Detection of Passive Integrated Transponder (PIT) Tags on Piscivorous Bird Colonies in the Columbia River Basin, 2002

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EXECUTIVE SUMMARY

During 2002, we detected 49,398 passive integrated transponder (PIT) tags on piscivorous bird colonies from juvenile salmonids marked for migration year 2002 in the Columbia River Basin (525 of these were detected by BioMark Inc.). These PIT tags accounted for 2.8% of the 1,774,525 PIT-tagged juvenile salmonids released into the Columbia River Basin, or 10.4, 4.2, 1.9, and 2.0% of the PIT-tagged steelhead *Oncorhynchus mykiss*, coho salmon *O. kisutch*, Chinook salmon *O. tshawytscha*, and sockeye salmon *O. nerka*, respectively.

Caspian tern *Sterna caspia*, double-crested cormorant *Phalacrocorax auritas*, gull *Larus* spp., and American white pelican *Pelecanus erythrorhynchos* colonies were sampled. We did not conducted sampling on the colonies of three species of herons (*Ardea alba*, *A. herodias*, and *Nycticorax nycticorax*) that were studied in previous years due to a lack of PIT tags on these colonies. Our primary detection locations were on piscivorous bird colonies in the Columbia River estuary.

At Bonneville Dam (the first hydroelectric project upstream from the Columbia River estuary), 99,823 PIT-tagged juvenile salmonids were detected in the bypass systems in 2002, of which 49,774 originated in the Snake River Basin (SRB). Detections on estuarine bird colonies accounted for respective proportions of 15.8, 13.1, 5.8, 2.6, and 1.6% of the SRB steelhead, coho, sockeye, spring/summer Chinook, and fall Chinook previously detected at Bonneville Dam. Of the remaining 50,049 non-SRB tags previously detected at Bonneville Dam, detections on bird colonies accounted for respective proportions of 10.6, 8.0, 0.8, 2.4, and 1.4% of the steelhead, coho, sockeye, spring/summer Chinook, and fall Chinook salmon.

The second largest number of PIT-tags was detected on Crescent Island in the McNary Dam reservoir. At Lower Monumental Dam, the nearest PIT-tag detection facility upstream from Crescent Island, detections during 2002 included 92,765 juvenile spring/summer Chinook, 7,476 fall Chinook, and 24,069 steelhead. Of these detections, the tags from 7.2% of the steelhead, 1.1% of the spring/summer Chinook, and 0.9% of the fall Chinook salmon were subsequently detected on the Crescent Island tern colony.

In 2002, 188,419 PIT-tagged juvenile salmonids were transported through the Federal Columbia River Power System (FCRPS) and released downstream from Bonneville Dam. Of these, we detected 5,824 tags, which accounted for 10.5, 7.8, 4.3, and 1.8% of the PIT tagged steelhead, coho, sockeye, and Chinook, respectively.

In addition, we PIT tagged 31,337 juvenile salmonids and released them into rivers that discharge directly into the Columbia River estuary during migration year 2002. From these releases we detected 14.7, 11.9, 6.8, and 5.9% of the fall Chinook, coho, steelhead and spring Chinook, respectively. Among these releases, the proportions of fall and spring Chinook detected on colonies were considerably higher than those of their upriver cohorts previously detected at Bonneville Dam. In contrast, the proportion of tags detected on colonies from steelhead releases was lower than that their upriver cohorts, while the proportion from coho releases was about equal to that of fish released upriver.

In 2002, our PIT-tag detections continued to provide minimum estimates of avian predation in the Columbia River Basin, along with relative vulnerabilities of juvenile salmonids to bird predation. In addition, these data were entered into the Columbia Basin PIT Tag Information System for use by other researchers and salmon managers.

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INTRODUCTION

Since 1991, the National Marine Fisheries Service (NOAA Fisheries) has listed 12 evolutionarily significant units (ESU) of Pacific salmon *Oncorhynchus* spp. in the Columbia River Basin as threatened or endangered under the U.S. Endangered Species Act (NMFS 2000). Under its mandate to identify and protect depressed or endangered salmonid populations, NOAA Fisheries has undertaken research on several fronts, from evaluating criteria to define these genetically distinct populations (Waples 1991) to identifying causes of their decline at different life history stages (NMFS 2000).

Recovery planning is at the forefront of this research, which includes a recent evaluation of the effects on Chinook salmon *O. tshawytscha* demographics of potential reductions in mortality at different life stages (Kareiva et al. 2000). This evaluation found that reductions as low as 5% in early ocean and estuarine mortality could arrest population declines. Ironically, even as the habitats and life history stages central to recovery are beginning to be identified, growing populations of piscivorous birds present an additional risk to salmonid populations in these same habitats and at the same life history stages (Collis et al. 2001a).

