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ARTICLE

Predation by American White Pelicans on Yellowstone Cutthroat Trout in the Blackfoot River Drainage, Idaho

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Abstract
Expansion of the American white pelican *Pelicanus erythrorhynchos* colony on Blackfoot Reservoir, Idaho, and the associated declines in adfluvial Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* in the upper Blackfoot River drainage has generated concern about the impact of pelican predation on this native trout stock. During a 4-year study, 4,653 wild Yellowstone Cutthroat Trout were tagged using a combination of radiotelemetry and PIT tags. Annual predation rate estimates were made by recovering Yellowstone Cutthroat Trout tags from the nesting islands of American white pelicans. On-island tag recovery rates were corrected for ingested tags that went undetected during island searches and for tags that were deposited away from the nesting islands. American white pelicans consumed tagged Yellowstone Cutthroat Trout ranging from 150 mm to 580 mm TL and showed no size selection within that range for their prey. Predation rates on adult and juvenile Yellowstone Cutthroat Trout generally exceeded 20%, and the highest values were above 60%. Our independent methods (telemetry and PIT tagging) for estimating pelican predation on adult Yellowstone Cutthroat Trout produced similar results. Annual river flow conditions varied markedly and may have contributed to some of the observed range in predation rate estimates. Predation by the pelican colony appears to be a likely contributor to the recent collapse of Yellowstone Cutthroat Trout in the upper Blackfoot River drainage. In the past, overexploitation by anglers severely reduced the trout population and was remedied by implementing catch-and-release regulations. The current predation impact poses a greater management challenge, namely, finding a balanced approach for conserving both the native trout stock and the pelican colony.

The impact of piscivorous birds on commercially and socially important fish stocks has been a broad concern throughout North America and Europe (Harris et al. 2008) and the potential negative effects of populations of the American white pelican *Pelicanus erythrorhynchos* on such fisheries are no exception (Lovvorn et al. 1999; Glahn and King 2004; King 2005). Keith (2005) reported that the numbers of American white pelicans in North America increased from 30,000 in 1933 to about 100,000 by 1985 and to 400,000 by 1995. King and Anderson (2005) documented that American white pelican breeding abundance from 20 North American colonies doubled between 1979 and 2001. While most of the continental

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American white pelican population breeds east of the Continental Divide, populations have also increased in many parts of the west and in the western metapopulation collectively (Findholt and Anderson 1995a; King and Anderson 2005; Murphy 2005). In southeastern Idaho, the first successful nesting event by American white pelicans on Blackfoot Reservoir was visually observed in 1993. The estimated production of pelicans that year was about 200 juveniles. Annual monitoring of the pelican population nesting at Blackfoot Reservoir began in 2002, and the breeding bird estimate was 1,352. The pelican population increased to a peak of 3,418 adult birds in 2007.

American white pelicans are typically reported to be highly adaptable, opportunistic foragers, readily selecting sites and prey that are most available (Hall 1925; Knopf and Kennedy 1980; Lingle and Sloan 1980; Flannery 1988; Findholt and Anderson 1995b), a trait that is problematic for some fish spawning aggregations. For example, American white pelicans seek out spawning concentrations of Tui Chub *Gila bicolor* at Pyramid Lake, Nevada, particularly when these fish enter shallow littoral areas and display "quick jerking motions" associated with spawning (Knopf and Kennedy 1980). More recently, American white pelican predation has been identified as a hindrance to conservation efforts for Cui-ui *Chasmistes cujus*, an adfluvial sucker that is listed as endangered under the U.S. Endangered Species Act and ascends the Truckee River from Pyramid Lake to spawn (Scoppettone and Rissler 2002; Scoppettone et al. 2014). Because American white pelicans prey on adult Cui-ui immediately prior to spawning, their impact on this endangered species could be severe (Murphy 2005). Similarly, American white pelicans detect and use adfluvial Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* spawning aggregations at inlets of rivers and streams (Kaeding 2002; Stapp and Hayward 2002). Davenport (1974) reported that adfluvial Yellowstone Cutthroat Trout were the preferred prey of American white pelicans in a study on Yellowstone Lake, Wyoming, an observation reiterated by Varley and Schullery (1996). In southeastern Idaho, concentrations of American white pelicans (hereafter, pelicans) are becoming increasingly abundant at the mouths of well-known Cutthroat Trout spawning tributaries such as the Blackfoot River, St. Charles Creek, and McCoy Creek (IDFG 2009).

