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ARTICLE

Predation by American White Pelicans and Double-Crested Cormorants on Catchable-Sized Hatchery Rainbow Trout in Select Idaho Lentic Waters

Kevin A. Meyer,* Christopher L. Sullivan, Patrick Kennedy, and Daniel J. Schill
Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686, USA

David M. Teuscher and Arnie F. Brimmer
Idaho Department of Fish and Game, 1345 Barton Road, Pocatello, Idaho 83204, USA

D. Tommy King
U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Post Office Box 6099, Mississippi State, Mississippi 39762, USA

Abstract
In southern Idaho, population growth of American white pelicans *Pelecanus erythorhynchos* at the Blackfoot Reservoir and Lake Walcott colonies since the early 1990s has generated concerns about whether pelican predation is impacting angler catch of hatchery trout stocked in Idaho waters. To evaluate this concern, we estimated rates of pelican predation (i.e., the proportion of fish consumed by pelicans) and angler catch (i.e., the proportion of fish caught by anglers) for 19 unique springtime fish stocking events over 3 years across 12 study waters; where feasible we also estimated double-crested cormorant *Phalacrocorax auritus* predation. Stocked Rainbow Trout *Oncorhynchus mykiss* averaged 247 mm in length and were internally PIT-tagged (to monitor bird predation) and externally anchor-tagged (to monitor angler catch) before stocking. Additional hatchery trout were PIT-tagged, euthanized, and fed directly to pelicans to estimate PIT tag deposition rates at the colonies; feeding was unsuccessful for cormorants. After the juvenile pelicans and cormorants fledged in the fall, we recovered PIT tags from stocked and fed fish that were deposited at the two colonies. Deposition rates for pelican-consumed tags averaged 21% and declined exponentially as distance increased from the colonies. Pelican predation on hatchery trout averaged 18% and ranged from 0 to 48%, whereas angler catch averaged 21% and ranged from 0 to 82%. Mean angler catch was nearly four times higher when pelican predation was low (i.e., <25%) than when pelican predation was high (≥25%). Cormorant predation estimates (available for seven stocking events) were minimum estimates only (i.e., they assumed 100% of tags consumed by cormorants were recovered) and averaged 14% (range, 2–38%). Our results suggest that predation by American white pelicans and double-crested cormorants on catchable-sized hatchery Rainbow Trout stocked in southern Idaho waters often exceeds the total catch of those fish by anglers who compete directly with avian predators for use of stocked trout.

American white pelicans *Pelecanus erythorhynchos* (hereafter pelicans) experienced long-term declines in abundance across North America until the 1960s (Knopf and Evans 2004). The cause of the decline is not clear but was likely related to a lack of federal and state protection and the extensive use of pesticides prior to the 1960s (Keith 2005). Regardless of what caused the decline, since the early 1990s pelicans have experienced an almost exponential rebound in abundance (King and Anderson 2005), including in Idaho (IDFG 2009).

*Corresponding author: kevin.meyer@idfg.idaho.gov
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While recent increases in abundance are positive signs for the conservation of American white pelicans across North America, the increasing population size has also resulted in documented cases of pelican predation impacts on native fish populations and important recreational fisheries. For example, pelicans can capitalize on fish spawning migrations (Findholt and Anderson 1995; Murphy and Tracy 2005; Scoppettone et al. 2014), including in Idaho where pelicans frequently consume substantial portions of the spawning migration of native Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* in the Blackfoot River system (Teuscher and Schill 2010; Teuscher et al. 2015). Substantial levels of pelican predation have also been documented on hatchery trout within days of individual stocking events (Derby and Lovvorn 1997). Such impacts are not surprising for a generalist predator such as the American white pelican that exhibits plasticity in its opportunistic feeding habits (Hall 1925; Knopf and Kennedy 1980). With the noticeable increase in the presence of pelicans at local fisheries, anglers and fisheries management agencies are increasingly interested in quantifying the impact that pelicans may be having on fisheries.

Recent innovative research investigating avian predation on salmonids in the Pacific Northwest has focused on the recovery of PIT tags at bird colonies that were implanted in salmonids and subsequently consumed by nesting birds and deposited at the colonies (Evans et al. 2012; Sebring et al. 2013). Although PIT tag recovery efficiency at the colonies has been estimated by intentionally sowing “control tags” onto the bird colony before PIT tag recovery efforts are undertaken, a shortcoming to this approach is that off-colony deposition rate is unknown. Consequently, PIT tag recoveries using this methodology only provide minimum predation estimates since not all tags that are consumed by birds are deposited at and recovered from the colony. We used an updated modification to this approach that incorporates off-colony deposition into the predation estimates (Osterback et al. 2013; Scoppettone et al. 2014; Hostetter et al. 2015; Teuscher et al. 2015), thereby producing estimates of total predation (rather than minimum predation) by pelicans. The primary objective of this study was to estimate predation rates by American white pelicans on catchable-sized (i.e., ~250 mm TL) hatchery Rainbow Trout *O. mykiss* stocked in several southern Idaho reservoirs and community ponds to gauge their general impact on hatchery-supported trout fisheries in southern Idaho.

In instances where pelican predation of stocked hatchery fish is relatively high, it follows that angler catch (i.e., the proportion of the stocked fish caught and therefore used by anglers) of those same fish would likely be minimal since a large portion of the stocked fish would have been consumed by pelicans before anglers could successfully catch them. However, angler catch of hatchery trout stocked in lentic environments is affected by numerous factors other than pelican predation, such as rearing conditions in the hatchery (e.g., Davison 1997; Barnes et al. 2009), season of stocking and size at release (Yule et al. 2000), water quality (Koenig and Meyer 2011), and the presence of piscine and other avian predators (Derby and Lovvorn 1997). Thus a low rate of pelican predation would not necessarily translate directly into high rates of angler catch. Likewise, we expected that pelican predation, at least by breeding adults, would always be low at great distances from a colony because breeding birds would choose to forage at waters closer to their nest. However, at waters in close proximity to colonies, pelican predation would not necessarily be high since it is affected by more than just travel distance from the nest to the foraging water, such as water depth (Kaeding 2002; Ivey and Herziger 2006) and water clarity (Anderson 1991) where the birds are foraging, the vulnerability of specific prey (Findholt and Anderson 1995), and forage abundance (Kaeding 2002). Secondary objectives were to evaluate relationships between rates of pelican predation and angler catch, and rates of pelican predation and distance from colonies.

Similar to American white pelicans, double-crested cormorants *Phalacrocorax auritus* (hereafter cormorants) have also increased in abundance in recent decades throughout North America (Wires and Cuthbert 2006; Adkins et al. 2014), including in Idaho. The increased abundance of this fish predator has led to numerous conflicts with important economic fish industries in North America, especially Great Lakes sport fisheries (Burnett et al. 2002; Lantry et al. 2002; Fielder 2008) and the aquaculture industry in the southeastern United States (Glahn et al. 2000; Dorr et al. 2012). As with pelicans, cormorants can also be very effective predators of hatchery trout (Modde et al. 1996; Derby and Lovvorn 1997; Skiles 2008). Accordingly, a final study objective was to estimate cormorant predation on catchable-sized Rainbow Trout stocked in some of these same Idaho waters.