Colonies of Caspian terns *Sterna caspia* along the north Pacific coast have expanded rapidly, growing from 3,500 breeding pairs in 1960 to 12,500 in 2001 (USACE 2001). Since the mid-1960s, Caspian tern colonies have shifted northward from California, and by the 1980s they began to concentrate on small islands in the Columbia River estuary (Gill and Mewladt 1983). In 2002, the number of breeding pairs of Caspian terns on East Sand Island near the mouth of the Columbia River was estimated at 9,900 (Figure 1; CBR 2004).

Colonies of double-crested cormorants *Phalacrocorax auritas* also expanded rapidly in the Columbia River estuary, from initial sightings in the 1980s (Carter et al. 1995) to over 8,000 breeding pairs in 2002 (Daniel Roby, USGS, personal communication).

In addition to terns and cormorants nesting in the Columbia River estuary, there are at least nine islands in upstream areas of the Columbia River that host colonies of piscivorous birds. These include the tern, cormorant, gull *Larus* spp., American white pelican *Pelecanus erythrorhynchos*, and three species of herons *Ardea alba, A. herodias, and Nycticorax nycticorax*.

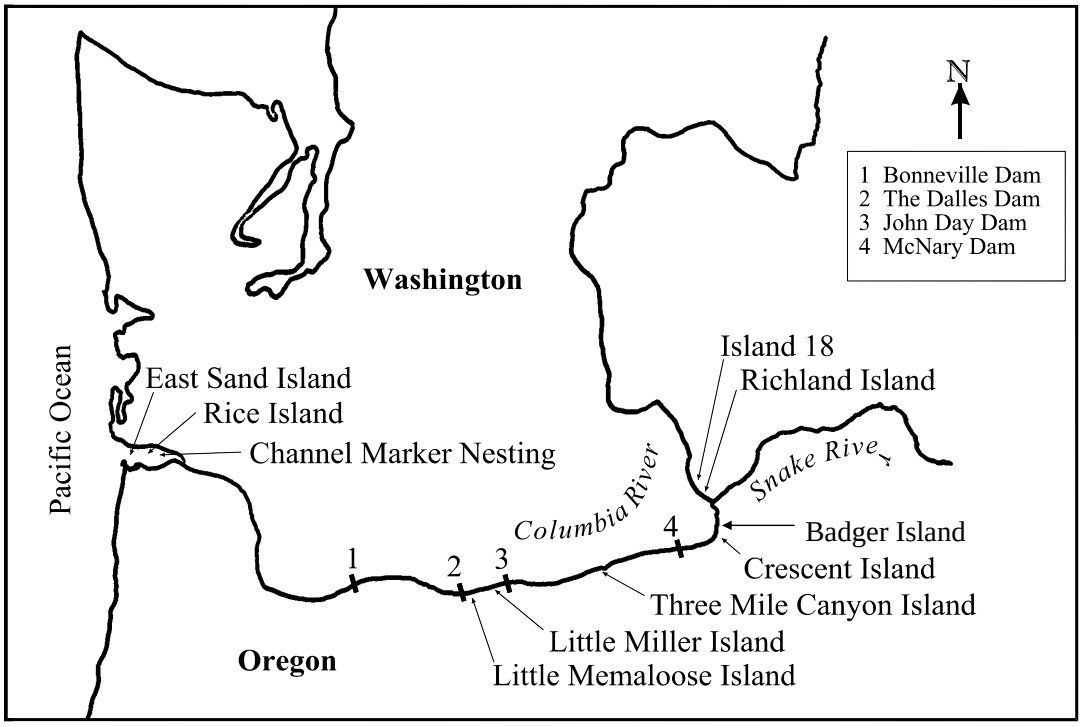

Figure 1. Locations of avian nesting areas where PIT tags were detected in the Columbia River Basin, 2002.

To evaluate the effects on juvenile salmonids of piscivorous birds nesting in the Columbia River Basin (CRB), we used juvenile salmonids tagged with passive integrated transponder (PIT) tags. A PIT tag is a microchip bonded to an antenna coil and sealed in a glass cylinder, measuring 2.1 mm in diameter and 12 mm in length (Prentice et al. 1990a). When a PIT tag is within range of a magnetic field generated by a detection antenna, it is energized and transmits its unique electronic code to the antenna (Prentice et al. 1990b). At the time of tagging, individual PIT-tag codes and information such as species and origin are recorded in the Columbia Basin PIT Tag Information System (PTAGIS), a regional database (PSMFC 1996). Codes in PTAGIS 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 1987, juvenile salmonids have been PIT tagged to evaluate measures implemented to improve their survival through the Federal Columbia River Power System (FCRPS). The total number of PIT-tagged juvenile salmonids released in the CRB varies each year, but has increased from less than 50,000 in 1987 to over 1.7 million in 2002 (PSMFC 1996).