Historically, the upper Blackfoot River drainage supported angler harvest of tens of thousands of wild Yellowstone Cutthroat Trout (hereafter, Cutthroat Trout). For example, Cuplin (1963) reported harvest of 17,000 and 11,000 Cutthroat Trout in the upper Blackfoot River in 1959 and 1960, respectively. As the popularity of the fishery increased, angler exploitation became a limiting factor for the population (LaBolle and Schill 1988). In 1990, a management plan was implemented to reduce harvest and bolster the wild stock. The first step of that plan was to close harvest on Cutthroat Trout in the reservoir. In 1998, further protection was afforded by closing harvest of Cutthroat Trout in the spawning and rearing environments upstream from the reservoir in the Blackfoot River and its tributaries. Over the ensuing decade, the Cutthroat Trout population responded dramatically. Adult escapement estimates increased from a few hundred spawning fish to an estimated run size of nearly 5,000 in 2001.

Despite the early success of harvest closures, the run collapsed to an all-time measured low of only 16 fish in 2005. Since then, the population has remained low with an average run size of about 800. This more recent Cutthroat Trout collapse coincided with a rapidly expanding pelican breeding colony on Blackfoot Reservoir and observed increases in pelican use of the Blackfoot River to forage (Teuscher and Schill 2010). In 2004, 70% of adult Cutthroat Trout migrants exhibited wounds consistent with pelican attacks (Teuscher and Schill 2010). Those observations indicated that predation was occurring, but a quantitative assessment was needed to determine whether that predation could be the cause of recent declines and thus could impede our management goal to restore the Cutthroat Trout population. Our specific objective was to directly measure pelican predation rates on adfluvial Cutthroat Trout in the upper Blackfoot River drainage.

STUDY AREA

Blackfoot Reservoir is located in southeastern Idaho at an elevation of 1,685 m at full pool and covers 7,284 surface ha (Figure 1). The reservoir is shallow (mean depth, <5 m) and has summer Secchi disk readings ranging from 0.5 to 2.5 m. Numerous islands were created when the reservoir filled. The Blackfoot River is the reservoir's primary tributary with a mean annual flow of 3.65 m^3/s and an average peak flow of 14.47 m^3/s during spring runoff. The Blackfoot River's confluence with the reservoir has many shallow areas (<2 m), an open canopy, and is heavily used by foraging pelicans (Figure 2). In addition to the adfluvial Cutthroat Trout, other common species in the reservoir include Utah Chub *Gila atraria*, Utah Sucker *Catostomus ardens*, Common Carp *Cyprinus carpio*, Yellow Perch *Perca flavescens*, and hatchery-produced triploid Rainbow Trout *O. mykiss*. Triploid Rainbow Trout are stocked to enhance the sport fishery and provide harvest opportunity.

The life cycle of Cutthroat Trout in the upper Blackfoot River drainage includes two migrations pertinent to this study. Juvenile Cutthroat Trout rear in the Blackfoot River and its tributaries from 1 to 2 years before migrating downstream to the Blackfoot Reservoir. Juvenile migrants range in size from 80 to 250 mm TL. After 1–2 years in the reservoir, mature Cutthroat Trout re-enter the river and travel up to 70 km to spawn in the upper main stem and tributaries. Mature Cutthroat Trout range in size from 400 to 650 mm TL. Both juvenile and adult migrations occur primarily between May and July, which overlaps with the arrival and nest initiation of the pelican colony.

Pelicans nest on Gull and Willow islands in Blackfoot Reservoir. The combined surface area of the islands varies

