

RIFLE GAP RESERVOIR FISHERY INVESTIGATION



Photo: Willow Hibbs

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March 2009

INTRODUCTION

Rifle Gap Reservoir (RGR), near the town of Rifle in western Colorado, hosts a popular recreational fishery. Historically, stocked rainbow and brown trout have been the mainstays of the fishery. During the present decade, CDOW has stocked an average of 38,000 catchable rainbow trout (RBT) per year into RGR (Table 1). In 1972 walleye (WAL) and smallmouth bass (SMB) were stocked by CDOW and established self-sustaining populations. In 1993 it was determined that black crappie (BCR) had been illegally introduced and by 1999 yellow perch (YPE) and northern pike (NPK) populations were also illegally established in the reservoir (L. Martin, pers. comm., 09/18/08). Fishing regulations for the 2008 season at RGR included a 2 fish daily bag limit and minimum size limit of 15 inches for SMB, a closed season on SMB during May 1-June 15, and a 3 fish bag limit and minimum size limit of 18 inches for WAL. Statewide rules applied for all other species.

Table 1. Number of catchable rainbow trout stocked by CDOW in Rifle Gap Reservoir each year since 2002.

Year	Number stocked	Mean size (in.)
2008	43,395	9.3
2007	58,280	9.2
2006	21,794	9.6
2005	43,500	9.5
2004	38,868	9.4
2003	34,371	9.4
2002	23,736	9.5
Mean	37,706	9.4

A variety of concerns from anglers, including an apparent decline in the WAL population, conflicting views over NPK management, and dissatisfaction with the YPE fishery have prompted CDOW to revise the Lake Management Plan for RGR. To assist with this process, Colorado State University offered to perform laboratory and quantitative analyses for a fishery investigation conducted by CDOW. Dr. Brett Johnson used RGR as a case study in his senior level Fishery Science (FW401) class during the fall 2008 semester. This report documents work performed by the class and by Dr. Johnson after the semester concluded.

METHODS

A survey of the fish populations at RGR was conducted by CDOW biologist Lori Martin during June, September and October, 2008. A combination of sampling methods was used (gill nets, trap nets, electrofishing). Fish were measured (TL) and weighed in the field (Figure 1) and a total of 503 fish of 9 species were collected. Whole fish or tissue samples were transferred to CSU for age and growth determination and diet

analysis. Tissue samples were also gathered for mercury assays by the CDPHE, and for microchemical analysis of otoliths, for another study in Dr. Johnson's lab examining escapement of nonnative fish from RGR and other reservoirs in the Upper Colorado River basin. Samples of northern pike were also collected in 2006 and 2007 for the mercury and escapement studies and age and growth structures were taken from those fish as well.



Figure 1. FW 401 Fishery Science student Jamie Fike shows a hefty Rifle Gap northern pike while Bill Pate and Matt Kuti measure fish during a CDOW sampling trip. Photo: Willow Hibbs.

Size structure

Length-frequency distributions of six species of primary interest: BCR, NPK, RBT, SMB, WAL, and YPE, were compiled from all fish captured during sampling conducted in June, 2008. Proportional size distribution (PSD; Guy et al. 2007) was computed for each species. The PSD is a ratio of the number of fish over a designated “quality” size benchmark divided by the number of fish of “stock” size:

$$PSD = \frac{\text{number of fish} \geq \text{quality length}}{\text{number of fish} \geq \text{stock length}} \cdot 100$$

The higher the PSD value, the greater the proportion of the fish in the sample that are of a larger size relative to the stock size. A low PSD could indicate a “stunted” or heavily cropped population and a high PSD could indicate a population with poor recruitment. Stock and quality sizes for the six species above are shown in Table 2.

Table 2. Stock and quality sizes (inches) used in computation of PSD (proportional size distribution; Guy et al. 2007), and standard intercept (a) and slope (b) coefficients for \log_{10} -transformed metric standard weight (W_s) formulae used to compute relative weight (W_r) for six species of sport fish in Rifle Gap Reservoir. Minimum TL is the minimum total length that the formula is applicable to for each species. Source: Anderson and Neumann (1996).

Species	Stock size (in)	Quality size (in)	a	b	Minimum TL (mm)
BCR	5.0	8.0	-5.618	3.345	100
NPK	14.0	21.0	-5.437	3.096	100
SMB	7.0	11.0	-5.329	3.200	150
WAL	10.0	15.0	-5.453	3.180	150
RBT	10.0	16.0	-4.898	2.990	120
YPE	5.0	8.0	-5.386	3.230	100

Body Condition and Growth

Scales, dorsal fin spines (YPE and WAL) and anal fin spines (YPE), cleithra (NPK) and otoliths were removed for age and growth determination. Scales were aged by magnifying them at 32X with a microfiche reader. Ninety NPK cleithra were aged by an experienced reader and distances from the focus to each annulus were measured for use in back-calculation. We fit lengths- and weights-at-age to the von Bertalanffy growth function (Isely and Grabowski 2007), a commonly used growth model useful for expressing lifetime growth of fish. We computed relative weight (W_r) as a measure of body condition using standard weight values from the literature (Anderson and Neumann 1996; Table 2).

Abundance

No mark-recapture abundance estimates were computed at RGR during sampling in 2008. We obtained mark-recapture abundance estimates of NPK in four other western slope reservoirs to approximate NPK abundance in RGR (5,960 ft). Estimates (fish/ac) developed by Orabutt (2006) for Lake Catamount, Stagecoach Reservoir and Spinney Mountain Reservoir, and by Kowalski (pers. comm. 12/05/08) for Crawford Reservoir were averaged (Table 3). This mean was assumed to represent a reasonable estimate of abundance of NPK \geq 19 inches TL in RGR. We also computed the average 95% confidence limits on the estimates, expressed as a proportion of abundance. The abundance of NPK in the four reservoirs averaged 1.30 fish/ac, +/- 65% (Table 3). This abundance estimate, multiplied by RGR's area at full pool (349 ac), yielded an absolute abundance (453) which was apportioned into age-classes evenly assuming an annual total mortality rate of $A=0.51$ (Table 4).

Table 3. Mark-recapture abundance estimates (N) and their 95% confidence limits (CL) of adult northern pike (\geq age-3) computed at four reservoirs on Colorado's western slope. Means of the estimates and the average confidence interval, expressed as a proportion of estimate, are also shown. Lake areas from Orabutt (2006).

Water body	Elevation (ft)	Area (ac)	N/ac	95% CL	Source for N
Lake Catamount	7,028	563	1.86	1.69-2.09	Orabutt (2006)
Crawford Reservoir	6,553	393	1.14	0.98-1.38	D. Kowalski (pers. comm. 12/05/08)
Spinney Mtn Reservoir	8,675	2,506	1.00	0.08-2.75	Orabutt (2006)
Stagecoach Reservoir	7,500	781	1.18	0.88-1.72	Orabutt (2006)
Mean	7,439	1,061	1.30	0.65•N-1.64•N	

NPK Consumptive Demand

We estimated consumptive demand by NPK (per capita and population level) using a bioenergetics model (Hanson et al. 1997). This model, essentially an energy budget that computes amount of food required to grow an observed amount, requires information on water temperature, food quality, and predator population characteristics. Experience in other Colorado reservoirs (Orabutt 2006; Johnson, unpublished data) and elsewhere in the western U.S. (McMahon and Bennett 1996) has demonstrated that NPK will prey heavily on trout. To determine the potential impact of NPK on RGR's trout fishery we simulated per capita and cohort-level consumptive demand of age-4 through age-10 NPK assuming their diet consisted entirely of catchable RBT (TL = fd10 in., weight = 6.6 oz, energy density = 5,500 J/g wet (Baldwin et al. 2003)). We chose to begin our simulations with age-4 because this is the NPK age at which catchable RBT:NPK length ratio drops below 45% (Table 4), and is the approximate maximum size ratio we have observed in NPK preying on trout. Northern pike also prey on YPE so we performed a simulation to compute NPK consumption of YPE \geq 8 in. (195 mm, weight = 3.6 oz., energy density 5,500 J/g wet (Hanson et al. (1997))). This simulation included age-3 through age-10 NPK.

