FISHERY RESEARCH

PROJECT 5: LAKE AND RESERVOIR RESEARCH

ANNUAL PROGRESS REPORT
July 1, 2016 — June 30, 2017

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IDFG Report Number 17-12
September 2017

PROJECT 5: LAKE AND RESERVOIR RESEARCH

Annual Performance Report

June 30, 2016 to July 1, 2017

Grant #F-73-R-39

Project 5 – Lake and Reservoir Research

Subproject 1: Predation by double-crested cormorants and other avian piscivores on hatchery stocked rainbow trout in reservoir fisheries

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IDFG Report Number 17-12
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State of: Idaho

Grant No.: F-73-R-39, Fishery Research

Project No.: 5

Title: Lake and Reservoir Research

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Contract Period: June 30, 2016 to July 1, 2017

ABSTRACT

Abundance of many piscivorous birds such as double-crested cormorants *Phalacrocorax auritus* and American white pelicans *Pelecanus erythrorhynchos* has increased in recent decades in North America. Predation by these birds on fisheries in Idaho has become a concern for fisheries managers. We stocked two sizes of hatchery trout (250mm and 300mm) tagged with PIT, radio, and T-bar anchor tags into ten Idaho waterbodies and estimated angler catch and predation by avian piscivores. The estimated angler catch averaged 14% while avian predation averaged 36.6%. Predation specifically attributed to double-crested cormorants and American white pelicans was estimated at 22% and 14%, respectively. Avian predation rates were similar for standard (250mm) and magnum (300mm) sized catchables. Our results suggest that in some southern Idaho fisheries, piscivorous birds, rather than anglers, are the dominant users of the hatchery trout resource.

INTRODUCTION

Abundance of many piscivorous birds such as double-crested cormorants *Phalacrocorax auritus* (hereafter cormorants) and American white pelicans *Pelecanus erythrorhynchos* (hereafter pelicans) has increased in recent decades in North America. Population increases are generally attributed to the passage of the Migratory Bird Act and to the discontinued use of organochlorine pesticides such as DDT. Avian predators such as cormorants and pelicans have exerted measurable predation pressure on several freshwater fisheries and aquaculture facilities (Dorr and Fielder 2017). The Idaho Department of Fish and Game (IDFG) stocks approximately 1.5 million catchable sized (≥250mm) Rainbow Trout *Oncorhynchus mykiss* annually into lakes and rivers around the state. Recently, substantial levels of predation of wild and hatchery reared trout by cormorants and pelicans in Idaho has been documented (Teuscher et al. 2015; Meyer et al. 2016).

Methods for estimating such predation typically involve tagging a proportion of stocked fish and recovering those tags at bird nesting, roosting, or loafing areas. Such estimates are considered to be minimum predation estimates because they do not account for consumed tags that are not recovered, thus tag recovery efficiency must be accounted for to produce total predation estimates. Teuscher et al. (2015) estimated tag recovery efficiency by directly feeding dead trout tagged with passive integrated transponders (PIT) to pelicans and recovering tags deposited at nesting and roosting sites. Using this approach, the authors estimated that 6.4-60.6% of adult Yellowstone Cutthroat Trout were consumed by pelicans in the Blackfoot River drainage of Idaho. Using the same methods, Meyer et al. (2016) estimated that pelicans consumed an average of 22% (range: 0-65%) of Rainbow Trout stocked in 12 Idaho Reservoirs. The estimated total predation of hatchery fish by cormorants averaged 21% (range: 5-69%), when using the tag recovery rate calculated for pelicans. However, estimating tag recovery efficiency for cormorants by feeding tagged hatchery fish was not possible because of different behavior.

In our study, we released fish tagged with both PIT and radio tags and used the recovery ratio of each tag type to calculate tag recovery efficiency and estimate total rather than minimum predation. We also estimated angler exploitation to compare to avian predation. Previous research comparing angler exploitation of different sized fish suggests that larger fish return to creel at higher rates than smaller fish (Cassinelli et al. 2016), and IDFG subsequently switched from stocking trout averaging ~250mm (hereafter “standards”) to trout averaging ~300mm (hereafter “magnums”) in lentic waters. We estimated avian predation on both sizes of trout to evaluate whether larger fish have an advantage in avoiding predation due to their size.

OBJECTIVES

1. Estimate total predation rates of hatchery stocked Rainbow Trout by cormorants, pelicans, and other avian predators in select southern Idaho reservoir fisheries.

2. Estimate angler exploitation and total use for stocked hatchery trout at the same waters.

3. Compare predation rates of “standard” and “magnum” sized fish by cormorants and pelicans.

METHODS

Study areas

In 2015, we estimated bird predation and angler exploitation by stocking tagged hatchery Rainbow Trout into Lamont, Johnson, Deep Creek, Foster, Glendale, and Treasureton reservoirs. These reservoirs are primarily irrigation water storage reservoirs but are also popular sport fisheries. Tags were recovered at cormorants nesting/roosting sites at Blackfoot Reservoir, Foster Reservoir, along shore at Johnson and Treasureton, and a great blue heron *Ardea herodias* (hereafter herons) roosting site near Smithfield, Utah.