In 1998, we began detecting PIT tags on piscivorous bird colonies in the CRB (Ryan et al. 2001). These tag codes 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).

Prior to 2001, PIT-tagged salmonids had been released throughout the CRB; however, no PIT-tagged salmonids had been released from populations residing in streams and rivers that discharge directly into the Columbia River estuary. We theorized that these stocks may be more vulnerable to avian predators nesting in the estuary than their upriver counterparts if they rely more heavily on estuarine habitat. For example, Reimers (1973) found a diverse number of estuary rearing periods and strategies for fall Chinook in the Sixes River, Oregon. To evaluate whether estuarine salmonids were more vulnerable to avian predation, we tagged a subset of these fish to compare with their upriver counterparts.

Here we report the results of continuing PIT-tag detection efforts on piscivorous bird colonies in the CRB in 2002, along with our estuary PIT-tagging effort. These data will be added to a growing database (PTAGIS) that will be used to evaluate the relative vulnerability of juvenile salmonids to bird predation based on species, rear-type, and migration history.

STUDY SITE

Our study site ranged from East Sand Island (rkm 8) near the mouth of the Columbia River to Solstice Island in the Potholes Reservoir (Fig. 1) approximately 40 km east of the Wanapum Dam Reservoir on the mid-Columbia River (rkm 665). The sampling locations within our study site consisted of 14 bird colonies on 12 islands.

Columbia River Estuary

East Sand Island (rkm 8) hosted a colony of Caspian terns and a separate colony of double-crested cormorants. The tern colony consisted of about 9,900 breeding pairs on 1.6 ha of open sand (CBR 2004). The cormorant colony consisted of over 8,000 breeding pairs (Daniel Roby, USGS, personal communication) on a 500 by 30-m jetty of large boulders. Rice Island (rkm 34) hosted a colony of about 50 breeding pairs of cormorants on 0.7 ha of open sand (Daniel Roby, USGS, personal communication).

The Dalles Dam Reservoir-Lake Celilo

Little Memaloose Island (rkm 314) hosted a gull colony with a population index[1] of about 300 on a small rock island (0.2 ha) in 2001; however, no birds appeared to nest there in 2002. Little Miller Island (rkm 331) hosted a gull colony with a population index of about 1,700 on several small rock outcroppings (0.5 ha).

John Day Dam Reservoir-Lake Umatilla

Three Mile Canyon Island (rkm 412) hosted a colony of gulls with a population index of about 10,000 on a combination of 0.5 ha of grassy field and sparsely vegetated rocky substrates.

[1] Population index is derived from a direct count of adult individuals on colony grounds late in the nesting season. An estimate of breeding pairs is then made using this count.

McNary Dam Reservoir-Lake Wallula

Crescent Island (rkm 509) hosted a tern colony of 580 breeding pairs on 0.1 ha of open sand (CBR 2004). This island also hosted a gull colony for which we did not find census data, but which we estimated was at least several hundred breeding pairs. Badger Island (rkm 512) hosted an American white pelican colony, with a population index of about 200 on 0.1 ha of shrubbery and sand. Foundation Island (rkm 519) hosted cormorant and heron colonies, with population indices of about 400 and 200, respectively, in 0.2 ha of deciduous trees. Due to the two colonies being intermixed within the trees, and our previous experience of detecting insignificant numbers of PIT-tags from heron colonies (Ryan et al. 2002), all the tags from Foundation Island were assumed to be cormorant tags in 2002. Richland Island (rkm 545) and Island 18 (rkm 549) hosted gull colonies, with population indices of about 19,000 and 12,000 on 1.0 and 0.5 ha of cobble, respectively.

Potholes Reservoir

Solstice Island is a small sand island in Potholes Reservoir approximately 40 km from the Wanapum reservoir in the Columbia River. The island hosted a tern colony for which we estimated a population index of about 400 on 0.05 ha of open sand. West Tern Island is a small sand island in Potholes Reservoir that hosted a tern colony with a population index of about 90 on 0.05 ha of open sand and grass. This colony was prematurely abandoned due to egg destruction by an unknown source (Chris Thompson, WDFW, personal communication).

METHODS

We sampled Caspian tern, double-crested cormorant, gull, and American white pelican colonies with a potentially significant impact to juvenile salmonid populations in the Columbia River Basin (50 or more nesting pairs) (Ryan et al. 2001). During the spring nesting season (April-July) researches from NOAA Fisheries and Oregon State University (OSU) established the boundaries of piscivorous bird colonies for each species by location and number of nesting pairs.