We used epilimnial water temperatures measured at RGR during June-October and extrapolated to January and December assuming a typical seasonal, sinusoidal temperature pattern (Figure 2, Appendix 1). Assumed temperatures during April and May matched those measured at Blue Mesa Reservoir (BMR; Johnson and Koski 2006)

after adding the mean difference (2°F) between RGR and BMR that was observed during the period over which temperature was measured at both systems, suggesting that the assumed temperature pattern was reasonable. Growth and abundance of cohorts were derived as described in previous sections of this report; inputs are shown in Table 4.

Table 4. Hypothesized abundance of adult northern pike in Rifle Gap Reservoir based on an assumed total annual mortality (A) of 51% and densities computed in four other Colorado western slope reservoirs. Ages 4-10 (cumulative abundances = 230, 149 and 377 fish) were used in bioenergetics scenarios. LCL = lower 95% confidence limit, UCL=upper 95% confidence limit. The size of NPK (TL and weight) and the size ratio of catchable RBT to NPK length, based on NPK size at age are also shown.

Age (years)	Total length (in)	Weight (lbs)	RBT:NPK length	Number of pike (mean)	Number of pike (LCL)	Number of pike (UCL)
3	19	1.7	0.52	223	145	365
4	23	3.2	0.42	114	74	186
5	27	5.3	0.36	58	38	95
6	30	7.7	0.32	30	19	48
7	33	10.2	0.30	15	10	25
8	35	12.8	0.28	8	5	13
9	37	15.4	0.26	4	3	6
10	39	17.9	0.25	2	1	3
No. >19"=				453	294	742
No. >23"=				230	149	377

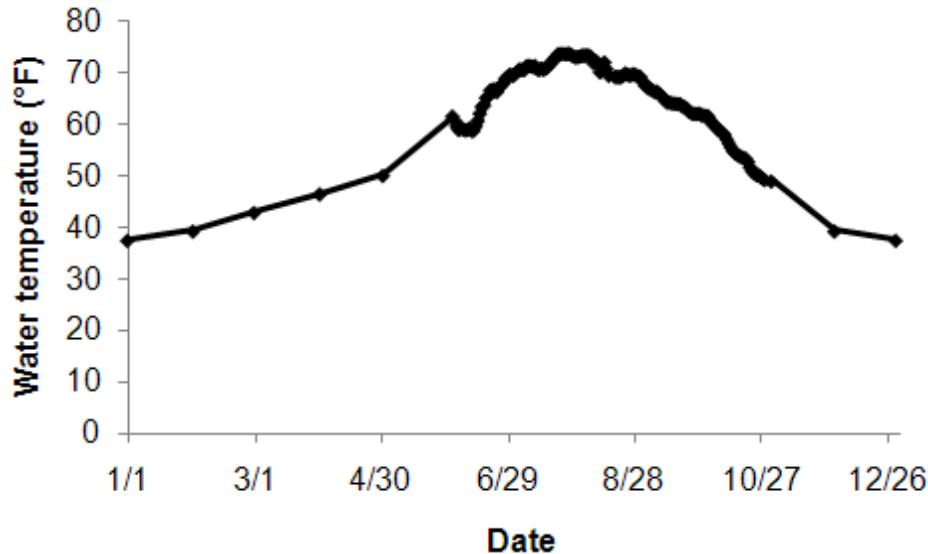


Figure 2. Water temperatures used in bioenergetics simulations of northern pike consumptive demand at Rifle Gap Reservoir. Temperatures during June 3-October 29 were measured by a temperature logger placed in the epilimnion near the dam in 2008; other temperatures were assumed.

Escapement

Otoliths were extracted from BCR, NPK, SMB, WAL and YPE with non-metallic forceps, cleaned with milli-Q water and stored in clean microcentrifuge tubes until they could be imbedded in epoxy resin for sectioning. Otoliths were then thin sectioned with an Isomet low-speed diamond saw, polished to reveal annuli and mounted on glass microscope slides. Slides with thin sections were sonicated in ultrapure water, dried in a laminar flow hood and stored in acid washed Petri dishes within sealed plastic containers. Just prior to analysis thin sections were acid washed with ultrapure 1% nitric acid and rinsed with ultrapure water. Samples were analyzed for trace element concentration and strontium isotope ratio ($^{87}\text{Sr}:$ ^{86}Sr) at the Woods Hole Oceanographic Institution. We compared trace element and isotopic signatures in otoliths of a sample of fish collected from Rifle Gap Reservoir with signatures of otoliths in samples of fish collected by USFWS in the Colorado River between Rifle and Rulison to evaluate our ability to trace origins of fish that may have escaped from Rifle Gap Reservoir into the Colorado River.

RESULTS AND DISCUSISON

Fish Consumption Advisories

On February 25, 2009, Colorado Department of Public Health and Environment (CDPHE) issued fish consumption advisories for RGR because samples from northern pike, smallmouth bass, and walleye met or exceeded the mercury action level of 0.5 parts per million set by the state health department (CDPHE 2009). The advisory states:

The fish consumption advisory for Rifle Gap Reservoir recommends that children aged 6 or younger do not consume any smallmouth bass larger than 15 inches or walleye larger than 18 inches and limit consumption of northern pike larger than 20 inches to only one meal per month. For pregnant women, nursing women and women who plan on being pregnant, the advisory recommends not consuming walleye larger than 18 inches and consuming only one meal per month of smallmouth bass larger than 15 inches and northern pike larger than 20 inches. For the general population, the recommendation is a limit of two meals per month of smallmouth bass larger than 15 inches and northern pike larger than 20 inches. The advisory also recommends the general public consume only one meal per month of walleye larger than 18 inches.

The size classes of smallmouth bass and walleye covered by the fish consumption advisory correspond to the sizes of legally harvestable fish under the 2008 fishing regulations at RGR. Because mercury is bioaccumulated, this means a fish accumulates more of the toxin as it gets older and larger. Thus, smallmouth bass and walleye smaller than the current size limits may have lower mercury levels than fish above the size limits. Northern pike also bioaccumulate mercury, so pike smaller than 20 inches may have lower mercury concentrations than larger NPK. Future harvest regulations for any of these species should take into account that protecting these top level carnivores from angling harvest carries with it the human health implications of increased body burdens of mercury that should be expected in larger fish.

Size structure

Length distributions of fish populations can convey useful information about growth, recruitment and predator-prey relationships. However, it can be difficult to obtain unbiased samples from fish populations because fish sampling gears are size-selective. For example, catch in gill nets is highly sensitive to mesh size. Further, time of year can influence sizes of fish captured, for example, with mature fish being particularly vulnerable during the spawning period. With these biases in mind, some gross patterns are evident in the length distributions of fish captured during the June survey.

Mostly “quality” size NPK (≥ 21 inches) were captured in June (Figure 3), resulting in a high PSD (90.3). The dearth of 300-500 mm fish suggests a few poor year-classes in recent years. Based on age-growth information (below), these missing year-classes most likely correspond to 2003-2005. NPK reproduction is dependent on high water levels in spring time and this period of failed recruitment in RGR corresponds to a period of drought in the region and lower than normal water levels in the reservoir (Figure 4).

Few WAL were captured and no fish < 490 mm were observed resulting in a high PSD (100). This indicates that recruitment has probably been lacking in the population for a number of years in the recent past. Aging the WAL that were captured will provide a more precise estimate of when recruitment began to fail, and may lead to clues about mechanisms for the decline in the WAL population.

Many more SMB were captured and the length-frequency distribution suggests the presence of two strong cohorts with modes of approximately 175mm and 375 mm. Again, aging, we suggest from otoliths, will be required to determine if these groups are representative of recruitment patterns. The size structure of BCR is difficult to judge due to small sample size but the PSD is good (52.4). PSD of RBT is somewhat irrelevant since the population is entirely stocked. The length distribution suggests that there is a small amount of growth of the fish after stocking, but the majority of the fish are approximately 12 in. TL.

The length distribution and PSD of YPE suggest a population dominated by small adults. Few “quality” size fish were captured in June. The length distribution shows a precipitous decline in abundance of fish >200 mm (8 in) which can indicate selective mortality of larger fish, by anglers or large piscivores such as NPK. Reduced size structure of YPE populations in the presence of northern pike predation is a common phenomenon (Paukert and Willis 2003; Margenau 1995). However, age-growth information from aging structures will be required to delve deeper into factors responsible for the truncated YPE size structure. The size distributions in June vs. fall (Figure 5) suggest the presence of at least six cohorts in June and the emergence of the age-0 cohort by fall.

