American white pelican predation of upper Smith River fisheries

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Introduction

Passive integrated transponder (PIT) tags from Montana Fish, Wildlife and Parks (FWP) and Montana State University (MSU) fishery projects have been recovered from American white pelican (*Pelecanus erythrorhynchos*, hereafter referred to as white pelican) nesting islands within the Missouri River drainage. The recovery rate of consumed PIT tags from these projects is unknown, thus the associated predation rate of fish in the Smith and Missouri rivers is also unknown.

Within Montana, there are two distinct groupings and four notable colonies of white pelicans (Pacific Flyway Council 2012). The western grouping includes colonies at Canyon Ferry Reservoir (CFR) and Arod (also known as Eyraud) Lake and the eastern grouping includes colonies located at Bowdoin Lake National Wildlife Refuge (NWR) and Medicine Lake NWR. In 1989, there were 13 white pelican nests at CFR. Within 10 years, the population increased to 1,487 nests. Since that time, annual white pelican nest counts have remained high averaging 1,879 over the past 20 years (Grove 2017). At Arod Lake, nest counts have varied from 300-500 over the past 20 years (Audubon 2017). At the state level, white pelicans are classified as S3B (the breeding population is potentially at risk because of limited or declining range and/or habitat) and as a Species of Greatest Conservation Need (SGCN3) (Montana Natural Heritage Program 2017). The groupings at CFR and Arod Lake comprise 9% of the western population of American white pelicans that are distributed across 19 breeding colonies within 8 states and British Columbia (Pacific Flyway Council 2012).

Based on the average ingestion of 1.2-1.8 kg of prey per day by an adult pelican (Hall 1925; Anderson 1987), a colony the size of CFR (~3,400 adults) would equate to 4,080-6,120 kg of prey consumed per day. White pelicans tend to forage in shallow areas where prey is most abundant. For the CFR colony, skeletal remains observed at the site indicates a portion of their prey base consists of nongame fish, such as suckers (*Catostomus* spp.) and carp (*Cyprinus carpio*). However, they have also been observed foraging on trout and whitefish in the nearby Missouri and Smith Rivers. The impact on fish populations within heavily predated sections of river may be significant, particularly in a river such as the Smith River with a mean 754 trout per mile compared to the Missouri River with a mean 3,913 trout per mile. As the Missouri and Smith River fisheries are economically, intrinsically, and recreationally valuable to central Montana, evaluating the predation rate by white pelicans is pertinent to future fishery management strategies and the expectations and demands anglers have for these fisheries.

Background

Montana Fish, Wildlife and Parks initiated a radio telemetry migration movement study on the Missouri River from 2008-2010 (Grisak et al. 2012). The observed movements of fish within the Missouri River led to subsequent studies within the Missouri River drainage to better understand the resiliency to whirling disease (*Myxobolus cerebralis*) and overall life history characteristics of trout populations in these systems.

In 2010, a Montana State University graduate student investigated migration movements of fish populations in Tenderfoot Creek, a main tributary of the Smith River (Ritter 2015). An ongoing study by graduate student Michael Lance expanded Ritter's research to investigate fish movement patterns throughout the Smith River drainage. In coordination with the Smith River

study, FWP initiated a study in 2014 to investigate fish movement patterns in the Missouri River and the associated major spawning tributaries (Mullen et al. 2016; Mullen et al. 2017).

As part of these FWP and MSU research projects, since 2014, 11,159 passive integrated transponder (PIT) tags have been deployed into the Smith, Missouri, and Sun River drainages. Since that time 6,575 tags (fish) or 58% of tagged fish have never been redetected. While emigration, angler harvest, natural mortality, and tag expulsion are all factors in tag loss, the number lost to avian predation is a large unknown. Based on initial surveys, the abundance of pelicans, and observations from field personnel and the public, we suspect that white pelicans are the largest contributor to avian predation. To estimate white pelican predation rates on fish in the Smith River, with further inference drawn to the Missouri and Sun rivers, our objectives are to quantify PIT tag recovery rate, estimate efficiency of tag detection, and quantify total predation.

Population

White pelican populations have increased greatly in recent decades. White pelicans occur naturally throughout North America, but experienced large population declines throughout the 19th and early 20th centuries from pollution, habitat loss, and hunting pressure (Thompson 1933; Schaller 1964). A 1933 continental study, estimated 30,000 breeding adults in North America (Thompson 1933); however, since that time, populations have improved to a conservative estimate (1998-2001) of 134,000 breeding adults across 42 colonies (King and Anderson 2005).

The continental population of white pelicans is divided into two migratory groupings: western and eastern populations. The western population declined to a low of 16,000 individuals across 5 to 8 colonies but is now estimated to be approximately 45,996 breeding adults across 19 colonies (Pacific Flyway Council 2012). The colonies at CFR and Arod Lake fall within this category as they largely migrate south and west across the Continental Divide to southern California and western Mexico. The eastern grouping is much larger than the western grouping and contains the two eastern Montana populations of white pelicans, Bowdoin NWR and Medicine Lake NWR. These bird colonies migrate south and east along the Missouri and Mississippi rivers to the Gulf of Mexico (Henricks and Johnson 2002; Pacific Flyway Council 2012).

Montana Pelicans

During the 1933 continental survey (Thompson 1933), Montana was not considered significant breeding grounds for pelicans (Hendricks and Johnson 2002). Of the two populations identified, Bowdoin Lake NWR had approximately 336 nests in 1935 (Weydemeyer and Marsh 1936) and Medicine Lake NWR first recorded breeding activity with 50 nests in 1939 (Madden and Restani 2005). Over time, these small populations increased and by the 1964 continental survey, Montana was considered an important breeding area (Lies and Belhe 1966). By 1981, Medicine Lake NWR and Bowdoin Lake NWR were estimated at 3,200 and 2,384 breeding adults, respectively (Sidle et al. 1985). Montana white pelican populations experienced declines in the 1960's and 70's due to flooding of nesting sites (Sloan 1982) but have now grown to approximately 10,000 breeding pairs across four breeding colonies (Henricks and Johnson 2002). Medicine Lake NWR boasts the largest white pelican population in Montana with a 10-year average of 4,000 breeding pairs (Madden and Restani 2005).

In 1989, 13 nests were found at the Canyon Ferry Reservoir Wildlife Management Area (WMA) within the dust abatement ponds (Henricks and Johnson 2002). These dust abatement ponds were created in 1978 by the construction of a dike system to suppress dust pollution from mud flats along the edges of Canyon Ferry Reservoir. This dike system created four ponds along the southeast and southwest sides of Canyon Ferry Reservoir that encompassed 1,925 acres and created 325 artificial islands for waterfowl production (Carlsen 2006). Since 1989, the CFR white pelican population has dramatically increased (Fig. 1). As of 2016, CFR has an estimated 3,432 breeding adults (Stinson 2016; Grove 2017) or 1,610 nests across 18 islands in Pond 3 (Fig. 1). Since 1999, the number of pelican nests at CFR has fluctuated between 1,500 to 2,500 (Fig. 1). These colonial nesting birds dominate the islands at CFR and make up a majority of the birds that use the islands for nesting, especially within Pond 3.

Arod Lake is a reservoir impounded by an earthern dam since 1936 and serves as a municipal water source for the town of Brady. In 1993, the lakes and surrounding 800 acres were purchased from farmers and converted into the Arod Lakes Waterfowl Production Area (Arod Lake 2017) cooperatively managed by the Benton Lake Wetland Management District (U.S. Fish and Wildlife Service) and the Fishing Access Site division of Montana Fish, Wildlife and Parks. In 1990, a pelican population of ~300 nests was discovered at Arod Lake (Henricks and Johnson 2002). Though annual surveys are not conducted at this location, it is estimated to hold 300-500 breeding pairs annually (Henricks and Johnson 2002; Audubon 2017).

While large white pelican colonies are in only a few locations in Montana, feeding by birds in these colonies has the potential to influence fish populations throughout the state. Foraging white pelicans frequently travel 100-300 km from nesting colonies (Lingle and Sloan 1980; Findholt and Anderson 1995), and each adult consumes approximately 1.2-1.8 kg of prey per day (Anderson 1987; Evans and Knopf 1993). In the Smith River, trout populations have been relatively reduced since white pelicans became abundant around 1989 (Fig. 2). The median number of trout per mile since 1989 is 638 compared to 774 per mile before 1989. While numerous other factors could also influence the lower trout population numbers in recent years (e.g., drought, water demands, changes in irrigation practices, etc.), the recent decline, along with the known potential of impacts from white pelicans based on other studies (Teuscher et al. 2015; Meyer et al. 2015), warrants further investigation in the Smith River and Montana.

