). The majority of tags were detected on colonies in the Columbia River estuary, followed by colonies in Lake Wallula, with tags detected on colonies outside of these areas accounting for only a small percentage of the total recovery (Table 2).

Table 2. The number of PIT-tagged juvenile salmonids released into the Columbia River Basin in 2006, and percentages of these tags detected on piscivorous bird colonies by river reach. An additional 705 PIT tags from juvenile salmonids of unknown species were detected on these colonies.

		Detected (%)				
Species	Released	Estuary	Lake Wallula	Lake Umatilla	Potholes Reservoir	Total
Spring/Summer Chinook	651,597	1.2	0.3	0.0	0.0	1.5
Fall Chinook	611,811	0.6	0.4	0.0	0.0	1.0
Coho	76,211	1.0	0.3	0.0	0.1	1.4
Steelhead	354,229	6.1	1.1	0.1	0.3	7.6
Sockeye	10,548	0.8	0.3	0.0	0.1	1.2
Total	1,704,396	2.0	0.5	0.0	0.1	2.6

Detection efficiencies based on tags planted on colonies by Oregon State University and Real Time Research, Inc. ranged from 46 to 67% depending on colony and detection method (Table 3). The exception was the East Sand Island cormorant colony, were detection efficiency was estimated at 75% for the localized area where tags were planted. However, using this detection efficiency, as well as observations of nesting pairs in the area, OSU and RTR estimated an overall detection efficiency of only 19.5% for tags deposited on the East Sand Island cormorant colony (CBR 2006).

Table 3. Detection efficiency (DE) of test tags intentionally released on colonies in the Columbia River Basin during discrete time periods in 2006.

	Number of tags (n)		
Date	Planted	Detected	Detection efficiency (%)
East Sand Island Tern	1200	769	64.1
Crescent Island Tern	962	440	45.7
Foundation Island Cormorant	400	269	67.3
Potholes Reservoir Tern	600	319	53.2
Badger Island Pelican	200	129	64.5
Total	3,362	1,926	57.3

Colony-Specific Predation

Columbia River Estuary

For the 2006 migration year, we estimated proportions of tags by salmonid species from PIT-tagged juveniles detected at Bonneville Dam and later deposited on a tern or cormorant colony. These proportions ranged from 0 to 18%, with steelhead always preyed upon at the highest rate (Table 4). In addition to PIT-tagged salmonids that migrated in the river in 2006, over 281,000 PIT-tagged salmonids were transported past dams of the Federal Columbia River Power System and released downstream from Bonneville Dam (Table 5). The estimated proportion of fish with tags detected on a piscivorous bird colony in the Columbia River estuary was generally lower for transported salmonids than for in-river migrants detected at Bonneville Dam, with a high of 11.9% for transported steelhead (Table 5).

Table 4. Detection numbers with actual and estimated proportions of PIT-tags from inriver migrant fish detected at Bonneville Dam that were subsequently detected on piscivorous bird colonies in the estuary, 2006. Estimates are based on detection efficiencies (DE). Species with less than 100 detections at Bonneville Dam were excluded from analyses.

		Detections on East Sand Island (%)			
	Detected at	Tern (DE = 65%)		Cormorant (DE = 19.5%)	
Species	Bonneville (n)	Actual	Estimate	Actual	Estimate
Spring/Summer					
Chinook	23,284	1.2	1.9	1.2	6.1
Fall Chinook	12,815	1.1	1.7	0.5	2.8
Unknown Chinook	23,595	1.2	1.9	1.4	7.0
Steelhead	10,005	11.5	18.0	2.4	12.5
Coho	2,124	2.5	4.0	2.0	10.1
Sockeye	406	0.0	0.0	1.7	8.8
Total	72,229	2.6	4.1	1.3	6.8

Table 5. Detection numbers with actual and estimated proportions of PIT-tags from transported fish released just below Bonneville Dam that were subsequently detected on piscivorous bird colonies in the estuary, 2006. Estimates are based on detection efficiencies (DE). Species with less than 100 detections at Bonneville Dam were excluded from analyses.