In 2016, we released tagged fish into Foster, Glendale, Treasureton, Chesterfield, American Falls, Emerald, and Rupert Gun Club reservoirs. The reservoirs were chosen as study sites due to their proximity to cormorants nesting/roosting sites and the observed presence of cormorants at these waters (Table 1.) Tags were recovered at the nesting colonies at Blackfoot Reservoir, Minidoka National Wildlife Refuge (NWR), Foster Reservoir, and along shore at Treasureton and Chesterfield reservoirs.

Fish tagging

In 2015 and 2016 stocked fish were tagged using various combinations of T-bar anchor tags, PIT tags, and radio tags (Table 2.) T-bar anchor tags were placed on fish by inserting the T-bar into the base of the dorsal fin according to standard methods (Dell 1968). The anchor tags were printed with the tag number and the website/phone number where anglers can report the tags to IDFG's "Tag You're It" tag reporting system, designed to track the catch and harvest of fish by anglers statewide. Half-duplex PIT tags (23 x 3mm) were inserted into body cavity using a 6 gauge hypodermic needle according to Prentice et al. (1990). In 2015, only standard sized catchables were tagged and stocked. In 2016, equal numbers of "standard" and "magnum" sized catchables were tagged with anchor and PIT tags. Radio tags (MST-093 Lotek) were surgically implanted into the body cavity of the fish by making a small incision into the ventral wall anterior to the pelvic girdle (Hart and Summerfelt 1975). A grooved needle shield was inserted posteriorly past the pelvic girdle and a 6 gauge needle was inserted between the pelvic girdle and the anal vent using the shielded needle technique to protect the internal organs and direct the needle under the pelvic girdle and through the incision on the body wall (Ross and Kleiner 1982). The radio antenna was threaded through the needle so the antenna exited through the hole made by the needle. While threading the antenna, the tag was inserted into the body cavity along with a PIT tag. The incision was closed using 2 sutures. Fish were placed in recovery water and monitored for at least 24 h prior to release. Only "magnum" sized fish were implanted with radio tags in 2016. These radio tags were equipped with internal motion sensors to emit a mortality signal if the tag had not moved for 12 h, allowing for identification of fish mortalities due to predation or other causes, depending on location and detection history.

Radio telemetry

Fixed radio receivers (Lotek SRX-400) were installed at American Falls, Blackfoot, Chesterfield, Foster, and Glendale reservoirs to monitor lifespan of radio-tagged fish where they were stocked and also to determine if they were removed by predators. Fixed receivers were also installed to scan the cormorant and pelican colonies at Minidoka NWR and at Blackfoot Reservoir. Receivers were programmed to scan tag-specific frequencies (150.380, 150.360, and 150.320 Mhz) every six seconds. At Rupert Gun Club Pond and Emerald Lake, mobile telemetry tracking was conducted from the shore because of the concern for vandalism of fixed sites. At fixed sites, we installed a lockable metal box that held the receiver and a 12V battery. Two Yagi antennae with 3-4 elements were mounted on a t-post and connected to the receiver with coaxial cable. Antenna were set with elements perpendicular to the ground and aimed in directions to maximize scanning area.

Tag recovery

We recovered PIT tags deposited by birds at the colony sites comprising three small islands at Minidoka NWR, Gull Island at Blackfoot Reservoir, and the island at Foster Reservoir. Several PIT tags were also recovered at the primary bird loafing areas at Treasureton and Chesterfield Reservoirs; however, we were not able to feasibly scan all the possible bird use areas at these reservoirs. We detected PIT tags using Oregon RFID HDX backpack PIT tag readers attached to a 2m long pole with a 0.5m diameter hoop antenna on the end with a detection range of approximately 0.5m from the edge of the hoop. The recovery area was searched systematically by walking 2m transects while sweeping the antenna side to side until all the ground at recovery locations was scanned. When tags were detected, locations were marked with a survey flag. We used Biomark 601 handheld PIT tag readers (Biomark, Boise, Idaho) to precisely locate tags, and recovered tags by digging and scanning small amounts of material and using trowels and sieves when necessary (Teuscher et al. 2015; Meyer et al. 2016).

We recovered deposited radio tags using a handheld Lotek SRX-800 telemetry receiver and Yagi antenna. In addition to searching for radio tags in the same areas we searched for PIT tags, we conducted a more extensive scan over all of the study waters in a fixed wing aircraft outfitted with 3 directional antennae. A single flight was done at the end of each season, when bird surveys and tag recoveries on colonies were complete. Tags detected aerially were subsequently located by foot.

