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Ecology of Redband Trout in the Donner und Blitzen River Basin

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Abstract

Redband Trout *Oncorhynchus mykiss newberrii* are present on the Malheur National Wildlife Refuge (MNWR) and abundant in the Donner und Blitzen River upstream from Page Springs Diversion Dam. A proportion of this population exhibits migratory behavior and uses the lower reaches of the Blitzen River, and possibly Malheur Lake. Construction and subsequent colonization of a tern island constructed on Malheur Lake by Caspian terns *Hydroprogne caspia* has raised concern regarding the potential impacts to Redband Trout and other native fish species on the MNWR. Due to the paucity of information regarding the life history and ecology of migratory Redband Trout on the MNWR, it is difficult to assess the potential effects of putative increases in avian predation pressure on Redband Trout associated with construction of the tern island. Therefore we used electrofishing surveys, adult fish traps, rotary screw traps, hook and line sampling, and PIT interrogation arrays to characterize the abundance, distribution, and migratory behavior of Redband Trout on the MNWR to provide resource managers with baseline information associated with the ecology of Redband Trout in the Blitzen River basin. We observed high densities of Redband Trout in the Blitzen River sub-basins. However, Redband Trout density was variable among sub-basins and among years. We also documented dispersal of Redband Trout from the Blitzen River sub-basins into the mainstem Blitzen River and PIT tags from Redband Trout were recovered from the tern island as well as from Singhaus Ranch. These data suggest that avian predators using man-made structures (e.g., the term island) are preying on Redband Trout. The PIT tags recovered on the tern island and Singhaus Ranch generally came from small Redband Trout (i.e., 148 ± 54 mm FL) that were likely juvenile fish rearing in the mainstem Blitzen River based on their capture histories (i.e., last know detection location). However, a concurrent study showed that Caspian terns on the MNWR tern island preyed extensively on Common Carp *Cyprinus carpio* (i.e., about 95% of their diet in 2014). We observed no Redband Trout migrating from the Mainstem Blitzen River into the Blitzen River sub-basins. Although this may be an artifact of our sampling or detection probabilities it could represent density dependence or source-sink dynamics, or both. Overall, these data provide new insight into the ecology of Redband Trout in the Blitzen River basin and may be used by resource managers to develop studies focused on the effect of predation on Redband Trout.

Introduction

Predation on juvenile salmonids by Caspian terns *Hydroprogne caspia* has prompted efforts to reduce Caspian tern nesting habitat on East Sand Island in the Columbia River Estuary. To mitigate for the loss of nesting habitat on East Sand Island, the US Army Corps of Engineers (USACE) has constructed a Caspian tern nesting island (hereafter, tern island) on Malheur Lake, Malheur National Wildlife Refuge (MNWR; Figure 1), Oregon (USACE 2011). Construction and subsequent colonization of the tern island by Caspian terns has raised concern regarding the potential impacts to Redband Trout *Oncorhynchus mykiss newberrii* and other native fish species on the MNWR.

Redband Trout are present on the MNWR, and abundant in the Donner und Blitzen River (hereafter, Blitzen River) upstream of Page Springs Diversion Dam. A proportion of this population exhibits migratory behavior and uses the lower reaches of the Blitzen River, and possibly Malheur Lake, during part of its life history (USACE 2011). Migratory Redband Trout may use Malheur Lake and the lower portions of the Blitzen River as foraging and over-wintering habitat, but use the Blitzen River and its tributaries for spawning, rearing, and as a migratory corridor during juvenile outmigration. Additionally, adult (≥ 30 cm) and juvenile (< 30 cm) Redband Trout may use portions of the Blitzen River as a thermal refuge during time periods when the temperature of Malheur Lake is physiologically stressful (see Northcote 1997 for review).

The status of migratory Redband Trout on the MNWR is unknown. Therefore, estimates of the potential impacts of predation on migratory Redband Trout by Caspian terns (USACE 2011) have been based on professional opinion. For example, it has been suggested that there is little risk to Redband Trout viability if their contribution to the diet of the Caspian tern colony remains below 5% (based on a colony of 300 breeding pairs) (USACE 2011). However, a comprehensive understanding of Redband Trout spatio-temporal distribution and demography on the MNWR is critical for an objective evaluation of the potential impacts of predation by Caspian terns (see Draulans 1988). Additionally, it has been suggested that because Caspian terns are opportunistic feeders they will likely feed on carp Cyprinus carpio in Malheur Lake, as opposed to Redband Trout. However, it is not clear whether Caspian terns will exhibit prey selection or avoidance on the MNWR and Caspian terns have been shown to prey on juvenile salmonids (Lyons et al. 2005; Anderson et al. 2007), including rainbow trout *O. mykiss* (Gill 1976).

Redband Trout may be seasonally and locally abundant during migratory periods, which may make them more vulnerable to opportunistic predators. The lower, slow-moving reaches of the Blitzen River, as well as slow-moving waters upstream of dams and near diversions on the Blitzen River, may provide productive Caspian tern feeding habitats during upstream (spawning and thermoregulation; Anderson 2009; Anderson et al. 2011) and downstream (juvenile outmigration) migratory periods for Redband Trout, and these areas are within the foraging range of Caspian terns (Anderson et al. 2007; Lyons et al 2005; Lyons et al. 2011). Additionally, delayed fish passage at dams and entrainment in diversion canals (see Anderson 2009; Anderson et al. 2011) may increase the amount of time and locations in which migrating Redband Trout may be susceptible to predation by Caspian terns or may provide a source of mortality to Redband Trout that must be considered when evaluating the effects of Caspian terns on Redband Trout mortality.

Due to the paucity of information regarding the life history and ecology of migratory Redband Trout on the MNWR, it is difficult to assess the potential effects of putative increases in avian predation pressure on Redband Trout associated with construction of the tern island. Therefore gaining a better understanding of the distribution, abundance, and migratory patterns of Redband Trout in the Blitzen River basin may identify factors of interest to resource managers. Therefore, the objectives of this study

were to identify population and demographic characteristics of Redband Trout in the Blitzen River basin and identify the proportion of Redband Trout that exhibit dispersal or migratory behaviors within the Blitzen River basin.

Methods

Redband Trout Sampling and PIT Tagging

Backpack electrofishing.—We conducted electrofishing surveys in Bridge Creek, Indian Creek, and Little Blitzen River from 2013 through 2016; these streams were surveyed during summer base-flow conditions and not all streams were surveyed each year (Table 1). Bridge Creek, Indian Creek, and Little Blitzen River were divided into contiguous, 100-m stream segments and geographic coordinates were generated for the downstream location of each stream segment using ArcMap software. Sample sites for each stream were selected following a systematic sample design with two random starting points; the two random starting points were selected from the downstream-most 10 stream segment. From 2013 through 2015 we systematically sampled every third stream segment in an upstream direction beginning from each of the two random starting points until we reached the upper limit of sampleable water or the end of the field season. A similar procedure was followed in 2016 with the exception that we systematically sampled every fifth stream segment in order to increase the spatial representation of our sampling effort.

Geographic coordinates (see above) represented the downstream boundary for each sample site. When the downstream boundary fell within a habitat unit the downstream boundary was moved to the closest habitat unit break. We measured 100 m upstream from the downstream boundary to locate the upstream boundary of the sample site. From 2013 through 2015 we installed block nets at the downstream and upstream boundary of each sample site prior to sampling. During 2016 we did not install block nets at single pass electrofishing sample sites, but we did install block nets at mark-recapture electrofishing sample sites (see below).