		Detections on East Sand Island (%)			
	Transported	Tern (DE = 65%)		Cormorant (DE = 19.5%)	
Species	(n)	Actual	Estimate	Actual	Estimate
Spring/Summer					
Chinook	93,344	1.7	2.6	1.2	6.3
Fall Chinook	25,907	1.0	1.5	0.5	2.5
Unknown Chinook	57,933	1.2	1.8	1.1	5.7
Steelhead	104,636	7.6	11.9	1.8	9.0
Total	281,820	3.7	5.8	1.3	6.8

Lake Wallula

We evaluated the numbers of PIT-tags detected on avian predator colonies in Lake Wallula from all juvenile salmonids from migration year 2006 that had been detected at Lower Monumental Dam. For steelhead, we estimated that 2.4% of tags detected at the dam were later deposited on the Foundation Island cormorant colony, and another 4.9% ended up on the Crescent Island tern colony (Table 6). Predation estimates for other salmonid species were considerably lower. For steelhead smolts migrating from the upper Columbia River Basin (i.e., detected at Rock Island Dam), we estimated only 0.15% were deposited on the Foundation Island cormorant colony and 1.86% ended up on the Crescent Island tern colony.

Table 6. Numbers of PIT-tagged juvenile salmonids available to piscivorous birds nesting on the Caspian tern colony on Crescent Island and on the cormorant colony on Foundation Island in Lake Wallula (McNary Dam reservoir) in 2006. Fish interrogated at Lower Monumental or Rock Island Dam were determined to be available. Fish released at Rock Island Dam were included as a primary source of PIT-tagged fish from the Upper Columbia River Basin migrating through Lake Wallula. Transported fish were excluded from analysis.

	Snake River Basin			Upper Columbia River Basin		
Species	Lower Monumental (n)	Actual DE (%)	Estimated DE (%)	Rock Island (n)	Actual DE (%)	Estimated DE (%)
	Crescent Island (DE = 46%)					
Spring/Summer Chinook	47,167	0.4	0.8	--	--	--
Fall Chinook	25,523	0.5	1.0	--	--	--
Steelhead	32,134	2.3	4.9	3,972	0.86	1.86
Total	104,824	1.0	2.1	4,074	0.01	0.02
	Foundation Island (DE = 65%)					
Spring/Summer Chinook	47,167	0.4	0.6	--	--	--
Fall Chinook	25,523	0.1	0.1	--	--	--
Steelhead	32,134	1.6	2.4	3,972	0.10	0.15
Total	104,824	0.7	1.0	4,074	0.00	0.00

Estuary Tagging

In 2006, we PIT tagged more than 11,000 hatchery subyearling fall Chinook and juvenile steelhead from the lower Columbia River (Table 7). We subsequently detected the tags of nearly 3,500 of the subyearling fall Chinook on piscivorous bird colonies in the Columbia River estuary.

In addition, only 1.5% of tagged subyearling fall Chinook released from barges and 1.8% tagged fish detected at Bonneville Dam during the same period were recovered on East Sand Island (Table 7). This pattern of higher predation rates for lower river fall Chinook was consistent with our previous results (Ryan et al. 2006). Monthly comparisons (Figure 2) also showed a consistently higher predation rate for lower river subyearling Chinook. Upper river steelhead stocks, on the other hand, had higher predation rates than lower river steelhead stocks when compared monthly (Figure 3).

Table 7. Number of hatchery PIT-tagged salmonids (R) and percentage of tags from these fish that were subsequently detected on the estuary tern or cormorant colonies in 2006. Numbers of fish released from barges or detected at Bonneville Dam include only Snake River hatchery fish.

