Transactions of the American Fisheries Society 115:382-391, 1986

Production and Habitat of Threatened

Greenback and Colorado River Cutthroat Trouts in

Rocky Mountain Headwater Streams

DENNIS L. SCARNECCHIA 1 AND ERIC P. BERGERSEN

Colorado Cooperative Fish and Wildlife Research Unit, 2 Colorado State University
Fort Collins, Colorado 80523, USA

Abstract. -- Field studies conducted in 1979 and 1980 to assess the production and habitat of cutthroat trouts Salmo clarki in three headwater tributaries in north-central Colorado yielded the following estimates of production (g/me): greenback cutthroat trout S.c. stomias in Roaring Creek, 3.3 in 1979 and 2.3 in 1980; greenback cutthroat trout in the Right Hand Fork of Roaring Creek, 3.6 in 1979 and 1.5 in 1980; Colorado River cutthroat trout S.c. pleuriticus in Little Green Creek, 2.2 in 1979 and 3.6 in 1980. Biomass and production in Roaring Creek and Right Hand Fork of Roaring Creek were dominated by old (->3 years) slow-growing fish. Little Green Creek was the warmest and slowest moving of the creeks studied and had a low diversity of substrates dominated by fine and coarse gravel--it also had the highest biomass and production of young of the year. Right Hand Fork Roaring Creek had faster flows and more extensive undercut banks--it also had
the most large fish (-> 152 mm long). Biomass and production of cutthroat trout within the three streams depended mainly on stream-specific physical characteristics. In addition, year-class strength appeared to be mainly affected by the time of emergence and growth rates of juveniles prior to
their first winter and by the abundance of large resident fish.

The greenback cutthroat trout $almo clarki sto-
mias and Colorado River cutthroat trout $. c.

pleuriticus are two of several rare subspecies of
cutthroat trouts native to high-elevation streams
in western North America. The greenback cut-
throat trout is native to the South Platte and Ar-

kansas river basins in Colorado and Wyoming, and the Colorado River cutthroat is native to up-per tributaries of the Colorado River in Colorado, Wyoming, New Mexico, and Utah (Langlois et al. 1977; Behnke and Benson 1980). In the past 100 years, nearly all stocks of both subspecies have suffered one of three fates: (1) extirpation because of habitat destruction resulting from mining, ir-rigation diversions, or grazing (Langlois et al. 1977);
(2) extirpation because of unsuccessful competi-tion with introduced stocks offall-spawning brook trout Salvelinusfontinalis and brown trout $almo trutta; or (3) hybridization with introduced stocks of cutthroat trout and rainbow trout Salmo gaird-neri (Behnke and Benson

PRODUCTION OF HIGH-ALTITUDE CUTTHROAT TROUT 383

_• •.. WYOMING
eee • •: • ß Deedmen

% • r•).% I •R/9•t Hood For• of Roor/n 9 Cree• ß • V,¾ • •
ß I • Cu•"• /o Poudr•

t nAq . • • •Fort

Little Green 1 •

• •o•O ru• - •'• • I •'"";:

• / COLORADO RIVER • ' / • / ...... •. • c o L'•..O , A 0 0 ,
/ BAS,N I ....
•. • .... • ,

•= I '• •__•
COLORADO

L--Locations o• three sections o• streams in which production o[cutthroat trout was Jnvcsfisatcd. Columbine and Deadman Hi• arc stations where sno•ack was measured.

of Roaring Creek, designated Right Fork (first or-
der) was 3,139 m above sea level and 200 m long.
During midsummer, an average discharge was 0.02
m3/s and mean width was 1.6 m. The small, closely
confined channel resulted from the confluence of

many rivulets draining the wet meadow above. The upper half of the section was heavily shaded by willows Salix sp., and the lower half by lodge-pole pine Pinus contorta and Engelmann spruce Picea engelmanni.
Our second study site, on Roaring Creek (second order), was 2 km downstream from Right Fork. The section was 2,987 m above sea level and 200 m long. During midsummer, mean discharge was
0.075 m3/s and mean width 3.1 m. The channel was less shaded and less confined than that of