We conducted single pass electrofishing at all sample sites and mark-recapture electrofishing at a subsample of sample sites. For single pass electrofishing, we started sampling at the downstream boundary of the sample site and electrofished upstream proceeding systematically by electrofishing discrete habitat units and strategically working complex areas (e.g., undercut banks and areas of woody debris accumulation). We placed captured fish in a bucket filled with stream water and equipped with an aerator. Frequent visual inspections of the fish were made to ensure that they were not showing signs of stress (e.g., gulping, loss of equilibrium). When stream temperatures were warm (about 16-21°C), extra care was given to the fish and the water in the buckets was changed frequently. Electrofishing was not conducted if stream temperatures exceeded 21°C. Once we reached the upstream site boundary we ceased electrofishing and exited the stream.

Redband Trout ≥ 65 mm (FL) were anesthetized with Aqui-S 20E (26 $mg \cdot L^{-1}$) and scanned for the presence of a passive integrated transponder (PIT) tag. If a PIT tag was present (i.e., the fish had been previously captured and tagged), individual Redband Trout were measured for length (FL; mm) and were placed in a recovery bucket filled with aerated stream water. If a PIT tag was not present, individual Redband Trout were measured for length, a PIT tag was inserted into the abdominal cavity if the individual was ≥ 65 mm, and the Redband Trout was placed in a recovery bucket filled with aerated stream water; Redband Trout < 65 mm were placed in the recovery bucket without being PIT tagged. Redband Trout ≥ 65 mm and < 100 mm were PIT tagged with a 12 mm PIT tag and Redband Trout > 100 mm were PIT tagged with a 23 mm

PIT tag. After recovery from anesthetic, Redband Trout were redistributed throughout the sample site that they were captured from.

For mark-recapture electrofishing, we performed electrofishing methodologies and processed fish as above. However, after completion of our electrofishing pass we left the block nets in place, processed fish as above and redistributed them throughout the sample site, and left the block nets in place overnight. We returned to the sample site after about 24-h, conducted another electrofishing pass (as above), and processed fish (as above).

Adult fish traps.—We sampled adult Redband Trout during their putative upstream spawning migration in the mainstem Blitzen River using adult fish traps at each of four diversion dams located within the MNWR (Figure 1). Fish were sampled at Sodhouse, Busse, Grain Camp, and Page Springs diversion dams from 03/14/13 through 06/16/13 and from 03/20/14 through 06/05/14. Each diversion dam has been retrofitted with a fish ladder and a trap box to capture fish moving upstream. The trap boxes were checked daily and all Redband Trout were measured and tagged as above and released upstream from the diversion dam they were captured at. At Sodhouse Diversion Dam, the trap catch was dominated by large numbers of Common Carp *Cyprinus carpio*. On many occasions, this resulted in overcrowding of the trap and likely reduced the amount of dissolved oxygen in the water. To minimize additional stress, any Redband Trout captured at the Sodhouse Diversion Dam were released above the trap without additional handling (e.g., tagging and measuring).

Rotary screw traps.—We sampled juvenile Redband Trout in the mainstem Blitzen River using a rotary screw trap deployed near the P-Ranch historical site (Figure 1). The trap was anchored to cemented wooden posts with high tensile strength 19.05mm double braid polyester rope and a series of pulleys. We operated the trap from 04/30/13 through 06/15/13 and from 04/17/14 through 06/05/14. Personnel checked it daily while it was in operation, measured, tagged and released captured Redband Trout as above, and released other fishes present in the livewell. An additional two rotary screw traps were deployed in 2013, one at the Romallie Bridge and one at the Sodhouse Diversion Dam; however, low water conditions were not conducive to the operation of these traps and they were not re-deployed in 2014.

Hook and line sampling.—We sampled Redband Trout using hook and line at the MNWR Headquarters pond on 04/03/13. Volunteers from the MNWR were hosting a fishing day at the headquarters pond and Redband Trout that were caught were measured and tagged as above, and were released into the mainstem Blitzen River.

Trap netting.—We used 1.8 m X 0.9 m trap nets to characterize the fish assemblage in Malheur Lake; trap netting occurred from 08/28/13 through 09/26/13. We divided Malheur Lake into 100 m x 100 m sample plots and the geographic coordinates at the center of each sample plot were generated using ArcMap software. Sampling was limited to portions of Malheur Lake that had water depths sufficient to deploy and operate the trap nets (about 0.75 m). This resulted in a total sampling frame of 6984 sampling plots (Figure 2). A hierarchical grid was created to group the sample plots into 80 larger grid plots, each comprised of 90 sample plots; with the exception of the top row, which only had 63 sample plots due to shallow water preventing us from sampling the remaining 27 plots. A random number generator was used to select 23 (out of 80) of these larger grid plots. Within these randomly selected larger grid plots, 2 random sample plots were selected to be sampled. A large list of sample plots was created and selected

plots that were close in proximity to each other were grouped together to minimize travel time between sites.

A single trap net was placed at the center of each selected sample plot. A total of 68 plots were sampled during 17 d of trap netting. Each trap net was allowed to soak for about 24 h, captured fish were identified to species, and a subsample of Carp were binned into one of the following four size categories: 1-100 mm, 101-200 mm, 201-300 mm, and > 300 mm.

PIT interrogation arrays.—We installed and maintained a total of nine PIT interrogation arrays within the Blitzen River basin to detect movement of Redband Trout. Three PIT interrogation arrays were located on the mainstem Blitzen River within 10 km of Malheur Lake (Lower Bridge, CATO Bridge, and Sodhouse Diversion Dam), two PIT interrogation arrays were located on the mainstem Blitzen River near Page Springs (Page Springs Diversion Dam, Page Springs Campground), one PIT interrogation array was located on the mainstem Blitzen River near its confluence with Indian Creek (Blitzen Crossing), one PIT interrogation array was located on Indian Creek within 5 km of its confluence with the mainstem Blitzen River (Indian Creek), and PIT interrogation arrays were located on the lower portion of Bridge Creek (Lower Bridge Creek, Upper Bridge Creek) (Figure 3). Each PIT interrogation array consisted of a long-range, multi-antenna, half-duplex (HDX) reader (Oregon RFID; Portland, Oregon) that operated up to four antennas. PIT interrogation arrays logged PIT tagged Redband Trout that passed within the detection range of the antenna; detection ranges varied depending on numerous factors including the size, shape, and orientation of the antenna.

Redband Trout Density

We used backpack electrofishing survey data to estimate density of Redband Trout in Bridge Creek, Indian Creek, and Little Blitzen River. We used the Chapman Estimator to estimate abundance of Redband Trout within each mark-recapture electrofishing sites as:

$$\widehat{N}_c = \frac{(K+1)(n+1)}{k+1} - 1$$

where $\widehat{N}_c$ is the estimated abundance of Redband Trout, *K* is the number of Redband Trout captured on the second visit to the site, *n* is the number of Redband Trout PIT tagged on the first visit to the site, and *k* is the number of Redband Trout recaptured on the second visit to the site that were PIT tagged on the first visit to the site. We used simple linear regression to evaluate the relationship between the estimated abundance of Redband Trout ($\widehat{N}_c$) and the number of Redband Trout captured on the first visit to a sample site (*n*); the simple linear regression model was fit without an intercept term. The results of this analysis showed that on average the abundance of Redband Trout was 5.18 times greater than the number of Redband Trout captured on the first visit. Therefore, we estimated abundance of Redband Trout for each sample site as 5.18 times the number of Redband Trout captured during single pass electrofishing. Density of Redband Trout for each sample site was estimated as abundance of Redband Trout divided by the site length (fish·m^{-1}). Redband Trout density was averaged by sample year and sub-basin.