Source	Number of tagged fish released (R)	Estuary detections (%) Tern colony	Cormorant colony	Total
		Subyearling fall Chinook		
Lower river				
Big Creek Hatchery	3,031	2.0	15.4	17.5
Bonneville Hatchery	2,993	0.7	0.8	1.5
Upper river				
Detected at Bonneville Dam	6,576	1.1	0.7	1.8
Released from barge	25,839	1.0	0.5	1.5
		Steelhead		
Lower river				
Merwin Hatchery	2,964	6.2	2.7	8.9
Elochoman Hatchery	2,691	5.2	3.3	8.6
Upper river				
Detected at Bonneville Dam	5,100	11.2	3.4	14.5
Released from barge	75,478	9.9	2.4	12.4

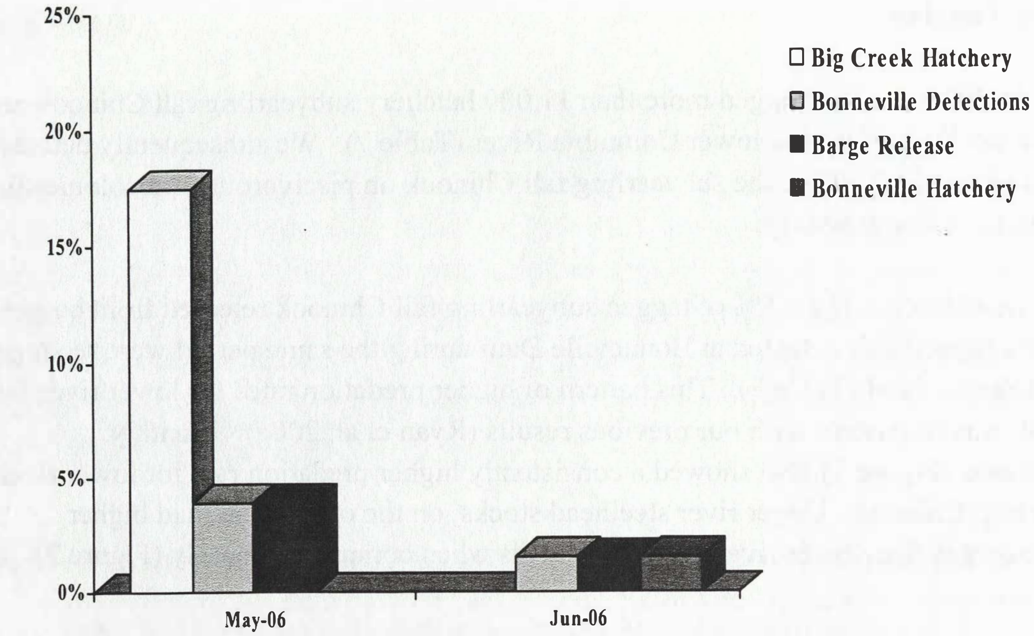

Figure 2. Proportions of subyearling Chinook recovered on tern and cormorant colonies in the Columbia River estuary by release location and date.