Bird surveys

While tags recovered in avian nesting/loafing/roosting areas were considered known fish mortalities by avian predators, assigning predation to cormorants, pelicans, or other avian predators sometimes (but not always) required knowledge of avian predator abundance either at the tag recovery location or the stocking water. To gather data on bird abundance, non-random bird counts (n=10) were conducted at Foster and Treasureton reservoirs in 2015 when technicians were present for radio telemetry tracking or radio receiver maintenance. In 2016, bird counts were randomly conducted at each waterbody once per week from 31 May to 3 October. Survey days and times (between 800-1800hr) were randomly assigned for each group of waterbodies. Due to the relative proximity of waterbodies, Rupert Gun Club Pond and Emerald Lake were surveyed on the same day. Likewise, Treasureton, Foster, Glendale, and Chesterfield Reservoirs were surveyed during the same day. Using binoculars either from shore or from a boat, we counted the number of cormorants, pelicans, herons, and osprey *Pandion haliaetus* present at the time of the count.

Data analysis

Predation estimates

Minimum predation estimates from recovered PIT ($Pred_{PIT}$) and radio tags ($Pred_{RADIO}$) were calculated by dividing the number of tags recovered by the number of tags stocked at each location. Variances for these proportions (Fleiss et al. 2003) were calculated using the formula:

$$Var(proportion) = \sqrt{\frac{P(1-P)}{n}}$$

where P is the proportion of recovered tags and n is the number of stocked tags. Ninety percent confidence intervals were calculated accordingly for each waterbody. A t-test was used to compare fish lengths of preyed upon fish that were PIT tagged.

Tag recovery efficiency

Recovery of PIT tags alone provides only minimum predation estimates because the actual number of deposited tags is unknown. Therefore, a tag recovery efficiency based on double-tagged fish (radio and PIT) was calculated to partially correct minimum predation estimates. We assumed that any radio tags deposited in our searched areas were detected and recovered because the detection range for radio tags (>150m) is many times greater than for PIT tags (<1m). Tag recovery efficiency (Tag_{rec}) estimates were calculated as the proportion of recovered radio tags that also had the accompanying PIT tag recovered. Total predation ($Pred_{Total}$) was calculated as

$$Pred_{Total} = \frac{Pred_{PIT}}{Tag_{rec}}$$

For example, if 10 radio tags from double-tagged fish were recovered, but only 5 PIT tags were recovered, then the PIT tag recovery efficiency (Tag_{rec}) would be 50%. Therefore, minimum predation estimates based on PIT tag recoveries would be doubled. We did not include radio tags that were detected or recovered in areas not also scanned for PIT tags in the recovery efficiency estimate.

Species specific predation

We assigned predator species according to the locations tags were found. Tags were often found in nests and were thus assumed to be eaten by that bird species. For tags found in ambiguous locations, we used the relative proportions of cormorants, pelicans, herons, and osprey counted at the waters from which those tags were stocked to assign predation events to a predator species (Meyer et al. 2016). Species-specific predation was assigned to predation estimates after adjusting for tag recovery efficiency.

Angler exploitation estimates

We estimated total angler use (harvested fish + caught and released fish) and exploitation (harvested fish) of fish stocked into the study waters using T-bar anchor tag returns reported to the IDFG "Tag You're It!" tagged fish reporting program (Meyer and Schill 2014). Estimates were adjusted to account for reporting rate using the equation:

$$\lambda = \frac{Rr/Rt}{Nr/Nt}$$

where Rt and Rr are the number of non-reward tags stocked and reported and Nr and Nt are the number of $50 reward tags stocked and reported (Pollock et al. 2001). We used a $50 reward tag reporting rate of 88% (Meyer et al. 2012). For our study, we used statewide averages of non-reward tag reporting rates and tag loss rates. We estimated angler exploitation (u') using the equation:

$$u' = \frac{u}{\lambda(1 - Tag_l)(1 - Tag_m)}$$

where u is the number of non-reward tagged fish harvested divided by the number of non-reward tags stocked, Tag_l is the first year tag loss rate based on returns data for double tagged fish, and Tag_m is the tagging mortality rate. To estimate total angler use, u was modified to include fish caught and released as well as harvested.

RESULTS

Avian predation

In 2015, 2,490 tagged Rainbow Trout were stocked into six waterbodies in southern Idaho. These fish were tagged with a combination of either T-bar anchor only, PIT only, T-bar anchor and PIT, or PIT and radio tags (Table 2). We estimated minimum avian predation from recovered PIT tags at 20.1%, ranging from 12.5% at Treasureton Reservoir to 37.1% at Foster Reservoir (Table 4). We were only able to estimate recovery efficiency at Treasureton and Foster reservoirs. Using those recovery efficiencies, we adjusted minimum predation upwards to 26.1% at Treasureton and 55.6% at Foster. Predation estimates based solely on radio tag recoveries averaged 22.7%, ranging from 10% at Treasureton to 58.6% at Foster Reservoir.

In 2016, 2,095 Rainbow Trout were stocked into seven waterbodies. These fish were tagged with either T-bar anchor and PIT, PIT only, or PIT and radio tags (Table 2). In 2016, minimum avian predation estimated from PIT tag recoveries averaged 22.1%, ranging from 6.0% at American Falls Reservoir to 55.2% at Rupert Gun Club Pond (Table 4). When accounting for water-specific tag recovery efficiency, mean predation estimates averaged 35%, ranging from 11.6% at American Falls Reservoir to 100% at Rupert Gun Club Pond (Figure 1). Predation rates between magnum and standard sized fish did not differ significantly (t=2.14, P=0.08) (Figure 2).