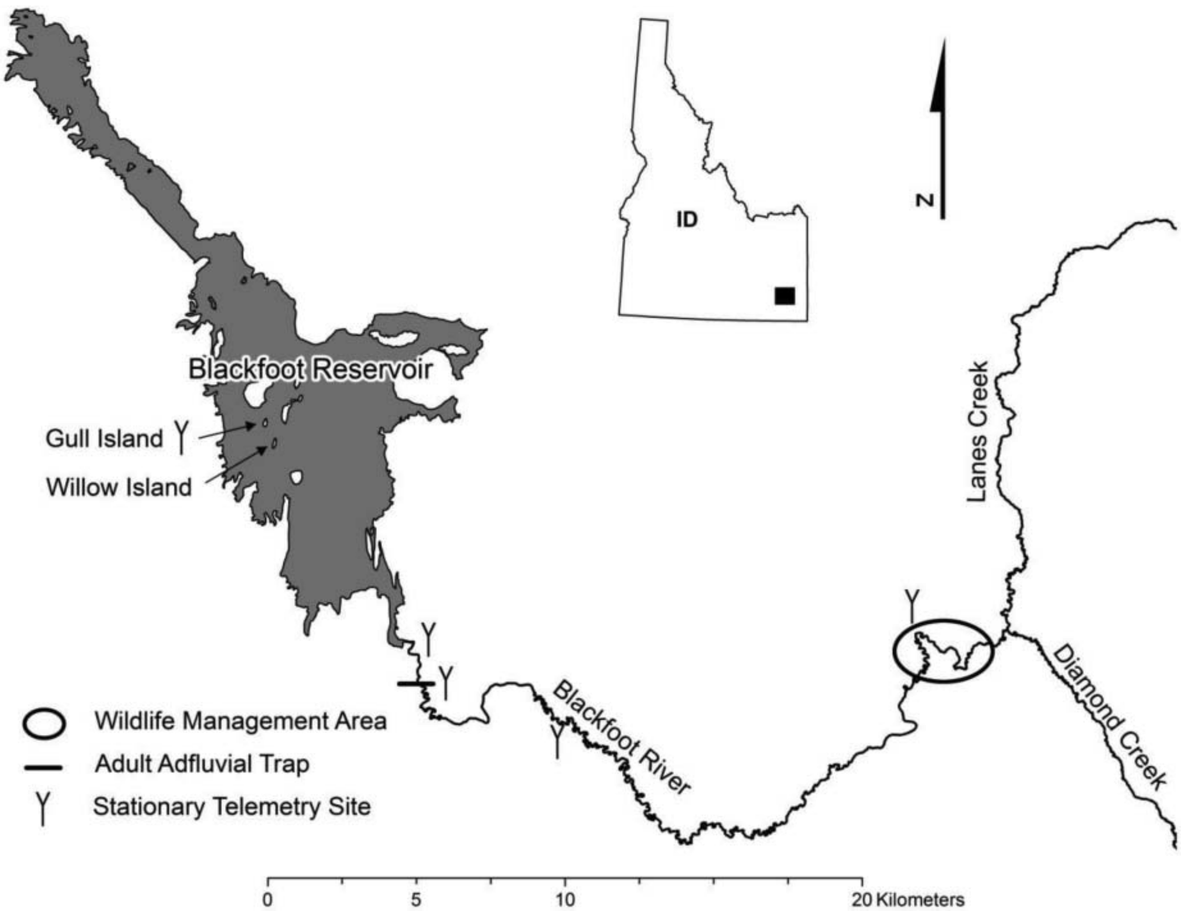

FIGURE 1. Study area showing general locations within the Blackfoot River drainage, Idaho, where Yellowstone Cutthroat Trout were tagged with PIT tags and/or radiotelemetry tags and where radio-tagged fish were relocated from 2010 to 2011. American white pelican nesting colonies are located on Gull and Willow islands.

from 1.5 to 8 ha with reservoir elevation. At full pool, Willow Island is completely inundated; this occurred only once between 2000 and 2013. In addition to pelicans, Gull Island supports other colonial nesting species. California gulls *Larus californicus* and ring-billed gulls *L. delawarensis* are consistently the most abundant birds nesting on Gull Island. Gulls do not nest on Willow Island. Similarly, double-crested cormorants *Phalacrocorax auritus* nest exclusively on Gull Island and have a mean active nest count of 451 (range, 177–899; Table 1). Other fish-eating birds that intermittently nest on the Blackfoot Reservoir islands and that occur at low abundance include snowy egrets *Egretta thula*, black-crowned night herons *Nycticorax nycticorax*, great blue herons *Ardea herodias*, and Caspian terns *Hydroprogne caspia*.

METHODS

We implanted PIT and radiotelemetry tags in wild Cutthroat Trout. The recovery of those tags from pelican nesting islands was used to estimate annual predation rates. Radiotelemetry tags were used exclusively for adult Cutthroat Trout caught in the reservoir. Passive integrated transponder tags were implanted in adult and juvenile Cutthroat Trout. We defined juvenile Cutthroat Trout as being <225 mm TL. Collection sites varied for PIT-tagged fish and represented different levels of predation exposure over the Cutthroat Trout life cycle. Because the methods of data collection and analysis vary between PIT and radiotelemetry tags, we described them separately.

Predation estimates derived from PIT tags.—We collected and PIT-tagged wild Cutthroat Trout from three locations. The locations included the Blackfoot Reservoir, an adult Cutthroat Trout escapement trap located on the Blackfoot River about 3.2 km upstream from the reservoir, and an upriver tagging site. The upriver tagging site, surrounded by state land and managed for wildlife benefits, is referred to as the Blackfoot River Wildlife Management Area and is located about 55 river kilometers upstream from the reservoir (Figure 1). Each tagging location enabled predation loss estimates during different segments of the adfluvial Cutthroat Trout life cycle. Cutthroat Trout tagged on the Wildlife Management Area experience

FIGURE 2. American white pelicans foraging on the Blackfoot River during the spring Yellowstone Cutthroat Trout migration in 2007. This site is 8.7 km from the pelican nesting colony on Blackfoot Reservoir. This type of concentrated foraging occurs in years with average and below-average spring flow conditions. This photograph is one of 95,860 images taken since 2007 to monitor avian predator use of the Blackfoot River.

exposure to predation in the upper river and during downriver migration, and potential losses in the reservoir during the later portion of the pelican nesting period. Fish tagged at the adult escapement trap (May–June) experienced all of the abovementioned exposure and additional predation risk as they migrated upriver from the trap. It is important to note, however, that adult Cutthroat Trout tagged at the trap excluded predation in the 3.2 km of river located downstream from the trap. This river reach often receives intense pelican foraging pressure and contains many shallow areas (<1.5 m deep) ideal for pelican foraging (Figure 2). Cutthroat Trout tagged in the reservoir experienced predation during upstream and downstream spawning migrations as well as in-reservoir predation during the summer.