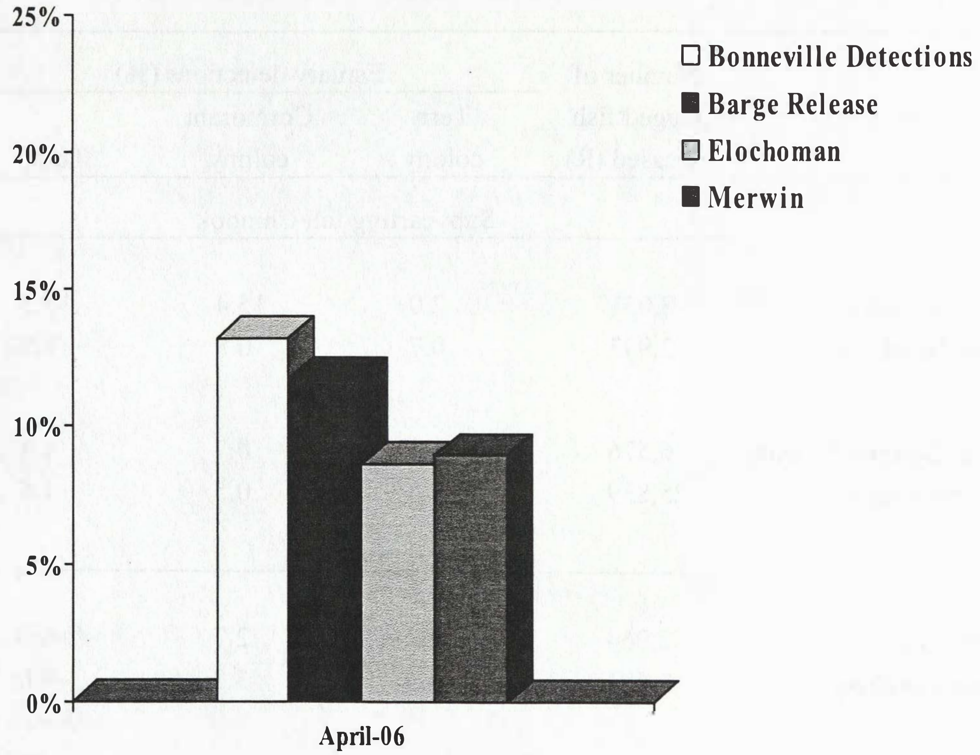

Figure 3. Proportions of steelhead recovered on tern and cormorant colonies in the Columbia River estuary by release location and date.

DISCUSSION

Prior to the first year of this study, it was clear that piscivorous birds, particularly those nesting in the Columbia River estuary, were preying upon large numbers of juvenile salmonids. However, colonies of birds having the greatest impact, as well as the salmonid species and populations at greatest risk, were not known. To answer this and other questions, we have focused on recovering as many juvenile salmonid PIT tags as possible from piscivorous bird colonies throughout the basin. We have used these recoveries to evaluate which species, runs, and rearing-types were being preyed upon at rates that might warrant management action (Ryan et al. 2003).

Our efforts to date have consistently indicated that steelhead, regardless of run or rear-type, are preyed upon at higher levels than other species, and deserve continued monitoring and possibly further management action (Ryan et al. 2003; Collis et al. 2001a). In addition, through our tagging effort, which was funded by the U.S. Army Corps of Engineers Walla Walla District, we found that juvenile fall Chinook originating in the lower Columbia River suffer extensive predation from cormorants nesting on East Sand Island. This cormorant colony has expanded quickly to become the world's largest, and it continues to grow each year.

To address these issues, we are gradually changing the focus of our study to recovery efforts in the Columbia River estuary. Researchers from Oregon State University and Real Time Research, Inc, will continue to recover tags from the upper river colonies. The OSU monitors these colonies throughout the season evaluate changes by extrapolating information from repeated detection efficiency tests. This method relies less on estimates from raw numbers of recovered tags over an entire colony and instead focuses on recovery from specific plots, which are then extrapolated to estimate the number of tags on a colony. We believe that a cooperative approach incorporating these and other additional methods will produce more accurate system-wide estimates.

However, it is important to note that to date, all methods of estimating avian predation represent only PIT-tagged salmonids. In addition, without systematically PIT tagging all representative stocks migrating past avian predator colonies, it will be difficult to compare predation rates within or among ESUs. Because the proportion of fish tagged within a given population or ESU differs annually, it is difficult to make valid comparisons among years.

The use of fish detected at Bonneville Dam as a basis for predation rates presents a similar obstacle to producing valid estimates, since these estimates do not include ESUs from the Lower Columbia River or Willamette River. While we have made some progress tagging stocks in the Lower Columbia River, predation on Willamette River stocks has not been addressed. A concerted effort to tag salmonids in the Willamette River will be needed to evaluate the impacts of avian predation on those stocks. This effort could be combined with investigations of estuary habitat use.