Species-specific total estimates of predation ranged widely between waters, averaging 22.8% for cormorants, ranging from 2.4% at Chesterfield Reservoir to 90.1% at Rupert Gun Club pond. We estimated that pelican predation averaged 14.1%, ranging from 6.5% at Treasureton Reservoir to 35.3% at Rupert Gun Club pond (Table 5). Predation by GBH was estimated at 11% at Glendale in 2016 and 8.5% and 7% at Foster Reservoir in 2015 and 2016. Great Blue Heron predation was generally negligible elsewhere. Species-specific predation estimates from Rupert Gun Club Pond exceed 100% because of a likely overestimate of tag recovery rate.

Catch and harvest

In 2015 total angler use, which consists of trout caught and released as well as trout harvested, averaged 10.8%, ranging from 1.4% at Lamont and Treasureton reservoirs to 19.4% at American Falls Reservoir (Table 6). During this year, only standard-sized catchables were stocked. Year specific tag reporting rate was 0.52% and tag loss was 0.07%.

In 2016 standards and magnums were stocked in equal proportions into each study water. Estimated angler use was highest at Emerald Lake and Chesterfield Reservoir (26.6%) and lowest at Rupert Gun Club Pond (0.0%), averaging 13.6% among study waters (Table 6). Tag reporting rate was 0.45% and tag loss was 0%.

Bird surveys

We conducted a total of 141 randomized bird counts at Chesterfield, Emerald, Foster, Glendale, Rupert Gun Club, and Treasureton reservoirs from 31 May 2016 to 3 October 2016. Cormorants were the most abundant birds observed at four of the reservoirs. Chesterfield Reservoir had the highest average number of cormorants (12) and pelicans (9) observed. At Glendale Reservoir herons were the most numerous, while pelicans were the most abundant at Treasureton Reservoir (Table 3.)

DISCUSSION

Avian predation on salmonid populations has been the subject of much research across the western United States (Modde et al. 1996; Derby and Lovvorn 1997; Evans et al. 2012; Teuscher et al. 2015; Meyer et al. 2016). These studies use either diet samples or tag recoveries from tagged fish to quantify predation. In studies using tagged fish, tag detection probabilities are estimated by either sowing tags into recovery areas (Evans et al. 2012), an approach that does not account for off-site tag deposition, or by feeding tagged fish directly to birds (Osterback et al. 2013; Scoppettone et al. 2014; Hostetter et al. 2015; Teuscher et al. 2015; Meyer et al. 2016), an approach that is not feasible with some species, including cormorants. We instead used double-tagged fish (PIT and radio), allowing us to account for both consumed PIT tags that went undetected at the nesting colonies and consumed PIT tags that were deposited off colony.

Though our approach to adjusting minimum estimates differed from previous studies, our estimates of predation by cormorants and pelicans are similar to those reported for inland resident fisheries (Modde et al. 1996; Derby and Lovvorn 1997; Teuscher et al. 2015; Meyer et al. 2016). In the Blackfoot River of Idaho, total predation rates on adfluvial Yellowstone Cutthroat Trout by pelicans averaged 26% over four years and ranged from 6-70% (Teuscher et al. 2015). In a more widespread study of avian predation on Idaho fisheries, hatchery-stocked rainbow trout were preyed upon at an average rate of 18% by pelicans (0-65%), with additional predation attributed to cormorants (2-38%), and total bird predation often exceeding angler use (Meyer et al. 2016). Our results add to the growing body of evidence demonstrating predation impacts by cormorants and pelicans on Rainbow Trout among southern Idaho fisheries. We documented avian predation on hatchery stocked Rainbow Trout in 12/13 stocking events in nine waters in 2015 and 2016 using PIT tags and radio tags recovered from nesting colony sites. We also show that the use of double-tagged fish can correct for undetected predation events and adjust minimum predation estimates. Our results suggest that in some southern Idaho fisheries, piscivorous bird predation on hatchery trout exceeds angler exploitation.

During tag recovery efforts on bird colonies, tags recovered directly from bird nests were assumed to be eaten by those specific birds. Many tags were found in ambiguous areas used by cormorants and pelicans. In these instances, proportional bird abundances based on counts at the waters from where these tags were stocked were used to assign predation to a bird species. Limitations to using this method exist, as noted by Meyer et al. (2016). Using proportional abundance to assign predation events to respective bird species assumes that they consume fish at the same rate. It is known that pelicans have a higher daily energy requirement (Hall 1925; Ferguson et al. 2011) than cormorants (Seefelt and Gillingham 2008). Despite this, the numbers of PIT tags found specifically in cormorants nests at Minidoka exceeded the number found in pelicans nests. This suggests that the cormorants simply consumed more Rainbow Trout regardless of the discrepancy in daily energy requirements. It may be that cormorants are simply more effective at preying upon these fish and therefore the trout make up a larger proportion of their diet.

