Salmonid Population Size in the Colorado River, Grand Canyon, Arizona

Fishery Fact Sheet
Arizona Game and Fish Department
Grand Canyon Monitoring and Research Center
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INTRODUCTION

Over the passed decade, considerable research and monitoring has been conducted on the effects of varied flow regimes on aquatic biota of the Colorado River below Glen Canyon Dam (GCD). Management recommendations for native fish arising from this work assume that physical habitat features (seasonality of flow, habitat morphometry) are the primary limiting factors for native fish populations. However, much less is known of population size and dynamics of exotic fish and, in particular, the risk of predation that salmonid populations pose to native fish. The objective of this study was to estimate population size and distribution of non-native salmonids rainbow trout (*Oncorhynchus mykiss;* RBT) and brown trout (*Salmo trutta;* BNT) in Grand Canyon for use in assessing predation risks to native fishes.

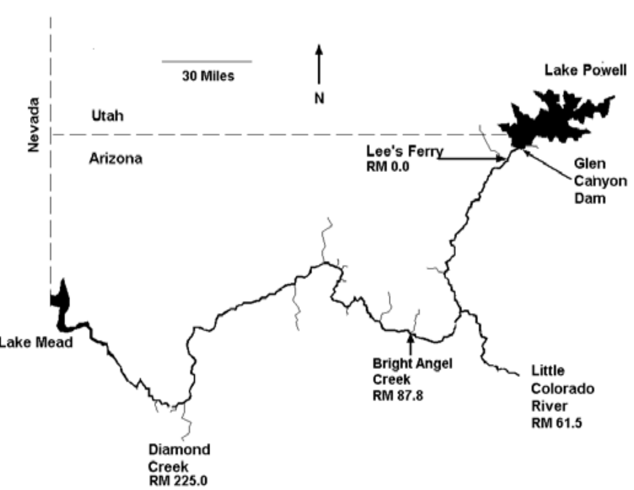


Figure 1. Study area.

METHODS

Population Estimate Approach and Assumptions

We estimated system-wide (RM 18-225) population size by calibrating single-pass electrofishing (EF) catch-per-effort (CPE) values to absolute, local estimates of fish density (N_o). The latter were obtained by a series of spatially and temporally discrete depletion and/or mark-recapture (M/R) electrofishing experiments conducted over a range of fish densities. The focus of this report is on results from depletion experiments. We have no observational model for M/R data at this time, but hope to evaluate them using mark-rate techniques in the coming year.

Relation of depletion estimates to index samples (single-pass CPE) was made assuming

$$CPE = q\,(N_o)$$

where catchability coefficient q is some fraction of absolute fish abundance removed per unit of effort (Hilborn and Walters 1992). In this manner, single-pass index EF samples collected throughout the river system can be "translated" into absolute fish numbers, which are then expanded and plotted longitudinally against river mileage. The resulting curve is then integrated to provide a system-wide population estimate.

The theory behind depletion electrofishing is illustrated in Figure 2, whereby increases in cumulative numbers (K) of fish over a consecutive series of electrofishing passes is plotted against the accompanying decline in CPE with each pass (Leslie and Davis 1939). The value of the x-axis intercept of the regression line in figure 2 (98, or estimated K at CPE = 0 after multiple passes) is the estimate of fish present prior to electrofishing. In our analysis, we used a maximum binomial likelihood routine to search for N_o estimates (Walters, unpublished; Hilborn and Walters 1992) while also accommodating occurrences of zero CPE values.

We treated all depletion data as originating from closed populations (see *Field Methods*). We restricted our inferences on N_o to areas effectively sampled by EF (within ca. 15 m of the shoreline; AGFD, unpublished March 2001 data). Fish with capture probability (q) of near zero (fish inhabiting deep, offshore areas) were modeled indirectly by extrapolating near shore estimates across river length and width.

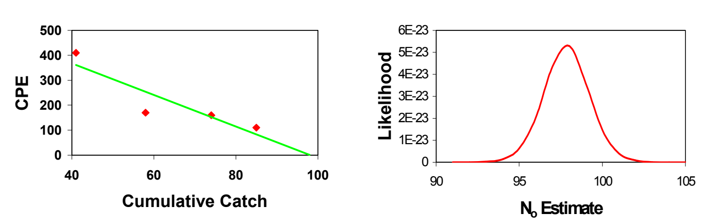


Figure 2. A typical RBT depletion sample (left, RM 22.3, 6/2/2000) and associated likelihood profile on N_o = 98 fish (right).