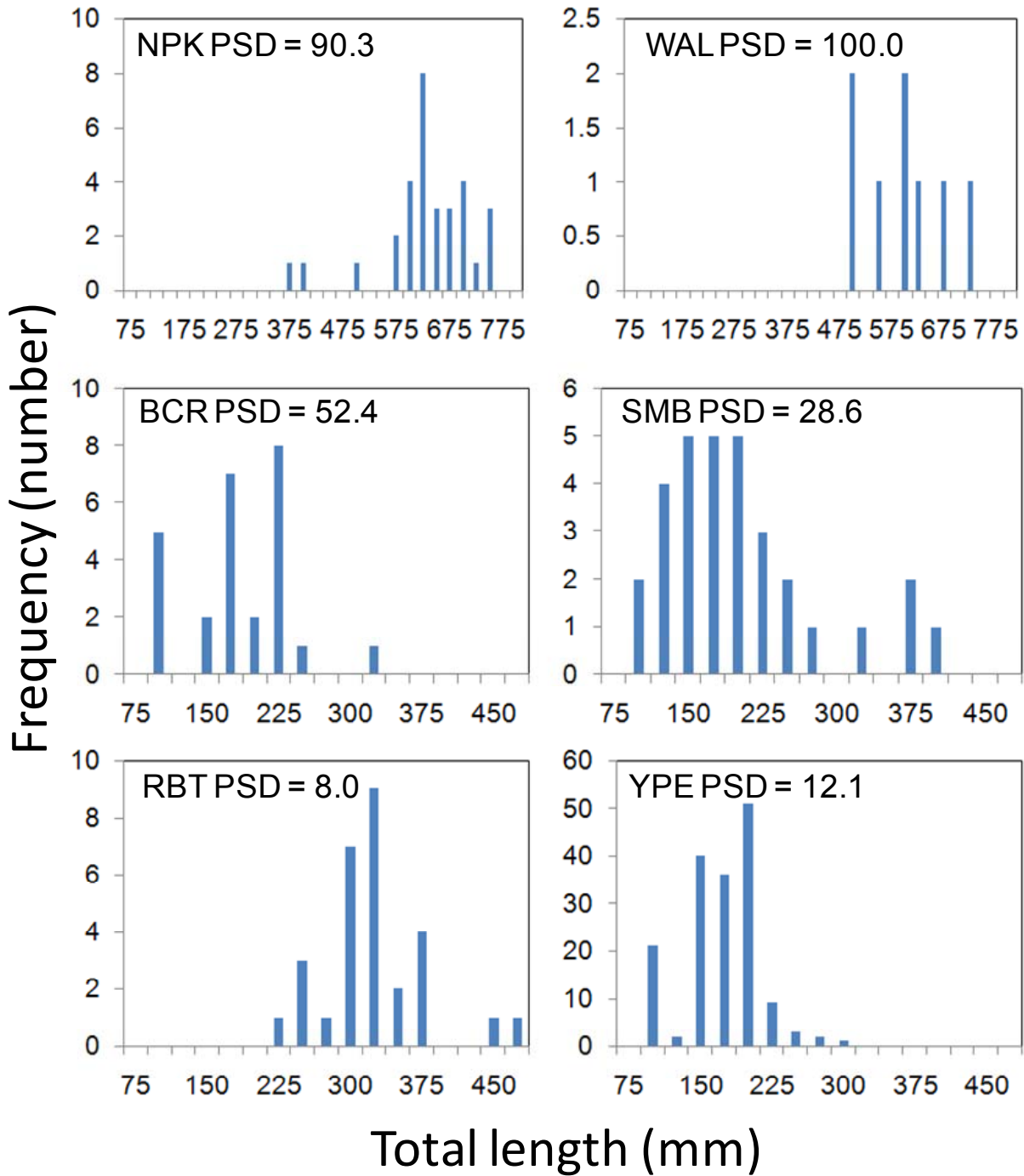


Figure 3. Length (TL, mm) distributions of six species of sport fish in Rifle Gap Reservoir sampled during June 2008. PSD (proportional size distribution, Guy et al. 2007) is shown for each species.

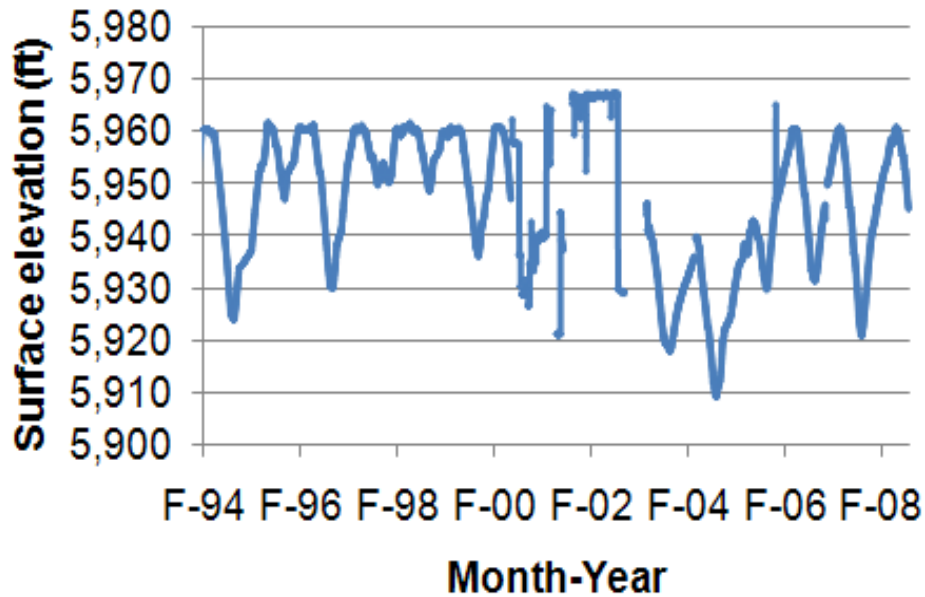


Figure 4. Surface elevation of Rifle Gap Reservoir during 1994-2008 showing effects of drought during 2003-2005. “F” represents February.

Body Condition

Body condition, as indicated by W_r , was only fair for most fish species and sizes of fish in RGR (Figure 6). Body condition of most sizes of SMB was slightly below what would be considered average, 92, and well below the optimal level of 100. Body condition of RBT and YPE, species that likely show considerable diet overlap, were only average to fair, suggesting that these two species may be competing with each other for food resources. Only BCR and NPK > 600 mm showed W_r values that would be indicative of fish in good to excellent body condition ($W_r > 100$). Sample size of WAL was low and W_r values were somewhat variable, but most W_r values were below 100, and almost half below 90, indicative of fish in only fair body condition. It may be that WAL are not as effective predators on catchable RBT as are NPK. Most of the WAL were < 600 mm TL, and 250 mm (10”) catchable RBT exceed the gape limit of these fish.

Only BCR and YPE showed a clear seasonal change in body condition, with both improving from June to fall. It is possible that post-spawn individuals sampled in June accounted for the low W_r of BCR and YPE and that the fall W_r values more accurately represent “normal” body condition for these species in this system. Body condition of NPK may have declined from June to fall but sizes of fish sampled in the two time periods differed somewhat making comparisons difficult.

Body condition of large NPK (> 600 mm TL) was significantly better (mean $W_r=112.8$) than body condition of smaller NPK (< 600 mm TL, mean $W_r =88.6$). We believe the improved body condition of larger pike is likely due to their ability to exploit catchable RBT as prey. We developed a length-weight relationship (mm, g) for NPK from all fish sampled (June, September and October): $a = -5.996$, $b = 3.305$, $N = 75$, $r^2 = 0.994$.