Fish handling procedures were similar for all collection sites. We anesthetized, measured the TL, tagged, and released Cutthroat Trout near their collection site. We captured Cutthroat Trout at the Wildlife Management Area and Blackfoot Reservoir with boat-mounted electrofishing equipment using typical pulsed-DC waveforms. We tagged trout at the trap and Wildlife Management Area sites during May through July, which coincides with the period when most juvenile and adult Cutthroat Trout migrations occur (Thurow 1981). Tagging in the reservoir occurred in the fall and early spring. For reservoir tagging, we targeted Cutthroat Trout that exceeded 400 mm TL and were likely mature.

Although minimum predation rates of salmonid-eating birds derived using data from the PIT-tagged fish have recently been reported (Evans et al. 2012; Frechette et al. 2012; Sebring et al. 2013), we sought to estimate total predation rates. We used the term total predation because our methods estimated predation rates on PIT-tagged fish even when some of the tags from depredated fish were not recovered. Several factors contributed to unrecovered tags from consumed fish: (1) tags were deposited on the islands but not detected, (2) tags were deposited on the islands but were destroyed during digestion or by trampling, and (3) ingested tags went undetected because they were deposited in any location other than the nesting islands (e.g., tags deposited at loafing sites or tags consumed by pelicans from a different colony).

We accounted for unrecovered tags by feeding a known number of live PIT-tagged fish to pelicans and then attempted to recover the tags within pelican nesting colonies. Our methods of estimating total predation by feeding tagged fish to avian predators are similar to those reported in recent studies of western gulls

TABLE 1. Breeding bird abundance for colonial nesting species on Gull and Willow islands in Blackfoot Reservoir. Actual species are indicated in Study Area section. The abundance estimates were made by ground counts of active nests. The letter P denotes that birds were present but not counted. The American white pelican colony expanded to Willow Island in 2007.

	Breeding bird abundance				
Year	Pelicans	Cormorants	Herons/egrets	Gulls	Terns
		Gull Island			
2002	1,352	820	P	P	0
2003	1,674	546	P	P	0
2004	1,748	708	P	P	0
2005	2,806	648	74	12,206	0
2006	2,548	810	116	9,376	78
2007	1,766	1,220	P	P	74
2008	1,180	1,798	P	P	90
2009	438	1,268	88	13,528	14
2010	684	354	P	P	0
2011	688	236	34	P	0
2012	620	850	56	P	0
2013	894	676	36	12,300	2
		Willow Island			
2007	1,652	0	0	0	0
2008	1,210	0	46	0	0
2009	2,736	0	68	0	0
2010	1,050	0	0	0	0
2011	36	0	0	0	0
2012	2,414	0	0	0	0
2013	1,102	0	0	0	0

L. accidentalis (Osterback et al. 2013) and American white pelicans (Scoppettone et al. 2014). The feeding method assumes that tag recovery rates for fish fed to pelicans are the same as recovery rates for tags from at-large fish that have been preyed on. For example, if 10% of tagged fish fed to pelicans are recovered, then the number of at-large Cutthroat Trout recoveries is assumed to be 10% of the total number of Cutthroat Trout consumed.

The feeding process was completed one fish at a time. The process consisted of PIT tagging the fish, injecting air under the skin to keep the fish floating at the surface, and then releasing the fish close to a group of foraging pelicans. We fed these fish to pelicans near the river's confluence with the reservoir where the greatest concentration of foraging pelicans occurs. The confluence and first 2 km of upriver habitat contain many shallow sections (<1.5 m) that attract foraging pelicans. We released fish in the general area where we believed the greatest predation on Cutthroat Trout occurred. A fish was considered to have been fed to a pelican only if it was captured by a pelican and ingestion was confirmed by observing the pelican raising its head and performing a swallowing motion, sometimes referred to as a head toss (Anderson 1991). We fed PIT-tagged fish over a period of several weeks overlapping with peak adult and juvenile Cutthroat Trout river migrations (May–July). That period mirrors peak use of the Blackfoot River by foraging pelicans (Teuscher and Schill 2010). Fish species used for feeding were Utah Sucker, Utah Chub, and hatchery-raised Rainbow Trout. Only fish similar in lengths to juvenile and adult migrating Cutthroat Trout were used in PIT tag feeding trials.