Redband Trout Growth Rate

We calculated individual growth rates for PIT tagged Redband Trout that were captured during more than one year. Individual growth rates were calculated as:

$$GR = \frac{Fork\ length_Y - Fork\ length_{Y-x}}{x}$$

where *GR* is growth rate (mm·year^{-1}), *Y* is year, and *x* is the number of years between capture events. We calculated the median, lower quartile, and upper quartile growth rate among Redband Trout.

Redband Trout Movement Patterns

We constructed capture histories for PIT tagged Redband Trout that were detected at least one time following initial tagging to provide information on the proportion of tagged Redband Trout that putatively express a migratory life history or disperse from their natal sites. Data from electrofishing surveys, adult fish traps, rotary screw traps, hook and line sampling, and PIT interrogation arrays were combined to calculate the proportion of Redband Trout that were:

1) Tagged in Bridge Creek and recaptured in Bridge Creek (putative non-migratory)
2) Tagged in Bridge Creek and detected leaving Bridge Creek (putative migratory)
3) Tagged in Indian Creek and recaptured in Indian Creek (putative non-migratory)
4) Tagged in Indian Creek and detected leaving Indian Creek (putative migratory)
5) Tagged in the Little Blitzen River and detected leaving the Little Blitzen River (putative migratory)

We assumed that if a Redband Trout was tagged in Bridge Creek and was detected at any PIT interrogation array then it had left Bridge Creek. We assumed that if a Redband Trout was tagged in Indian Creek and was detected at any PIT interrogation array with the exception of the Indian Creek array then it had left Indian Creek. We assumed that if a Redband Trout was tagged in the Little Blitzen River and it was detected at any PIT interrogation array then it had left the Little Blitzen River.

Putative Predation on Redband Trout by Avian Predators

From 2013 through 2015 Real Time Research conducted mobile PIT tag surveys on the tern island (as well as at Singhaus Ranch in 2013). PIT tags detected (hereafter, recovered) on the tern island or at Singhaus Ranch were assumed to be excreted by avian predators that had consumed PIT tagged fishes. We cross-referenced PIT tag recovery data acquired from Real Time Research with PIT tag data from electrofishing surveys, adult fish traps, rotary screw traps, hook and line sampling, and PIT interrogation arrays. We used these data to identify the last known location of Redband Trout that had recovered PIT tags from the tern island and Singhaus Ranch.

Malheur Lake Fish Assemblage

We summarized the number and size structure of Carp sampled during trap netting. We did not summarize data for other fishes because out of 779 individual fish sampled only 3 fish were not Carp; these 3 individuals were classified as unidentified warmwater game fish.

Results and Discussion

Redband Trout Sampling and PIT Tagging

We used backpack electrofishing, adult fish traps, rotary screw traps, hook and line sampling, and PIT interrogation arrays to capture, PIT tag, and monitor movement of Redband Trout in the Blitzen River basin from 2013 through 2016. Here we report on data from 11,240 PIT tagged Redband Trout (Figure 4).

Redband Trout Density

In 2013 we conducted electrofishing surveys at a limited number of samples sites. From 2014 through 2016 we generally sampled Bridge Creek from about 6 km upstream from its confluence with the Blitzen River upstream until the stream was dry. During 2014 and 2015 we sampled Indian Creek from about 5 km upstream from it confluence with the Blitzen River upstream to about 10 km from its confluence with the Blitzen River. In 2016 we sampled Indian Creek from about 3 km upstream from its confluence with the Blitzen River upstream to an impassible barrier to upstream movement (about 17 km upstream from the confluence of Indian Creek and the Blitzen River).

Redband Trout density was variable among years, but was greater in Indian Creek than in Bridge Creek among years (Figure 5). Redband Trout density was generally greater in this study than previously observed in the Blitzen River basin. For example, Redband Trout density varied from 0.33 through 0.72 fish·m^{-1} in the Blitzen River basin from 2007 through 2012 (Meeuwig et al. 2014). However, the sampling frame used in the present study differed from Meeuwig et al. (2014) and in the present study we observed a potential longitudinal pattern in Redband Trout density. In 2014 and 2015 we observed an increase in Redband Trout density followed by a rapid decrease in Redband Trout density as sample sites progressed from downstream to upstream in Bridge Creek and Indian Creek (Figure 6). This pattern was less prevalent in 2016; however, overall Redband Trout density was lower in 2016 than in 2014 and 2015, which may be a result of increased mortality rates following extreme drought conditions in 2015.

Redband Trout Growth Rate

Growth rates were calculated from 225 Redband Trout observations. Median growth rate was 32 mm·$year^{-1}$ (lower quartile = 19 mm·$year^{-1}$; upper quartile = 44 mm·$year^{-1}$).

Redband Trout Movement Patterns

The number of Redband Trout detected at least once after being PIT tagged in the sub-basins was 327 for Redband Trout PIT tagged in Bridge Creek, 600 for Redband Trout PIT tagged in Indian Creek, and 22 for Redband Trout PIT tagged in the Little Blitzen River. Of these Redband Trout, the proportion that exhibited migratory behavior or dispersed from their natal sites varied among sub-basin with the greatest proportion dispersing from the Little Blitzen River followed by Bridge Creek and Indian Creek (Figure 7). We had a low sample size of Redband Trout tagged in the Little Blitzen River so results from this sub-basin should be evaluated with caution. Regardless, at least some proportion of the Redband Trout PIT tagged during electrofishing surveys in the Blitzen River sub-basins exhibit behavior consistent with a migratory life-history and this proportion appears to vary among sub-basins.

Putative Predation on Redband Trout by Avian Predators

A total of 90 Redband Trout PIT tags were recovered by Real Time Research; 76 from the tern island and 14 from Singhaus Ranch. Prior to recovery, 85 of the PIT tagged Redband Trout were last detected in some portion of the mainstem Blitzen River, 3 were last detected at the upper Bridge Creek PIT interrogation array, 1 was last detected when tagged in Bridge Creek during backpack electrofishing surveys, and 1 was last detected when tagged in the Little Blitzen River during backpack electrofishing surveys (Figure 8). The majority of the PIT tagged Redband Trout were last detected at the P-Ranch screw trap (Figure 8).

Malheur Lake Fish Assemblage

We sampled 779 individual fish of which 776 were Carp and 3 were warmwater game fish. We sampled from 0 through 54 Carp per trap net (11 ± 12; mean ± SD). We binned a subsample of 556 Carp into four size categories. The greatest number of Carp sampled were from 201-300 mm followed by 101-200 mm, > 300 mm and 1-100 mm (Figure 9).