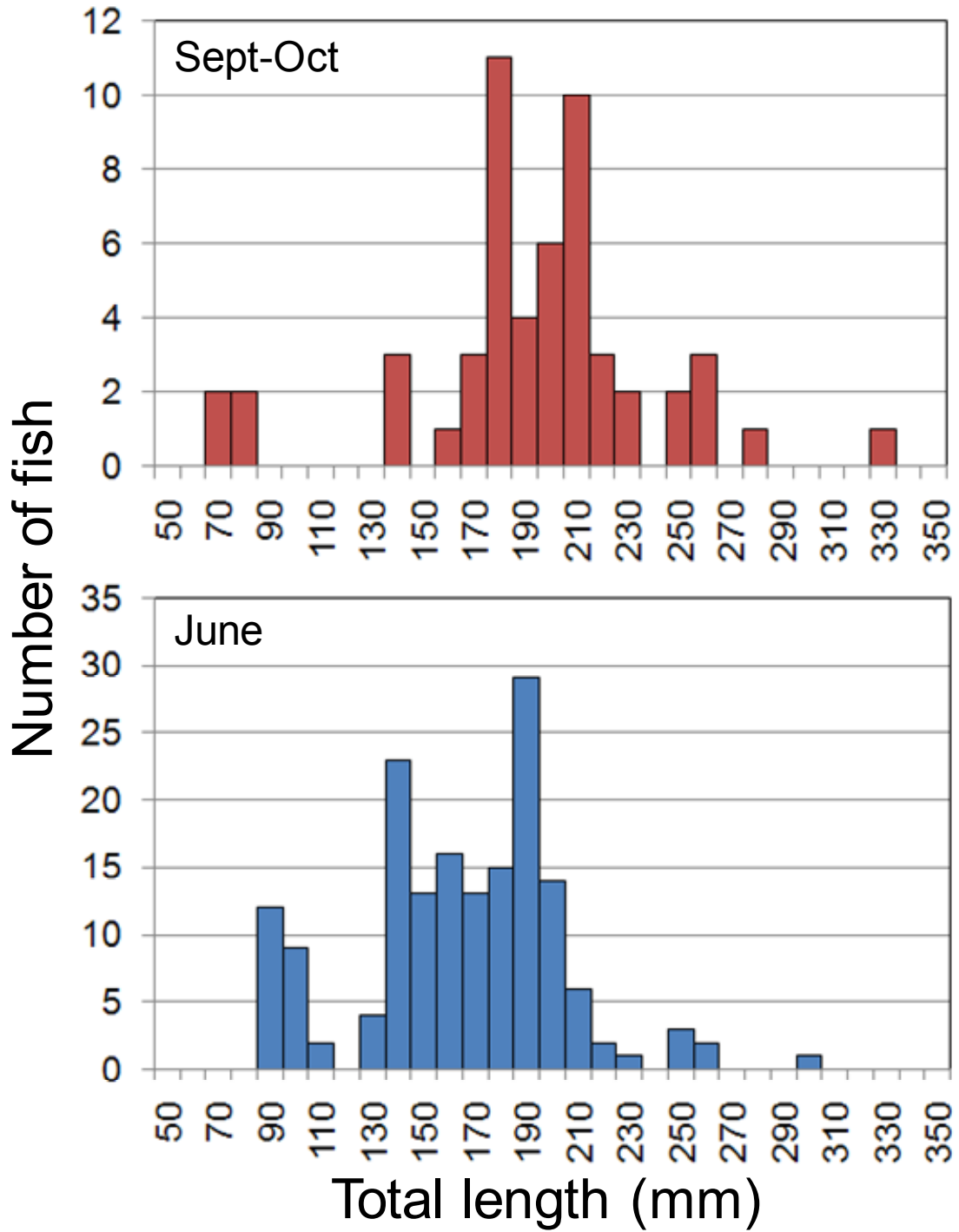


Figure 5. Length-frequency distribution of yellow perch captured during sampled at Rifle Gap Reservoir in September and October, 2008 (upper panel) and June, 2008 (lower panel).

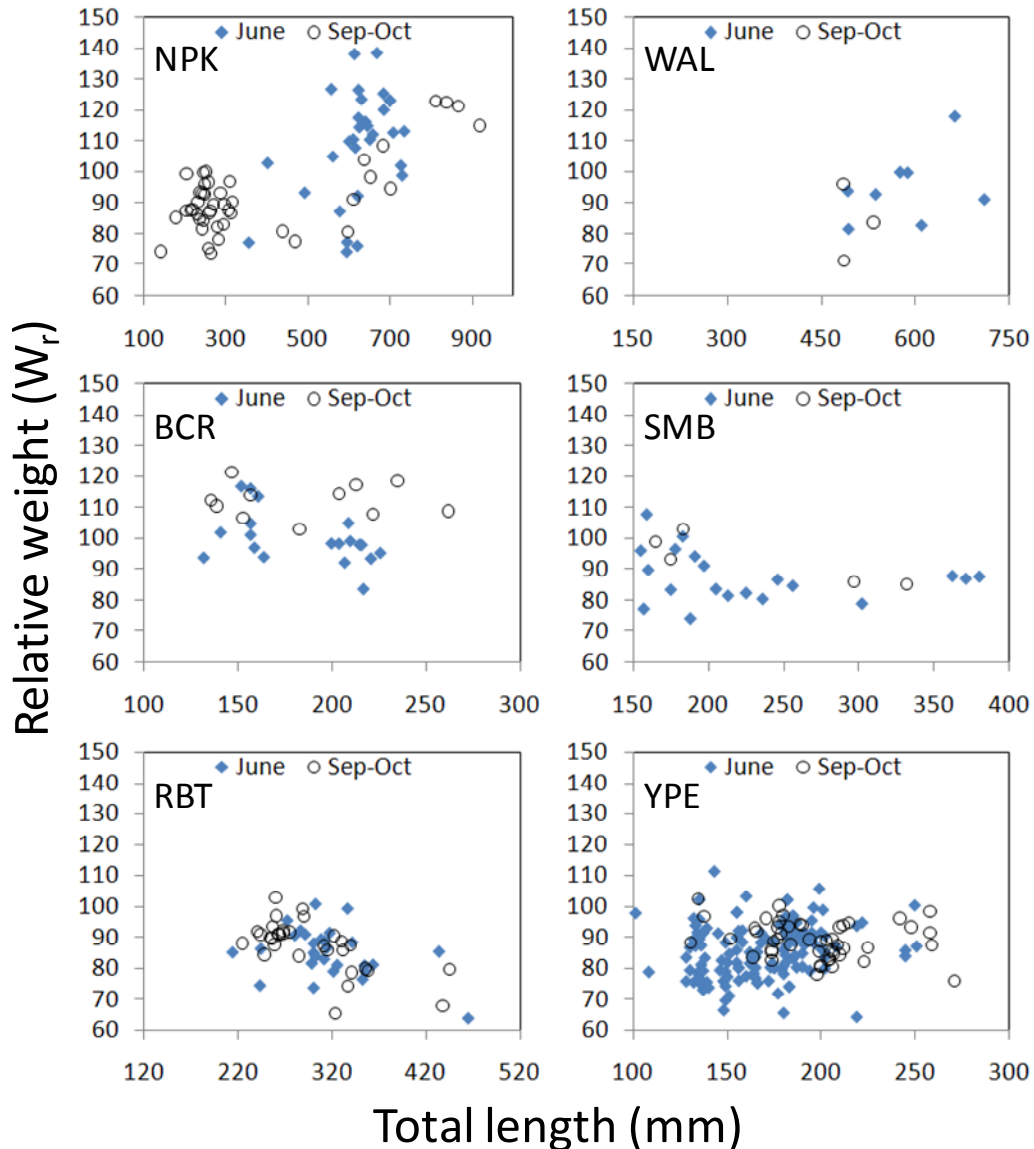


Figure 6. Relative weight (W_r , Anderson and Neumann 1996) of six species of sport fish sampled in summer (diamonds) and fall (circles) 2008 at Rifle Gap Reservoir.

Growth

We aged a sample of YPE scales and found that annuli were not clear, we had high variation in age determinations among readers and generally we had low confidence in our age assignments. We recommend that alternative aging structures, specifically anal fin spines and otoliths, be employed to obtain accurate and precise age estimates of YPE from RGR. Both of these methods are more time consuming than scales but yield much better information when scales are problematic. Otoliths or fin spines should be used to age BCR, SMB, and WAL when funds become available to support staff to perform that work. Some otoliths from all those species have been sectioned and polished for another CSU research project on otolith microchemistry. This

provides a good opportunity to take advantage of the large amount of prep work that is already completed because these otoliths are essentially ready to be aged.