PIT tags were detected on bird colonies using three types of detectors:

1) A flat-plate detector passed over the surface of abandoned colonies with a four-wheel-drive vehicle

2) A pole-mounted detector passed by hand over nest areas inaccessible to the vehicle (Ryan et al. 2001)

3) A watertight, pole-mounted antenna used in shallow water

Detection efficiency was evaluated by distributing known PIT tags on colonies prior to the nesting season and then calculating the percentage of these tags detected at the end of the nesting season. Three hundred PIT tags were distributed on each of the following islands: East Sand, Little Miller, Foundation, Richland, and Island 18. One hundred fifty PIT tags were distributed on Little Memaloose, Three Mile Canyon, Badger, Crescent, and Solstice Islands. PIT tags were not distributed on Rice Island due to the uncertainty of colony boundaries prior to the nesting season.

In addition, researchers from Biomark Inc. used manual sifting techniques to recover PIT tags from Crescent Island after we had completed our detection efforts (Dare et al. 2002). We calculated the percentage of tags recovered by Biomark that were missed during our detection effort as an additional evaluation of our detection efficiency.

In spring 2002, we PIT tagged approximately 20,000 spring Chinook, 9,000 fall Chinook, 3,000 steelhead *O. mykiss*, and 3,000 coho *O. kisutch* and released them into rivers that discharged directly into the Columbia River estuary. Juveniles were tagged according to protocols and standards outlined in the PIT Tag Marking Procedures Manual (CBFWA 1999), using mass marking and simple PIT-tag injectors. Following tagging, fish were held at the hatcheries for a minimum of 7 days to remove any tagging mortalities and rejected tags.

Fall Chinook and coho were tagged and released from Sea Resources Hatchery on the Chinook River, 6 km upstream from where it enters the Columbia River. Fall Chinook were also released from Big Creek Hatchery, 6 km upstream from where Big Creek enters the Columbia River. Spring Chinook were released from net-pens in Deep River 2 km upstream from its confluence with the Columbia River and from net-pens in Blind Slough 47 km upstream from where it enters the Columbia River.

For tagging purposes, spring Chinook from Blind Slough were moved to Grays River Hatchery where they were tagged and held in a raceway for a minimum of 7 days before being returned to the Deep River net-pens. Spring Chinook from the Blind Slough net-pens were tagged at Willamette Hatchery prior to being placed in the net-pens. Steelhead were tagged and released from the Elochoman Hatchery on the Elochoman River 19 km upstream from its confluence with the Columbia River at rkm 58. A chi-square test was used to compare detection rates between estuarine salmonid stocks and their cohorts at Bonneville Dam.

Release data and PIT-tag detections at Bonneville and Lower Monumental Dams were obtained from PTAGIS. To estimate the numbers of steelhead and yearling Chinook migrating in-river from the Snake River into the McNary Dam reservoir, we used a four-step process for each species "X" by migration year "Y." First, from the Fish Passage Centers (FPC) web site (FPC 2003) we took the number of species X that encountered Lower Monumental Dam by migration year. Second, we divided that number by the estimated PIT-tag detection efficiency for species X, which resulted in an estimate of the total number of species X that encountered Lower Monumental Dam for year Y. Third, we subtracted from the total the number of species X transported from Lower Monumental Dam or that died at the dam. Finally, we estimated 10% mortality for fish that remained in-river and passed through Ice Harbor Dam to yield our final estimate of species X migrating in-river to McNary Dam pool for year Y.

To estimate the proportion of in-river migrating juvenile Snake River salmonids impacted by birds nesting in the McNary Dam pool, we divided the number of PIT-tagged fish detected at Lower Monumental Dam into the number of these tags that were subsequently detected on a bird colony. We then divided the Lower Monumental Dam tag recovery percentages by 0.9 to account for mortality due to Ice Harbor Dam. To estimate the impact of avian predators nesting in McNary Dam pool on all (in-river and transported) Snake River salmonids, we first estimated the total number of salmonids that exited the Snake River by adding our estimate of in-river migrants entering the McNary Dam pool to the number transported in either barges or trucks which we downloaded from the FPC web page. Finally, we multiplied the predation rate by the estimated number of juvenile salmonids migrating in-river to McNary Dam pool and divided the product by the total number exiting the Snake River.

RESULTS

In 2002, we detected 55,729 previously undetected juvenile salmonid PIT tags on piscivorous bird colonies in the Columbia River Basin. In addition, Biomark Inc. recovered 651 (525 from migration year 2002) tags from Crescent Island that we had not previously detected, increasing the total to 56,380. Of these tags, 49,398 were among the 1,774,525 salmonids PIT tagged and released into the Columbia River Basin for the 2002 migration year (2.8% of all salmonids). By species, tags detected on colonies accounted for 1.9% of the Chinook, 4.2% of the coho, 10.4% of the steelhead, and 2.0% of the sockeye *O. nerka* (Table 1). The majority of these tags were detected on colonies in the Columbia River estuary and McNary Dam reservoir, where there are large colonies of terns and cormorants (Table 2).