STUDY AREA

In Idaho, American white pelicans nest primarily at two adjacent islands in the Blackfoot Reservoir and at three adjacent islands in Lake Walcott (also a reservoir), the latter of which is part of the Minidoka National Wildlife Refuge. Pelicans in recent years have also been attempting to nest at an island in Island Park Reservoir in eastern Idaho but success has been limited. Neighboring pelican colonies include Molly Island at Yellowstone National Park in northwestern Wyoming, Gunnison Island at the Great Salt Lake in northern Utah, Badger Island on the Columbia River in southwestern Washington, and the Malheur National Wildlife Refuge in eastern Oregon (Figure 1). Double-crested cormorants also nest at the Blackfoot Reservoir and Lake Walcott pelican colonies, as well as several other locations throughout Idaho.

The Idaho Department of Fish and Game (IDFG) annually stocks about 1.8 million hatchery Rainbow Trout of catchable size (i.e., about 250 mm TL)—hereafter referred to as hatchery catchable trout—in numerous lakes and rivers of Idaho to

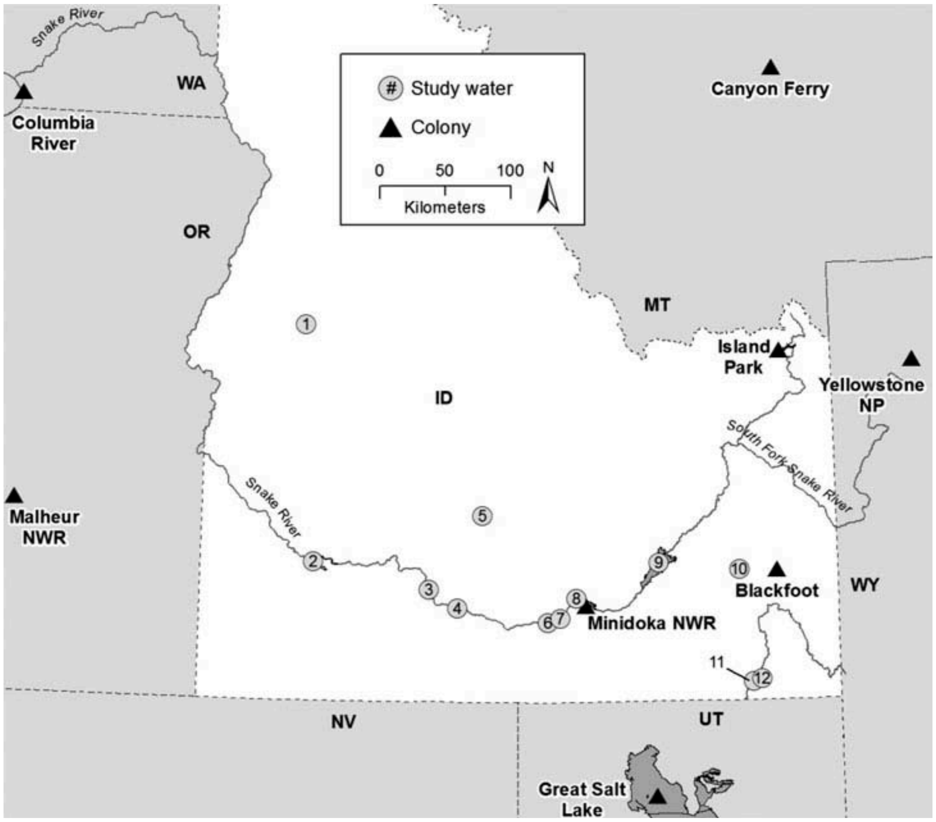

FIGURE 1. American white pelican colonies nearest to the study waters in southern Idaho where American white pelican and double-crested cormorant predation of hatchery catchable Rainbow Trout was evaluated. Study-water numbers correspond to study-water names in Table 1.

provide put-and-take trout fisheries for Idaho anglers. For this particular study, we monitored pelican and cormorant predation and angler catch of hatchery catchable trout stocked in 12 study waters across southern Idaho (Figure 1; Table 1). Study waters were not selected at random, but instead were selected primarily to (1) investigate pelican predation in several southern Idaho fisheries known or suspected to be receiving substantial pelican use and (2) gain perspective on possible geographical gradients in pelican predation rates across southern Idaho in relation to Idaho's primary pelican nesting locations. Cormorants were known to forage on all study waters as well. In some waters, hatchery catchable trout were the only fish present, but in most waters pelicans and cormorants could forage on a variety of other fishes (Table 1), including several species of centrarchids, cottids, cyprinids, catostomids, and other salmonids.

Distances from the study waters to the nearest of the two primary Idaho pelican colonies ranged from 0 to 304 km (Table 1). The soaring ability of pelicans enables them to forage at distances of up to 300 km from their nests (Johnson and Sloan 1978; Trottier et al. 1980; O'Malley and Evans 1982). In contrast, the maximum foraging distance for cormorants is only about 50 km from their nests (Custer and Bunck 1992; Bugajski et al. 2012). Thus, for study waters within 50 km of the colonies, PIT-tagged fish consumed by avian predators and deposited at the Blackfoot Reservoir or Lake Walcott colonies could have been the result of pelican or cormorant predation, whereas for waters more than 50 km from a colony, tag deposition at the colony likely could only have been the result of pelican predation. This distinction was important for our approach to estimating pelican and cormorant predation.

METHODS

Estimating the rate of pelican and cormorant predation on hatchery catchable trout involved four steps outlined in detail below but summarized here. The first step was to stock PIT-tagged hatchery catchable trout into our study waters that were then vulnerable to pelican and cormorant predation. A second step was to PIT-tag other hatchery fish, euthanize them, and feed them directly to pelicans at many (but not all) of the study waters, which allowed us to estimate tag deposition rates at the colonies; direct feeding of cormorants was attempted but was unsuccessful. The third step occurred after pelicans and cormorants on the Blackfoot Reservoir and Lake Walcott colonies had fledged

TABLE 1. Characteristics of the study waters and their distance (km) from the nearest colonies to the waters stocked with PIT-tagged, catchable-sized Rainbow Trout that were then exposed to American white pelican and double-crested cormorant predation. Numbers in bold italics indicate study water × colony combinations where PIT tag recoveries actually occurred at colonies. Numbers also underlined indicate study water × colony combinations where cormorants may also have contributed to consumption and deposition of PIT tags (based on maximum foraging range). Numbers assigned to study waters are used for geographical orientation in Figure 1; Res. = Reservoir

					Nearest pelican colonies (km)				
Number assigned to study water	Study waters	Water body size (ha)	Number of fish species present	Number of catchable trout annually stocked	Yellowstone National Park	Island Park Res.[a]	Blackfoot Res.	Lake Walcott	Great Salt Lake
1	Cascade Res.	10,994	11	62,000	459	363	412	304	448
2	CJ Strike Res.	3,035	23	102,000	483	385	354	***201***	313
3	Riley Creek Pond	7	0	17,000	415	323	274	***118***	***231***
4	Filer Pond	1	0	7,600	403	314	252	***95***	202
5	Magic Res.	1,569	8	6,000	366	268	231	***111***	230
6	Freedom Park Pond	1	0	1,000	346	272	181	***<u>32</u>***	154
7	Rupert Gun Club Pond	4	0	900	347	271	181	***<u>32</u>***	156
8	Lake Walcott	3,335	11	40,000	315	***248***	148	***<u>0</u>***	152
9	American Falls Res.	22,369	11	51,000	259	199	95	***56***	***170***
10	Chesterfield Res.	504	7	57,000	213	174	***<u>27</u>***	***119***	***187***
11	Foster Res.	52	5	5,900	275	252	84	140	111
12	Glendale Res.	82	6	9,200	275	253	83	141	113

[a] Pelican nesting is annually attempted here, but successful offspring are rarely produced.

their young; at that time we searched the two colonies (as well as a few other cormorant roosting and loafing areas) for regurgitated and/or defecated PIT tags. The final step was to apportion the recovered tags into those known or assumed to have been consumed by either pelicans or cormorants.