Foraging

White pelicans are opportunist, generalist foragers and are documented to feed on a variety of nongame and game fish species (Stapp and Hayward 2002; Knopf and Evans 2004). Previous studies have suggested the white pelicans choose areas to forage based on prey availability or abundance and not prey type (Lingle and Sloan 1980; Findholt and Anderson 1995). White pelicans are able to forage in a variety of habitats but prefer habitats that are 0.30-0.60 m deep or where fish are within 1 m of the surface (Anderson 1991; McMahon and Evans 1992; Finholdt and Anderson 1995; Ivey and Herziger 2006) potentially exerting heavy pressure within shallow, wide rivers or during low water years.

Foraging by white pelicans and other avian predators can account for a substantial portion of observed mortality in fish populations. In tributaries of Yellowstone Lake, white pelicans and grizzly bears (*Ursus arctos*) consumed 5% of the adult spawning cutthroat trout (Stapp and Hayward 2002). In the Blackfoot River in Eastern Idaho, white pelicans consumed from 20 to

60% of adult Yellowstone cutthroat trout as they made annual spawning migrations (Teuscher et al. 2015). In reservoirs, white pelicans consume as much as 48% of stocked hatchery trout and can harvest more fish than recreational anglers (Meyer et al. 2015). These high predation rates on trout species can reduce angler catch (Meyer et al. 2015) and may also have long term consequences to the sustainability and health of fisheries. Scoppettone et al. (2014) evaluated predation of Ciu-ui (*Chasmistes cujus*) in Pyramid Lake, Nevada by white pelicans through feeding tagged fish to pelicans. Based on the number of recovered tags, they estimated over seven years, white pelicans consumed 90% of tagged fish. In addition to potential population impacts, white pelican predation may also have impacts on the ongoing migration and movement studies in the Missouri River drainage, by removing an unknown quantity of tagged fish, and thereby decreasing movement rates.

In 2016, a survey of white pelican nesting sites at CFR and Arod Lakes by FWP personnel found 307 PIT tags from consumed fish (Table 2). Two hundred and sixty-five of these tags belonged to fish tagged in the Missouri, Smith, and Sun rivers (Fig 3). Recovered tags were associated with multiple species including: ling (*Lota lota*), brown trout (*Salmo trutta*), longnose sucker (*Catostomus catostomus*), mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*) and white sucker (*Catostomus commersonii*). In addition to these tags, 16 tags from the Big Hole River including one arctic grayling (*Thymallus arcticus*), 26 unmatched tags, and 1 Floy tag from a channel catfish (*Ictalurus punctatus*) tagged near Billings, MT in the Yellowstone River were recovered. Assuming the fish are depredated near their initial tagging location, it is estimated that white pelicans from Arod Lake and CFR colonies travel up to ~187 km (116 miles) to prey upon a variety of fish species (Fig. 3).

Objectives

1. Quantify PIT tag recovery rate
2. Estimate efficiency of tag detection
3. Quantify white pelican minimum and total predation rates

Study Area

The Smith River is located in central Montana southeast of Great Falls, Montana (Fig. 4). It is a major tributary to the Missouri River and is a highly prized trout fishery. As the only regulated-float river in Montana, the Smith River draws tourists from across the state and country who compete for the ~5,500 launches. The annual economic contribution of the Smith River was estimated at $5,844,274 in 2015 (MFWP, unpublished data) with many of the issued permits being fishing trips.

Large groups of +100 pelicans are observed annually on the Smith River (Fig. 5). Flight distance from CFR to Camp Baker on the Smith River is approximately 50 km and due to its wide and shallow morphology, provides optimum foraging habitat. Above Camp Baker the river has a type “E” stream morphology (Rosgen and Silvey 1996) and pelicans congregate downstream of large pools. These congregations form pelican “weirs” on these narrow, shallow sections of the river. Downstream of Camp Baker to Eden Bridge, the 94 km stretch becomes more restricted by limestone cliffs and increases in size through the contribution of several tributaries.

Methods

The design of this study is modeled after work completed by Idaho Department of Fish and Game (Teuscher et al. 2015; Meyer et al. 2016). Principal Investigator, David Teuscher, was contacted in the spring of 2017 to discuss efficient methods of feeding white pelicans and potential confounding factors with the recovery rate calculations.

Recovery rate of PIT tags

With the assistance of FWP Giant Springs Hatchery personnel, 750 hatchery raised rainbow trout were euthanized with CO_2 narcosis. These fish were weighed, measured, PIT tagged, and frozen. After pelicans arrived in early May, feeding attempts began on the Smith River above Camp Baker. Several methods were attempted but none were successful due to high sensitivity to human presence and river morphology making it difficult to get close to the white pelicans. To be able to calculate a tag recovery rate, feeding attempts were moved to the Missouri River below Wolf Creek bridge. Pelican foraging is observed annually on the Missouri River, and birds are exposed to much more boat traffic. Flight distance from Wolf Creek Bridge to CFR Pond 3 is ~77 km which was deemed comparable to the 51 km flight distance from the Smith River to CFR Pond 3. In 2016, tag search efforts recovered tags from over 187 km away originating from the Big Hole River, thus the change in feeding locations from the Smith River to the Missouri River was not deemed significant (Fig. 6).

Beginning in July, FWP technicians and a MSU undergraduate student floated the Missouri River daily. When a group of pelicans were found, a PIT tagged deceased hatchery fish was injected with air, and floated downstream to the pelican group (Scoppettone et al. 2014; Teuscher et al. 2015). Ingestion of a tagged fish was considered when a pelican "head tossed" (Teuscher et al. 2015). Efforts to feed only one fish per bird were made to maintain independence of tag distribution. If two tags were confirmed to be ingested by the same bird in succession, the second tag was not included in analysis. If birds were loafing on an island and no active foraging was observed, an untagged hatchery "test" fish was deployed to see if birds could be lured from loafing to active feeding in the river. Tag number, feeding location, total number of birds present, tag lost to gull predation, and tag consumption or loss were recorded.

Total Predation Estimate

To calculate a total fish predation estimate, a known number of fish were tagged along the longitudinal length of the Smith River before pelicans arrived in Montana (Fig. 7). Beginning in March 2017, fish were captured with mobile anode (crawdad) electrofishing upstream of Camp Baker and with a raft and fixed-boom anode electrofishing system downstream of Camp Baker. Both electrofishing set-ups employed DC pulsed current with a Smith-Root VVP-15B electrofisher. Standard methods were used at all tagging locations. Fish were anesthetized with MS-222, measured for total length (TL), weighed, and implanted with a sterile 23 mm HDX PIT tag. Fish recuperated in a live well before being released back into the river.

From March to April 2017, we tagged 811 fish of eight species with 134.2 kHz 23 mm HDX PIT tags (Oregon RFID, Portland, Oregon) at 14 locations on the Smith River (Fig. 7). Total length of tagged fish ranged from 134 to 858 mm. Most fish captured and tagged were trout or mountain whitefish (Table 1).

Table 1. Passive integrated transponder tagged fish from spring 2017 tagging events within the Smith River, Montana.

Species	Count
Brown trout	205
Rainbow trout	145
Mountain whitefish	416
Long-nosed sucker	10
White sucker	23
Westslope cutthroat trout	2
Ling	5
Brook trout	5

These tagged fish were added to the previously tagged fish population within the Smith River drainage. Including previously tagged fish since 2014, we have tagged 6,848 fish within the Smith River.

Efficiency of Tag Detection

One week prior to widespread searching of PIT tags at CFR, 200 tags were randomly distributed on 10 islands at Pond 3. These tags were equally categorized into two tag sizes (12 mm and 32 mm), five habitat types (cobble, mud, water, nettle/shrub, and willow), and two depths (surface and buried). This resulted in 10 tags per unique habitat/depth/tag size group.

Effort was made to disguise walking and placement of tags to maintain independence during searching periods. The "hider" of the tags did not search the islands on which tags were randomly distributed.

Tag Collection and Statistical Analysis

In August, after juvenile pelicans fledged and were no longer residing on nesting islands, a systematic search for the tags was conducted on all known white pelican nesting sites at CFR (Ponds 2, 3, and 4) and Arod Lake. Feeding locations along the Missouri River were also searched to determine what percentage of fed tags remained at loafing locations. Backpack PIT tag detectors were used to sweep the nesting/colony locations. At each island, the scanner would begin on the outer edge of the island (~0.3 m into the water), and would walk the circumference of the island. They would then continue walking in concentric circles moving inward until the entire island had been searched (swept with a backpack reader wand). For each tag detection, a 10-minute effort to recover the PIT tag was made but recovery efforts were abandoned if search time exceeded this limit. For all detected tags, GPS location, island number, habitat type, tag number, depth, recovery status, and distance and type (pelican or cormorant) of nearest nest was recorded.

After a thorough and complete search of all nesting islands (current and historic) for the tags, data was organized and analyzed by: tags detected in 2016 and redetected in 2017, hatchery fed tags, and natural origin tags.