Of the PIT-tagged juvenile salmonids that migrated in-river and were detected at Bonneville Dam (the first impoundment upstream from the Columbia River estuary) in 2002, 49,774 originated from the Snake River Basin (SRB), while 50,049 originated from other areas in the CRB (Table 3). Of the SRB salmonids detected at Bonneville Dam, the percentages subsequently detected on piscivorous bird colonies in the Columbia River estuary ranged from 1.6% for fall Chinook to 15.8% for steelhead (Table 3). Of the non-SRB salmonids detected at Bonneville Dam, the percentages subsequently detected on piscivorous bird colonies in the Columbia River estuary ranged from 0.8% for sockeye to 10.6% for steelhead.

In addition to PIT-tagged salmonids that migrated in-river, 188,419 PIT-tagged salmonids were barged around the FCRPS and released approximately 10 km downstream from Bonneville Dam (Table 4). Percentages of these salmonids that were subsequently detected on piscivorous bird colonies in the Columbia River estuary ranged from 1.5 for fall Chinook to 10.5 for steelhead (Table 4). The proportions detected on colonies were generally lower for barged fish than for in-river migrants detected at Bonneville Dam for both SRB and non-SRB salmonids.

We also PIT tagged an additional 31,337 salmonids for the 2002 migration year and released them into rivers that discharge directly into the Columbia River estuary (Table 5). From these releases, we detected tags on estuarine bird colonies ranging from 4.2% for spring Chinook to 15.0% for fall Chinook (Table 5). Detection rates for estuarine releases of both fall and spring Chinook were higher than for their upriver cohorts detected at Bonneville Dam and subsequently detected on an estuarine bird colony (Table 6). Detection rates on bird colonies in the estuary were lower for estuarine steelhead than for their upriver cohorts detected at Bonneville Dam, while detection rates were similar between the areas for coho.

Table 1. Total number of PIT tags released into the Columbia River Basin by migration year and percentages of those tags detected on Caspian tern colonies in the Columbia River estuary. Land-based detection did not begin until 1998, and the lower percentages for detections from earlier years may be a result of tags being swept off the colonies during winter storms.

Migration year	Unknown		Chinook		Coho		Steelhead		Sockeye		**Total**	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	**(n)**	**(%)**
1987	12,997	0.0	7,755	0.0	-	-	5,166	0.0	1,934	0.0	**27,852**	**0.0**
1988	7,793	0.0	19,849	0.0	-	-	17,029	0.1	145	0.0	**44,816**	**0.1**
1989	2,137	0.0	88,040	0.1	-	-	32,335	0.3	3,979	0.0	**126,491**	**0.1**
1990	-	-	73,754	0.0	3	0.0	23,659	0.3	7,441	0.0	**104,857**	**0.1**
1991	-	-	79,530	0.1	6,040	0.0	23,286	0.4	8,578	0.0	**117,434**	**0.2**
1992	-	-	72,144	0.1	4,455	0.4	29,514	0.3	12,400	0.0	**118,513**	**0.1**
1993	-	-	132,464	0.2	5	0.0	34,543	1.4	33,440	0.0	**200,452**	**0.4**
1994	-	-	242,388	0.5	-	-	143,185	0.8	3,884	0.1	**389,457**	**0.6**
1995	-	-	478,488	0.5	10	0.0	80,499	1.3	8,134	0.1	**567,131**	**0.6**
1996	-	-	333,242	0.6	5,338	0.5	80,391	2.0	16,347	0.1	**435,318**	**0.8**
1997	-	-	440,354	0.8	47,359	2.7	127,003	3.9	4,267	0.3	**618,983**	**1.6**
1998	-	-	764,759	1.0	76,009	3.2	85,144	6.5	21,108	0.3	**947,020**	**1.7**
1999	2	0.0	1,081,477	1.4	60,960	2.5	353,827	5.8	13,243	0.4	**1,509,509**	**2.4**
2000	2,340	0.2	938,129	1.6	95,272	2.6	241,666	5.2	8,707	0.6	**1,286,114**	**2.3**
2001	5	0.0	915,466	1.6	47,356	0.4	131,442	1.6	5,893	0.7	**1,100,162**	**1.6**
2002	192	0.5	1,546,431	0.8	56,533	2.5	163,354	4.9	8,015	0.4	**1,774,525**	**1.2**
Total	**25,466**	**0.0**	**7,214,270**	**0.9**	**399,340**	**2.0**	**1,572,043**	**3.2**	**157,515**	**0.2**	**9,368,634**	**1.5**

Table 2. Migration year 2002 salmonid PIT tags detected on piscivorous bird colonies in the Columbia River Basin.