Predation Impacts and Relative Vulnerability

Basin-wide PIT-tag-detections from piscivorous bird colonies indicated that approximately 2.6% of the mortality for all PIT-tagged juvenile salmonids released into the Columbia River Basin during the 2006 migration year was attributable to avian predation. This proportion is based on raw PIT-tag recoveries, and represents a minimum estimate of predation. Detection efficiencies varied substantially among colonies, the deposition rates on colonies of tags from consumed fish is not known, and not all avian predator colonies were represented by these recovery efforts (Ryan et al. 2001). Therefore, we must assume that the overall predation rate may be considerably higher than 2.6%.

For steelhead, the high levels of predation are disturbing in light of the fact that hatchery and wild fish of this species have been found equally vulnerable to avian predators (Ryan et al. 2003; Ryan 2005). From these findings it is clear that not only hatchery steelhead, but endangered wild steelhead are affected.

Consistent with results from previous study years, the areas of highest predation impact coincided with the largest populations of Caspian terns and cormorants. These areas were the Columbia River estuary and Lake Wallula, also consistent with findings in previous years.

Due to concern that in earlier study years, PIT-tagged salmonids from the upper Columbia River had been underrepresented in detection efforts on Island 18 and Richland Island, we revisited Island 18 in 2006. However, tag recoveries were so few at Island 18 that we do not plan to include it in future sampling efforts of this kind. Moreover, the methods we have to estimate detection efficiency in other locations were not appropriate for this island. Therefore, were unable to estimate the total impact of avian predation from Island 18 on upper Columbia River stocks.

Detection Efficiency

In 2006, we recovered low proportions (64 and 46%, respectively) of test tags planted on the East Sand and Crescent Island tern colonies. Prior to 2006, we have never observed detection efficiencies lower than 70% on either colony, and have found average detection efficiencies of nearly 90% on East Sand Island. We were concerned about the accuracy of our flat-plate detection equipment in light of these low efficiencies. Colonies scanned with pole-mounted detectors produced efficiencies similar to those obtained in previous study years. On Crescent Island, detection rates may also have been affected by a large windstorm that passed through the Lake Wallula area during the 2006 nesting season. Wind and waves from this storm may have swept tags off the colonies.

An additional concern is the accumulation of tags on colonies over the years, which may be contributing to tag collisions. In tag a collision, detection is impaired when the codes of two or more PIT tags in the same RF field are transmitted simultaneously, preventing the identification of either code by the detector. Tag collision may be a considerable problem on colonies with high tag retention rates, such as the East Sand Island tern colony. We recommend planting tags to test this hypothesis, as well as the continued removal of tags accumulated from previous years.

On the East Sand Island cormorant colony, we evaluated detection efficiencies only in localized areas. Considering that this colony is situated along an intertidal area and a long rock jetty, we believe that a large proportion of tags deposited on the colony were removed throughout the season by wind and waves. Using the overall detection efficiency of 19.5% provided by Oregon State University and Real Time Research, Inc., we believe that an accurate estimate of the overall number of tags deposited on the island by cormorants during 2006 would be at least 90,000. This highlights the need to develop reliable methods to estimate PIT-tag detection efficiencies on these colonies.

Estuary Tagging

We observed differences in predation rates between ocean-type (lower river) and stream-type (upper river) Chinook stocks, and these difference were consistent for monthly and annual comparisons. Ocean-type Chinook showed an appreciably higher predation rate of 17.5% contrasted with only 1.6% for stream-type Chinook. Steelhead, on the other hand, showed predation rates that were similar between upper and lower river stocks.

We recommend that estuarine tagging continue for lower river Chinook in order to further elucidate the differences between upper and lower river stocks. We do not believe that continued tagging of lower Columbia River steelhead is appropriate given the similarity of predation rates between lower and upper river steelhead stocks.

PIT-tag data collected from piscivorous bird colonies throughout the Columbia River Basin continue to provide estimates of relative vulnerability to avian predation, as well as to inform management actions such as colony relocation (Collis et al. 2001a; Ryan et al. 2003). Because these data are stored in a central database, researchers can improve their accuracy by removing known mortalities from their data sets. The end result is an accurate data set which can be used to address present and future research and management needs.

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