After juvenile pelicans fledged, we systematically scanned Gull and Willow islands for PIT tags. For the first 3 years of this study (2010–2012), we assumed that all the tags recovered from the islands were deposited by pelicans. The assumption was made because tag recoveries on Willow and Gull islands were consistent with pelican production, the large portion of tagged Cutthroat Trout that were too large to be consumed by other avian predators, and the paucity of double-crested cormorants observed foraging on the Blackfoot River (Teuscher and Schill 2010). To verify our assumption, in 2013, we scanned double-crested cormorant nests for PIT tags. Cutthroat Trout tags recovered from double-crested cormorant nests were removed from the 2013 pelican predation estimate. The equation for estimating pelican predation rates on PIT-tagged Cutthroat Trout was

$$\mathrm{PR} = x/y,$$

where PR = pelican predation rate, x = number of Cutthroat Trout PIT tags found on the Blackfoot Reservoir islands divided by the total number of Cutthroat Trout PIT tags implanted, and y = number of tags from fish fed to pelicans and found on the colony divided by the total number of fish fed to pelicans.

We calculated 90% confidence bounds using the approximate formula for the variance of a ratio (McFadden 1961; Yates 1980):

$$\mathrm{S}^2\left(\frac{x}{y}\right) = \left(\frac{x}{y}\right)^2 \times \left(\frac{S_x}{x^2} + \frac{S_y}{y^2}\right),$$

where $\mathrm{S}x^2$ = variance of x (returns of Cutthroat Trout tags) and $\mathrm{S}y^2$ = variance of y (returns of tags from fish fed to pelicans).

We constructed 90% confidence bounds around pelican predation rates by tagging location and year using the following formulas:

$$\text{Lower limit} = \text{predation rate (PR)} - \sqrt{\mathrm{S}^2\left(\frac{x}{y}\right) \times \left(\frac{t_{\propto}}{2}\right)},$$

and

$$\text{Upper limit} = \text{predation rate (PR)} + \sqrt{\mathrm{S}^2\left(\frac{x}{y}\right) \times \left(\frac{t_{\propto}}{2}\right)},$$

where $t_{0.1,\,2}$ was 1.645.

Predation estimates derived from radio tags.—We collected adult Cutthroat Trout from the Blackfoot Reservoir via boat-mounted electrofishing. All radio-tagged fish were of spawning size, averaging 494 mm and ranging from 393 to 583 mm TL. We used the surgical procedure described by Ross and Kliener (1982) to implant radio transmitters. To decrease surgery times, we used staples rather than sutures to close incisions. Gills were continually irrigated with freshwater during surgery. Tagged Cutthroat Trout were allowed to recover in an oxygenated live well and monitored until swimming ability was reestablished. Surgery times averaged 2.75 min. Upon recovery from anesthesia, fish were released into the reservoir near their initial capture location. Most of the telemetry tagging (70%) occurred in the fall after pelicans had migrated south. The remainder of the tagging occurred in the early spring at least 1 month prior the onset of spawning migrations. Those tagging periods provided substantial time for Cutthroat Trout to recover from surgery and minimize the potential of tagged fish being more vulnerable to pelican predation than untagged fish.

Recovery of telemetry tags and tracking histories were used to estimate the total number of Cutthroat Trout consumed. Fixed-site receivers (ATS model R4500S) were deployed at four locations along the Blackfoot River corridor and at one location on Gull Island (Figure 1). Fixed-site receiver locations enabled the tracking of individual fish that exhibited rapid movement consistent with transportation by pelicans. Fish tracking histories showed fish traveling from the river receivers to the islands in just a few minutes. Such travel speeds are impossible for fish unless they are being carried by birds. However, not all of the Cutthroat Trout that matched the bird-flight tracking pattern were recovered from the nesting islands. Unrecovered telemetry tags that matched the bird-flight tracking pattern and were detected on the fixed telemetry receiver on Gull Island were included in the predation rate estimate. Those tags were summed with the direct on-island recoveries to estimate the total number of Cutthroat Trout consumed. The predation rate estimates were calculated by dividing the total number of Cutthroat Trout consumed by the number originally tagged. Variance for these predation estimates was calculated according to the formula in Fleiss (1981) as

$$\mathrm{Var} = \sqrt{\frac{PQ}{n}},$$

where P is the total number of Cutthroat Trout consumed divided by the number originally tagged, Q is $1 - P$, and n is the total number originally tagged. From the estimate of variance we calculated 90% CIs.