By recovering PIT tags at the colonies from fish stocked in our study waters, we were able to estimate a minimum rate of pelican predation at each study water, which was simply the number of tags recovered from a particular study water (and assigned to pelicans) divided by the number of tagged fish stocked at that water. For the four study waters within 50 km of the nearest colony, we could similarly estimate a minimum rate of cormorant predation. These minimum rates of predation did not account for stocked fish with tags that were consumed by pelicans or cormorants but were either not deposited on or not recovered at the two colonies.

By recovering tags from fish fed directly to pelicans at various study waters, we could directly estimate water-specific tag recovery efficiency for pelicans. This was important because (1) not all tags consumed by birds nesting at one of the two colonies would necessarily be deposited on the island where they were nesting, and (2) birds foraging in Idaho that were not nesting at these two colonies (e.g., nonbreeding birds and birds nesting at other colonies) had little to no chance of depositing a tag at these colonies. Estimating tag recovery efficiency for each water allowed us to transform (for pelicans only) minimum predation estimates into estimates of total predation on hatchery catchable trout that included predation by all pelicans, not just those nesting at the colonies we were studying (cf. Teuscher et al. 2015). Because cormorant feeding was unsuccessful, tag recovery efficiency was unknown for cormorants. Thus, all tag recoveries ascribed to cormorants resulted only in minimum estimates of cormorant predation (cf. Evans et al. 2012; Sebring et al. 2013).

Fish stocking.—To accomplish the first step in the methodology outlined above, we stocked PIT-tagged catchable Rainbow Trout into each study water in conjunction with regularly scheduled hatchery trout stocking events. The PIT-tagged fish comprised on average about 2% of the total number of hatchery catchable trout stocked in any given water in any given year. Mean size of stocked fish averaged 247 mm TL (SD = 24.9). Prior to tagging, hatchery fish were sedated with peppermint oil (in a 1:10 stock solution ratio with ethanol, using 0.3–0.5 mL of stock solution per liter of water). Once sedated, PIT-tags (23-mm half-duplex tags) were injected using a 7-gauge hypodermic needle inserted into the abdominal cavity; the insertion point was posterior to the pectoral fin, offset slightly to the right or left side depending on the handedness of the individual tagger. Fish were then transferred to net pens in the raceways and held for 1–2 d prior to stocking. To reduce the rate of tagging mortality, individual fish were judged, up to the point of release, according to whether they were unfit for this study due to visible signs of stress from capture and handling procedures (Nielsen 1992). This monitoring protocol applied to the implantation of anchor tags as well (see below). Mortality rate for fish tagging before stocking was <1%, but individual mortalities were noted and subtracted from the number of fish actually stocked. Postrelease mortality from tagging was assumed to be zero (Acolas et al. 2007).

Pelican feeding.—During this same time frame, we fed hatchery fish (also abdominally tagged with PIT tags) directly to pelicans at many (but not all) of the study waters. Feeding occurred between late May and mid-July, which encompassed much of the time when breeding pelicans were foraging and traveling between the breeding colonies and foraging sites to feed their chicks. For each pelican feeding event, hatchery fish were obtained from a state fish hatchery and were euthanized with an overdose of peppermint oil while traveling to the study water. These fish were injected with a PIT tag into the abdominal cavity along with a small amount of air under the skin before being thrown individually in the direction of loafing or foraging pelicans. The purpose of the injected air in the euthanized fish was to help ensure the fish did not sink after being thrown, thereby increasing the likelihood that a pelican would consume the PIT-tagged fish. Although loafing and foraging pelicans were initially wary of our approaching boat, they became more comfortable with our close proximity after a few days and readily consumed fish thrown in their direction. Each fish thrown in the direction of pelicans was monitored with binoculars until a pelican captured and swallowed the fish.

Attempts were made to minimize the occurrence of individual birds consuming more than one tagged fish in any given day in order to achieve independence in tag recoveries. Although at times 100 or more pelicans were attempting to consume fish being fed to them, no more than 40 tagged fish were fed on any given day. This also allowed us to temporally disperse colony deposition of fed tags throughout more of the pelican breeding season. How many fish were successfully fed to pelicans on any given day was variable depending on the size and wariness of the pelican flock; thus at most waters, several feeding events were employed each year throughout the feeding period.

Loafing and foraging cormorants never allowed us to be close enough in proximity to engage in direct feeding, so feeding events targeted at cormorants were abandoned. Consequently, they also did not interfere with pelican feeding.

PIT tag recoveries.—We searched for regurgitated and/or defecated PIT tags from fed and stocked fish at the Blackfoot Reservoir and Lake Walcott colonies after the juvenile pelicans and cormorants had fledged in the fall. We used a PIT tag reader (Oregon RFID HDX Backpack Reader) with a 0.5-m-diameter hoop antenna attached to the end of a 2-m-long pole. The read range for PIT tags was generally about 0.5 m regardless of whether the tag was on the surface or buried slightly in a nest or below ground level. Searchers scanned the entire colonies by "sweeping" the antenna back and forth just above the ground while slowly walking in 2-m-wide transects that overlapped one another to ensure that all of the ground was covered once. We also scanned shallow water (<0.3 m deep) surrounding the islands (submersing the antenna while sweeping these areas) and cormorant nests in bushes. When a tag was detected, surveyors noted the location as being in or very close to a cormorant nest, in or very close to a pelican nest, or not close to a nest. Surveyors then used a hand trowel and sieve to recover and remove the tag, if it was not visible on the surface in order to avoid interference with other PIT tags in the same area or in subsequent years. In the few instances where we were unable to recover and remove the tag, attempts were made to ensure no other PIT tags were in the same location, and individual PIT tag numbers were recorded. We assumed that any tag we recovered from stocked fish was from a live fish that a bird consumed, not from stocked fish that had died of natural causes and was later eaten by a pelican or cormorant.

Apportioning colony tag recoveries to pelicans or cormorants.—For 8 of the 12 study waters (which produced 14 of the 19 individual pelican predation estimates), the nearest colony was presumably outside the foraging range of all avian predators except pelicans, so all PIT tags recovered at the colonies from those waters were assigned to pelican predation. For one other study water, tag deposition occurred at the Blackfoot Reservoir colony, and this water was within the foraging range of that colony for both pelicans and cormorants. However, pelican and cormorant nesting did not overlap at the Blackfoot Reservoir colony during our study (D. M. Teuscher, unpublished data), so tags recovered from this water were assigned to pelican or cormorant predation based on tag recovery location at the colony. Thus, assigning PIT tags recovered at the colonies to pelican or cormorant predation was unambiguous for 9 of the 12 study waters (or 15 of the 19 pelican predation estimates).