Field Methods

We collected electrofishing data during six mainstem Colorado River trips in Grand Canyon National Park during 2000 (table 1). Samples were collected by Arizona Game and Fish Department (AGFD) and SWCA, Inc., Environmental Services (SWCA). Discharge from GCD was relatively constant at 8,000 cfs during the entire study period. An additional mainstem trip was conducted during December
2001, but mark-rate and distributional data from that trip are pending analysis.

All data used in population estimates were collected by electrofishing at night. We used a 16' Achilles inflatable sport boat outfitted for electrofishing, applying an average output of 310 volts and 14 amps to a 35 cm spherical electrode. All salmonids were measured (maximum total length, mm). We clipped adipose fins of all fish larger than 100 mm. As relatively little is known of brown trout population parameters (growth rates, survival, movement), we implanted all BNT >120 mm with passive internal transponder (PIT) tags. We also clipped adipose fins of all PIT tagged brown trout to allow evaluation of tag loss.

We selected experimental depletion electrofishing transects according to availability of shoreline structural features to minimize immigration and/or emigration from the study area between multiple EF passes (Figure 2). We found that sandbars usually provided the best barrier to immigration and emigration from the transect, because trout generally do not utilize such areas. Debris fans, rapids and rock outcrops also served as barriers, but they were not as effective as sandbars (Speas and Rogers, personal observations). In most cases, few fish were captured at the extremities of the EF transects, and we believe effects of immigration and emigration were minimal. Transects averaged 0.13 miles in length.

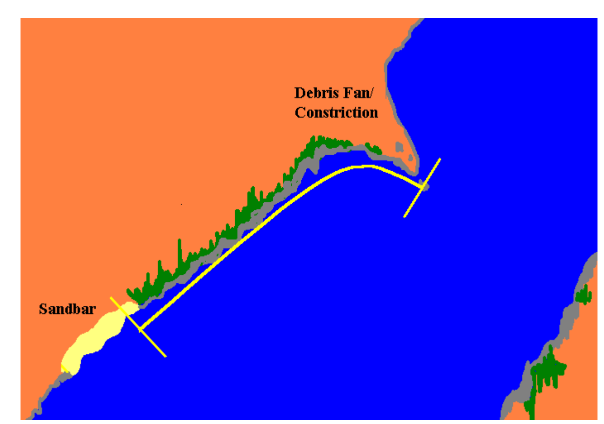


Figure 3. Schematic of a typical depletion/mark-recapture experimental transect.

Each depletion experiment was conducted over a period of 2-3 hours each night. We electrofished depletion transects repeatedly until the catch was reduced to about 20% of the first-pass catch. Fish were processed between passes and retained in a mesh live well until the experiment was concluded. At select locations, depletion transects were revisited 24 h later to collect recapture observations using the same amount of effort applied during the previous night.

RESULTS AND DISCUSSION

Combined efforts between AGFD and SWCA resulted in over 500 EF samples collected between river miles (RM) 0 and 225 during June-September, 2000 (table 1). AGFD conducted 77 depletion experiments. Gastrointestinal tracts were collected from almost 900 fish and are currently being analyzed by Grand Canyon Monitoring and Research Center (GCMRC).

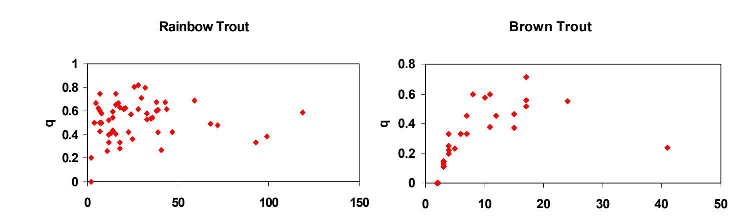
Table 1. Size and type of electrofishing samples collected on the Colorado River in Grand Canyon, 2000

Agency	Trip Dates (2000)	N Index CPE	N Depletion[1]
AGFD	6/4-5/18	83	21
AGFD	7/21-8/3	53	37
AGFD	8/25-9/6	26	19
SWCA	6/7-6/23	174[2]	-
SWCA	8/7-8/22	50	-
SWCA	9/14-9/28	43	-
Total	-	429	77

[1]First pass from these samples also functioned as index CPE
[2]Not included in population estimate due to EF power output differences

Catchability coefficients

Estimates of q were unbiased by fish density for rainbow trout (Figure 4, left). Catchability may be positively related to density for brown trout, but this bias did not preclude calibration of CPE to absolute density (Figure 5, right). There was little evidence that q varied with successive electrofishing passes. Mean q for RBT including first depletion passes (0.52) was nearly identical to



that based on second and later passes only (0.51), but q for BNT from first pass inclusion (0.16) was slightly greater than that for second pass (0.11).