Pelican predation rates (PR) of tagged fish within the Smith River were calculated as:

Total PR = $\frac{Y_1}{Y_2}$

Where Y_1 = number of wild tags found / number of wild fish tagged and Y_2 = number of fed hatchery tags found / number of fed hatchery tags consumed (Teuscher et al. 2015). Variance of the ratio was calculated with 95% confidence intervals (95%) as (Yates 1949; McFadden 1961):

$$V\left(\frac{Y1}{Y2}\right) = \left(\frac{Y1}{Y2}\right)^2 \times \left(\frac{V(Y_1)}{Y_1^2} + \frac{V(Y_2)}{Y_2^2}\right)$$

Lower CI = PR - $\sqrt{V\left(\frac{Y1}{Y2}\right) \times \left(\frac{t\propto}{2}\right)}$

Upper CI = PR + $\sqrt{V\left(\frac{Y1}{Y2}\right) \times \left(\frac{t\propto}{2}\right)}$

Minimum predation rate = Y_1 = number of wild tags found / number of wild fish tagged, where the number of wild tags found is adjusted based on the detection efficiency

Total consumed = total predation rate $\left(\frac{Y_1}{Y_2}\right)$ × total tagged fish

Results

All current and historic nesting islands at Canyon Ferry Reservoir and Arod Lake and all observed loafing areas on the Missouri River were scanned for PIT tags. Two FWP technicians and four MSU students worked in pairs from August 22 to 30 for a total of 160 man-hours.

A total of 268 PIT tags were found during our 2017 search efforts. Thirty-two of these tags were previously found in 2016, 12 of these tags were hatchery fish that were deployed into the Missouri River but were not eaten, and four of the tags were eaten but deposited on the loafing islands of the Missouri River. Removing these tags, we found 220 new PIT tags in 2017 at pelican nesting areas, 122 (55.5%) of which were fish of natural origin that had been tagged in the Missouri or Smith rivers from 2014-2017, 12 (5.4%) were of unknown origin, 78 (35.5%) were tags distributed as part of the efficiency study, and eight (3.6%) were recovered tags from fed hatchery fish (Table 2, Fig. 8).

Table 2. Recovered passive integrated transponder (PIT) tags at American white pelican nesting colonies in central Montana in 2017.

Origin of Tags	2017	2016
Hatchery Tags	8	N/A
Efficiency Tags	78	N/A
2017 Smith Fish	39	N/A
2014-2016 Smith Fish	79	216
2014-2016 MOR Fish	4	27
2014-2016 Sun Fish	0	10
Big Hole River	0	16
Tagged Before 2014	0	12
Unknown Origin	12	26
Total	**220**	**307**

Recovery rate of PIT tags

From mid-July to mid-August 2017, 110 deceased PIT tagged hatchery fish were fed to pelicans on the Missouri River. Of these 110 tags, eight were recovered at pelican nesting locations (7.3% recovery rate). Four additional fed tags were found on loafing islands on the Missouri. Finding only four tags on the loafing sites and eight at nesting colonies indicates that birds were returning to the nesting colonies regularly during feeding activities.

Efficiency of Tag Detection

All PIT tags were collected with the same methods and were not differentiated in the field. During data analysis, efficiency tags were identified and categorized based on the original designated habitat, depth, and tag size. A total of 78 efficiency tags of both 12 mm and 32 mm were found (Table 3).

Table 3. Efficiency of PIT tag detection at pelican nesting colonies with a backpack PIT tag detector across two tag sizes, five habitat types, and two depths.

Depth	Tag Size (mm)	Willow	Nettle/ Shrub	Mud	Cobble	Water
Buried	12	2 (20%)	2 (20%)	4 (40%)	7 (70%)	1 (10%)
Buried	32	4 (40%)	5 (50%)	1 (10%)	7 (70%)	4 (40%)
Buried Total		**6/20 (30%)**	**7/20 (35%)**	**5/20 (25%)**	**14/20 (70%)**	**5/20 (25%)**
Surface	12	1 (10%)	0 (0%)	4 (40%)	7 (70%)	1 (10%)
Surface	32	2 (20%)	1 (10%)	7 (70%)	9 (90%)	9 (90%)
Surface Total		**3/20 (15%)**	**1/20 (5%)**	**11/20 (55%)**	**16/20 (80%)**	**10/20 (50%)**
Habitat Total		**9/40 (23%)**	**8/40 (20%)**	**16/40 (40%)**	**30/40 (75%)**	**15/40 (38%)**

Of the 78 tags, 29 were 12 mm and 49 were 32 mm. A higher percentage of the 32 mm tags was expected as the larger tags have a larger read range than the smaller 12 mm tags (Table 3). In ideal conditions, maximum read ranges for a 12 mm sized tag is 0.45 m and for a 32 mm sized tags is 0.7 m (Warren Leach, Oregon RFID, personal comm.). Forty-one of the 78 tags were from the surface while 37 of the 78 were buried. Of all habitat types, willow and nettle/shrub decreased tag detection more so than mud or cobble (Table 3). This was expected to due to the inability to maneuver the scanning wand through the bushes effectively.

Overall, we had an average 39% detection rate of tags across all habitat types and tag sizes. As most tags implanted in the Smith River fish are 23 mm, an average of a 12 mm and 32 mm detection efficiency is representative of the tags from our wild fish cohort and is used in the correction of minimum and total predation calculations.

This average detection rate of tags is similar to the average of detection efficiency of tags redetected in 2017 that were first detected in 2016. In 2016, 307 tags were detected on pelican nesting colonies (Table 2). Of these 307 tags, 227 were physically recovered leaving 80 tags on the islands. During our search efforts, we detected 31 of these 80 tags for an average detection rate of 38.8%.

Total Predation Estimate

Of the 220 new tags recovered at pelican nesting locations, 39 were from the 811 fish tagged in the Smith River in the spring of 2017. Based on this tag group, there is a minimum predation rate of 12.3% and a total predation estimate of 66.1% ± 14.4% (Table 4) or a total predation of 536 fish of the 811 tagged. However, if we include all tags found from past tagging events (2014-2017), we have a minimum predation rate of 4.4% with a total predation estimate of 23.6% ± 4.8% or 1,616 of 6,848 tagged fish (Table 4).

Fifty-one percent of the fish tagged in 2017 were mountain whitefish (n=416); however, fishermen along the Smith River typically target trout species. Analyzing just 2017 trout (brown and rainbow trout) recovered tags, there was a minimum predation rate of 9.6% and a total predation rate of 51.6% ± 13.2% or 178 of 346 tagged fish. Including all tag years (2014-2017), the minimum predation rate of trout is 2.5% and the total predation is 13.7% ± 2.9% or 602 of 4,398 trout (Table 4).

These predation rates and variances are calculated to include the 39% detection rate of tags. Original and adjusted numbers of tags found are reported in Table 4.

Table 4. Minimum and total predation of Smith River, Montana fisheries by American white pelicans. Specific PIT tagging groups are shown. "All tagged" includes fish tagged in other FWP and MSU studies in the Smith River from 2014-2017. Adjusted number of tags recovered corrects the number of tags recovered based on a 39% detection efficiency.

Tag Group	Tags Recovered	Tag # Adjusted	Total Tagged	Min. PR	Hatchery Found	Hatchery Fed	Total PR	95% Lower CI	95% Upper CI	Estimated Total Consumed
2017 spring tag fish	39	100	811	12.3%	8	110	66.1%	51.7%	80.5%	535
All tagged fish	118	302	6,848	4.4%	8	110	23.6%	18.8%	28.5%	1,616
2017 spring tagged trout	13	33	346	9.6%	8	110	51.6%	38.4%	64.8%	178
All tagged trout	44	112	4,398	2.5%	8	110	13.7%	10.7%	16.7%	602

Using the 2014-2017 trout tag group and extrapolating these minimum and total predation rates to our average population estimate of 754 trout 8 inches and greater per mile in the Eagle Creek section of the Smith River, we calculated a minimum predation estimate of 19 trout per mile and total predation estimate of 103 trout per mile.

Size of depredated trout and whitefish from the 2017 tag group ranged from 7.7 to 20.9 inches. The median lengths for brown and rainbow trout were 11.7 and 11.8 in. while the maximum lengths were 20.9 and 14.3 in., respectively (Table 5). No clear trend in prey size preference was observed as predation was distributed across length groups (Fig. 9). This elastic, generalist foraging behavior across prey species and size has been observed in other studies (Scoppettone et al. 2014; Evans et al. 2015).

Table 5. Minimum, median, and maximum lengths of depredated PIT tagged brown trout, rainbow trout, and mountain whitefish in the Smith River. Fish were tagged in spring 2017 and the PIT tags were recovered at American white pelican nesting colonies on Canyon Ferry Reservoir, MT.