Detection Location	Tern (n)	Cormorant (n)	Gull (n)	Pelican (n)	Unknown (n)	**Total (n)**
			Columbia River Estuary			
East Sand Island	21,872	4,956	--	--	--	**26,828**
Rice Island	--	1,623	--	--	--	**1,623**
			Dalles Dam Reservoir			
Little Memaloose Island	--	--	--	--	--	**0**
Little Miller Island	--	--	3,116	--	--	**3,116**
			John Day Dam Reservoir			
Three Mile Canyon Island	5	--	476	--	133	**614**
			McNary Dam Reservoir			
Crescent Island	10,532	--	1,671	--	164	**12,367**
Badger Island	--	--	--	178	--	**178**
Foundation Island	--	2,247	--	--	--	**2,247**
Richland Island	--	--	731	--	--	**731**
Island 18	--	--	442	--	--	**442**
			Potholes Reservoir			
Solstice Island	1,078	--	--	--	--	**1,078**
West Tern Island	174	--	--	--	--	**174**
Total	**33,661**	**8,826**	**6,436**	**178**	**297**	**49,398**

Table 3. PIT-tagged Snake River Basin (SRB) and non-SRB salmonids detected at Bonneville Dam, and the percentage of these tags detected on piscivorous bird colonies in the estuary (2002).

		East Sand Island				Rice Island			
		Terns		Cormorants		Cormorants		Total	
	Bonneville	n	%	n	%	n	%	n	%
SRB salmonids									
Spring/summer Chinook	30,541	585	1.9	151	0.5	65	0.2	801	2.6
Fall Chinook	4,868	53	1.1	21	0.4	3	0.1	77	1.6
Unknown Chinook	6,502	120	1.8	34	0.5	18	0.3	172	2.6
Steelhead	7,598	1,108	14.6	62	0.8	34	0.4	1,204	15.8
Coho	145	19	13.1	0	0.0	0	0.0	19	13.1
Sockeye	120	5	4.2	2	1.7	0	0.0	7	5.8
Total	49,774	1,890	3.8	270	0.5	120	0.2	2,280	4.6
Non-SRB salmonids									
Spring/summer Chinook	34,575	585	1.7	200	0.6	61	0.2	846	2.4
Fall Chinook	10,281	102	1.0	45	0.4	2	0.02	149	1.4
Unknown Chinook	1,203	28	2.3	17	1.4	3	0.2	48	4.0
Steelhead	790	74	9.4	6	0.8	4	0.5	84	10.6
Coho	3,074	224	7.3	6	0.2	15	0.5	245	8.0
Sockeye	126	0	0.0	1	0.8	0	0.0	1	0.8
Total	50,049	1,013	2.0	275	0.5	85	0.2	1,373	2.7

Table 4. PIT-tagged salmonids barged downstream of Bonneville Dam and the percentage of those tags detected on piscivorous bird colonies in the estuary (2002).

	Barged	Tern	Cormorant	Cormorant		**Total**
Species	(n)	(%)	(%)	(n)	(%)	**(%)**
Spring/Summer Chinook	97,140	1.5	0.4	124	0.1	**2.0**
Fall Chinook	39,863	0.7	0.7	59	0.1	**1.5**
Unknown Chinook	23,857	1.0	0.4	41	0.2	**1.6**
Steelhead	27,462	9.5	0.7	84	0.3	**10.5**
Coho	51	5.9	2.0	0	0.0	**7.8**
Sockeye	46	4.3	0.0	0	0.0	**4.3**
Total	**188,419**	**2.4**	**0.5**	**308**	**0.2**	**3.1**

Table 5. PIT-tagged salmonids released into estuarine rivers downstream from Bonneville Dam and the percentage of these fish detected on piscivorous bird colonies in the estuary, 2002.

		Release		East Sand Island		Rice Island	
				Tern	Cormorant	Cormorant	**Total**
Species	Release site	Date	Number	(%)	(%)	(%)	**(%)**
Fall Chinook	Chinook River	27 May	2,981	5.1	9.4	0.5	**15.0**
Fall Chinook	Big Creek Hatch	6 May	2,927	5.1	7.9	1.3	**14.3**
Spring Chinook	Deep River	16 May	2,711	3.2	1.0	0.0	**4.2**
Spring Chinook	Blind Slough	10 April-30 May	16,854	5.5	0.6	0.0	**6.2**
Steelhead	Elochoman River	24 April	2,887	6.3	0.2	0.2	**6.8**
Coho	Chinook River	13 May	2,977	8.3	3.6	0.0	**11.9**

Table 6. PIT-tagged salmonids detected at Bonneville Dam and the percentage of tags from these fish detected on piscivorous bird colonies in the estuary in 2002.