For the remaining three study waters (which produced the remaining four pelican predation estimates), tag deposition occurred at the Lake Walcott colony, and these waters were all within the foraging range of that colony for both pelicans and cormorants. At this colony, pelicans and cormorants were generally segregated in their nesting locations, but there was not complete separation. For example, cormorants often nested in bushes elevated a meter or more off the ground, and they sometimes roosted in willows, while some pelicans nested underneath these cormorant nesting or roosting areas. Moreover, some fed tags (known to have been consumed by pelicans) were recovered closer to a cormorant nest than a pelican nest (K. A. Meyer, unpublished data). Also, trail cameras showed that cormorants were occasionally present amid numerous nesting pelicans, and both birds were seen loafing near one another near the island shores.

It was clear that both birds were foraging at these waters because PIT tags from stocked fish were recovered in both cormorant and pelican nests. However, because pelican and cormorant nesting and loafing was not entirely segregated at Lake Walcott, correct tag assignment for these waters at this colony was questionable. Consequently, we compared the assignment of predation to pelicans or cormorants using three approaches in order to assess variability in tag assignment (Table 2). First, recovered tags were assigned to pelicans or cormorants based on the proportional abundance of these birds at the colony. This was determined by mounting several cameras on fence posts placed strategically around the Lake Walcott islands to best capture images of birds present on the islands. The cameras captured images at hourly intervals each day from May through September each year, resulting in tens of thousands of images. We subsampled the images by randomly selecting six photographs (from daylight times only) from each camera for each month (from May to September), for a total of 180 images being used each year. We counted the number of pelicans and cormorants visible in each picture (mean = 46 pelicans and cormorants per picture; range, 0–253), and estimated the mean number of pelicans and cormorants present across the entire period from May to September at each island. We used these estimates of bird abundance to proportionally assign tags recovered from stocked fish to either pelican or cormorant predation (Table 2). This approach assumed that pelicans and cormorants were equally successful at foraging on hatchery catchable trout, and that their energetic demands were equivalent.

A modification of this approach accounted for differences in energetic demand between these birds, which are reasonably well defined. Adult double-crested cormorants require approximately 320 g of fish per day (Hatch and Weseloh 1999) compared with 1,500 g for American white pelicans (Ferguson et al. 2011), and cormorant chicks require an estimated 8–9 kg of food from hatching to fledging (Seefelt and Gillingham 2008) compared with 68 kg for American white pelican chicks (Hall 1925). Tag assignment based solely on bird abundance was thus modified to account for these energetic differences (Table 2).

A final approach for assigning recovered tags from these three waters to either pelican or cormorant predation was based on tag recovery location relative to the nearest pelican or cormorant nest (Table 2). Although as noted above, there was not complete separation in pelican and cormorant nesting and loafing areas at the Lake Walcott colony, we nevertheless recorded the location of each recovered tag relative to the nearest pelican or cormorant nest. Under this approach, any tags recorded in or very near a pelican or cormorant nest was assigned according to the nest that the tag was in or closest to; any remaining tags recovered near shore or nowhere near a nest were assigned to pelican or cormorant predation based on estimates of bird abundance, as outlined above. This approach assumed that all tags found in or near pelican nests were consumed by pelicans and likewise for cormorants.

All three approaches generally resulted in similar numbers of tags being assigned to either pelican or cormorant predation (Table 2). Considering this similarity, we felt that for the three study waters in question, assigning pelican or cormorant predation to recovered tags based solely on bird abundance was the best approach because it appeared to balance the various assumptions of these approaches and it resulted in relative tag assignments that were intermediate to the other two approaches.

Because only 4 of the 12 study waters were within the range of cormorant foraging from the Blackfoot Reservoir or Lake Walcott colonies, basing cormorant predation only on tag recoveries at colonies would have limited our ability to characterize cormorant predation. Therefore, to augment colony

TABLE 2. Summary of PIT tags recovered at the Lake Walcott colony from stocked catchable Rainbow Trout and assigned to predation by either American white pelican or double-crested cormorant based on three possible tag assignment approaches. Approach one assigned tags proportional to pelican and cormorant abundance at the colonies, approach two assigned tags proportional to abundance with an adjustment for energetic differences between pelicans and cormorants, and approach three assigned tags according to tags recovery location in proximity to pelican and cormorant nesting and loafing areas. See text for more details regarding each apporach.

		Number of PIT-tagged fish		Recovered tags assigned to pelicans or cormorants					
				Approach one		Approach two		Approach three	
Hatchery trout stocking water	Year	Stocked	Recovered at nearest colony	Pelicans	Cormorants	Pelicans	Cormorants	Pelicans	Cormorants
Freedom Park Pond	2013	100	19	16	3	18	1	12	7
Rupert Gun Club Pond	2013	99	18	16	2	18	0	14	4
Lake Walcott	2013	397	82	65	17	79	3	54	28
Lake Walcott	2014	208	63	41	22	58	5	39	24

tag recoveries, at a few waters we scanned for additional tags at cormorant roosting and loafing areas. We only scanned cormorant roosting and loafing areas that were (1) well defined spatially, (2) rarely if ever visited by other avian predators (namely pelicans and herons), and (3) logistically feasible to scan. We assigned all PIT tags recovered at cormorant roosting and loafing areas to cormorant predation. Recovered tags from this step were combined with colony-recovered tags assigned to cormorants before final estimates of cormorant predation were made.

Calculating pelican predation rates.—For each stocking event that was coupled with pelican feeding, proportions of recovered tags were calculated independently for both the fed tags (FT) and stocked tags (RT), where FT = tag recovery efficiency, i.e., the number of fed PIT tags found on the colony divided by the total number of tags fed to pelicans, and RT = number of stocked PIT tags found on the colony (that were assigned to pelicans) divided by the total number of tagged fish stocked.

Variance for these proportions was calculated according to the formula in Fleiss (1981) as

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

where P is the numerator of a proportion (e.g., FT, RT), and n is the denominator. We calculated the pelican predation rate ($\mathrm{Pred}_{\mathrm{pel}}$) for each water body when both fed and stocked tags were recovered at a colony according to the following formula:

$$\mathrm{Pred}_{\mathrm{pel}} = \frac{\mathrm{RT}}{\mathrm{FT}}.$$

Because the numerator and denominator were both individual estimates, with their own estimates of variance, we used the approximate formula for the variance of a ratio (McFadden 1961; Yates 1980) to calculate the variance for $\mathrm{Pred}_{\mathrm{pel}}$, using the following formula:

$$\mathrm{Var}\left(\frac{\mathrm{RT}}{\mathrm{FT}}\right) = \left(\frac{\mathrm{RT}}{\mathrm{FT}}\right)^2 \times \left(\frac{\mathrm{Var(RT)}}{\mathrm{RT}^2} + \frac{\mathrm{Var(FT)}}{\mathrm{FT}^2}\right).$$

For each water-specific estimate of the rate of pelican predation, we calculated the 90% CI.