Species	Count	Min. (in.)	Median (in.)	Max (in.)
Brown trout	11	7.7	11.7	20.9
Rainbow trout	2	9.3	11.8	14.3
Mountain whitefish	25	8.3	12.7	18.5

Discussion

While numerous studies have been completed on avian predation of out-migrating salmonid stocks (Roby et al. 1998; Ryan et al. 2003; Evans et al. 2012), few have estimated white pelican predation of resident fish populations (Scoppettone et al. 2014; Teuscher et al. 2015). The design

of this study was based on Teuscher et al. (2015) to help estimate total American white pelican consumption rates of resident fish populations within the Smith River of central Montana.

Of the 6,848 PIT tags deployed into the Smith River from 2014-2017, 58% have never been redetected and avian predation is considered a potential significant source of tag loss. Based on the results from this study, and using the more conservative predation estimates from the larger 2014-2017 dataset, we can attribute at minimum 4.4% (273 tags) and up to 23.6% ± 4.8% (1,616 tags) of tag loss to pelican predation.

Assuming that the PIT tagged group of fish is representative of the entire fish population within the Smith River, a minimum predation estimate of 4.4% and a total predation estimate of 23.6% ± 4.8%, suggests that white pelicans are removing at minimum 3,251 fish and up to 17,438 ± 3,456 fish annually (using an average 754 trout/mile population estimate from the two mile Eagle Creek section of the Smith River). Utilizing the more broad-based estimates based on the 2017 tag group data of 12.3% and 66.1% minimum and total predation, respectively, would result in even greater number of fish removed from the Smith River annually by white pelicans.

Similar pelican predation rates were observed in the Blackfoot River drainage (Teuscher et al. 2015). From 2010-2013, researchers PIT tagged adult and juvenile Yellowstone cutthroat trout. From these tagging events and the feeding of tagged fish to pelicans (n=141-233), researchers calculated total annual predation rates between 6.4%-60.6% with most generally >20% (Teusher et al. 2015). Blackfoot Reservoir experienced a similar population increase of white pelicans as CFR. In 1993, the first successful breeding season was recorded and by 2012, there was an estimated 3,034 adult pelicans at Blackfoot Reservoir (Pacific Flyway Council 2012; Teuscher et al. 2015).

Without further analysis of mortality within the Smith River, this predation cannot be classified as compensatory nor additive. While review of basic graph trends of trout and pelican populations suggest that pelican predation may be at least partially additive (Fig. 2), population dynamics within the Smith River are complex and highly dependent on habitat conditions such as instream flows and water temperature. Within the past 12 years, Montana Fish, Wildlife and Parks has implemented time of day angling restrictions or completely closed angling for periods of time in the Smith River in 2006, 2007, 2012, 2013, 2014, 2016, and 2017 due to high water temperatures and/or low flows. In 2017, May daily flow was 67% of average and July daily flow was 37% of average (USGS 2017). For nearly the entire month of July, peak water temperature exceeded 72°F and average daily peak was 75.8°F (USGS 2017). The upper lethal temperatures for salmonids are generally greater than 77°F (Hokanson et al. 1977; Jobling 1981; Bjornn and Reiser 1991; Matthews et al. 1997). These extreme semi-regular habitat conditions are likely another factor limiting the fishery and could compound as fish are actively removed from the population. In addition to habitat restrictions, long term changes in community composition from a rainbow trout dominated fishery to one where rainbow and brown are in near-equal representation may also play a role in the reduced trout densities in some recent years (Fig. 2).

With different life history strategies than trout, mountain whitefish may experience even greater predation pressure from pelicans. As a fish species that schools, “cooperative herding” (Anderson 1991) feeding strategies by pelicans may be especially successful. Of the 39 2017 spring tagged fish found at CFR, 25 were whitefish and 11 were brown trout. Of the 118 tags from 2014-2017 tagging events, 70 were whitefish and 29 were brown trout. Based on these tag

returns, whitefish have a slightly higher minimum predation rate than brown trout (1.7-3.5%) and a substantially higher minimum predation rate than rainbow trout (7.5-11.8%) dependent upon which tagging cohort is analyzed (Table 6).

Table 6. Minimum predation rates of brown trout, rainbow trout, and mountain whitefish by American white pelicans in the Smith River, Montana. Minimum predation rate is corrected with a 39% tag recovery rate.

Tag Group	Species	Tags Recovered	Adjusted Tags Recovered	Tags Deployed	Min. Predation Rate
2017 Tagging Group	Brown trout	11	28	205	13.7%
	Rainbow trout	2	5	141	3.6%
	Mountain whitefish	25	64	416	15.4%
2014-2017 Tagging Group	Brown trout	29	74	1,439	5.2%
	Rainbow trout	15	38	2,959	1.2%
	Mountain whitefish	70	179	2,052	8.7%

This study confirms pelican predation occurs throughout the Smith River drainage, including the remote recreational float section between Camp Bank and Eden Bridge (Fig. 6). Few tags were recovered at the white pelican nesting islands in 2016 from fish that were tagged within the float section (Fig. 3), despite some tags being deployed in this reach, albeit at much lower densities than upstream and downstream. By tagging fish throughout the Smith River in spring 2017, we were able to document pelican predation throughout the river, including in the float section (Fig. 8). Minimum predation rates varied throughout the float reach (Table 7). Fewer tags were recovered from fish tagged in the Upper Canyon section (Table 7, Fig. 10) compared to fish tagged in the other sections. These differences may be due to foraging or loafing habitat availability throughout these sections. The upper section of the Smith River (Canyon Ranch to Camp Baker) is a meandering river surrounded by agricultural fields and riparian habitat which becomes restricted as it flows into a steep limestone canyon (Camp Baker to Rattlesnake Bend). Below Rattlesnake Bend, the Smith River flows through prairie and grassland habitat before it joins the Missouri River. Based on field observations, available loafing sites seem necessary for large feeding congregations. While predation occurs throughout the entire length of the Smith River, most likely, sections with desirable habitat experience greater predation pressure than others.

Table 7. Minimum predation rates of Smith River fish tagged in spring 2017. Fish were tagged across 14 locations and these locations are divided by corresponding landscapes into four sections.

2017 Spring Tagging	Section Description	Tags Recovered	Adjusted Tags Recovered	Tags Deployed	Min. Predation Rate
Upper Section	Fort Logan and Canyon Ranch	15	38	353	10.8%
Upper Canyon	Spring Creek to Scotty Allen	3	7	168	4.5%
Lower Canyon	Sheep Wagon to Paradise Bend	13	33	179	18.6%
Lower Section	Rattlesnake Bend to Eden Bridge	8	20	111	18.4%

These conclusions are made with notable assumptions and restrictions. First, as this was one year of data collection, sample sizes are small, and variance of the proportions are high. Second, these predation rates are corrected with a 39% PIT tag detection rate. While this does not alter the total predation estimate as the 39% correction to Y_1 and Y_2 cancel each other out, it does increase the minimum predation rate. Third, 2014-2017 all tagged fish group calculations are assuming that all tagged fish are still within the system and does not back calculate previous years of predation or tag loss. It also assumes that all tags collected in 2017 are from 2017 predation after accounting for the tags detected during the 2016 search. Lastly, our extrapolation of tagged fish to the total population estimate is an assumption that the PIT tagged fish are representative of the entire fish population and the population estimate is representative of the extended portions of the Smith River upstream and downstream from the population estimate reach. These assumptions should be kept in mind when reviewing the data. However, even with those assumptions, this study has allowed us to estimate total predation by white pelicans on Smith River fisheries.

Future Analysis

In the fall of 2017, Pond 3 of CFR, where the majority of pelican nesting occurs, was drawn down to achieve a winter kill of the carp population and stimulate more desirable aquatic vegetation growth to benefit waterfowl. Based on the numerous carp carcasses found throughout the nesting areas, this fish population may constitute a significant portion of the prey base for the pelican population. With that prey source eliminated, increased foraging may occur in future years on the Smith River than previously observed.

Continued sampling of the trout population within the Smith River system will allow us to monitor trends in populations, monitor tags at nesting locations, and further evaluate whether the pelican predation is additive or compensatory to this fishery. In addition to continued monitoring of the fishery, periodic daily counts of pelicans and estimated total days present on the Smith River will help improve annual predation estimates and understanding of foraging behavior by central Montana white pelicans. If the loss of carp within Pond 3 of CFR increases predation on the Smith River and the trout or mountain whitefish population significantly declines,

management strategies should be discussed within the framework of the Pacific Flyway Council recommendations (Pacific Flyway Council 2012).

This study provides an estimate of the amount of pelican predation on the Smith River. Tags found at the CFR nesting colony in 2016 and 2017, indicate these pelicans travel up to 187 km (116 miles) to prey upon a variety of fish species, including channel catfish from the Yellowstone River and arctic grayling from the Big Hole River. This pelican population is artificially enhanced from the construction of the dust abatement ponds at CFR. The extent of the impact (if any) of pelican predation on fish populations in other waters in central Montana is unknown. Additional studies focusing on the interaction of pelican and fish populations in central Montana, may provide valuable information for managing recreational and native fisheries.