The relationship between NPK size and cleithrum size was linear, with essentially a zero intercept, and low variance ($r^2 = 0.975$; Figure 7). This indicated that a simple proportionality model was adequate for back-calculation, although we used the computed intercept ($a = -0.016$) in our calculations. A robust sample of NPK cleithra have now been aged and used for back-calculation from fish collected from RGR in 2006, 2007 and 2008 (Table 5). Growth of NPK in RGR is rapid (Figure 8), with age-5 through age-10 fish averaging 24% larger in length and 132% heavier than the median of 39 NPK populations from Fishbase (2009), a website which compiles demographic information on fishes from all over the world.

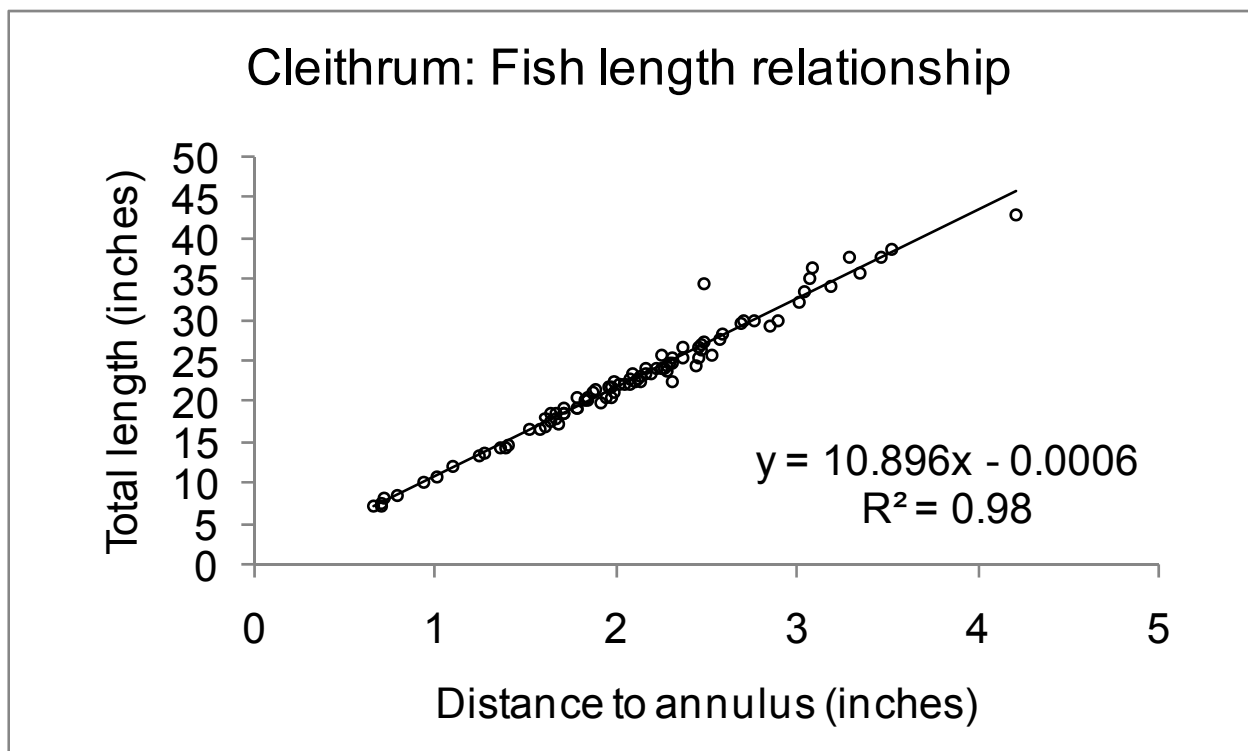


Figure 7. Fish length:cleithrum size relationship for 89 northern pike sampled from Rifle Gap Reservoir during 2006, 2007, and 2008.

Table 5. Average back-calculated length at age (inches) of 89 northern pike (males and females combined) collected from Rifle Gap Reservoir in 2006, 2007 and 2008. Ages and interannular distances were determined from cleithra.

N	Age	Year of life									
		1	2	3	4	5	6	7	8	9	10
2	10	7.4	14.9	23.5	27.0	30.7	33.2	35.8	37.4	39.1	40.0
3	9	6.9	15.1	22.9	25.3	27.1	29.7	31.5	33.4	34.5	
0	8	--	--	--	--	--	--	--	--		
7	7	7.8	14.9	21.2	26.6	30.6	32.9	34.3			
5	6	7.5	15.1	18.3	21.4	25.2	27.0				
12	5	6.4	14.9	17.4	21.5	23.7					
21	4	7.3	15.1	19.5	22.6						
21	3	8.7	14.9	19.6							
13	2	9.3	15.1								
5	1	8.1									
89	Mean	7.7	14.2	20.3	24.1	27.5	30.7	33.9	35.4	36.8	40.0

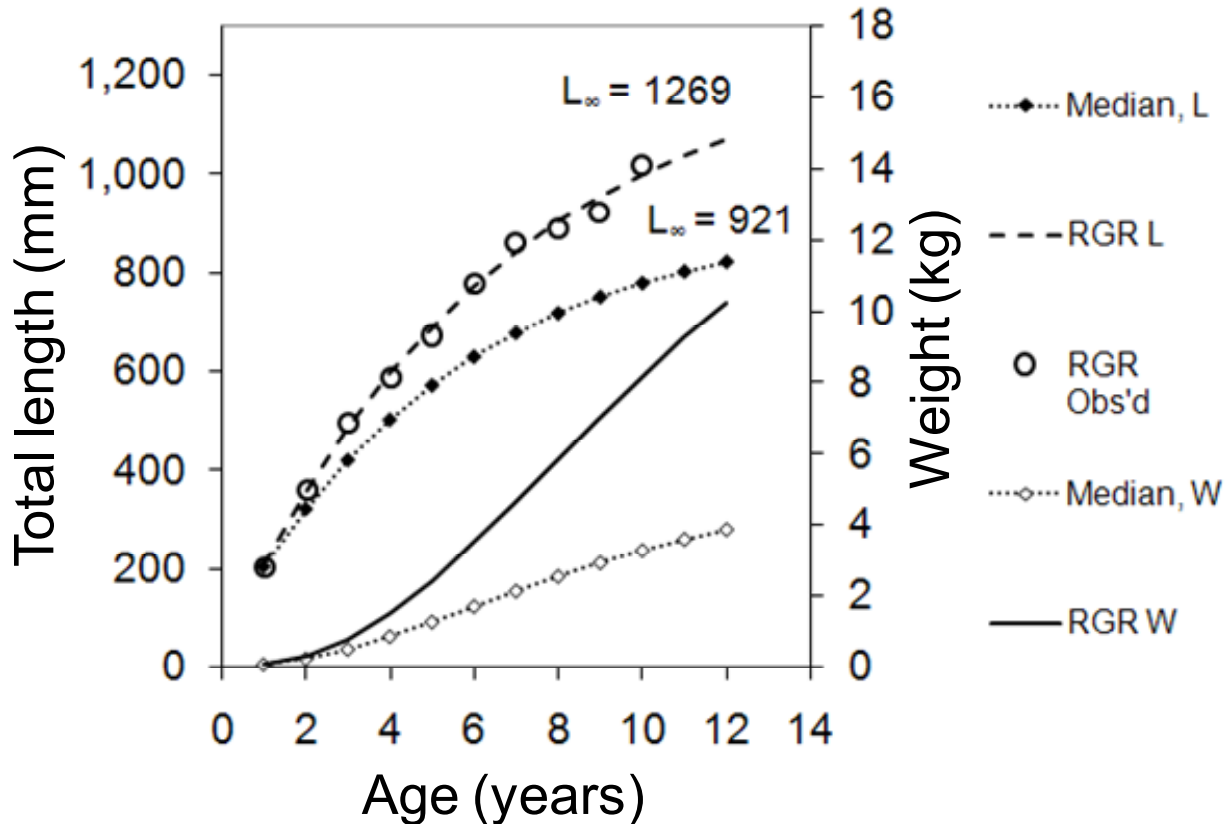


Figure 8. Growth of northern pike in Rifle Gap Reservoir in length (dashed line, circles) and weight (solid line) and the median growth of 39 populations of northern pike (dotted lines; Fishbase 2009). The von Bertalanffy parameter L_{∞} (theoretical maximum length, mm) for each group is also shown.