Trap netting was only conducted in 2013 on Malheur Lake because decreasing lake levels associated with drought conditions precluded effective sampling and trap netting suggested that the Malheur Lake exhibits low species diversity. Carp were there overwhelmingly dominant fish species in the Malheur Lake fish assemblage and there are limited data available to evaluate changes in the Malheur Lake fish assemblage associated with establishment of Carp.

Conclusion

Redband Trout in the Blitzen River basin are known to express resident and fluvial life histories, and potentially express an adfluvial life history. Dispersal of juvenile Redband Trout from the Blitzen River sub-basins (e.g., Bridge Creek and Indian Creek) into the mainstem Blitzen River could result in juvenile Redband Trout being in close proximity to avian predators that occupy portions of the MNWR. We observed high densities of Redband Trout in the Blitzen River sub-basins relative to other studies conducted in the northern Great Basin (e.g., Meeuwig and Clements 2014). However, similar to other studies, Redband Trout density was variable among sub-basins and among years. We also documented dispersal of Redband Trout from the Blitzen River sub-basins into the mainstem Blitzen River and PIT tags from Redband Trout were recovered from the tern island as well as from Singhaus Ranch. These data suggest that avian predators using man-made structures (e.g., the term island) are preying on Redband Trout. The PIT tags recovered on the tern island and Singhaus Ranch generally came from small Redband Trout (i.e., 148 ± 54 mm FL) that were likely juvenile fish rearing in the mainstem Blitzen River based on their capture histories (i.e., last know detection location).

The overall effect of avian predation on Redband Trout using portions of the Blitzen River basin will depend on the portion of Redband Trout in the diets of avian predators as well as the abundance of avian predators. Bill-load data suggest that Redband Trout make up a relatively small proportion of the diet of Caspian terns using the MNWR tern island. For example, in 2014, trout made up about 2% of identifiable prey items in the Caspian tern diet, some of which were likely Redband Trout; however, the majority of the Caspian tern diet was composed of Carp (Roby and Collis 2014). If resource managers are concerned about potential impacts of avian predators on Redband Trout in the Blitzen River basin a focused predation study should be conducted.

Although we detected Redband Trout within the mainstem Blitzen River that had been originally tagged in the Blitzen River sub-basins, we did not detect any Redband Trout in the Blitzen River sub-basins that had been previously detected in mainstem portions of the Blitzen River basin. This may be an artifact of our sampling or detection probability or it could represent density dependent dispersal out of the Blitzen River tributaries or source-sink dynamics. Further evaluations of this pattern may provide a greater understanding of the relative importance of the tributary and mainstem habitats to persistence of Redband Trout in the Blitzen River basin.

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Table 1: Blitzen River sub-basin sample period, number of electrofishing sites sampled (N), and mean and standard deviation (SD) Redband Trout density estimated for 2013 through 2016.

				Redband Trout density (fish·m^{-1})	
Year	Sub-basin	Sample period	*N*	Mean	SD
2013	Bridge Creek	06/18/13 – 07/03/13	6	1.82	0.83
	Little Blitzen River	07/08/13 – 08/22/13	13	0.98	0.67
2014	Bridge Creek	06/12/14 – 07/16/14	45	0.74	0.61
	Indian Creek	07/23/14 – 08/26/14	31	1.56	0.78
2015	Bridge Creek	06/17/15 – 07/28/15	39	1.80	1.62
	Indian Creek	08/06/15 – 09/15/15	36	2.39	0.72
2016	Bridge Creek	07/09/16 – 08/03/16	17	0.30	0.18
	Indian Creek	08/10/16 – 09/27/16	52	1.11	0.57

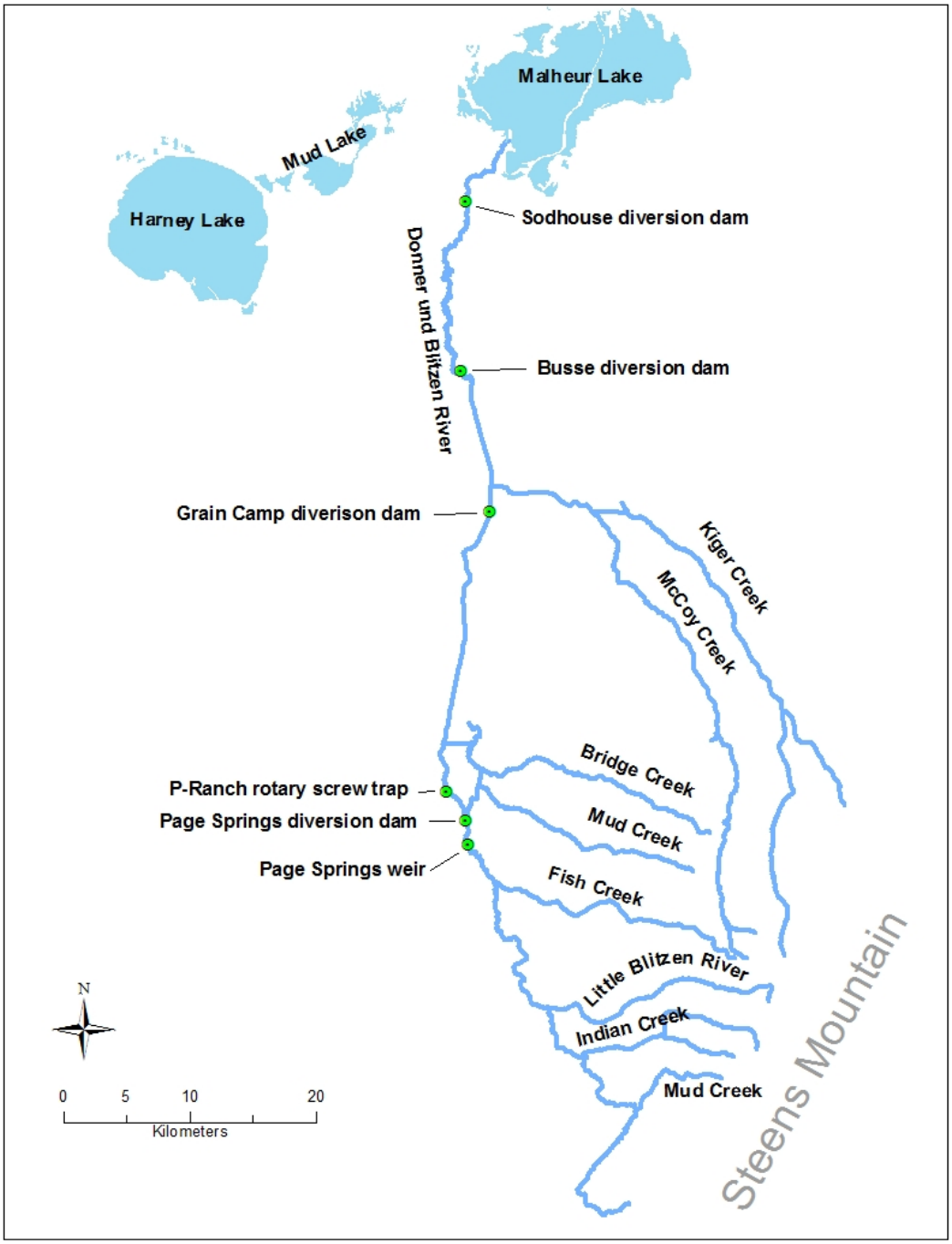

Figure 1: Blitzen River basin study area showing sub-basins diversion dams and the location of the P-Ranch screw trap. Adult fish traps were located at the Sodhouse Diversion Dam, the Busse Diversion Dam, the Grain Camp Diversion Dam, and the Page Springs Diversion Dam.