Figure 4. Catchability coefficient (q) in relation to estimated fish density for RBT (left) and BNT (right).

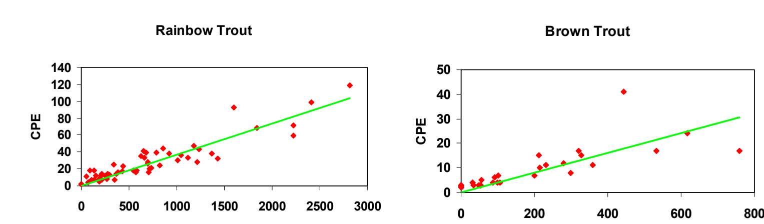


Figure 5. Calibration of local fish density (RBT, left, and BNT, right) estimates to observed first pass CPE from depletion experiments.

The usefulness of CPE calibration for long-term monitoring will depend on variability of q with variables such as water clarity and seasons, because such variation will affect the slopes of CPE on N_o (Figure 5). Catchability for RBT in samples collected from turbid water conditions was 0.58, compared with 0.51 from clear water. Catchability of brown trout, by contrast, was only 0.10 in turbid water, compared to 0.18 from clear water. Only 13 depletion experiments were conducted under turbid water conditions, and we consider variance of q with water clarity an information need to further refine the monitoring program.

Also, preliminary observations from samples collected during December 2000 and March 2001 (analysis in progress) suggest that behavioral changes in fish distribution associated with reproduction may also result in different estimates of q (Walters, personal communication).

Salmonid population estimates and longitudinal distribution

For both rainbow (figure 6) and brown trout (figure 7), mean fish/RM were modeled longitudinally by a cubic polynomial regression, in which all terms were significant (RBT $R^2 = 0.60$; BNT $R^2 = 0.24$; P<0.0001 for each) except for 2nd and 3rd order coefficients for RBT. These terms were retained, however, to obtain the best approximation of longitudinal variation and minimize negative fish density estimates.

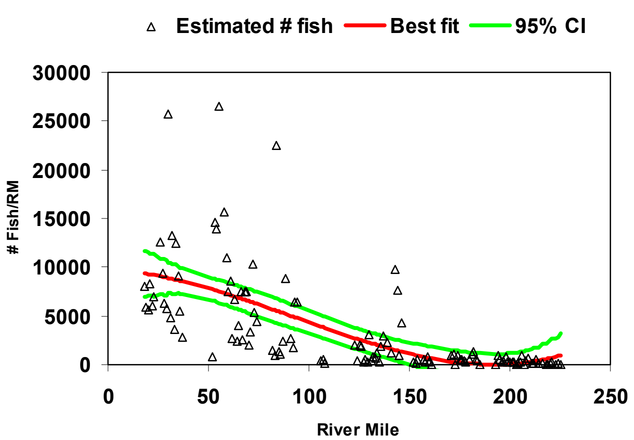


Figure 6. Estimated rainbow trout/river mile, best fitting line and 95% confidence intervals.

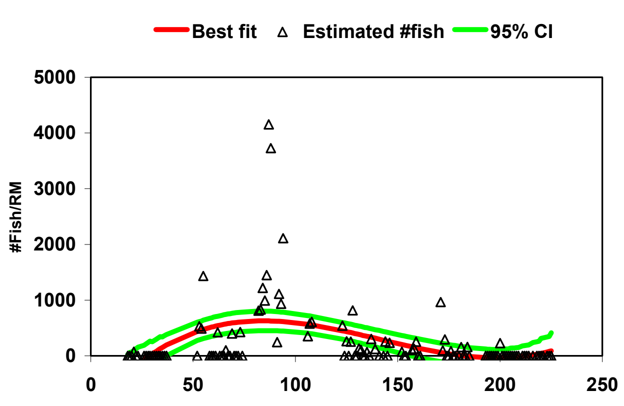


Figure 7. Estimated brown trout/river mile, best fitting line and 95% confidence intervals.

Integration of the polynomial curves yield an estimated 743,000 RBT (95% CI: 500,000-1,000,000 RBT) occurring in the Colorado River between RM 18 and 225 (figure 6). Estimated brown trout population size was 56,000 (95% CI: 20,000-100,000 BNT). Rainbow trout occurred predominantly in the first 100 river miles below Lees Ferry, whereas maximum brown trout numbers occurred between RM 50 and 150, especially in the vicinity of Bright Angel Creek (figure 7).