To evaluate possible prey size selection, we used a Kolmogorov–Smirnov two-tailed distribution test to compare pooled length-frequency histograms of all Cutthroat Trout tagged (radio and PIT tags) and those subsequently consumed by pelicans. We assumed there was no tagging mortality and no size-selective tagging mortality. Violating either of these assumptions would result in underestimates of actual pelican predation rates.

RESULTS

Predation Estimates Derived from PIT tags

We PIT-tagged 4,559 Cutthroat Trout over the 4-year study period. Adult Cutthroat Trout made up 88% of the sample. The majority of those adult fish were collected and tagged at the spawning trap (81%), followed by the Wildlife Management Area (17%) and the reservoir (2%). All of the juvenile Cutthroat Trout were tagged at the Wildlife Management Area site ($n = 558$). Average TLs for PIT-tagged juvenile and adult Cutthroat Trout were 185 mm and 449 mm, respectively.

On Gull and Willow islands, we recovered 392 PIT tags from Cutthroat Trout. For all years and tagging sites combined, we recovered 9% of the PIT tags from adult Cutthroat Trout and 9% of the PIT tags from juvenile Cutthroat Trout. We recovered the largest sample of PIT tags in 2013 ($n = 234$). That year, we recovered 106 PIT tags from Willow Island (exclusively pelican nesting) and 130 PIT tags from Gull Island. That same year, we searched double-crested cormorant nests and recovered two Cutthroat Trout tags. The Cutthroat Trout tags recovered in double-crested cormorant nests made up less than 1% (2 of 236) of the 2013 recoveries.

We fed 738 PIT-tagged fish to pelicans. Feeding trials were completed each year of the study and sample size and length statistics for the fish fed to pelicans are shown in Table 2. We recovered a total of 211 PIT tags and the annual tag recovery rates ranged from 12.0% to 48.4% (Table 2). These tag recovery rates followed trends in pelican nest success. The lowest recovery rates occurred in 2011, when nearly all of the pelican nests on Willow Island were inundated by a rising reservoir elevation. In 2012, we recovered the highest percentage of tags and also observed the highest number of successful pelican nests.

Total predation rate estimates varied by year, size-class, and tagging location. For juvenile Cutthroat Trout, predation rates ranged from 10.7% to 70.9% (Table 3). For adult Cutthroat Trout, a similar magnitude of variation occurred in predation rates (6.4% to 60.6%). The average predation rate for PIT-tagged adult Cutthroat Trout for all years and sample sites combined was 26.4%. No clear patterns were observed in adult Cutthroat Trout predation rates among the three tagging locations. For example, adults tagged at the Wildlife Management Area experienced both the lowest and highest predation rates measured (Table 3).

TABLE 2. Characteristics of Yellowstone Cutthroat Trout that were PIT-tagged and fed to American white pelicans at the mouth of the Blackfoot River. Sample sizes, mean TL, and recovery rates of tags from fish consumed are shown.

	Pelican-fed fish				Recovery rate		
			TL (mm)			90% CI	
Year	Number fed	Number recovered	Mean	Range	Estimate (%)	Lower limit	Upper limit
2010	180	37	404	300–568	20.6	14.5	26.6
2011	233	28	372	243–545	12.0	7.8	16.3
2012	184	89	350	195–580	48.4	42.0	54.7
2013	141	57	286	217–550	40.4	31.3	47.6

Predation Estimates Derived from Radio Tags

We tagged 94 adult Cutthroat Trout using radiotelemetry tags. All of the telemetry tagging occurred in the reservoir. We recovered 16 (17%) of the telemetry tags from the nesting islands. A similar number (17) of radio-tagged Cutthroat Trout exhibited the bird-flight tracking patterns but were not recovered from the nesting islands (Table 3). Predation rate estimates on adult Cutthroat Trout, derived from radio tags, were 37.8% in 2010 and 32.7% in 2011. Those predation rates paralleled the independently derived PIT tag estimates from the same years and reservoir tagging location (Table 3).

Pelicans did not show size-selective predation on tagged Cutthroat Trout. The size ranges of available fish and consumed fish were nearly identical (Figure 3), and there was no significant difference observed between the length-frequency distributions ($D_{0.05,26} = 0.259, D = 0.122, P > 0.50$).

DISCUSSION

In this study we documented a range of predation rates by pelicans on adult and juvenile Yellowstone Cutthroat Trout. For both size-classes, most of our predation rate estimates exceeded 20%, and the highest values were above 60%. Pelicans were not size selective in their predation of Cutthroat Trout. Even the largest Cutthroat Trout tagged (>400 mm TL) were consumed in proportion to their numbers released. Our independent methods

TABLE 3. Total predation rate estimates on Yellowstone Cutthroat Trout by American white pelicans in the upper Blackfoot River drainage, Idaho. Year-specific tagging data and estimated predation rates are shown. The Wildlife Management Area is abbreviated as WMA; NA = not applicable.