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Figures

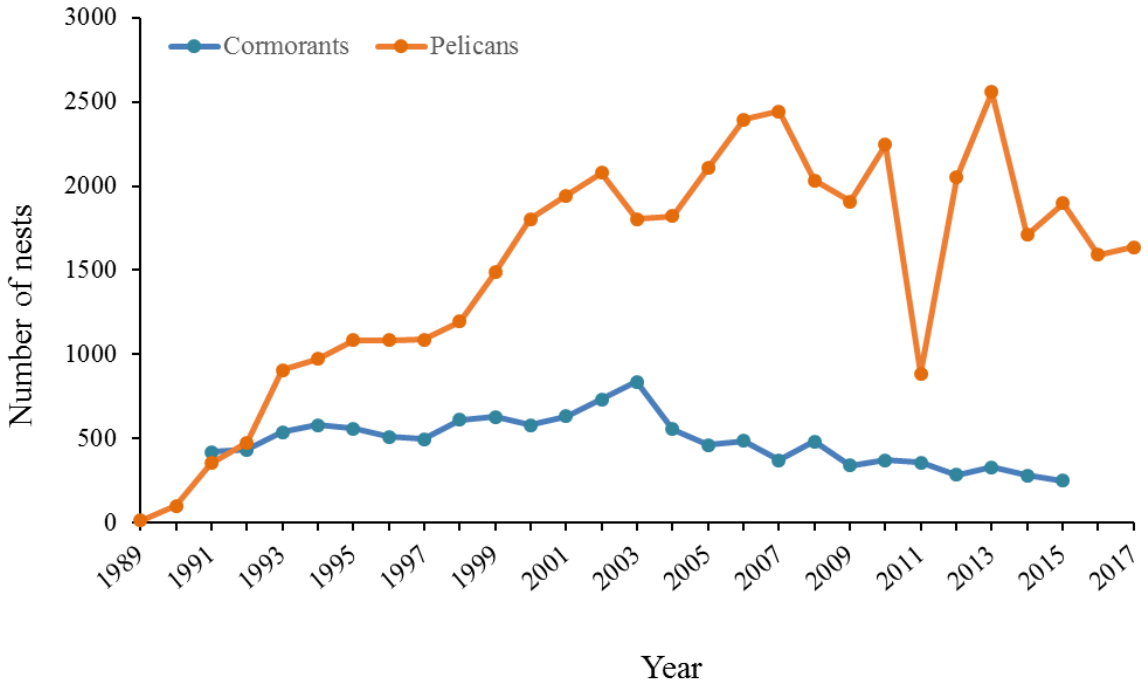

Figure 1. Total number of American white pelican (*Pelecanus erythrorhynchos*) and double-crested cormorant (*Phalacrocorax auritus*) nests at Canyon Ferry Reservoir, Montana from 1989 to 2017.

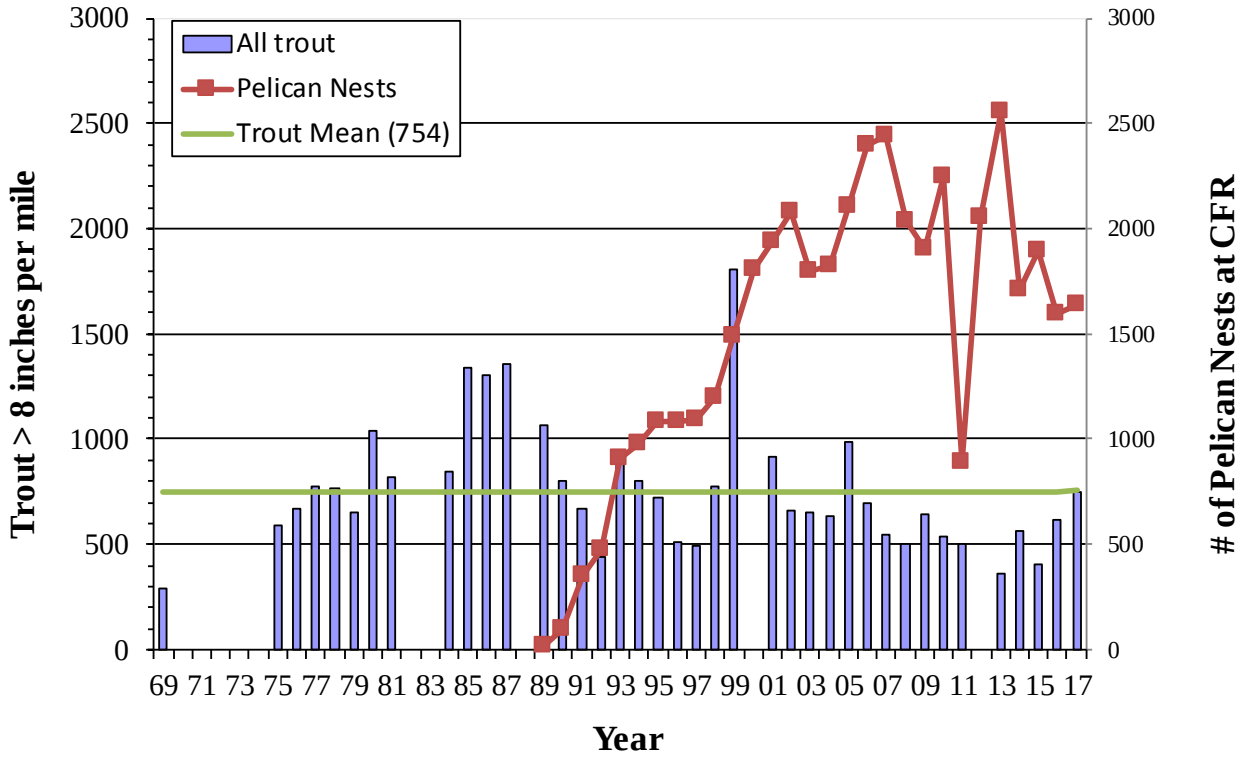

Figure 2. Number of total trout >8 inches total length per mile of the Smith River, Montana within the Eagle Creek section from 1969 to 2017 and total number of pelican nests at Canyon Ferry Reservoir, Montana from 1989 to 2017. In 2011, returns of adults were significantly reduced without explanation. Possible contributing factors may have included West Nile virus, localized weather events, or pollution through the wintering habitat (Wightman et al. 2011; Fred Jakubowski, FWP Fish and Wildlife Technician, personal comm.).