Total use by anglers was similar to predation by pelicans, but less than predation by cormorants. We did not see an overall relationship between predation and angler use, though a few exceptions were evident. Our highest estimated predation (100%) occurred at Rupert Gun Club pond, where 0% angler catch was reported. Overall, total avian predation was more than double the amount of estimated angler use. Because significant resources go into the rearing of hatchery Rainbow Trout, this presents not only an economic issue, but an angler satisfaction issue. If a third of all the Rainbow Trout that get stocked into these waters are eaten by the birds, then fewer fish are available for angler harvest.

RECOMMENDATIONS

Management alternatives for addressing pelican predation identified in the Management plan for the conservation of American white pelicans in Idaho (IDFG 2016) are also applicable to cormorants. These management actions include, but are not limited to, modification of hatchery trout stocking strategies, hazing or lethal take of birds at foraging, loafing, and nesting locations, oiling eggs to reduce recruitment, nesting exclusion or nest destruction, and establishing population number objectives.

ACKNOWLEDGEMENTS

We would like to acknowledge and thank all of the following people who contributed to this study. Staff at American Falls, Grace, and Nampa hatcheries provided fish for this study. Nate Tillotson conducted bird counts, radio telemetry tracking, and radio receiver data collection and maintenance. Dennis Daw tagged fish. Matt Knoff provided valuable technical support for the radio telemetry component of this project. University of Idaho provided radio telemetry equipment. Ross Winton, Doug Megargle, Liz Mamer, John Cassinelli, Kylie Porter, Leah Gunnink, and Chrissy Edwards helped recover tags. Arnie Brimmer and Dave Teuscher provided boats, equipment space, and crucial support from Region 5. Funding for this work was provided by anglers and boaters through their purchase of Idaho fishing licenses, tags, and permits, and from federal excise taxes on fishing equipment and boat fuel through the Sport Fish Restoration Program.

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TABLES

Table 1. Flight distances (km) between study reservoirs and nesting colonies (bolded).

	Foster	Glendale	Johnson	Lamont	Treasureton	Deep Creek	**Blackfoot**	American Falls	Chesterfield	**Minidoka**	Emerald	Rupert Gun Club
Foster		2	3	2.5	12	29	91	115	86	145	164	156
Glendale	2		3	2.5	12	31	91	116	86	147	166	158
Johnson	2	3		0.5	15	32	93	118	89	148	167	159
Lamont	2.5	2.5	0.5		14	31	93	117	89	148	167	159
Treasureton	12	12	15	14		26	83	104	74	140	159	152
Deep Creek	29	31	32	31	26		91	91	78	117	135	128
Blackfoot	91	91	93	93	83	91		94	29	153	177	170
American Falls	115	116	118	117	104	91	94		64	60	86	79
Chesterfield	86	86	89	89	74	78	29	64		124	149	142
Minidoka	145	147	148	148	140	117	153	60	124		30	19
Emerald	164	166	167	167	159	135	177	86	149	30		12
Rupert Gun Club	156	158	159	159	152	128	170	79	142	19	12	

Table 2. Tag types and fish numbers stocked into study waters.

Waterbody	Size (acres)	Size (hectares)	FLOY	PIT + FLOY	PIT	PIT + RADIO	Total	Stocking Date
American Falls Reservoir	55261.0	22363.4		400		30	430	5/17/2016
Chesterfield Reservoir	1245.7	504.1		400		30	430	5/20/2016
Deep Creek Reservoir	162.7	65.8	100	200	100	0	400	5/22/2015
Emerald Lake	33.7	13.6		100	99	30	229	5/16/2016
Foster Reservoir	129.3	52.3		200		30	230	5/16/2016
			100	200	101	29	430	5/21/2015
Glendale Reservoir	203.1	82.2		400		30	430	5/18/2016
			100	200	100		400	5/21/2015
Johnson Reservoir	43.1	17.4	101	199	100	0	400	5/21/2015
Lamont Reservoir	84.5	34.2	102	198	100		400	5/21/2015
Rupert Gravel Pond	10.7	4.3		50	50	16	116	5/16/2016
Treasureton Reservoir	151.7	61.4		200		30	230	5/18/2016
			102	198	100	30	430	5/21/2015

Table 3. The daily mean and total number of double-crested cormorants (DCC), American White Pelicans (AWP), Great Blue Herons (GBH), and Ospreys (OSP) counted at each waterbody from 31 May to 3 October 2016.