		East Sand Island		Rice Island		
	Bonneville	tern	cormorant	cormorant	**Total**	
Species	(n)*	(%)	(%)	(%)	(n)	**(%)**
Spring/Summer Chinook	65,116	1.8	0.5	0.2	1,647	**2.5**
Fall Chinook	15,149	1.0	0.4	0.0	226	**1.5**
Unknown Chinook	7,705	1.9	0.7	0.3	220	**2.9**
Steelhead	8,388	14.1	0.8	0.5	1,288	**15.4**
Coho	3,219	7.5	0.2	0.5	264	**8.2**
Sockeye	246	2.0	1.2	0.0	8	**3.3**
Total	**99,823**	**2.9**	**0.5**	**0.2**	**3,653**	**3.7**

* Species with less than 100 detections at Bonneville are not reported.

Outside of the Columbia River estuary, the second highest numbers of PIT tags were detected on piscivorous bird colonies in the McNary Dam reservoir (Table 2). Of the PIT-tagged salmonids from migration year 2002 detected at Lower Monumental Dam (the furthermost downstream detection facility on the Snake River and the first detection facility upstream from McNary Dam) and returned to the river, we detected 7.2% of the steelhead, 1.1% of the spring/summer Chinook, and 0.9% of the fall Chinook on the Crescent Island tern colony (Table 7).

On all of the piscivorous bird colonies in McNary Dam pool combined (including Crescent Island), we detected 9.9% of the steelhead, 1.6% of the spring/summer Chinook, and 1.3% of the fall Chinook (Table 8). When we considered all of the Snake River salmonids (in-river and transport) that migrated to McNary Dam pool, minimal predation by terns was 2.2% for steelhead and 0.4% for yearling Chinook; these rates were only slightly higher when all birds nesting in McNary Dam pool were considered (Table 9).

Detection efficiencies based on previously distributed tags ranged from 15.0 to 94.7%, depending on colony and detection method (Table 10). While our tag detection efficiency on Crescent Island was low (15.0%), tag recovery efforts conducted by Biomark Inc. only added 525 tag codes to the 11,842 migration year 2002 tag codes that we had already detected 4.4%.

Table 7. PIT-tagged salmonids detected at Lower Monumental Dam, and the percentage of these salmonids detected on the Crescent Island tern colony by migration year.

Migration Year	Spring/Summer Chinook					Hatchery fall Chinook[a]		Steelhead					Crescent Island population index (n)[b]
	Hatchery		Wild		Total			Hatchery		Wild			
	(n)	(%)	(n)	(%)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	Total	
1998	49,315	0.4	8,132	0.4	0.4	16,872	0.4	18,083	4.3	5,145	1.9	3.8	698
1999	113,687	0.7	21,096	0.7	0.7	11,297	0.7	38,682	4.4	8,229	3.0	4.1	999
2000	5,552	0.4	13,468	0.4	0.4	4,503	0.2	9,736	2.5	16,784	1.3	1.7	600
2001	38,268	4.4	10,402	3.2	4.1	8,649	3.0	8,976	12.5	6,266	14.2	13.2	720
2002	82,192	1.1	10,573	0.9	1.1	7,476	0.9	15,879	7.0	8,190	7.6	7.2	580

a There were insufficient numbers of wild fall Chinook detected at Lower Monumental Dam to report.

b Based on direct count of adult terns late in the nesting season, resulting in an estimate of breeding pairs.

Table 8. PIT-tagged salmonids detected at Lower Monumental Dam and the percentage of these salmonids detected on a bird colony in McNary Dam pool by migration year.

Migration Year	Spring/Summer Chinook					Hatchery fall Chinook*		Steelhead				
	Hatchery		Wild		Total			Hatchery		Wild		Total
	(n)	(%)	(n)	(%)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(%)
1998	49,315	0.5	8,132	0.5	0.5	16,872	0.5	18,083	4.8	5,145	2.1	4.2
1999	113,687	0.8	21,096	0.8	0.8	11,297	0.8	38,682	4.8	8,229	3.2	4.5
2000	5,552	1.1	13,468	0.9	1.0	4,503	0.9	9,736	5.1	16,784	2.8	3.7
2001	38,268	6.0	10,402	4.3	5.6	8,649	4.3	8,976	21.1	6,266	21.0	21.1
2002	82,192	1.6	10,573	1.5	1.6	7,476	1.3	15,879	10.2	8,190	9.9	10.1

* There were insufficient numbers of wild fall Chinook detected at Lower Monumental Dam to report

Table 9. Estimates of the percentages of Snake River steelhead and yearling Chinook that fell prey to avian predators in McNary Dam pool.