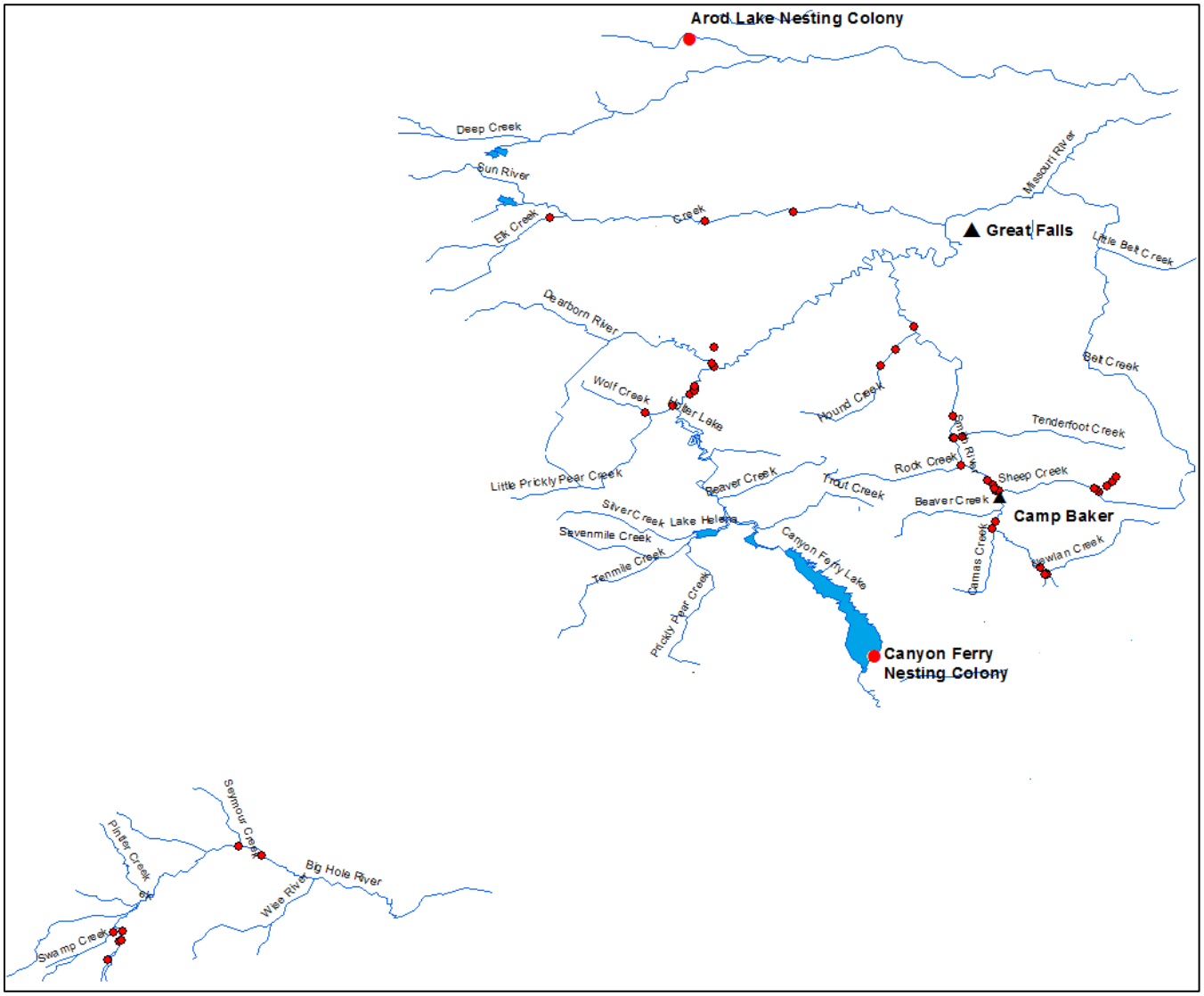

Figure 3. Approximate original tagging locations (red) of recovered PIT tags at American white pelican nesting locations on Canyon Ferry Reservoir, Montana during 2016 surveys by FWP personnel. Depredated fish are assumed to have been consumed near the original tagging location.

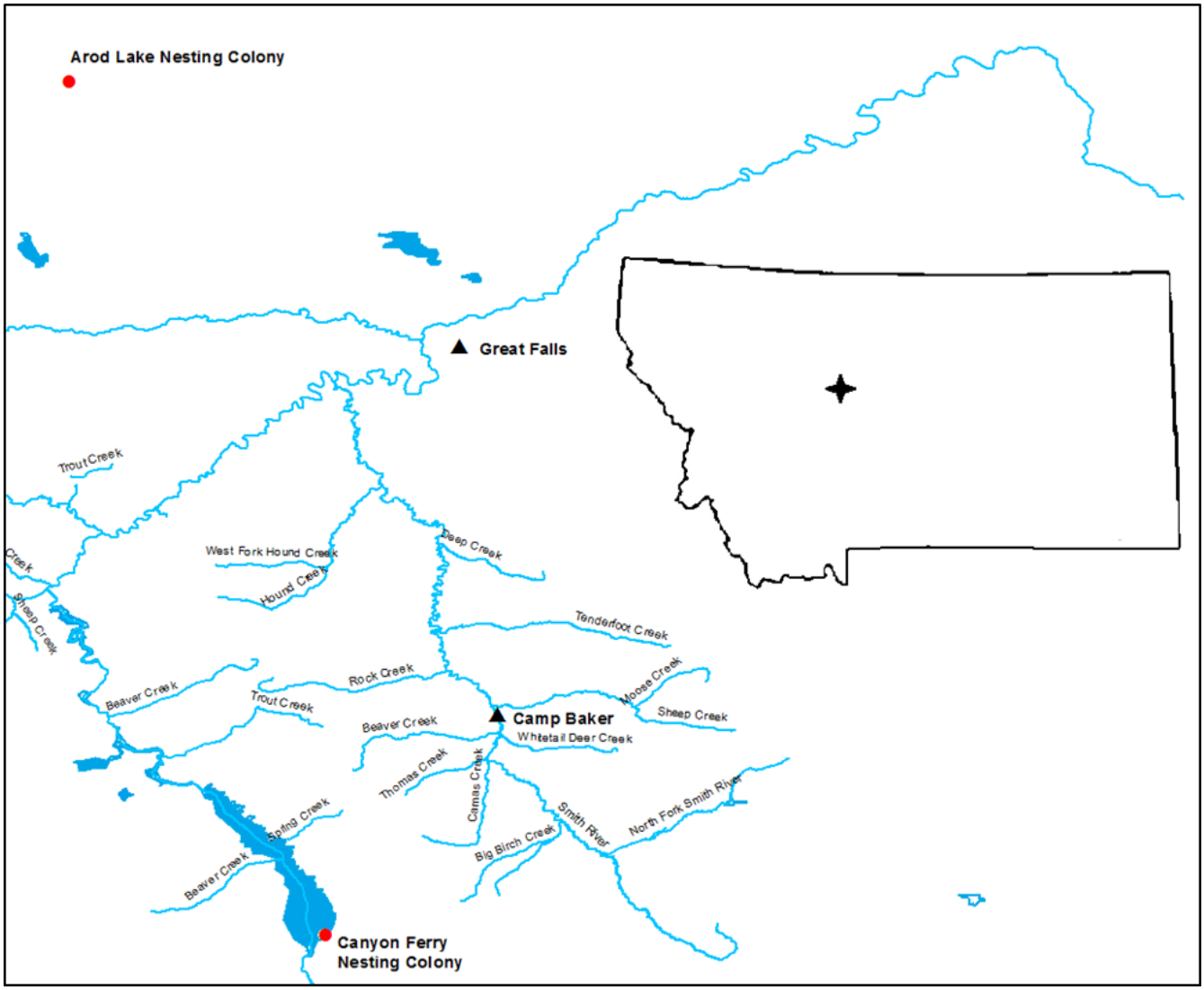

Figure 4. The Smith River and tributaries in central Montana. The confluence with the Missouri occurs near the town of Ulm, Montana south west of Great Falls. American white pelican breeding colonies are indicated by red circles.

Figure 5. American white pelicans loafing and foraging on the Smith River, Montana.

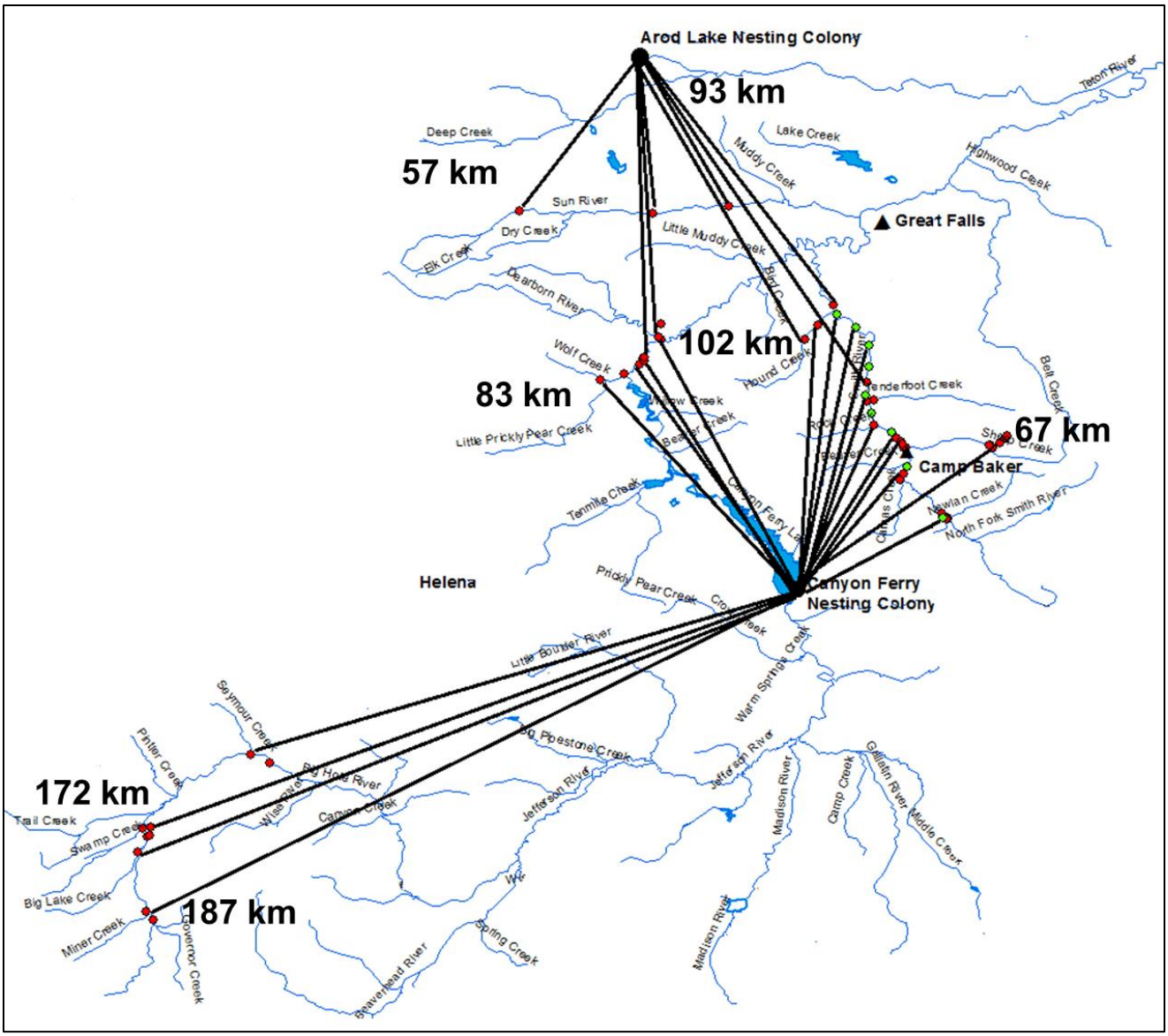

Figure 6. Approximate original tagging locations of recovered PIT tags at American white pelican nesting locations on Canyon Ferry Reservoir, Montana and Arod Lake. PIT tags recovered in 2016 are indicated in red and those recovered in 2017 are green. Depredated fish are assumed to have been consumed near the original tagging location. Associated foraging distance from nesting locations are attached.