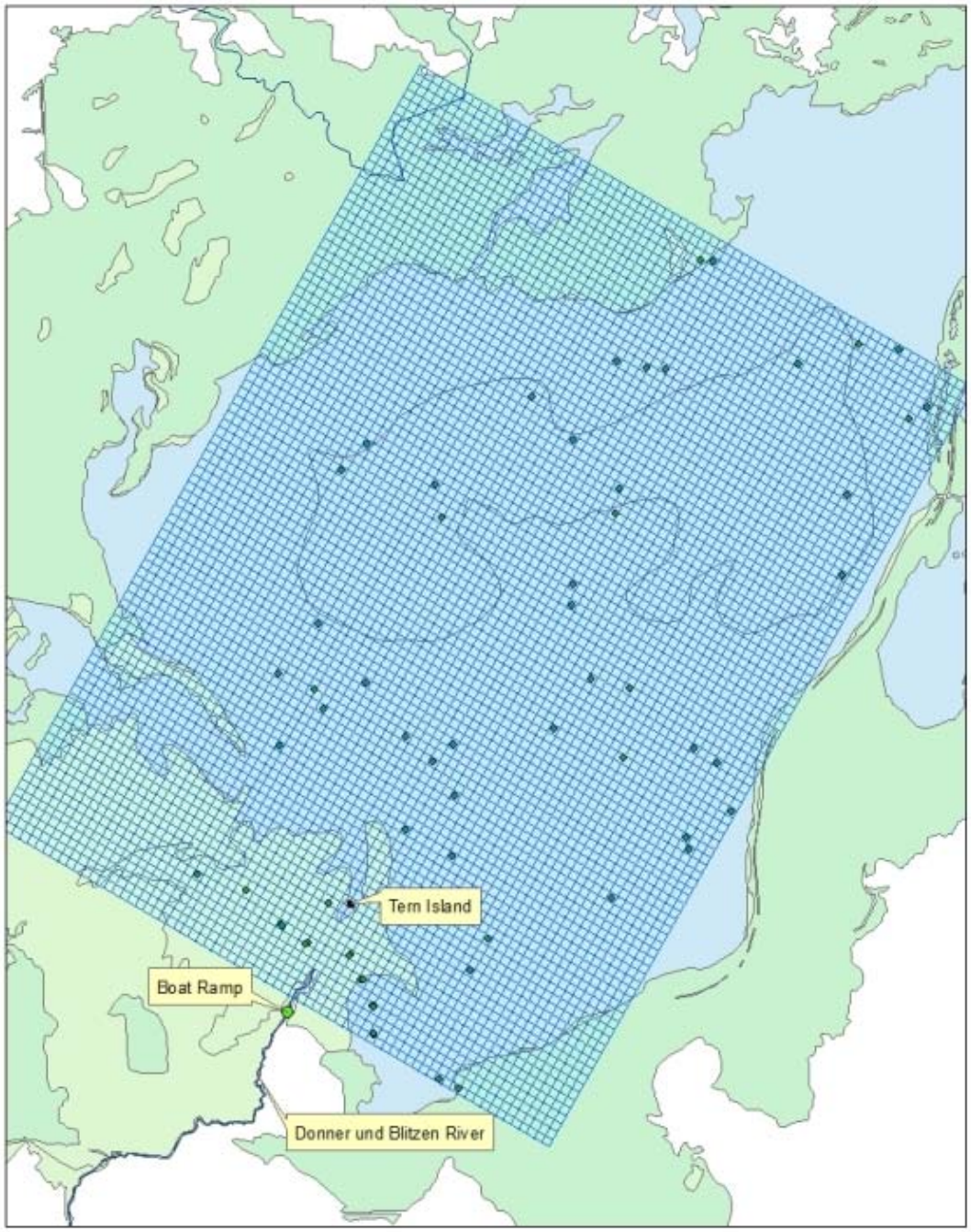

Figure 2: Map of randomization grid and sample locations (green dots) for trap net sampling on Malheur Lake.

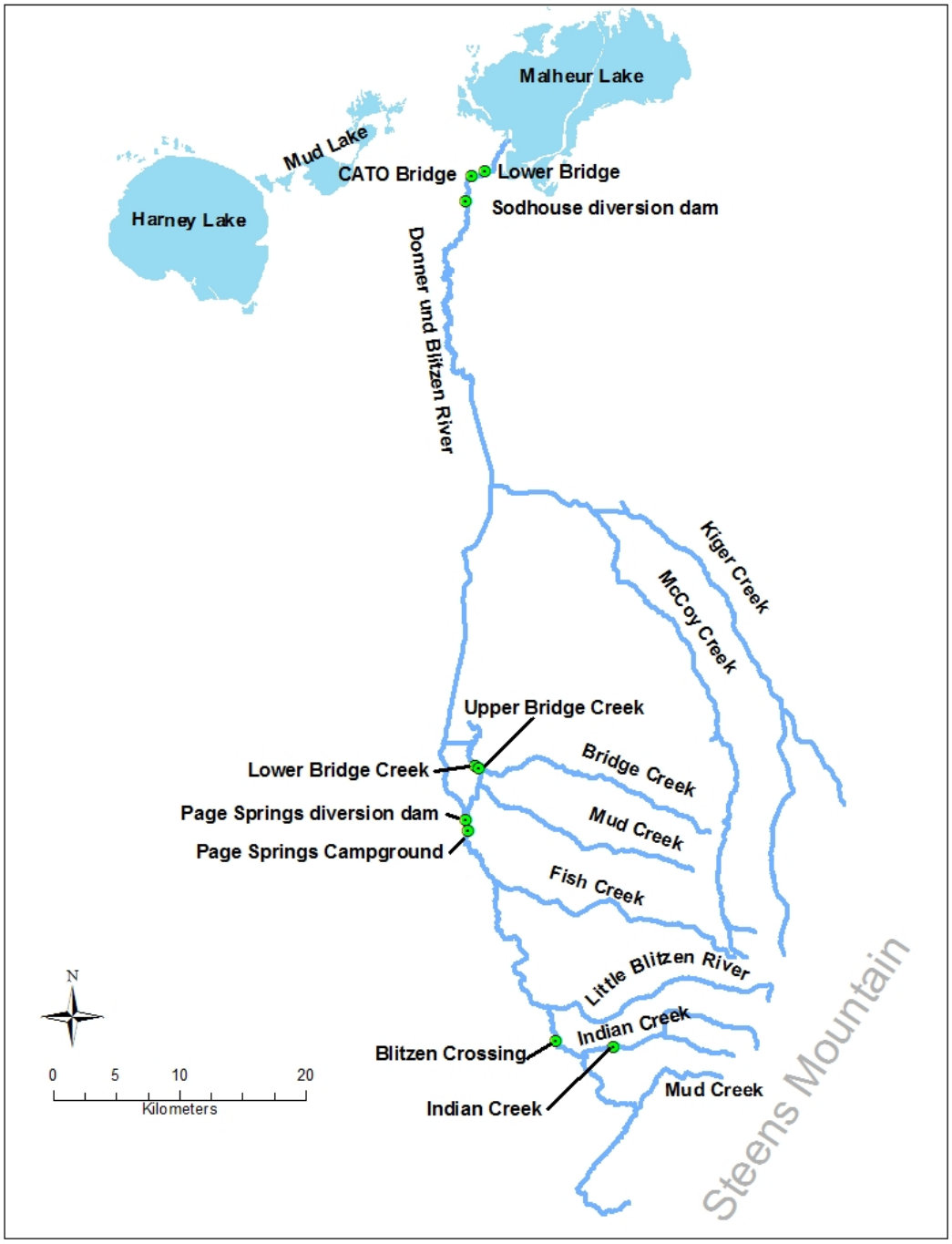

Figure 3: Blitzen River basin study area showing sub-basins and locations of PIT interrogation arrays (green dots).