NPK Consumptive Demand

Per capita consumptive demand of NPK increased steadily from age-4 to age-10 (Figure 9). An age-4 NPK was predicted to consume about 11 lbs or 26 individual catchable RBT per year, and an age-10 NPK consumes 33 lbs and 79 RBT per year. At the population level, the trend is reversed with the age-4 cohort consuming the most by virtue of their highest abundance, and the age-10 cohort the least (Figure 10). Cumulatively, the simulations indicated that the NPK population in RGR could be consuming between 2,145 and 5,412 lbs of stocked trout per year and between 5,208 and 13,140 catchables per year. On the high end of the estimated range, NPK could be consuming 3,285 bag limits of trout per year, or about 35% of the annual stocking quota, assuming that age-4 and older NPK ate only RBT. It should be noted that we do not have an estimate of the abundance of age-3 and under NPK. These younger NPK are probably more numerous than the age-4 and older fish, and they must consume fish smaller than trout, including YPE, and young BCR, SMB, and WAL. Abundance information on RGR's NPK population coupled with diet analysis of all size classes of NPK would allow for a more precise estimation of the predatory impact of the NPK population on RGR's other fish populations.

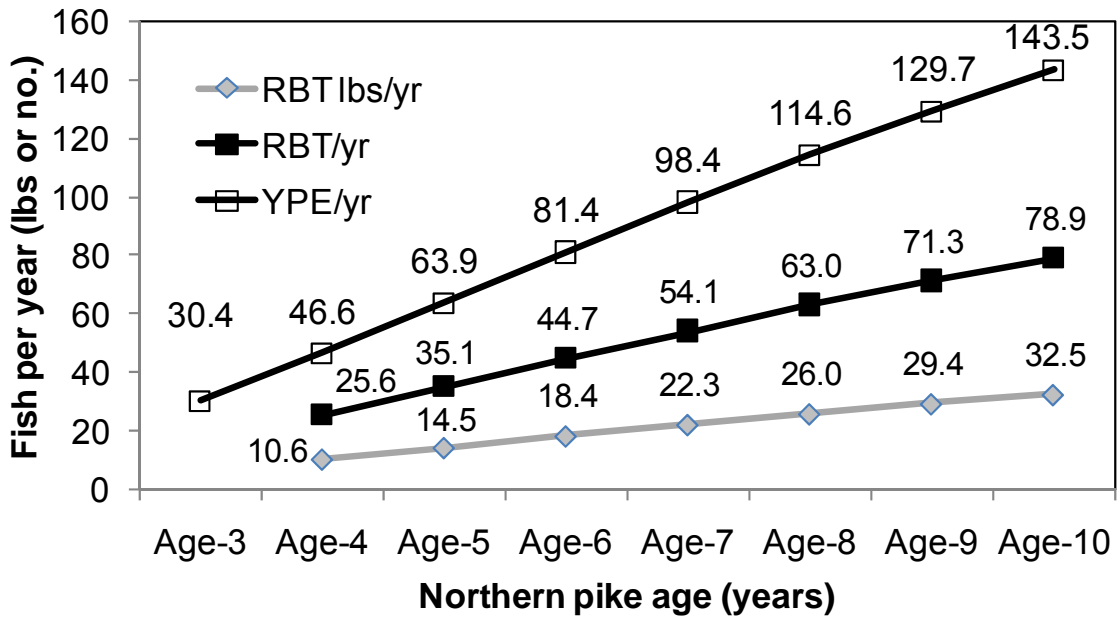


Figure 9. Per capita consumptive demand expressed as number (black line) and pounds (gray line) of fish consumed per pike per year of seven age-classes of NPK in Rifle Gap Reservoir. The actual numbers and pounds consumed are shown above each point.

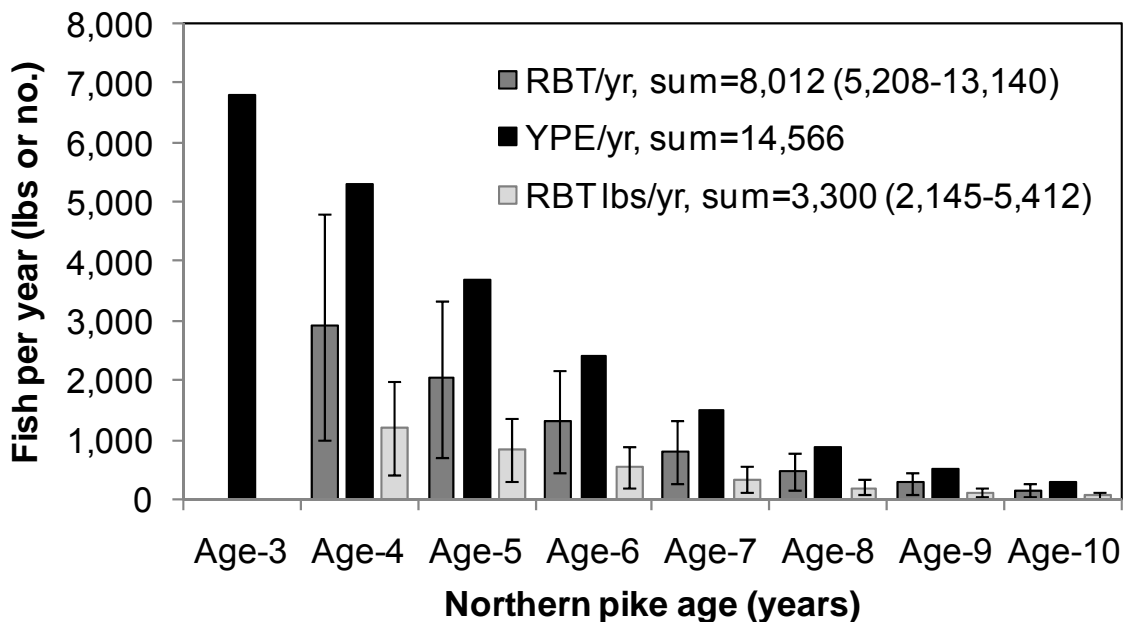


Figure 10. Annual number and biomass of fish consumed by seven or eight age-classes of northern pike in Rifle Gap Reservoir, based on bioenergetics simulations. Error bars are based on errors associated with abundance estimate; bars are omitted from the YPE consumption estimate so as not to obscure the RBT data.

Escapement

The completion of the \$10.2 million fish passage at the Colorado River's Price-Stubb diversion dam near Palisade in 2008 opened 52 miles of formerly inaccessible critical habitat to native fish (Figure 11), up to the town of Rifle. Because the fish passage system excludes nonnative fish from downstream, eliminating upstream sources of nonnative fish is an important tool for maximizing recovery potential of native fish in the newly opened habitat.



Figure 11. The Price-Stubb Diversion Dam fish passage on the Colorado River near Palisade, Colorado, was completed in 2008. Removal of this barrier to fish migration provides endangered fish access to an additional 84 km (52 miles) of critical habitat that has been blocked since 1911. Photo: U.S. Fish and Wildlife Service.

Fish surveys by USFWS during 2004-2008 on the Colorado River between Rifle and Rulison have turned up only one NPK (R. Burdick, USFWS, personal communication, 12/08/08) and thus we were unable to evaluate provenance of NPK in this reach of the river. Alternatively, large numbers of SMB have been sampled by USFWS in this reach, with concentrations particularly high in a connected backwater at river mile 236.6, near the confluence of the Colorado River and Rifle Creek. Many of these SMB, especially older adults collected during 2004 and 2005, are suspected of having escaped from RGR (R. Burdick, USFWS, personal communication, 12/08/08). WAL, BCR and YPE are also suspected of escaping from RGR into the Colorado River. Preliminary results from the otolith microchemistry study showed that both of the two walleyes collected from the study reach of the Colorado River had signature in the interior (first several years of life) portion of the otolith that matched the signature of walleyes collected from RGR (Figure 12). This demonstrates conclusively that these

two walleyes escaped from RGR before taking up residence in the Colorado River, and suggests that other species undoubtedly can escape from RGR to the Colorado River as well. As more samples are analyzed the otolith microchemistry study should be helpful in determining the degree of nonnative fish escapement from RGR and therefore the threat the coolwater fishes in RGR may potentially pose to native fishes in critical habitat downstream of the reservoir.