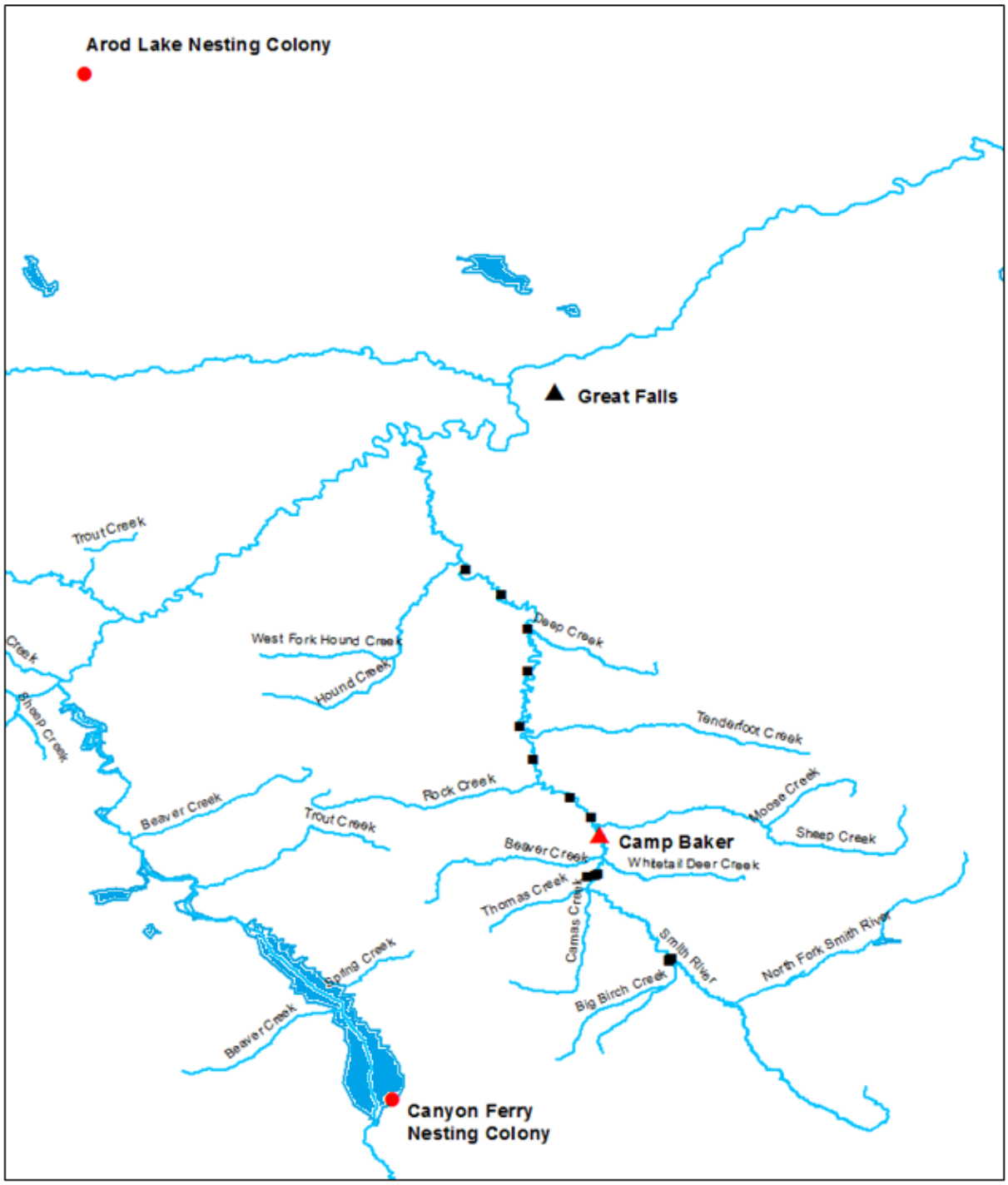

Figure 7. Tagging locations of 811 fish along the Smith River from March to April 2017 (black squares). Fish were tagged with passive integrated transponder tags as part of a pelican predation estimate.

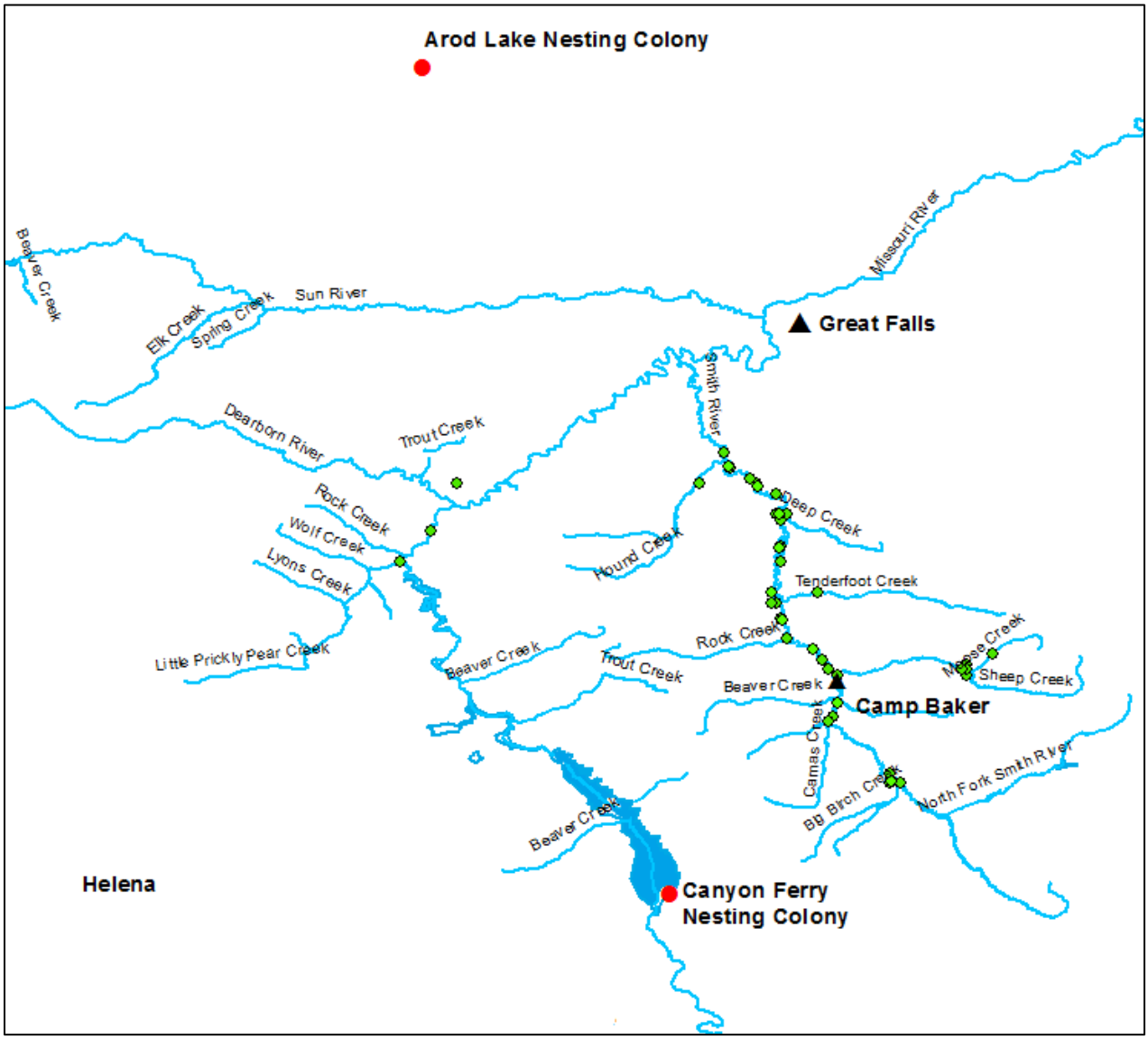

Figure 8. Approximate original tagging locations (green) of recovered PIT tags at American white pelican nesting locations on Canyon Ferry Reservoir, Montana during 2017 surveys by FWP personnel. Depredated fish are assumed to have been consumed near the original tagging location.