For stocking events that were not coupled with pelican feeding events, we could not directly estimate total pelican predation because tag recovery efficiency was not estimated. Instead, we predicted tag recovery efficiency for these stocking events based on a scatterplot of distance to colony (x-axis) and tag recovery efficiency (y-axis) for the stocking events that were coupled with pelican feeding. The relationship was curvilinear in nature, so we fitted an exponential regression to the data to evaluate the statistical significance of the relationship. Estimates of RT for waters where no feeding occurred were then adjusted by the predicted tag recovery efficiency in order to estimate total pelican predation for these waters.

Calculating cormorant predation rates.—Because cormorants were not fed directly, tag recovery efficiency could not be estimated for cormorants for any stocking events. Therefore, all cormorant predation estimates were minimum estimates only, based simply on the number of stocked PIT tags found at cormorant loafing and roosting areas or at the colonies and assigned to cormorants, divided by the total number of tags stocked.

Estimating angler catch.—To estimate angler catch, we attached T-bar anchor tags to the same hatchery catchable trout that were released with PIT tags in the study waters. Tags were inserted just below the dorsal fin following the recommendations of Guy et al. (1996). Anchor tagging occurred at the same time as PIT-tagging.

For more details on anchor-tagging methods and estimating angler catch see Meyer et al. (2012) and Meyer and Schill (2014). In short, anchor tags were fluorescent orange (so anglers could more easily notice them on fish), 70 mm in length (including 51 mm of tubing), and labeled with the agency and phone number (i.e., IDFG 1-866-258-0338) where tags could be reported. A toll-free automated telephone hotline and website were established through which anglers could report tags, although some tags were mailed to or dropped off at IDFG offices. Tag reporting by anglers in this program was voluntary, not mandatory.

We tested whether implanting hatchery catchable trout with fluorescent orange tags made them more visible to pelicans and cormorants and therefore more vulnerable to bird predation by implanting one-half of the stocked fish with dull green anchor tags at six waters in 2013 to evaluate tag recovery by tag color. We recovered a total of 108 and 99 PIT tags from fish stocked in these waters with dull green and fluorescent orange anchor tags, respectively. A Wilcoxon signed rank test indicated that tag recoveries did not differ by color ($P = 0.50$).

Unadjusted angler catch (c) for each stocking event was calculated as the number of tagged fish reported as caught by anglers (within 1 year of the stocking event) divided by the number of fish released with tags; variance for this proportion was again calculated according to the same formulas in Fleiss (1981) as noted above. Adjusted angler catch (c') incorporated estimates of angler tag reporting rate (λ), anchor tag loss rate (tag_l), and mortality rate of fish with tags (Tag_m) (estimated to be 49.4, 8.2, and 1%, respectively; see Meyer and Schill 2014) and used the following formula:

$$c' = \frac{c}{\lambda(1-\mathrm{Tag_l})\,(1-\mathrm{Tag_m})}.$$

Variance estimates for λ, Tag_l, and Tag_m came from data reported in Meyer and Schill (2014). Variance for the entire denominator in the above equation was estimated using the approximate formula for the variance of a product in Yates (1980):

$$s^2_{x_1 x_2} = x_1^2 \cdot s^2_{x_2} + x_2^2 \cdot s^2_{x1},$$

where $s^2_{x_1 x_2}$ is the variance of the product, x_1 and x_2 are independent estimates being multiplied together, and $s^2_{x_1}$ and $s^2_{x_2}$ are their respective variances. Variance for c' was calculated using the approximate formula for the variance of a ratio, as previously noted, from which 90% CIs were derived.

Scatterplots were constructed to evaluate relationships between rates of pelican predation and angler catch and rates of pelican predation and distance from colonies. The relationships were more curvilinear than linear in nature (with stronger effect sizes), so we fitted exponential regressions to the data to evaluate the statistical significance of the relationships. We also used a *t*-test to assess whether angler catch was reduced when pelican predation was high (i.e., ≥25%) compared with when pelican predation was low (<25%); a one-tailed test was used since we assumed that higher pelican predation would not positively affect angler catch rates.

We used $\alpha = 0.10$ for all statistical significance tests and for calculating CIs. This less-stringent significance level (compared with the more standard use of $\alpha = 0.05$) was adopted to balance type I and type II errors in our statistical tests (Cohen 1990; Stephens et al. 2005) and because resource managers in our agency were content with the tradeoff of having tighter bounds around the estimates of predation and angler catch at the expense of less confidence in the estimates.

RESULTS

We directly fed a total of 1,073 PIT-tagged hatchery catchable trout to pelicans over 3 years and subsequently recovered 189 (18%) of the tags at the Blackfoot Reservoir or Lake Walcott pelican colonies (Table 3). For the 13 water × study year combinations of pooled feeding events, tag recovery efficiency at the colonies averaged 21% and ranged from 0 to 65% (Table 3). There was a strong negative exponential relationship between the distance from a particular study water to the nearest pelican colony and tag recovery efficiency for the feeding events in that study water ($R^2 = 0.80$, $F = 43.99$, $P < 0.001$; Figure 2).

We stocked a total of 5,565 PIT-tagged hatchery catchable trout in 19 separate stocking events in our study waters and recovered 194 (4%) of the tags, which were known or assumed to have been consumed by pelicans, at the Blackfoot Reservoir or Lake Walcott colonies (Table 4). Resulting estimates of total pelican predation on hatchery catchable trout that were stocked averaged 18% and ranged from 0 to 48%.

In comparison, a total of 311 PIT tags implanted in stocked fish were recovered at the colonies or at cormorant loafing and roosting areas and were known or assumed to have been consumed by cormorants (Table 5). These tag recoveries came from 7 of the 19 stocking events; for the remaining 12 stocking events, cormorant tag recoveries were not attempted. Resulting estimates of minimum cormorant predation—assuming that 100% of tags consumed by cormorants were recovered—averaged 14% and ranged from 2% to 38% (Table 5). If we assumed that cormorant tag recovery efficiency was equivalent to pelican tag recovery efficiency, total cormorant predation was estimated to average 21% and ranged from 5% to 69%.

The maximum pelican foraging distance we documented was 248 km (Table 1). Pelican predation rates at individual waters declined exponentially at greater distances from the nearest colony ($R^2 = 0.26$, $F = 5.93$, $P = 0.03$; Figure 3).

Angler catch of anchor-tagged hatchery catchable trout stocked in study waters averaged 21% and ranged from 0 to 82% (Table 4). There was some evidence of a negative exponential relationship between pelican predation and angler catch for individual stocking events ($R^2 = 0.15$, $F = 3.11$, $P = 0.10$; Figure 4), although the relationship was weak and quite variable. Nevertheless, for stocking events where pelican predation was ≥25%, angler catch averaged only 8%, whereas when pelican predation was <25%, angler catch averaged 31%; this nearly fourfold difference in mean angler catch was statistically significant ($t = 1.33$, df = 17, $P = 0.03$; Figure 5).

DISCUSSION

Our results suggest that predation by American white pelicans and double-crested cormorants on catchable Rainbow Trout stocked in southern Idaho waters can be relatively high (i.e., >25%) and often exceeds the total catch of those fish by anglers who compete directly with avian predators for the use of stocked trout. Although our study includes results from only a small sample of locations, our findings support the supposition that in southern Idaho, pelican predation on hatchery catchable trout will negatively affect angler catch rates for these fish in some waters. In the neighboring state of Wyoming, pelicans quickly increased their focus on trout species (relative to other prey species available) as soon as hatchery trout were stocked (Derby and Lovvorn 1997). Rainbow Trout more often display pelagic (i.e., suspended in the water column) rather than benthic (near the substrate) behavior in lentic waters, making them particularly vulnerable to avian predation compared with other salmonids (Matkowski 1989). Moreover, fish reared in production raceways are naïve with regard to predators and once they are stocked they do not initiate avoidance behaviors exhibited by wild fish (Berejikian 1995).