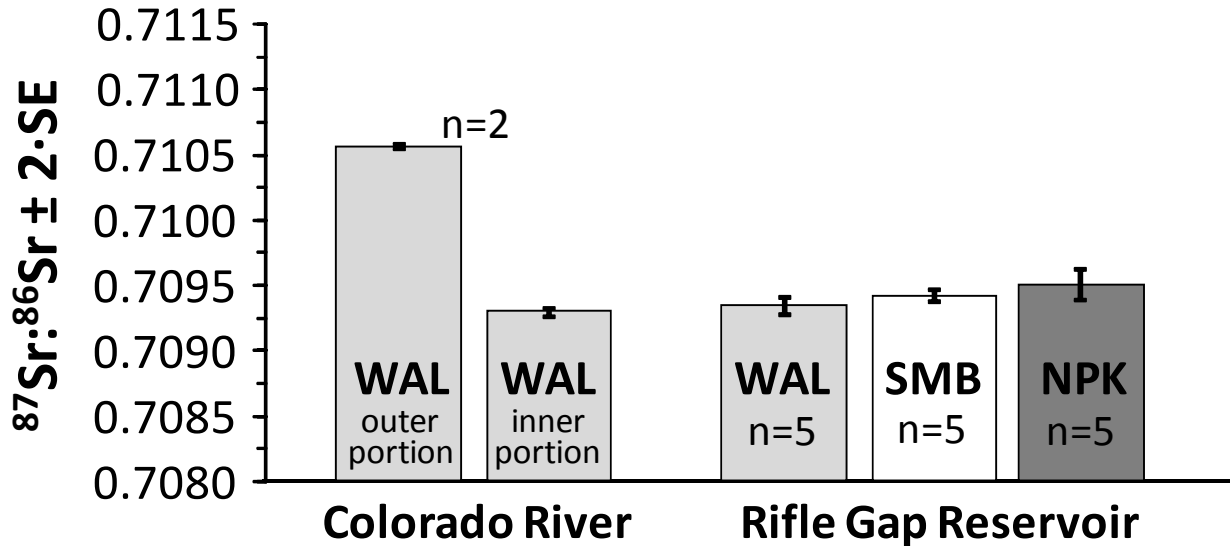


Figure 12. Strontium isotope signatures of outer and inner portions of otoliths from two walleyes collected in the Colorado River between Rifle and Rulison (left two bars) and strontium isotope signatures of otoliths of walleye, smallmouth bass, and northern pike collected from Rifle Gap Reservoir (right three bars).

MANAGEMENT ALTERNATIVES

One goal of the fishery investigation was to provide information useful for revision of the Lake Management Plan for RGR. We believe fishery management planning should consider the full range of reasonable management options available and then use a designated selection process to choose the preferred alternative. Obviously, the results of the fishery investigation at RGR are preliminary and this study is ongoing. However, our data analyses have rendered some insights that allow us to offer some tentative fishery management alternatives for this system, and potential consequences arising from each.

1. Status Quo

Continuing to manage the system in the current fashion may result in increased predation inertia from the NPK population, as the system accumulates biomass of large fish. This in turn will increase the consumptive demand of the NPK population and reductions in prey fish populations are likely to result. There may be reduced survival of catchable RBT and other sport fish (e.g., YPE, WAL, SMB) to a point that anglers experience reduced angling success. This scenario has already played out in several

other Colorado reservoirs and we expect RGR to follow a similar trajectory without management intervention.

2. Cease stocking RBT

We estimated that NPK may already be consuming up to 35% of the annual stocking quota of RBT. This is not only an inefficient use of hatchery resources, but continued stocking is counterproductive since it fuels increased biomass, reproductive potential, and consumptive demand of the NPK population. Cessation of RBT stocking at RGR would save catchable RBT for anglers to catch in other systems where they would not be eaten by predators. With no RBT to eat NPK may become more cannibalistic and NPK recruitment may be reduced. However, increased predation on other fish in RGR (e.g., YPE) would likely occur first, impacting fisheries for those species. If NPK growth rates decline it is possible that mercury bioaccumulation in NPK would increase.

3. Compensate for NPK

Estimates of NPK consumptive demand make it possible to know how much to increase RBT stocking to compensate for NPK predation losses so a desired number of RBT are always available to anglers. However, as discussed in #1 above, this number is likely to increase, making it necessary to continually increase the “feeding rate” to satisfy the growing NPK consumptive demand. The “collateral damage” to other species of this hatchery-fueled buildup of predators is hard to predict but could be substantial. This option would increase hatchery costs substantially and result in opportunity costs because hatchery capacity would not be available to produce fish for other fisheries. This approach also ignores the fact that NPK were illegally introduced into RGR and enhancing the NPK population by feeding it intensively with trout implicitly condones and legitimizes illegal stocking and could encourage further illegal stocking elsewhere.

4. Manage around NPK

Large RBT (~14-16 in. TL), so called “super-catchables”, could be used to sustain a trout fishery, as was necessary in South Park reservoirs (Orabutt 2006). Such fish are too large for most NPK to capture and consume. As in option #3, this option would increase hatchery costs substantially and result in opportunity costs because hatchery capacity would not be available to produce fish for other fisheries. If NPK no longer had RBT as prey they would turn to other species, potentially impacting other fisheries in the reservoir.

4. Suppress NPK

There are options to suppress the NPK population. We found evidence that unusually low water levels in the mid-2000s resulted in almost no NPK recruitment. This suggests that water level manipulation (springtime drawdown) would be a useful means of eventually reducing NPK abundance, if water users had the flexibility to change their operation of the reservoir. Mechanical removal, by fyke netting during spawning and gill netting later, could hasten population decline, but it is unlikely that the combined effects of all these approaches would completely eliminate NPK.

5. Sterile predators

Some anglers may be unhappy with the decision to suppress or eliminate NPK and alternative large predators with more controlled predation inertia could be sought to substitute for NPK. The utility and practicality of sterile hybrids such as wipers or tiger muskie could be investigated, along with the compatibility of such species with native fish conservation downstream of the reservoir. It should be noted that sterile predators like tiger muskie and wiper would be incompatible with NPK in RGR. Stocking such species in RGR would only be reasonable options after NPK had been reduced to a remnant population and the means for perpetual suppression of NPK reproduction were in place. Given the recent mercury advisory at RGR, it may be unwise to introduce any additional top predators that could become a human health concern for anglers that may wish to consume them.

7. Emigration barrier

Given that we have now confirmed escapement of nonnative predators from RGR into the Colorado River, and given the number of nonnative piscivore species of concern that exist in RGR, it seems prudent for agencies to move more quickly to investigate options for limiting escapement of nonnative fish from the reservoir. If barriers are to be considered, a barrier in Rifle Creek immediately below the dam could be a more feasible structure than one installed on the dam itself. Alternatively, devices that allow fish to pass but the fish do not survive passage are available. Regardless of its configuration or location, a barrier must be properly designed, installed and maintained to insure a very high level of reliability in perpetuity.

8. Predator Stamp

Anglers desiring a piscivore fishery could be required to pay for the increased costs associated with it through a “predator stamp” program. Funds generated from the predator stamp program could be used to a) maintain predator growth rates for quality angling and to minimize mercury bioaccumulation through additional trout stocking, b) sustain a trout fishery via stocking of “super-catchables”, and/or c) offset costs of any management actions required to prevent escapement of predatory species into critical habitat. Such a stamp program could be difficult to enforce, may not generate much funding, and unless explained thoroughly, could be viewed unfavorably by the angling public as simply an agency money making scheme.

9. Illegal stocking surcharge

Although not specific to RGR, CDOW could institute an “illegal stocking surcharge” that would be levied on all waters that have illegally established sport fish populations. Anglers fishing these waters would be required to pay a special fee, with funds generated used to offset costs associated with mitigating management costs incurred from the illegal introduction and to improve outreach and deterrence efforts to prevent future illegal stocking. Such a fee could create peer pressure against individuals who would stock fish illegally and subject all anglers to increased costs of fishing. Like the predator stamp program, an illegal stocking surcharge would need to be implemented carefully to insure that the public was aware of the rationale for the program.