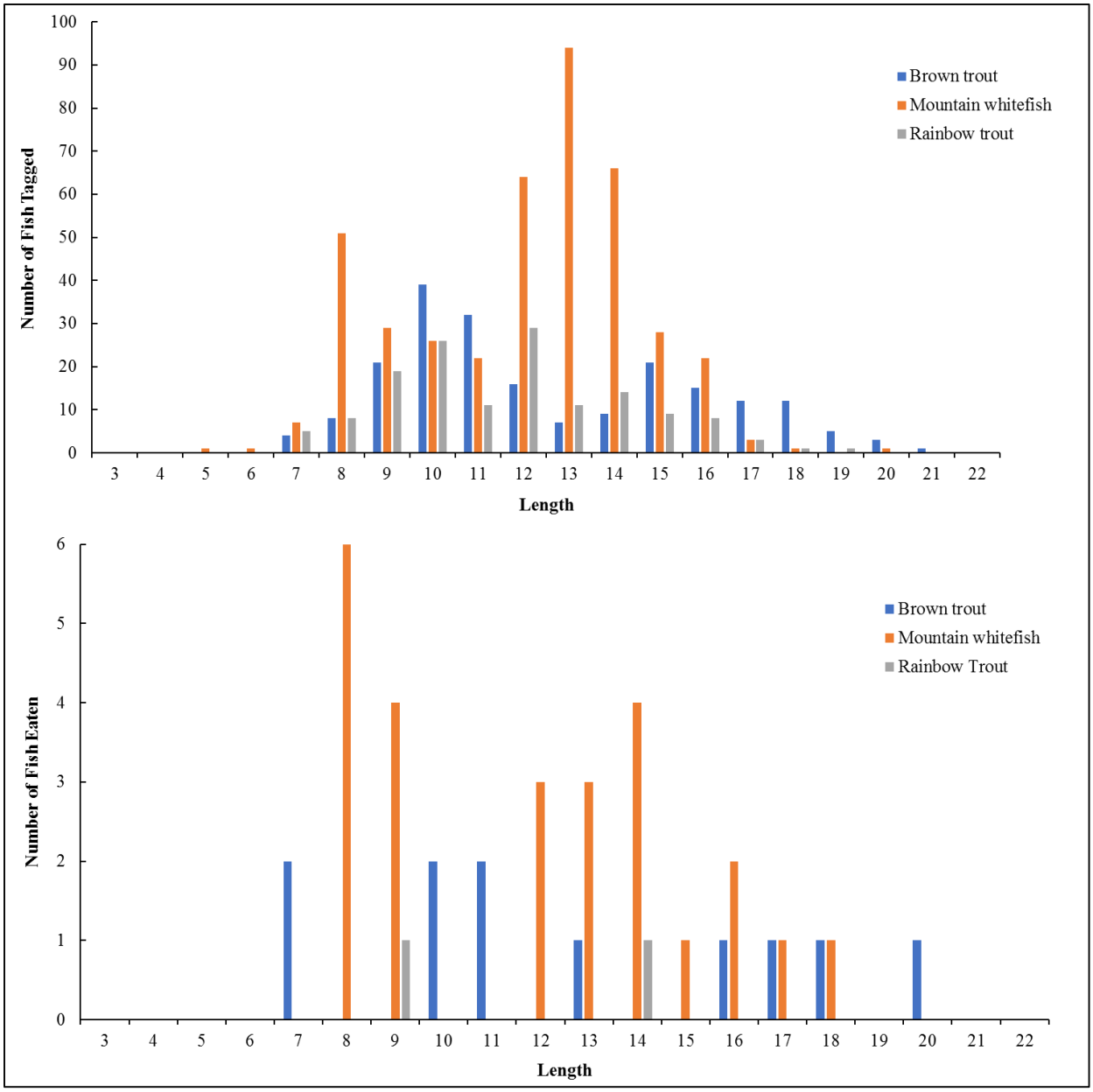

Figure 9. Length distribution of 2017 spring PIT tagged brown trout, rainbow trout, and mountain whitefish in the Smith River (top). The length distribution of consumed fish whose PIT tags were found at American white pelican nesting colonies on Canyon Ferry Reservoir, MT in 2017 (bottom).

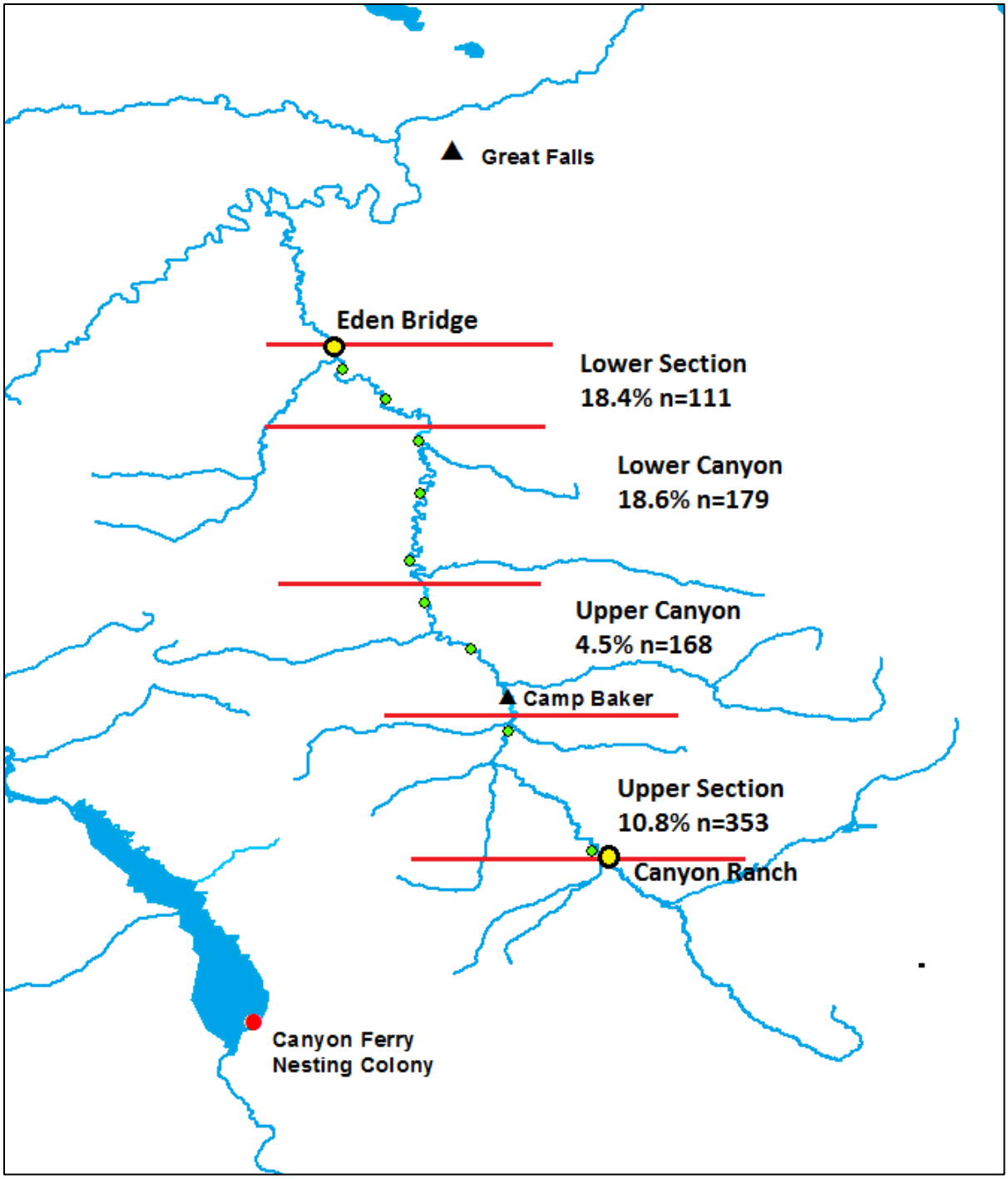

Figure 10. Original tagging locations (green) of recovered 2017 spring PIT tags at American white pelican nesting locations on Canyon Ferry Reservoir, Montana during 2017 surveys by FWP personnel. Red lines divide the Smith River into four sections of corresponding landscapes. Number of tags deployed during tagging events and associated minimum predation rates by section are indicated. A total of 811 tags were distributed across 14 locations from Canyon Ranch to Eden Bridge. Top and bottom of tag distribution area is marked with yellow circles.