Estimated predation rates by pelicans on stocked Rainbow Trout in the study waters we evaluated were quite variable, but were nonetheless inversely related to the distance from the

TABLE 3. Summary of feeding events for American white pelican at various southern Idaho waters, and subsequent estimates of tag recovery efficiency.

Water body	Year	Distance to nearest pelican colony (km)	PIT-tagged fish fed to pelicans: Number fed	PIT-tagged fish fed to pelicans: Number recovered at nearest colony	Fed tag recovery efficiency
Lake Walcott	2013	0	91	44	0.48
Lake Walcott	2014	0	81	53	0.65
Chesterfield Reservoir	2013	27	80	19	0.24
American Falls Reservoir	2013	56	101	9	0.09
American Falls Reservoir	2014	56	83	12	0.14
Riley Creek Pond	2012	118	64	16	0.25
Riley Creek Pond	2013	118	39	24	0.62
Riley Creek Pond	2014	118	10	2	0.20
CJ Strike Reservoir	2012	201	100	6	0.06
CJ Strike Reservoir	2013	201	100	2	0.02
CJ Strike Reservoir	2014	201	95	2	0.02
Cascade Reservoir	2012	304	104	0	0.00
Cascade Reservoir	2013	304	125	0	0.00
Total			1,073	189	

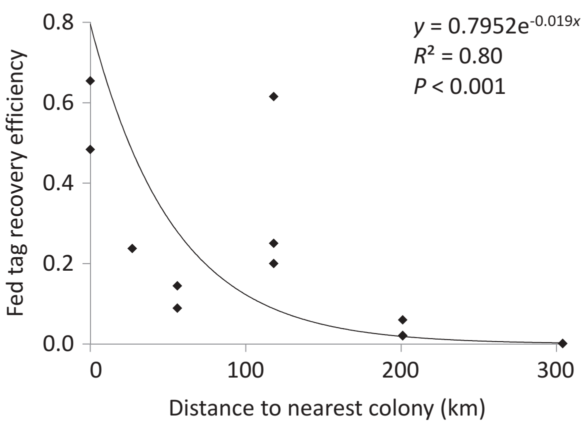

FIGURE 2. Relationship between the distance of study waters from the nearest American white pelican colony and the recovery efficiency (at the nearest colony) of PIT tags implanted in hatchery catchable Rainbow Trout and fed directly to pelicans at that study water. The line and equation depict an exponential relationship fitted to the data.

study water to the nearest colony. Declines in avian predation rates related to distance from colonies have been previously demonstrated (e.g., Fasola and Bogliani 1990; Osterback et al. 2013) and would be expected for birds such as adult pelicans that rear chicks with high energy needs and that have high energy demands of their own. The highest observed pelican predation rates in this study were usually at waters within 100 km of the nearest colony except at CJ Strike Reservoir, which was over 200 km from the nearest colony yet still received relatively heavy predation pressure by pelicans in some years.

The maximum recorded distance, of which we are aware, that American white pelicans can travel one way from colonies to foraging areas is 305 km (Johnson and Sloan 1978), suggesting that nearly all of the reservoirs and ponds in southern Idaho are subject to pelican predation. The maximum distance of travel we observed was 248 km, but in a concurrent related study we also recovered, at the Lake Walcott colony, a PIT tag implanted into a Yellowstone Cutthroat Trout at Henrys Lake, 278 km away (K.A.M., unpublished data).

Most hatchery catchable trout fisheries in southern Idaho are within the foraging range of pelicans nesting at colonies other than Lake Walcott and Blackfoot Reservoir. Pelicans from Gunnison Island at the Great Salt Lake are particularly concerning from a fisheries management perspective due to the large number of pelicans nesting there (8,000 nesting pairs in 2000: King and Anderson 2005) and their close proximity to southern Idaho fisheries. However, we searched Gunnison Island in October 2014 and found only 11 PIT tags from fish stocked in three of our study waters (up to 231 km away; Table 1). We also searched Molly Island and found 20 PIT tags, but none were from hatchery catchable trout; rather, they were all from Yellowstone Cutthroat Trout implanted with tags at Henrys Lake (97 km away). Finally, we searched for PIT tags at the Island Park Reservoir colony and found one PIT tag from a hatchery catchable trout that was stocked in Lake Walcott in 2014. Taken collectively, the number of pelican-consumed PIT tags recovered at the Lake Walcott and Blackfoot Reservoir colonies (n = 383), compared with those colonies at Gunnison Island, Molly Island, and Island Park Reservoir (n = 12), suggests that little of the pelican predation

TABLE 4. Number of PIT-tags implanted in catchable trout stocked in study waters that were recovered at colonies and known or assumed to have been consumed by pelicans; resulting estimates and CIs of pelican predation (i.e., proportion consumed) and angler catch (i.e., proportion caught) are also shown.

			PIT-tagged trout		Pelican predation		Angler catch	
Water body	Year	Distance to nearest colony (km)	Initially stocked	Recovered at nearest colony	Estimate	90% CI	Estimate	90% CI
Waters outside foraging range of cormorants								
American Falls Reservoir	2013	56	396	11	0.31	0.22	0.00	
American Falls Reservoir	2014	56	398	17	0.30	0.17	0.07	0.03
Glendale Reservoir	2013	83	399	0	0.00		0.25	0.07
Foster Reservoir	2013	84	293	0	0.00		0.30	0.07
Filer Pond	2012	95	100	3	0.23[a]		0.68	0.18
Magic Reservoir	2014	111	449	4	0.09[a]		0.06	0.04
Riley Creek Pond	2012	118	100	2	0.08	0.09	0.82	0.20
Riley Creek Pond	2013	118	100	4	0.07	0.05	0.06	0.07
Riley Creek Pond	2014	118	99	3	0.15	0.16	0.77	0.20
CJ Strike Reservoir	2012	201	399	1	0.04	0.07	0.32	0.07
CJ Strike Reservoir	2013	201	400	2	0.25	0.32	0.09	0.05
CJ Strike Reservoir	2014	201	400	4	0.48	0.67	0.14	0.05
Cascade Reservoir	2012	304	393	0	0.00		0.02	0.02
Cascade Reservoir	2013	304	450	0	0.00		0.09	0.03
Waters within foraging range of cormorants								
Lake Walcott	2013	0	397	65[b]	0.34	0.09	0.00	
Lake Walcott	2014	0	208	41[b]	0.30	0.09	0.04	0.03
Chesterfield Reservoir	2013	27	385	5[b]	0.05	0.04	0.02	0.02
Rupert Gun Club Pond	2013	32	99	16[b]	0.37[a]		0.00	
Freedom Park Pond	2013	32	100	16[b]	0.37[a]		0.31	0.16
Total			5,565	194				

[a]Pelican predation estimate not based on pelican-fed tags but rather on equation from Figure 2; CIs were not calculated for these estimates.
[b]PIT tags assigned based on results presented in Table 2.

occurring in hatchery trout fisheries in southern Idaho stems from pelicans breeding at colonies other than Lake Walcott and Blackfoot Reservoir. This appears so even after factoring in the decline in tag recovery efficiency we observed at greater distances from pelican colonies. Predation from pelicans nesting outside of southern Idaho reduces tag deposition rates at Lake Walcott and Blackfoot Reservoir, but because our study design accounted for off-colony deposition, our pelican predation estimates incorporated all pelican predation that was occurring, regardless of the origin of any particular bird.