Waterbody	DCC	AWP	GBH	OSP	Total
Chesterfield Reservoir					
Daily Mean	12.4	9.2	1.6	0.2	
Range	0-46	0-24	0-7	0-4	
Total	322	240	42	4	608
Emerald Lake					
Daily Mean	1.6	0.3	0.1	0.1	
Range	0-9	0-3	0-1	0-2	
Total	27	5	2	2	36
Foster Reservoir					
Daily Mean	7.5	0.5	2.0	0.2	
Range	2-31	0-8	0-9	0-2	
Total	196	14	52	5	267
Glendale Reservoir					
Daily Mean	1.3	NA	1.5	0.3	
Range	0-7	NA	0-6	0-2	
Total	32	0	37	6	75
Rupert Gun Club Pond					
Daily Mean	0.6	0.2	0.3	0.2	
Range	0-4	0-4	0-2	0-1	
Total	11	4	5	3	23
Treasureton Reservoir					
Daily Mean	4.7	6.8	1.1	0.1	
Range	0-14	0-31	0-2	0-1	
Total	141	204	34	3	382
Grand Total	729	467	172	23	

Table 4. Study waters with numbers of tagged fish stocked and resulting predation estimates for PIT tags, radio tags, and PIT tags adjusted for tag recovery efficiency (total predation).

Release Location	Release Date	PIT tags Recovered	PIT tags stocked	Minimum Predation	95% C.I.	Radio tags recovered	Radio tags stocked	Radio tag predation	95% C.I.	Radio Recovered	Radio with PITs Recovered	Tag recovery efficiency	Total Predation
Foster Reservoir	5/21/2015	122	329	0.371	0.052	13	29	0.448	0.181	12	8	0.67	0.556
Glendale Reservoir	5/21/2015	55	300	0.183	0.044					-	-	-	0.183
Johnson Reservoir	5/21/2015	43	329	0.131	0.036	6	30	0.200	0.143	6	3	0.50	0.261
Lamont Reservoir	5/21/2015	58	298	0.195	0.045					NA	NA	NA	0.195
Treasureton Reservoir	5/21/2015	41	328	0.125	0.036	1	30	0.033	0.064	1	0	NA	0.125
Deep Creek Reservoir	5/22/2015	0	400	0.000	0.000								0.000
American Falls Reservoir	5/17/2016	25	430	0.058	0.022	2	30	0.067	0.089	2	1	0.50	0.116
Magnums		9	230	0.039	0.025								0.078
Standards		16	200	0.080	0.038								0.160
Chesterfield Reservoir	5/20/2016	51	430	0.119	0.031	9	30	0.300	0.164	7	4	0.57	0.208
Magnums		34	230	0.148	0.046								0.259
Standards		17	200	0.085	0.039								0.149
Emerald Lake	5/16/2016	80	229	0.349	0.062	11	30	0.367	0.172	11	8	0.73	0.480
Magnums		42	129	0.326	0.081								0.448
Standards		38	100	0.380	0.095								0.523
Foster Reservoir	5/18/2016	59	230	0.257	0.056	11	30	0.367	0.172	10	8	0.80	0.321
Magnums		32	130	0.246	0.074								0.308
Standards		27	100	0.270	0.087								0.338
Glendale Reservoir	5/18/2016	39	430	0.091	0.027	5	30	0.167	0.133	5	2	0.40	0.227
Magnums		23	230	0.100	0.039								0.250
Standards		16	200	0.080	0.038								0.200
Rupert Gun Club Pond	5/16/2016	64	116	0.552	0.091	9	16	0.563	0.243	9	4	0.44	1.000
Magnums		36	66	0.545	0.120								1.000
Standards		28	50	0.560	0.138								1.000
Treasureton Reservoir	5/18/2016	28	230	0.122	0.042	6	30	0.200	0.143	3	3	1.00	0.122
Magnums		17	130	0.131	0.058								0.131
Standards		11	100	0.110	0.061								0.110

Table 5. 2015 and 2016 Bird specific total predation by double-crested cormorants (DCC), American White Pelicans (AWP), Great Blue Herons (GBH), and Ospreys (OSP).*Recovery efficiency estimates adjusted total predation to >100%

	DCC	AWP	GBH	OSP
2015				
Foster	28.5		8.5	
Treasureton	7.1	3.4	2	
2016				
American Falls	3.3	8.4	0.0	0.0
Chesterfield	2.4	18.4	0.0	0.0
Emerald	35.3	12.6	0.0	0.0
Foster	24.5	0.0	7.1	0.5
Glendale	9.9	0.0	11.0	1.7
RGC	90.1*	35.3*	0.0	0.0
Treasureton	4.3	6.5	1.3	0.0

Table 6. Angler exploitation and use of hatchery rainbow trout for study waters in 2015 and 2016. Estimates of angler exploitation and use are adjusted to account for year specific tag loss and tag reporting rates.