Right Fork; it traversed open meadows containing scattered lodgepole pines and willows.
In both sections, greenback cutthroat trout was the only species of fish present. R. J. Behnke (Col-orado State University, unpublished) quantified taxonomic characters of Roaring Creek cutthroat trout, and considered them to be slightly hybrid-ized with introduced Salmo, but still one of several "good representatives" of the subspecies. A1-

though we did not evaluate taxonomic differences between fish of these two sections, we observed that individual fish from Right Fork, the higher section, appeared more distinctive from hatchery-
reared cutthroat and rainbow trout stocks than did

fish from Roaring Creek.
Little Green Creek is a second-order headwater

tributary of the Colorado River, and flows near
Rabbit Ears Pass on the Continental Divide. The

section studied was 2,807 m above sea level and 200 m long. During midsummer, mean discharge
in the section was 0.009 m3/s and mean width was

1.5 m. Tall grasses along the banks shaded the watercourse, which was deeply incised into the surrounding meadow. Cutthroat trout was the only species of fish present. Wagner and Chapal (Col-orado Division of Wildlife, unpublished) charac-terized these fish, based on morphology, meristic and spotting patterns, as a pure or essentially pure genetic stock of Colorado River cutthroat trout.

Methods

Population estimates.- We sampled with back-pack electrofishing units in each of the three sec-tions, twice in 1979 and three times in 1980 (Table

384 SCARNECCHIA AND BERGERSEN

1). Before the sampling, each section was blocked
at upper and lower ends with fine-meshed seine
nets. We estimated abundance of cutthroat trout

by the three-pass removal method (Zippin 1956,
1958) from the y-intercept of the regression of
catch in the ith pass (x) on previous total catch (y). Population sizes were estimated separately forage-0 fish when sufficient sample sizes permit-ted it, but fish aged 1 and older were grouped for population estimation. The total population esti-mate was then partitioned back into separate ages in proportion to the number of fish caught of each age. Because of this grouping, confidence intervals about the population estimates are not very mean-ingful; however, we were able to capture over 80% of the estimated population of age-0 fish and over 97% of the estimated number of age-1 and older fish. Captured fish were retained temporarily in fine-meshed permeable baskets placed at intervals along each section. Lengths and weights were re-corded from all fish except some groups of young of the year, which we only subsampled. For each section, the densities of fish equaling or exceeding 152 mm and 202 mm in total length were calcu-lated from the average value of the population estimates and expressed as the number of fish of at least that length per unit of surface area. After we had obtained the required data, we returned each fish, when possible, to the pool or riffle from
which it had been removed.

The ages of fish were determined mainly from length-frequency distributions and scale analysis (Brown and Bailey 1952; Tesch 1971; Scarnecchia 1983). For fish aged 3 and younger, length modes were correlated closely with the number of clear annuli on scales. During the last population esti-mate in 1980, a small sample of otoliths was ob-tained from fish of Roaring Creek. Otoliths were prepared in glycerine and interpreted as outlined by Williams and Bedford (1974).
During the first population estimates for all three sections, a sample of fish longer than 135 mm was branded with silver-tipped branding irons (Groves and Novotny 1965). We used a coding system based on binary numbers to enable us to subsequently identify recaptured fish. During the second sam-pling of the streams, some previously unbranded fish were branded. During the second and subse-quent three samplings, branded fish were re-covered, identified, measured for length, and weighed.
Production estimates.--Population sizes (N) and average weights (W) by age of cutthroat trout could be estimated satisfactorily during summer and ear-