Several of our estimates of total pelican predation may have been biased low. For example, for 4 of our 19 pelican predation estimates, we assumed that pelicans and cormorants were equally successful at foraging on hatchery catchable trout, and that their energetic demands were equivalent. While the relative foraging success of pelicans and cormorants on hatchery catchable trout is unknown, energetic demands are four to eight times higher for pelicans (Hall 1925; Ferguson et al. 2011) than for cormorants (Hatch and Weseloh 1999; Seefelt and Gillingham 2008). By apportioning tags based solely on bird abundance without adjusting for differing energy requirements, we likely underestimated pelican predation (and consequently overestimated cormorant predation) unless cormorants were four to eight times more successful foragers on our stocked fish.

A limitation to our approach was, if a study water exceeded the foraging range of breeding pelicans, then there would be no chance of recovering a tag at the colony, and pelican predation would consequently be estimated to be zero regardless of whether any hatchery catchable trout were actually eaten by a pelican. For example, at Cascade Reservoir, we estimated that pelican predation was zero in 2012 and 2013 because no PIT tags were recovered at the Lake Walcott colony. However, at 304 km from Lake Walcott, Cascade Reservoir may indeed have been outside the foraging range of pelicans nesting at Lake Walcott (Johnson and Sloan 1978; Trottier et al. 1980; O'Malley and Evans 1982). Nevertheless, pelicans are generally quite abundant at Cascade Reservoir,

TABLE 5. Number of PIT tags implanted in catchable Rainbow Trout stocked in study waters that were recovered at colonies or cormorant loafing and roosting areas and were known or assumed to have been consumed by cormorants; resulting estimates of cormorant predation are also shown.

					Number of PIT tags recovered		Cormorant predation estimates	
Hatchery-trout stocking water	PIT tag recovery location	Year	Distance to nearest colony (km)	Number of PIT-tagged fish stocked	At nearest colony and assigned to cormorants	At cormorant loafing and roosting areas where fish were stocked	Assuming 100% tag-recovery rate	Assuming equivalent tag-recovery rates by distance for pelicans and cormorants
Lake Walcott	Lake Walcott colony	2013	0	397	17		0.04	0.05
Lake Walcott	Lake Walcott colony	2014	0	208	22		0.11	0.13
Chesterfield Reservoir	Blackfoot colony and Chesterfield Reservoir	2013	27	385	96	52	0.38	0.69
Rupert Gun Club Pond	Lake Walcott colony	2013	32	99	2		0.02	0.05
Freedom Park Pond	Lake Walcott colony	2013	32	100	3		0.03	0.07
Glendale Reservoir	Glendale Reservoir	2013	83	399	0	20	0.05	0.06
Foster Reservoir	Foster Reservoir	2013	84	293	0	99	0.34	0.42

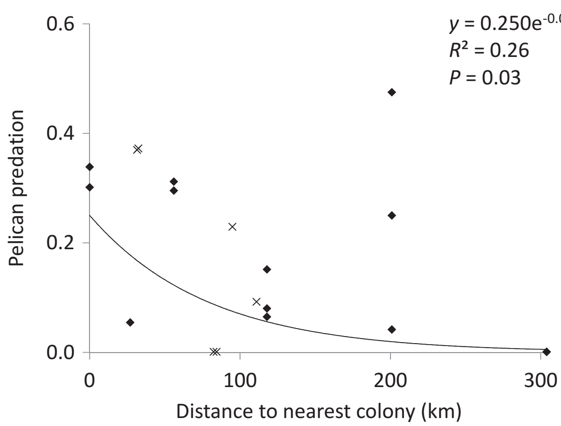

FIGURE 3. Relationship between the distance of study waters to the nearest American white pelican colony and the pelican predation rate on catchable Rainbow Trout stocked at that water. Predation rates for the waters labeled with an "×" were predicted (rather than estimated directly) based on the relationship in Figure 2. The line and equation depict an exponential relationship fitted to the data.

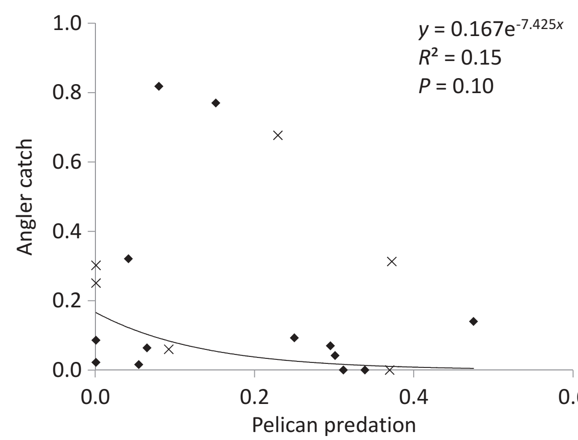

FIGURE 4. Relationship between estimates of American white pelican predation and angler catch of catchable Rainbow Trout stocked in southern Idaho study waters. Predation rates for the waters labeled with an "×" were predicted (rather than estimated directly) based on the relationship in Figure 2. The line and equation depict an exponential relationship fitted to the data.

and an average of 327 and a maximum of 989 pelicans have been counted by numerous ground surveys conducted between May and August 2013; similar numbers were present in 2012. Although pelican predation on catchable trout stocked in Cascade Reservoir in 2012 and 2013 may indeed have been zero, the large number of pelicans inhabiting this water suggests otherwise. We included Cascade Reservoir in our study precisely because it was at or beyond the foraging limit of pelicans from the Lake Walcott colony; if it exceeded that

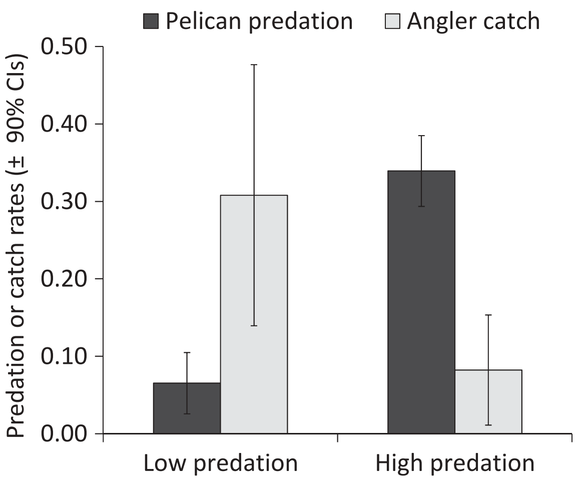

FIGURE 5. Mean rates (±90% CI) of American white pelican predation and angler catch of catchable Rainbow Trout stocked in southern Idaho waters grouped into stocking events where pelican predation was either high (i.e., ≥25%) or low (<25%).

limit, then our study design incorrectly resulted in an estimate of zero predation by pelicans, unless nonbreeding pelicans completely avoided consumption of hatchery catchable trout.