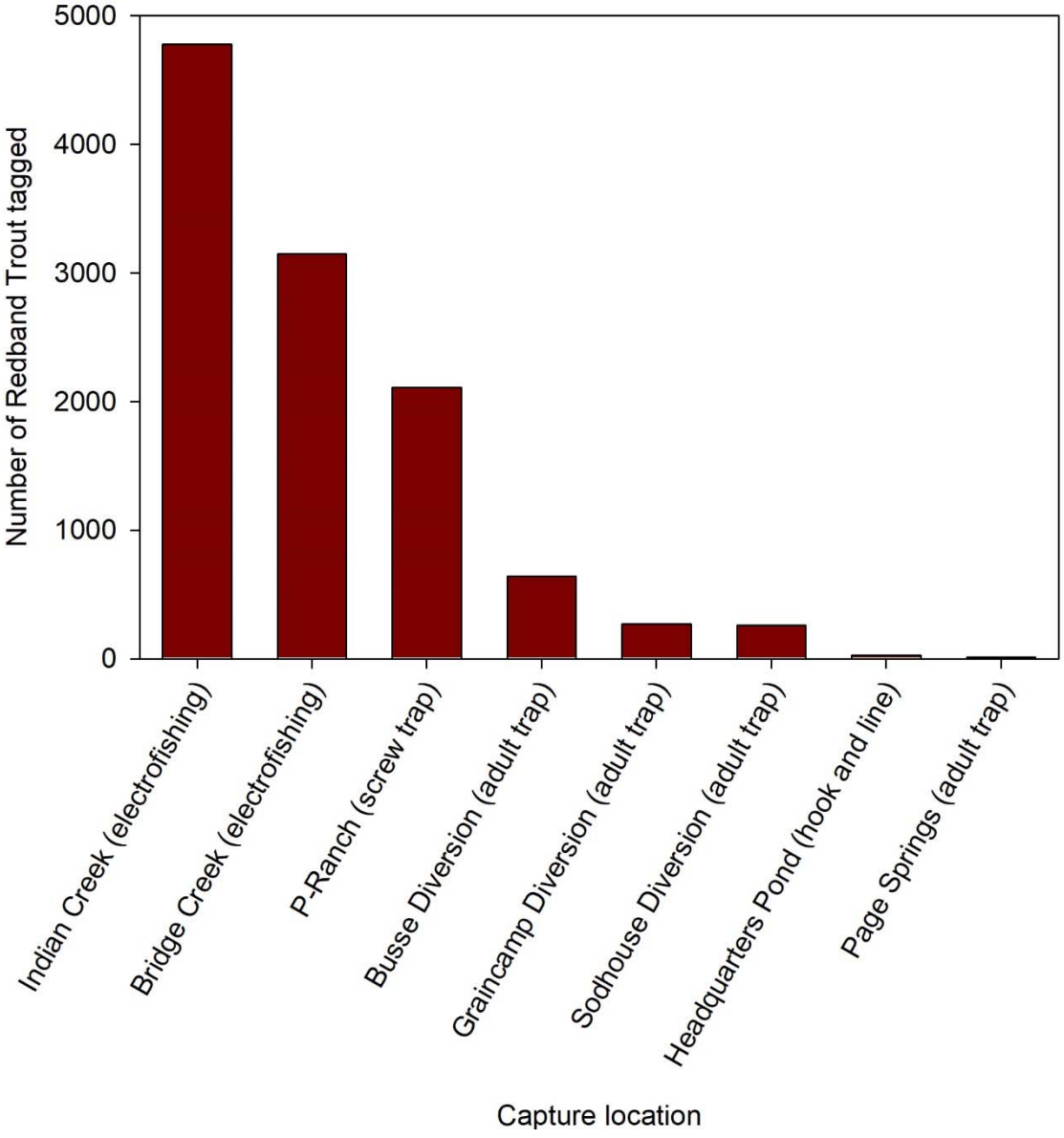

Figure 4: The number of Redband Trout tagged with PIT tags by capture location.

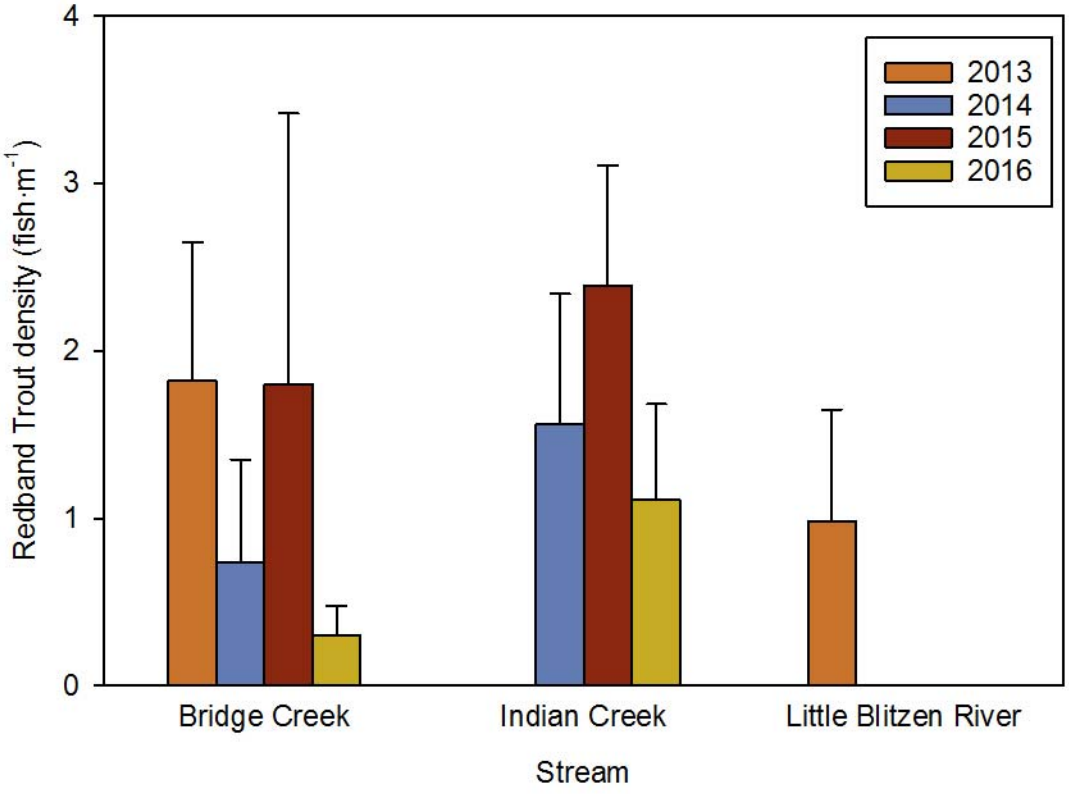

Figure 5: Redband Trout density in three Blitzen River sub-basins (stream).