Water Body	Hatchery	Tagging Date	Treatment	Exploitation	90% CI	Total Use	90% CI
2015							
Deep Creek Reservoir	Nampa	5/26/2015	Standards	9.7	4.8	19.4	7.1
Foster's Reservoir	Grace	5/21/2015	Standards	9.7	4.8	10.4	5.0
Glendale Reservoir	Grace	5/21/2015	Standards	6.2	3.8	17.4	6.7
Johnson Reservoir	Grace	5/21/2015	Standards	6.2	3.8	14.6	6.0
Lamont Reservoir	Grace	5/21/2015	Standards	0.7	1.2	1.4	1.7
Treasureton Reservoir	Grace	5/21/2015	Standards	0.0	0.0	1.4	1.7
2016							
American Falls Reservoir	American Falls	5/16/2016	Magnums	10.0	5.7	15.5	7.1
American Falls Reservoir	American Falls	5/16/2016	Standards	3.3	3.2	5.5	4.2
Chesterfield Reservoir	Grace	5/16/2016	Magnums	8.9	5.3	14.4	6.9
Chesterfield Reservoir	Grace	5/16/2016	Standards	17.7	7.7	26.6	9.6
Emerald Lake	Nampa	5/16/2016	Magnums	8.9	10.3	17.7	14.4
Emerald Lake	Nampa	5/16/2016	Standards	22.2	16.0	26.6	17.5
Foster's Reservoir	Grace	5/16/2016	Magnums	24.4	12.2	24.4	12.2
Foster's Reservoir	Grace	5/16/2016	Standards	13.3	9.0	15.5	9.7
Glendale Reservoir	Grace	5/16/2016	Magnums	17.7	7.7	22.2	8.7
Glendale Reservoir	Grace	5/16/2016	Standards	8.9	5.3	8.9	5.3
Rupert Rod and Gun Club	Nampa	5/16/2016	Magnums	0.0	0.0	0.0	0.0
Rupert Rod and Gun Club	Nampa	5/16/2016	Standards	0.0	0.0	0.0	0.0
Treasureton Reservoir	Grace	5/16/2016	Magnums	0.0	0.0	6.7	6.4
Treasureton Reservoir	Grace	5/16/2016	Standards	0.0	0.0	6.7	6.4