Length Frequencies

Modal length frequencies four adult RBT and BNT were 315 and 282 mm, respectively (figure 8). Juvenile model length frequency for RBT was 160 mm, and 120 mm for BNT. Given these distributions, it is likely that at least a portion of the salmonid populations exert predation pressure on small-bodied fish, but frequency of occurrence and composition of fish in salmonid diets are unknown at this time.

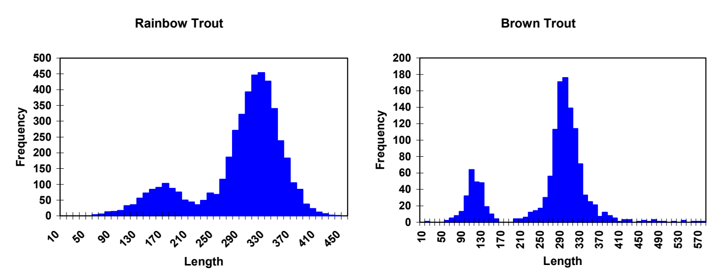


Figure 8. Length frequencies of rainbow trout (left) and brown trout (right) in the Colorado River, Grand Canyon during 2000.

Error Sources

We feel that depletion samples were conducted on highly discrete spatial (delimited transects ca. 0.1 mile in length) and temporal (consecutive EF removal passes) scales. Error associated with immigration, emigration, and within-experiment variance in capture probabilities is likely negligible in comparison to error introduced by cross-sectional extrapolation from the local to the system-wide level. While variance in fish numbers along the longitudinal axis of the river is captured by our method, very little is currently known of fish density gradients along the cross-section of the channel.

Fish in areas inaccessible to electrofishing—primarily deep (ca. > 2 m), offshore areas--are effectively invulnerable to depletion estimators in that their catchability approaches zero. Theoretically, however, such fish should be at least partially accounted for in mark-recapture estimates. For comparative purposes, we calculated M/R estimates for RBT and BNT using the same assumptions as we used with depletion estimates[3].

For rainbow trout, estimates of absolute fish numbers (N_o) from fish recaptured 24 h after marking in depletion transects were about 2.9 times larger than depletion estimates. Brown trout M/R estimates of N_o were only 1.5 times larger than depletion estimates. While these estimates of bias are admittedly crude, they do suggest that depletion estimates of local fish abundance are negatively biased. In practice, biases of 30-50% in depletion estimates are not uncommon (Hilborn and Walters 1992). It is very possible, however, that such negative biases may be overwhelmed by positive biases introduced by extrapolation.

We are confident that depletion-derived estimates will be useful in evaluating relative risk of predation for native fish because they are relatively precise estimates of population orders of magnitude. Use of such estimates in conjunction with independent estimates for native fish in a predator-prey model framework should reveal the degree of relative risk salmonids pose to native fish at the population level. Evaluation of stomach samples from summer 2000 should also aid in interpreting such models.

RECOMMENDATIONS

- CPE calibration is an effective technique to rapidly assess population size, but we recommend continued—albeit opportunistic—estimation of q under varied water clarity conditions, discharge regimen and seasons. Accumulation of such data should facilitate future population estimates despite effects of diverse sampling conditions.
- To facilitate independent estimators of population size, we recommend continued tagging of all salmonids on all mainstem Colorado River fish monitoring trips.
- The primary source of uncertainty in generating population estimates at the system level is making inferences of fish density in areas inaccessible to electrofishing. We recommend research on the cross sectional distribution of fish density in the Colorado River in Grand Canyon. At present, we are investigating use of snorkel surveys to quantify cross-sectional distribution in the Glen Canyon reach (Lees Ferry), and these data may prove useful in estimating fish densities downstream as well.
- Mark-recapture information is at present distributed over both diel and seasonal time scales. We feel that there is more information in the M/R data than just estimates of q, which warrants more comprehensive assessments than we can provide at this time.

ACKNOWLEDGEMENTS

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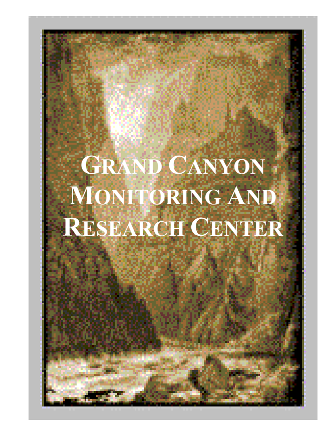

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[3] M/R estimates of N_o were calculated by maximizing the binomial likelihood for N_o in the formula

$$\Pr\{m|n,N_o\} = [n!/m!(n-m)!](n/N_o)^m(1-(n/N_o))^{(n-m)}$$

where n is total fish marked and m is total fish recaptured in an experimental transect 24 h after marking (Hilborn and Walters 1992).