							Predation rate		
								90% CI	
Tag location	Size-class	Tag type	Year	Number tagged	Number recovered	Total consumed	Estimate (%)	Lower limit	Upper limit
Reservoir	Adult	Radio	2010	45	8	17	37.8	23.6	51.9
Reservoir	Adult	Radio	2011	49	8	16	32.7	19.5	45.8
Reservoir	Adult	PIT	2010	59	4	19	32.2	17.1	47.3
Reservoir	Adult	PIT	2011	30	1	8	26.7	1.5	51.8
Trap	Adult	PIT	2010	901	14	68	7.5	5.5	9.6
Trap	Adult	PIT	2011	11	0	NA	NA		
Trap	Adult	PIT	2012	512	58	120	23.4	20.4	26.5
Trap	Adult	PIT	2013	1,820	178	441	24.2	21.5	27.0
WMA	Adult	PIT	2010	78	1	5	6.4	0.7	12.1
WMA	Adult	PIT	2011	77	3	25	32.5	15.0	49.9
WMA	Adult	PIT	2012	325	38	79	24.3	20.6	28.0
WMA	Adult	PIT	2013	188	46	114	60.6	51.6	69.6
WMA	Juvenile	PIT	2010	165	24	117	70.9	55.6	86.2
WMA	Juvenile	PIT	2011	161	7	58	36.0	22.6	49.5
WMA	Juvenile	PIT	2012	159	8	17	10.7	7.4	14.0
WMA	Juvenile	PIT	2013	73	10	25	34.2	24.7	43.8

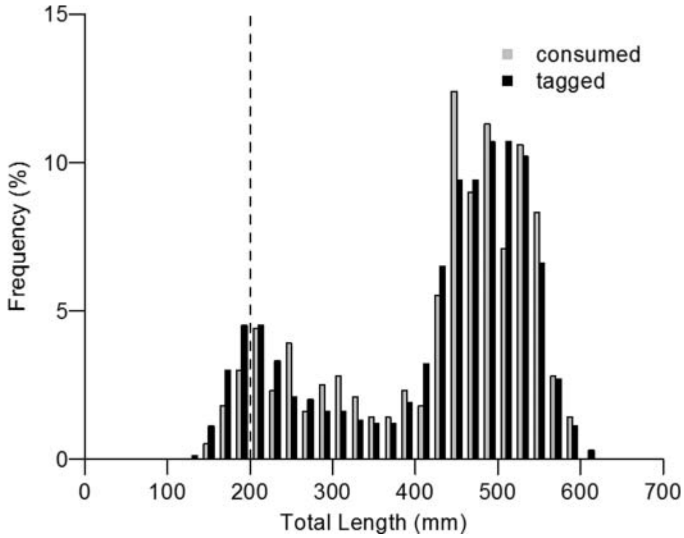

FIGURE 3. Comparison of length-frequency histograms for Yellowstone Cutthroat Trout tagged and recovered (i.e., consumed by American white pelicans) from the nesting islands on Blackfoot Reservoir. Total lengths from all years, tag types, and tagging locations were pooled. The majority of fish tagged and consumed by pelicans in this study exceeded common prey lengths (< 200 mm denoted by the vertical line) of other avian predators nesting on Gull Island.

(radiotelemetry and PIT tagging) used on adult Cutthroat Trout produced similar predation rate estimates.

Our findings contradict conclusions of previous authors that have documented markedly lower pelican predation rates on salmonid stocks. The apparent contradiction may be due to estimates of low trout composition in pelican diet samples and the observation that the American white pelican only forages on the water surface where trout are typically unavailable due to their deeper depth distribution (Findholt and Anderson 1995b; Derby and Lovvorn 1997). However, migrating salmonids are vulnerable to piscivorous birds (White 1957; Ruggerone 1986; Kennedy and Greer 1988). Adult Cutthroat Trout are especially vulnerable during spawning runs (Davenport 1974), and pelican foraging can be spatially and temporally associated with Cutthroat Trout spawning-related abundance on the Yellowstone River (Kaeding 2002). These observations are consistent with reports of pelicans preying heavily on spawning runs of the Tui Chub (Knopf and Kennedy 1980) and the Cui-ui (Scoppettone and Rissler 2002; Murphy 2005; Scoppettone et al. 2014) in the Pyramid Lake system, Nevada. The apparent focus of pelicans on spawning runs of various fishes is an example of their widely reported opportunistic nature in which they change diet and foraging locations in response to changes in prey vulnerability (e.g., Findholt and Anderson 1995b).