Compared with our estimates of total pelican predation generated for 19 fish-stocking events, the estimates of minimum cormorant predation we produced for 7 of the 19 stocking events were less rigorous. For some of the cormorant predation estimates, we assumed that cormorants and pelicans deposited PIT tags at colonies at a rate commensurate with their abundance, but this approach has other assumptions associated with it. One was that energetic requirements were equivalent between birds, though, as mentioned above, it has been well established that pelican diets greatly exceed cormorant diets in volume, and this may have led to overestimating cormorant predation (and underestimating pelican predation) at waters < 50 km from the Lake Walcott colony. Another assumption was that cormorants and pelicans exerted equal predation effort on and had equal capture efficiency of hatchery catchable trout. The fact that catchable trout are quite surface oriented after stocking makes them vulnerable to both birds, but if the diving ability of cormorants allowed them to target hatchery catchable trout more effectively in the months that followed the stocking events, our tag assignment approach may have led to underestimating cormorant predation (and overestimating pelican predation) for some waters. Expanding our estimates of minimum cormorant predation to total cormorant predation required a final assumption that tag recovery efficiencies were equivalent for pelicans and cormorants, when in reality tag recovery efficiencies for cormorants were unknown, and the likelihood of equal tag recovery efficiency curves between pelicans and cormorants is probably low (Hostetter et al. 2015). Despite these weaknesses, the similarity between tag assignments under a variety of approaches (Table 2) suggests that these assumptions did not lead to substantial biases in pelican or cormorant predation estimates for waters near the Lake Walcott colony. It was surprising that estimates of minimum cormorant predation exceeded total pelican predation in three of seven instances, suggesting that where cormorants are abundant, their impact on catchable trout stocked in southern Idaho waters often exceeds that of pelicans. In the North Platte River of Wyoming, cormorants and pelicans ate an estimated 80% of the subcatchable-sized trout (10–16 cm long) stocked during the summer, nearly all of which was attributed to cormorants (Derby and Lovvorn 1997).

We recovered only a fraction of the tags we fed directly to pelicans, which highlights the importance of correcting predation estimates for fish consumed by nesting avian predators but deposited off-colony. Our average tag recovery efficiency of 21% is slightly higher than several recent avian predation studies with similar direct-feeding study designs, all of which found that recovery of tags fed directly to birds was less than 10% (Osterback et al. 2013; Scoppettone et al. 2014; Teuscher et al. 2015). Hostetter et al. (2015) directly fed PIT-tagged hatchery trout to Caspian terns *Hydroprogne caspia*, double-crested cormorants, and California gulls *Larus californicus* and found tag deposition rates on nearby colonies of 71, 51, and 15%, respectively, but most of their feeding trials were conducted on birds while they were on or immediately adjacent to the colonies, which likely elevated their tag deposition rates greatly.

A simple explanation for the exponential decline in tag recovery efficiency at greater distances from the pelican colonies is that the increased energy demand of foraging at greater distance from the colony requires a proportional increase in food consumption to meet adult metabolism needs rather than for chick feeding, which would likely reduce tag deposition rates at the colonies. Also, pelicans that forage at waters further from colonies may be more likely to be nonbreeders, or as mentioned above, they may be breeding at other colonies, both of which would reduce tag deposition rates at the colonies we studied. Regardless of the causative mechanism, the strength of the relationship between tag recovery efficiency and distance from colonies allowed us to estimate total pelican predation at waters where direct feeding of pelicans was not conducted due to time constraints during our study or because pelican abundance was too low or too variable to create effective direct-feeding conditions. Future efforts to effectively feed cormorants would not only allow minimum cormorant predation estimates to be converted to total predation estimates, but might also allow predictions of total cormorant predation at waters where direct feeding was not conducted.

For several reasons we deem it unlikely that predatory birds other than pelicans and cormorants were responsible for tags that were recovered at these colonies. First, as we have already pointed out, for most of our predation estimates, pelicans were the only avian predator capable of foraging at the distance needed to consume stocked fish and subsequently transport PIT tags to the colonies. Second, although great blue herons *Ardea herodias* were present at the Lake Walcott and Blackfoot Reservoir colonies, their abundance was a fraction of the abundance of pelicans and cormorants at both colonies, and their maximum foraging distance from colonies has been estimated to be only about 15 km (Parris and Grau 1979; Thompson 1979; Dowd and Flake 1985), precluding them as a meaningful source of predation that was unaccounted for. Third, although ring-billed gulls *L. delawarensis* and California gulls are also common on both colonies, the foraging range for most gulls is generally less than 25 km (Fasola and Bogliani 1990; Belant et al. 1998), they generally have a nonfish diet (York et al. 2000), and the size of catchable trout we stocked (247 mm on average) is likely too large for these gulls to effectively consume at a meaningful level, all of which precludes them from being an appreciable source of predation as well.

The amount of pelican and cormorant predation that is occurring on catchable Rainbow Trout stocked in some southern Idaho waters as demonstrated in this study, as well as the low level of angler catch associated with many of those stocking events, begs the question of whether something can or should be done to either reduce predation or increase angler catch. Considering that IDFG annually stocks about 1.8 million hatchery catchable trout state-wide at a cost of about US$2.5 million, maximizing angler catch of these fish by any means possible (including reducing avian predation) is important. In terms of stocking strategies, Derby and Lovvorn (1997) suggest that altering the timing of stocking or the size of fish at release may reduce avian predation. Indeed, most stocking of catchable trout in southern Idaho occurs from April to June, which closely coincides with peak food requirements for colonial nesting avian predators. However, this also closely coincides with peak angler effort in southern Idaho fisheries, some of which are largely or entirely supported by stocking catchable fish. Thus, while stocking at a later date may reduce avian predation, it may also reduce angler catch even further. Moreover, while larger fish (e.g., >350 mm in length) would have a reduced vulnerability to pelicans and cormorants because of their increased swimming speed capacity, the added costs associated with raising catchable fish to such a large size for stocking may economically preclude such a strategy. In the Blackfoot River drainage, an extensive hazing program to reduce pelican nesting success has been undertaken by IDFG in recent years to help preserve a wild, native population of Yellowstone Cutthroat Trout that has been diminished by pelican predation (Teuscher and Schill 2010; Teuscher et al. 2015). However, hazing strategizes are not logistically feasible at the scale that would be required to protect catchable trout from avian predation in hatchery-trout fisheries in southern Idaho. A more controversial strategy would be to measurably reduce the numbers of pelicans and cormorants in an area using habitat alteration and/or lethal control, including lethal take as well as egg oiling (to reduce hatching survival). Such strategies have been considered and sometimes implemented for pelicans (Mwema et al. 2010; Teuscher et al. 2015) and cormorants (Belant et al. 2000; Glahn et al. 2000). An alternative strategy is the massive efforts currently underway on the Columbia River to reduce predation by cormorants and Caspian terns on juvenile anadromous salmonids by relocating entire colonies to areas outside of the Columbia River basin (USFWS 2005; NMFS 2010; Lyons et al. 2011). Advantages and disadvantages of each management action must be considered in light of the current status of cormorants and pelicans in North America and their cumulative impacts on economically important fisheries that anglers and policymakers value.

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