Migration year	Salmonids migrating in-river to McNary Pool	Salmonids transported through McNary Pool.	Transport (%)	Predation on Snake River salmon (McNary Pool)	
				Terns (%)	All birds (%)
		Steelhead			
1998	757,026	7,392,609	90.7	0.39	0.43
1999	1,736,901	7,789,113	81.8	0.84	0.91
2000	1,196,669	6,630,816	84.7	0.29	0.62
2001	253,458	6,483,917	96.2	0.55	0.88
2002	2,175,950	4,906,844	69.3	2.46	3.44
		Yearling Chinook			
1998	772,093	2,933,689	79	0.09	0.11
1999	2,564,462	7,275,653	74	0.21	0.24
2000	1,701,289	4,266,176	71.5	0.12	0.31
2001	293,735	3,157,045	91.5	0.39	0.53
2002	2,882,684	5,543,226	65.8	0.42	0.62

Table 10. Detection efficiency of PIT tags distributed on colonies prior to the nesting season.

Detection Location	Gull (%)	Tern (%)	Cormorant (%)	Pelican (%)
East Sand Island	-	94.7	35.3	-
Little Miller Island	36.3	-	-	-
Three Mile Canyon Island	32.7	-	-	-
Crescent Island	-	15.0	-	-
Badger Island	-	-	-	68.0
Foundation Island	-	-	67.0	-
Richland Island	54.0	-	-	-
Island 18	43.3	-	-	-
Solstice Island	-	28.7	-	-
Total	**41.6**	**46.1**	**51.2**	**68.0**

DISCUSSION

The primary area of avian predation continues to be the Columbia River estuary, where we detected over 28,000 juvenile salmonid PIT tags from the 2002 migration year. The predation rate on SRB salmonids in this area was again higher than the predation rate on non-SRB salmonids. While the difference was not as high as we had observed in 2001 (Glabek et al. 2003), it is still of concern, and we continue to investigate possible causes.

In 2002, we continued to expand our evaluation of the vulnerability of juvenile salmonids released into streams and rivers that empty directly into the estuary. With the addition of fall Chinook from Big Creek Hatchery, we found that predation rates for estuarine-released fall Chinook continued to be considerably higher than for their upriver cohorts. This is unique for these fish in that a large portion of the predation is by cormorants instead of terns. Initially we hypothesized that this was due to the tag site we had chosen in 2001, which forced these fish to pass though a narrow channel adjacent to the East Sand Island cormorant colony. However, in 2002, the Big Creek Hatchery fall Chinook showed similar predation rates, and they did not pass through this channel.

It appears that fall Chinook are more vulnerable to predation due to either a behavioral difference in fish or a prey preference by the birds. Based on results from 2002, it appears likely that estuarine fall Chinook may be preyed upon at greater rates because they are more dependent on the estuary for rearing, which exposes them to predation over a longer period. If their greater vulnerability were due to a preference by the birds for fall Chinook as prey, then upriver cohorts should also have suffered elevated levels of predation, but we found the opposite to be true. We plan to continue our investigation of avian predation on estuarine salmonids with a focus on fall Chinook.

We detected the second largest number of PIT tags on colonies in the McNary Dam pool, primarily on the Crescent Island tern colony. The predation rate by Crescent Island terns was over 7.2% for Snake River steelhead migrating in-river and over 10.0% when all of the bird colonies in McNary Dam pool were combined. Managers are concerned about reach survival, and avian predation could be a serious consideration for the McNary Dam reach. However, if managers are only concerned with the impacts by avian predators nesting in the McNary Dam reservoir on all Snake River salmonids, than transportation alleviates most of this concern, since the majority of Snake River salmonid smolts are transported and released downstream from Bonneville Dam. Therefore, birds nesting in McNary Dam reservoir do not have an opportunity to prey on these smolts.

PIT-tag data collected from piscivorous bird colonies throughout the Columbia River Basin continue to provide estimates of relative vulnerability to avian predation and data that can be used to evaluate relocation efforts in the Columbia River estuary (Collis et al. 2001a, Ryan et al. 2003). In addition, these data are stored in a central database, allowing researchers to remove known mortalities from their data sets. This produces a more accurate data set that can be used for many purposes, such as estimating survival past dams (Absolon et al. 2002).

While we have not developed a method to evaluate the rate at which tags are deposited on our sample sites, we have evaluated the detection efficiency of tags known to have been deposited on a colony. Evaluations of detection efficiency on the East Sand Island tern colony suggest over 90% of all the tags deposited on the colony over the past three years were detected. In contrast, our detection efficiency averaged around 47% for all colonies combined. However, the manual recovery of several thousand tags on Crescent Island by researchers from Biomark Inc. resulted in only 525 additional tag codes from migration year 2002, and increase of only 4.4% to the 11,847 tags we had already detected. This suggests that while our detection efficiency is probably greater than 47%, it is still below 100%. Therefore, the numbers produced by our sampling effort must continue to be considered as minimal estimates of predation.

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