ly autumn, but not during winter nor during pe-riods of high runoff in spring. Data on weights (Table 1) indicated that fish grew rapidly during May and June and we needed to estimate pro-duction for such periods. To estimate this pro-duction, we assumed that fish did not grow from November 1 until April 30. Mortality rates of all age classes over winter were assumed to be ex-ponential. Any deviations from exponential growth over winter would not substantially alter produc-tion estimates anyway if growth rates were low over winter. For both 1979 and 1980, population sizes and average weights were estimated for Oc-tober 31 and April 30 based on assumptions of steady-state growth and mortality, and on yearly growth and mortality trends.
The ages of cutthroat trout could not be accu-rately determined with scales or otoliths beyond age 4. For these fish, we assumed that annual growth in grams was equal to that of similarly sized brand-ed fish in that stream, as judged by weights of branded fish recaptured on successive sampling
dates.

Annual (January-December) production (g/m 2) for each age class and stream was calculated as P = G/} (Ricker 1946). The instantaneous rate of growth G is calculated as 1ogeWt - logeW0, where W0 and Wt are initial and final weights, respec-tively, for each time interval between samplings; /} is the average biomass over the interval t for which G is constant. Values for/} were calculated as • = Bo[e •c-z• - 1]/[G - Z] (Ricker 1975), where Bo is the biomass at the beginning of the
interval. The instantaneous rate of natural mor-

tality, Z, is calculated as logeN0 - 1ogeNt where No and Nt are initial and final weights, respectively, for each time interval between samplings. Annual average biomass for each stream each year was computed as the arithmetic average of/} values between sampling intervals.
Habitat measurements. -- Several physical char-
acteristics of each section were measured once in

1979 and once in 1980, between August 1 and October 31. In each section, a horizontal transect perpendicular to the flow was established at the downstream end of the section and every 20 m upstream to the other end of the section. Across each transect, seven equidistant stations were es-tablished, the fourth of which was in the center of the stream (Stewart 1970), so that each section had
11 transects and 77 stations.
We measured width of the stream at each tran-

sect. At each station, we measured the depth and evaluated the substrate visually by particle size

PRODUCTION OF HIGH-ALTITUDE CUTTHROAT TROUT 385

TABLœ 1.--Estimates of population size (N) and av-erage weights per fish (W) in grams for greenback and Colorado River cutthroat trout in Roaring Creek, Right Fork, and Little Green Creek in 1979 and 1980. Italic values were indirectly calculated or assumed.

Age

Vari- 5 and
Date able 0 I 2 3 4 older

1979

May 1

Jul 3 l-

Aug 1

Sep 25-
26

Oct 31

1980

May 1

Jul 9-10

Aug 27-
28

Oct 2-4

Oct 31

Roaring Creek: greenback cutthroat trout

N 0 35 60 60 30 14
W 0.0 0.9 5.0 13.0 29.0 47.5

N 0 25 55 56 27 14
W 0.0 1.7 15.3 23.0 45.5 68.3

N 271 23 42 66 23 18
W 0.3 3.8 12.7 27.8 43.5 69.0
N 179 21 42 59 21 18
W 0.4 4.0 13.0 28.0 43.5 69.0

N 0 24 13 48 35 33
W 0.0 0.4 4.0 12.7 28.0 53.6

N 0 11 11 48 29 31
W 0.0 1.0 4.7 12.7 29.9 55.4
N 545 18 22 59 48 20
W 0.08 4.3 10.2 24.3 38.6 62.6
N 505 29 31 53 55 24
W 0.3 4.7 12.2 22.9 35.7 55.9