10. Chemical reclamation

There is reason to believe that this system has been overstocked with species and that the current food web is suboptimal from a fishery standpoint. RGR once produced excellent RBT and brown trout and it had a self-sustaining WAL population. Illegal stocking has loaded this system up with NPK, BCR, and YPE. Now WAL are nearly extirpated, body condition of small NPK, RBT, YPE, and SMB is only fair and size structure of YPE and SMB populations is skewed to small fish. Further, NPK, SMB and WAL all have consumption advisories due to mercury contamination. Improving fishing quality and reducing mercury body burdens for all these species in RGR would be very difficult, probably impossible, given limited ecosystem productivity. A more direct and effective route to improved fishing at RGR would be to reclaim the system with rotenone and recreate a trout fishery. RGR has provided excellent trout fishing in the past, prior to the introduction of coolwater fishes, and trout would not be a concern from the standpoint of mercury bioaccumulation. Consequences of this alternative include: a high initial expense incurred, reduced visitation at the State Park during the project, unhappy stakeholders (WAL, YPE, SMB, and NPK anglers), and the possibility that the reservoir would be illegally restocked after the reclamation.

CSU RECOMMENDATIONS TO CDOW

We offer the following recommendations based on our analysis.

- This investigation is preliminary and a considerable amount of data collection and analysis remain to be done. Although we have identified tenable management alternatives, we urge CDOW to continue the study to improve their understanding of the system.
- Age-growth analysis has already provided some valuable insights for NPK; it will be critical to continue to gather age-growth information for other RGR species. In particular, age-growth information may help elucidate recruitment patterns, and help explain size distributions (e.g., truncated distribution of YPE).
- Management plans for the system should be formed in light of mercury contamination issues that have now been documented by CDPHE. In particular, harvest regulations for SMB and WAL may need to be changed to accommodate mercury contamination levels in fish above the current size limits.
- The mechanisms for the apparent decline of WAL are unknown and warrant continued investigation.
- A large number of diet and tissue samples for isotopic analysis have been collected but funds do not exist for analysis. CDOW should determine if data from these samples is desired, and if funds exist to process the samples. Diet of NPK and YPE are of particular interest.
- Solid demographic data arising from this study could be used by CSU to perform quantitative analyses of alternative fishing regulation scenarios should funding become available to support such work.

- Results from the ongoing CSU otolith microchemistry study should be considered when evaluating escapement barrier plans.
- An information and education program may help inform anglers about issues, constraints and management concerns (e.g., illegal stocking, NPK problems) at RGR. Signs, brochures, web pages, news outlets, Western Slope Anglers, kids programs, schools should all be used in outreach efforts.
- Illegal stocking has created a fishery management dilemma at Rifle Gap Reservoir, but illegal stocking is a widespread and ongoing problem in Colorado. This practice is jeopardizing sustainable fisheries and the economies that depend on them and Colorado Division of Wildlife should adopt more stringent policies to discourage illegal stocking in the future.

ACKNOWLEDGMENTS

We are grateful to several CDOW personnel, without whom this project would have been impossible. We thank Lori Martin for all her time and assistance with this class project, including providing fish samples and data, guest lectures and taking students on field sampling trips to RGR. We thank Sherman Hebein and Mike Japhet for committing funding for age and growth analyses. We are also grateful for the assistance and advice of Patrick Martinez, and for discussions with and unpublished data of Dan Kowalski. CSU student Adam Hansen performed an outstanding job on the age-growth analysis of NPK cleithra.

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APPENDIX 1.

Table A1. Mean daily water temperatures (Celcius, Fahrenheit) measured by a temperature logger in Rifle Gap Reservoir placed in the epilimnion, near the dam by Lori Martin, CDOW, during 2008.

06/03/08	16.4	62	07/10/08	21.8	71	08/19/08	20.7	69
06/04/08	16.0	61	07/11/08	21.8	71	08/20/08	20.7	69
06/05/08	15.3	60	07/12/08	21.9	71	08/21/08	20.7	69
06/06/08	15.0	59	07/13/08	21.5	71	08/22/08	20.7	69
06/07/08	15.3	59	07/14/08	21.4	71	08/23/08	20.8	70
06/08/08	15.0	59	07/15/08	21.6	71	08/24/08	21.1	70
06/09/08	14.9	59	07/16/08	21.5	71	08/25/08	20.9	70
06/10/08	15.0	59	07/17/08	21.6	71	08/26/08	20.8	69
06/11/08	15.1	59	07/18/08	21.7	71	08/27/08	20.9	70
06/12/08	14.9	59	07/19/08	22.0	72	08/28/08	21.0	70
06/13/08	14.9	59	07/20/08	22.3	72	08/29/08	20.9	70
06/14/08	15.4	60	07/21/08	22.5	73	08/30/08	20.8	69
06/15/08	15.9	61	07/22/08	22.8	73	08/31/08	20.7	69
06/16/08	16.7	62	07/23/08	23.2	74	09/01/08	20.3	68
06/17/08	17.5	63	07/24/08	23.1	74	09/02/08	19.8	68
06/18/08	17.6	64	07/25/08	23.2	74	09/03/08	19.7	67
06/19/08	18.4	65	07/26/08	23.2	74	09/04/08	19.4	67
06/20/08	18.6	65	07/27/08	23.1	74	09/05/08	19.4	67
06/21/08	19.2	67	07/28/08	23.2	74	09/06/08	19.2	67
06/22/08	19.3	67	07/29/08	23.1	74	09/07/08	19.1	66
06/23/08	19.3	67	07/30/08	22.9	73	09/08/08	19.1	66
06/24/08	19.0	66	07/31/08	22.8	73	09/09/08	18.8	66
06/25/08	19.5	67	08/01/08	22.8	73	09/10/08	18.6	66
06/26/08	19.7	67	08/02/08	22.8	73	09/11/08	18.4	65
06/27/08	20.0	68	08/03/08	23.0	73	09/12/08	18.1	65
06/28/08	20.5	69	08/04/08	23.0	73	09/13/08	17.9	64
06/29/08	20.7	69	08/05/08	23.0	73	09/14/08	17.9	64
06/30/08	20.9	70	08/06/08	23.0	73	09/15/08	17.8	64
07/01/08	20.8	70	08/07/08	23.0	73	09/16/08	17.8	64
07/02/08	20.8	69	08/08/08	22.7	73	09/17/08	17.8	64
07/03/08	21.1	70	08/09/08	22.1	72	09/18/08	17.8	64
07/04/08	21.3	70	08/10/08	22.4	72	09/19/08	17.7	64
07/05/08	21.5	71	08/11/08	22.1	72	09/20/08	17.5	63
07/06/08	21.5	71	08/12/08	21.2	70	09/21/08	17.4	63
07/07/08	21.4	71	08/14/08	22.2	72	09/22/08	17.3	63
07/08/08	21.8	71	08/15/08	21.5	71	09/23/08	16.9	63
07/09/08	21.9	71	08/16/08	20.8	69	09/24/08	16.8	62

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09/25/08	16.7	62	10/07/08	15.0	59	10/19/08	11.9	53
09/26/08	16.7	62	10/08/08	14.8	59	10/20/08	11.9	53
09/27/08	16.7	62	10/09/08	14.7	58	10/21/08	11.5	53
09/28/08	16.8	62	10/10/08	14.4	58	10/22/08	10.9	52
09/29/08	16.6	62	10/11/08	13.9	57	10/23/08	10.5	51
09/30/08	16.5	62	10/12/08	13.5	56	10/24/08	10.3	51
10/01/08	16.5	62	10/13/08	13.1	56	10/25/08	10.1	50
10/02/08	16.5	62	10/14/08	12.7	55	10/26/08	10.1	50
10/03/08	16.1	61	10/15/08	12.4	54	10/27/08	9.9	50
10/04/08	15.7	60	10/16/08	12.3	54	10/28/08	9.7	50
10/05/08	15.5	60	10/17/08	12.1	54	10/29/08	9.6	49
10/06/08	15.3	60	10/18/08	12.0	54			