Natural predation rates by pelicans on this Cutthroat Trout stock may have been higher than our estimates. During this study period, the Idaho Department of Fish and Game implemented hazing programs to reduce pelican predation. The hazing program included human disturbance by driving a vehicle or walking along the river and dispersing large flocks of foraging pelicans by shooting pyrotechnics. In addition to the hazing program, American badgers *Taxidea taxus* and striped skunks *Mephitis mephitis* were introduced to Gull Island in 2010 in an attempt to replace those removed from the island in 1990–1992. Those reintroductions have not been successful. We include these topics to inform readers that the predation rates reported herein may be conservative compared with systems without those types of management activities.

The importance of correcting for consumed but unrecovered tags in avian predation studies cannot be overstated. Many avian predation studies have reported minimum predation rate estimates because off-island tag depositions were unaccounted for (Evans et al. 2012; Frechette et al. 2012; Sebring et al. 2013). In two more recent publications, however, predation rate estimates were made that accounted for all ingested tags (Osterback et al. 2013; Scoppettone et al. 2014). Both of the most recent research groups fed a known number of tagged fish to birds. Their findings were similar to ours in that tag recoveries from nesting islands explained less than 10% of the known number of fish consumed. Therefore, without correcting for unrecovered tags, predation rate estimates of avian-caused mortality on two imperiled fish stocks would have been underestimated by nearly an order of magnitude. In this study, the corrections for unrecovered tags increased raw tag recoveries by an average of 70%. Given the magnitude of these unrecovered tag corrections, we recommend that future research on avian predation rates focus more on that variable.

There are several limitations of this study that should be considered. First, we assumed that tagged fish were not more vulnerable to predation than untagged fish. If tagging increased vulnerability to avian predators, then we would have overestimated predation rates. Secondly, some of our predation rate estimates are based on a small number of tag recoveries and should be interpreted cautiously (Table 2). Thirdly, if other avian birds consumed and deposited Cutthroat Trout tags on Gull Island, then we would have overestimated the predation rates by pelicans.

Although double-crested cormorants and Caspian terns were present in the study area and can be effective salmonid predators (Kennedy and Greer 1988; Evans et al. 2012), these species did not appear to contribute materially to Cutthroat Trout mortality in the upper Blackfoot River system during our study. First, Caspian tern abundance near the Blackfoot Reservoir is extremely low, with only a single nest observed during our 4-year study period (Table 1). Second, we had been documenting hourly use by piscivorous birds at numerous sites along the Blackfoot River using remote photography (Teuscher and Schill 2010); one of 95,860 remote images taken along the Blackfoot River since 2007 is shown in Figure 2. The vast majority of piscivorous birds observed (>99%) in those photographs have been pelicans. For example, in 2010, we archived 19,283 photographs. In those photographs, we counted 25,770 incidents of pelicans using the river compared with only 39 observations of double-crested cormorants. Third, PIT tag recoveries from Gull and Willow islands were highly correlated to pelican production on those islands ($r = 0.97$). For example, in 2012, we recovered 18% of the Cutthroat Trout tags from Gull Island where 20% of the pelican colony was nesting. The remaining 80% of the pelican colony nested on Willow Island and deposited 82% of the Cutthroat Trout tags on that island, where pelicans were nesting exclusively. If the other avian predators nesting on Gull Island were significant contributors to Cutthroat Trout mortality, we would expect to see a higher proportion of tag recoveries from Gull Island compared with the proportion of the pelican colony nesting there. Fourth, the size of prey commonly consumed by double-crested cormorants (<200 mm TL: Hatch and Weseloh 1999; Johnson et al. 2006) is smaller than the majority of Cutthroat Trout tagged in this study (Figure 3). Finally, in 2013 we scanned double-crested cormorant nests to document their relative contribution to Cutthroat Trout predation. We recovered two Cutthroat Trout tags in double-crested cormorant nests, which accounted for less than 1% (2 of 236) of all the Cutthroat Trout tag recoveries in 2013. Interestingly, during the nest searches of double-crested cormorants, we recovered hundreds of PIT tags from hatchery trout stocked in several other local fisheries.

The recently established American white pelican colony on Blackfoot Reservoir has created a new challenge for resource managers. Past overexploitation of the Yellowstone Cutthroat Trout stock by anglers was alleviated by implementing highly restrictive fishing regulations (LaBolle and Schill 1988). As anticipated, the Blackfoot Reservoir Cutthroat Trout stock expanded rapidly after eliminating nearly all angler-caused mortality. The Cutthroat Trout recovery, however, was short-lived, and it appears that predation from a burgeoning pelican population is reducing Cutthroat Trout abundance. Achieving fishery management goals that call for a recovery of the Cutthroat Trout stock to the levels experience by anglers in the late 1960s will require a reduction in pelican predation. Attaining that goal will require extensive coordination between state and federal agencies and will likely include a measured reduction in Blackfoot Reservoir's pelican nesting colony.

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