FIGURES

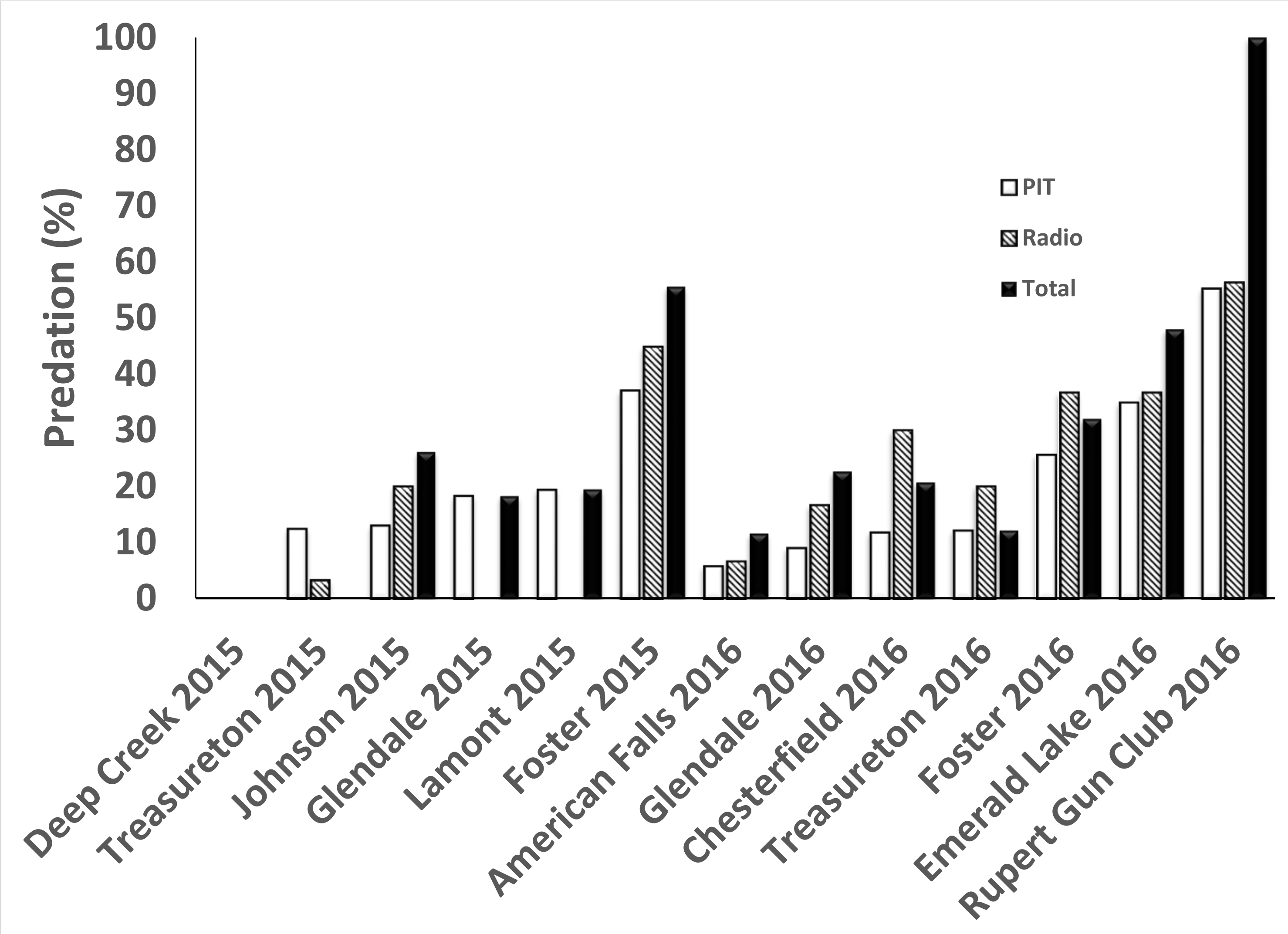

Figure 1. Avian predation estimates based on PIT tags, radio tags, and PIT tags corrected for tag recovery efficiency based on fish tagged with both PIT and radio tags (total).

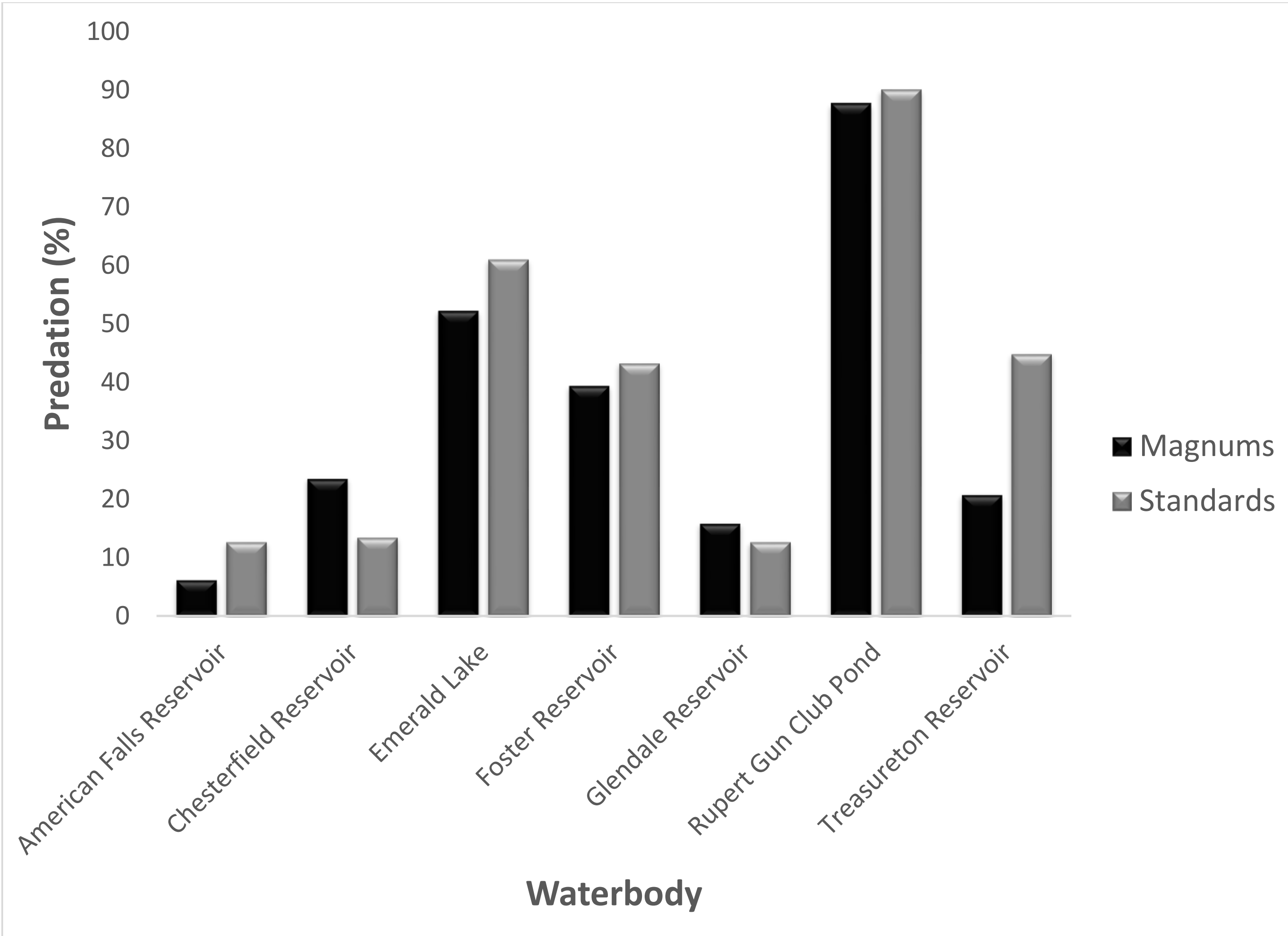

Figure 2. Minimum avian predation estimates of magnum (~300mm) and standard (~250mm) sized hatchery Rainbow Trout tagged with passive integrated transponders (PIT) and stocked into reservoir fisheries. Estimates are based on PIT tags recovered from bird nesting, loafing, or roosting locations.

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