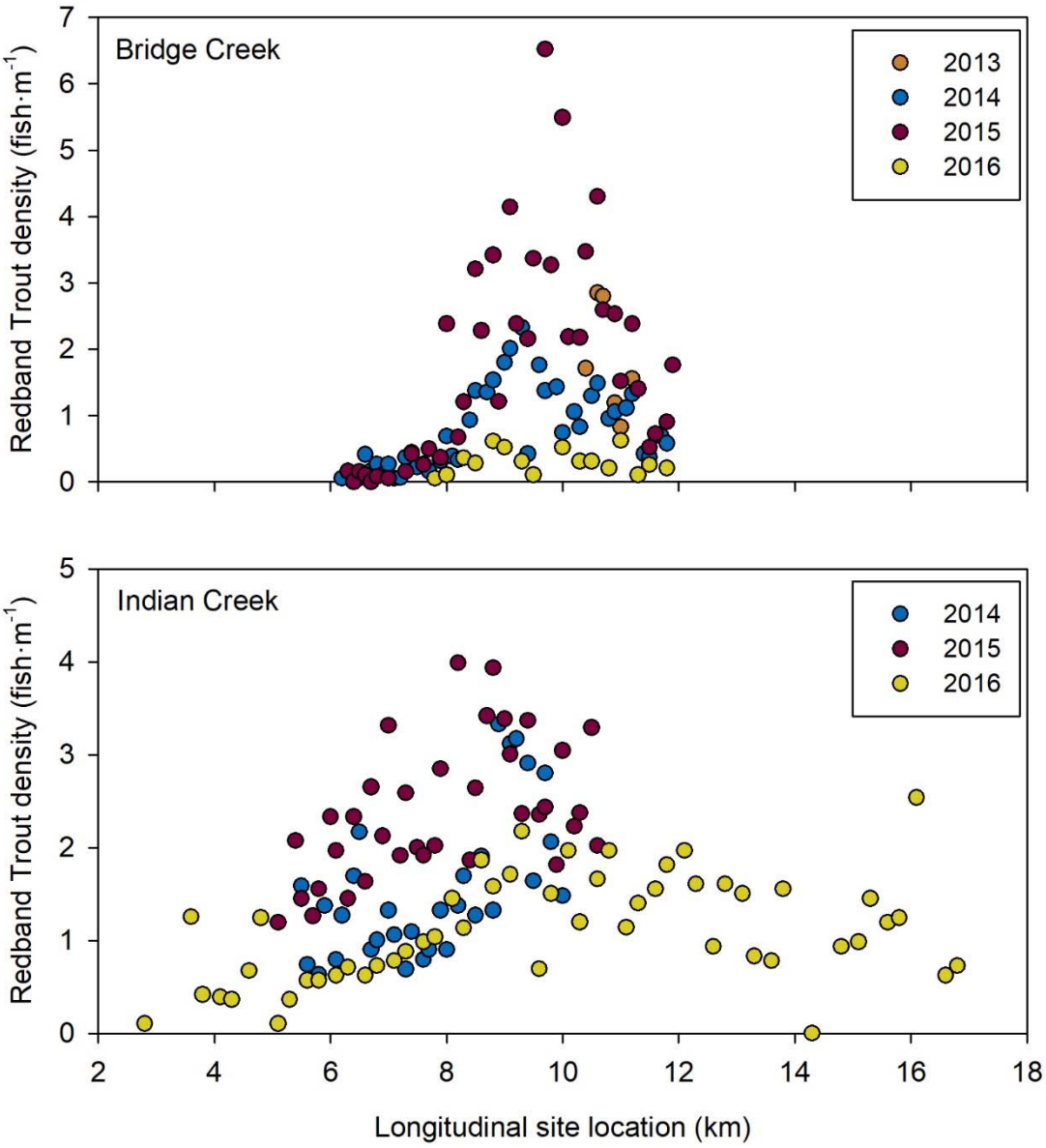

Figure 6: Redband Trout density plotted as a function of longitudinal locations within the Bridge Creek (upper panel) and Indian Creek (lower panel) sub-basins. Longitudinal site location is the distance (km) upstream from the confluence of each stream with the Blitzen River.

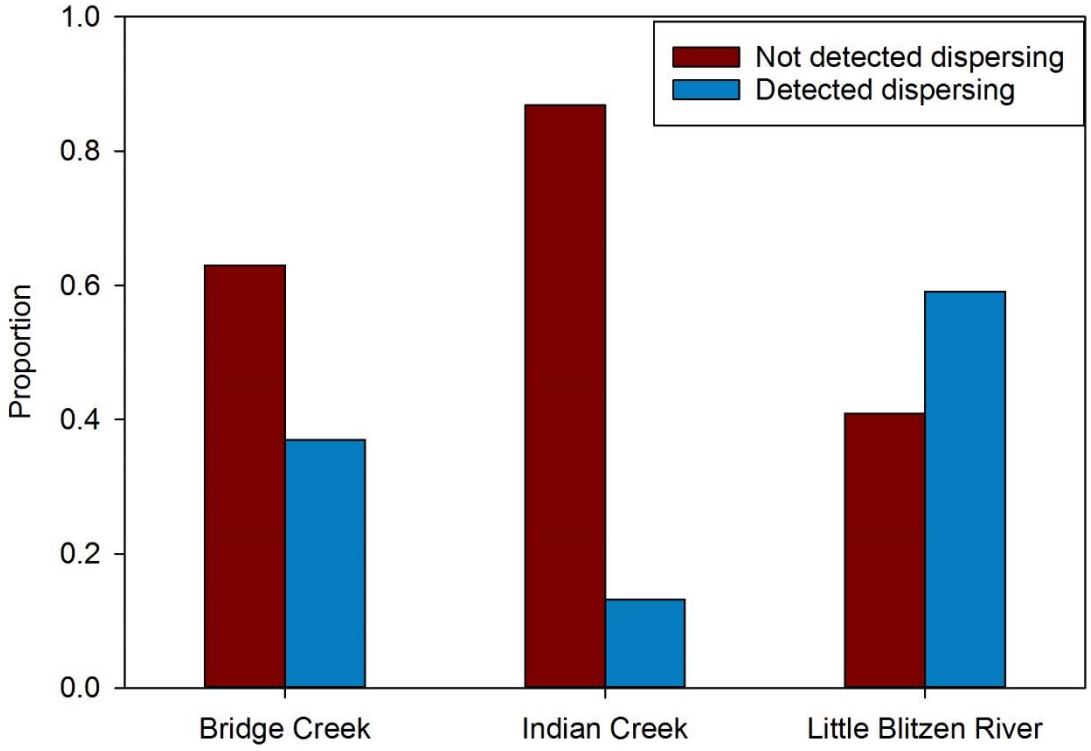

Figure 7: Proportion of Redband Trout not detected dispersing, and detected dispersing from the Blitzen River sub-basins. The proportion not detected dispersing is based on Redband Trout that were detected within the same sub-basin that they were tagged in at least once after being PIT tagged. The proportion detected dispersing is based on Redband Trout that were detected outside of the sub-basin that they were tagged in at least once after being PIT tagged.

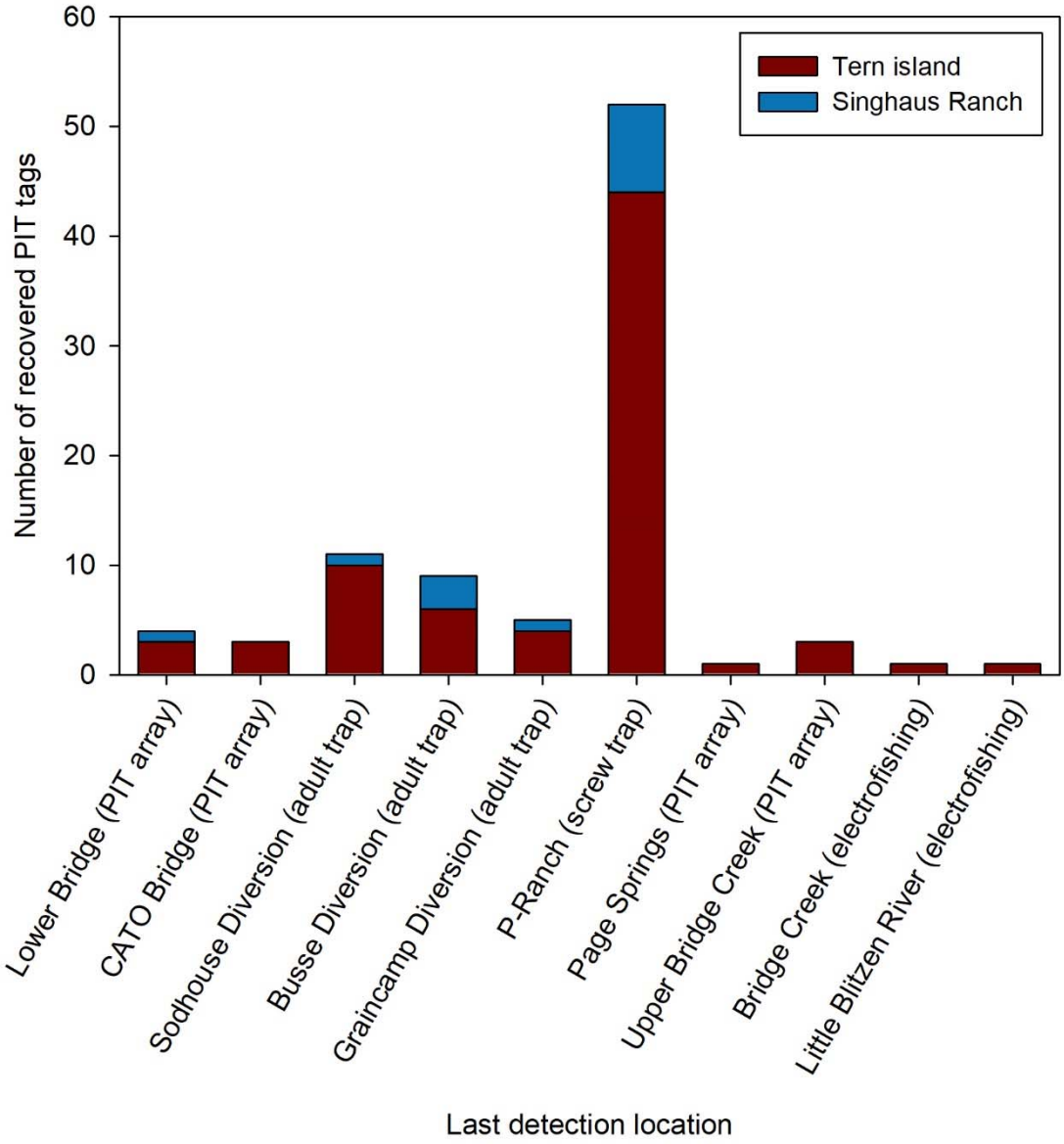

Figure 8: The number of PIT tags recovered by Real Time Research on the tern island or at Singhaus Ranch by the last location that we detected the tag.

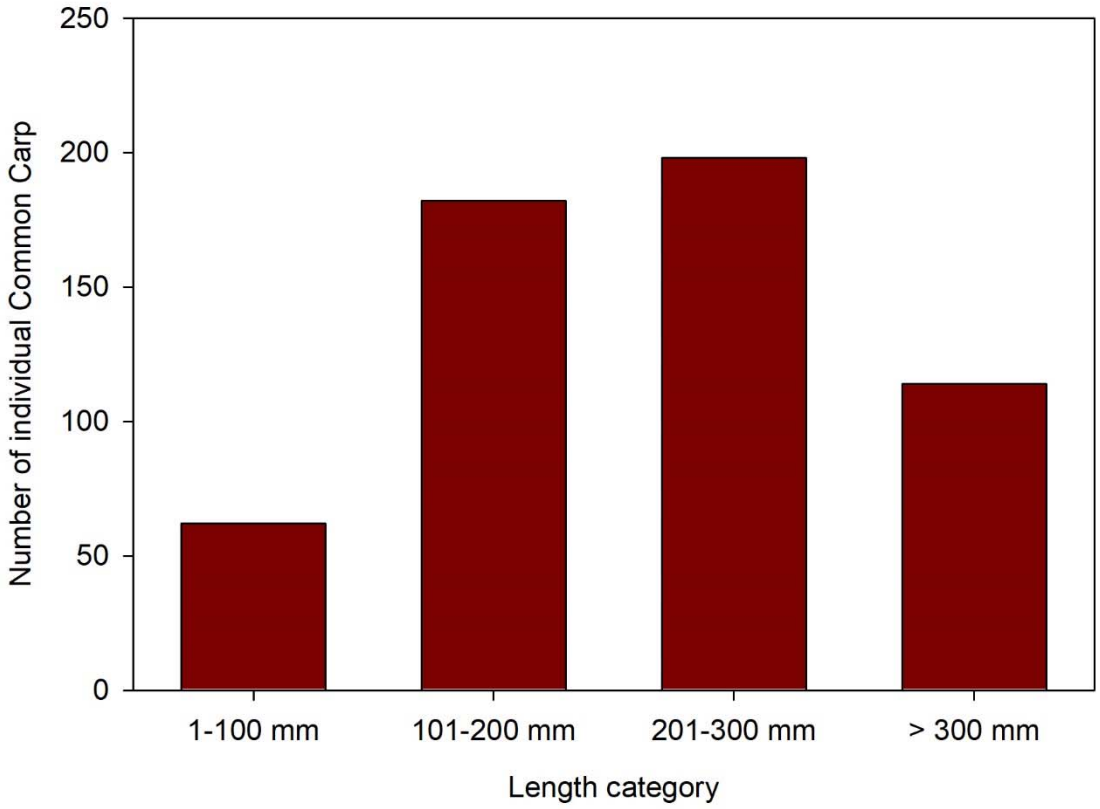

Figure 9: The number of individual Carp sampled on Malheur Lake by length category.

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