N 474 29 28 50 55 24
W 0.9 4.7 12.2 22.9 35.7 55.9

Right Hand Fork Roaring Creek: greenback cutthroat trout
1979

May 1 N 0 10 7 8 35 29
W 0.0 0.3 2.7 8.1 19.3 49.8

Aug 2 N 0 3 7 5 33 24
W 0.0 1.0 7.3 15.4 42.3 61.8

Sep 1-2 N 0 3 11 8 28 23
W 0.0 2.7 8.1 19.3 40.5 65.8

Oct 31 N 0 3 10 7 26 25
W 0.0 2.7 8.1 19.3 40.5 65.3

1980

May 1 N 0 0 3 9 6 37
W 0.0 0.0 2.7 8.1 19.3 50.1

Jul 11- N 0 0 3 8 5 33
12 W 0.0 0.0 10.7 15.1 29.4 53.3

Aug 24 N 5 6 6 13 15 30
W 0.1 3.3 10.3 19.8 36.3 68.8

Sep 30 N 76 9 4 14 7 20
W 0.1 3.8 8.8 19.4 41.0 61.3

Oct 31 N 70 9 4 14 6 20
W 0.3 3.8 8.8 19.4 41.0 61.3

Little Green Creek: Colorado River cutthroat trout
1979

May 1

Aug 7

Sep 16

Oct 31

N 0 10 20 9 17 4
W 0.0 0.7 6.2 13.5 30.8 45.5
N 13 8 14 9 17 3
W 0.1 2.6 15.4 23.6 42.1 54.0
N 158 6 9 5 15 2
W 0.4 6.2 17.2 30.8 45.5 45.0

N 129 6 9 5 15 2
W 0.5 6.2 17.2 30.8 45.5 45.0

TABLE 1.--Continued.

Age

Vari- 5 and DateAge

386 SCARNECCHIA AND BERGERSEN

AUGUST- SEPTEMBER BIOMASS g/m 2 ANNUAL PRODUCTION g/m2. yeor
ROARING CREEK, GREENBACK CUTTHROAT TROUT

• o o

• 0 • 2 3 4 5+ 0 m 2 3 4 5+

• '00 r I980:TOTAL=7.46g/m • '00 r,980:TOTAL:2.26 g/m •
50 50

25 o • 25 o

0 I 2 3 4 5+ 0 • 2 3 4 5+
AGE CLASS AGE CLASS

RIGHT HAND FORK ROARING CREEK, GREENBACK CU•HROAT TROUT

IO0 r 1979:TOTAL =11.13 g/m 2 IO0[1979:TOTAL = 3.57 g/m •
50 50
25 25

• 0 0 ' U 0 i 2 3 4 5• 0 i 2 • 4 5+

• I00• 1980:TOTAL: 1.51 g/m •
50 50
25 25

0 I 0
0 I 2 5 4 5+ 0 I • 3 4 5+
AGE CLASS AGE CLASS

LITTLE GREEN CREEK, COLORADO RIVER CUTTHROAT TROUT

iøø r 1979:TOTAL :3.86 g/m a iøø r 1979:TOTAL=2.21 g/m a
50 50
25 25

• 0 0 U 0 I 2 3 4 5+ 0 I 2 3 4

50 50

25 0 • 25 0

0 I 2 3 4 5+ 0 [2 3 4 5+
AGE CLASS AGE CLASS

F[gU•E •.--• distribution Of •u•ust-Septembcr b•omass and annul production of cutthroat trout • thr• Colorado streams, 1979 and

dominated by older fish (Figure 2). There were
nine fish at least 152 mm long but fewer than two
fish at least 202 mm long per 100 m 2 of stream.
Although many young of the year were sampled
in 1979, they contributed only 4% (0.15 g/m 2) of the total annual (January to December) produc-
tion.

Production of young of the year increased in 1980 to 28% of the total (Figure 2). Production by the weak 1978 year class was low in both 1979 (1-year-old fish) and 1980 (2-year-olds). Year classes produced in both 1978 and 1979 were weak compared to those in 1977 and 1980. Emergence of young of the year from the gravel

388 SCARNECCHIA AND BERGERSEN

T^BLœ 3.--Ratios of production to mean biomass for
cutthroat trout in three Colorado streams, 1979 and 1980.

Right Hand
Fork Roaring Little Green
Roaring Creek: Creek: green~ Creek: Colo-
greenback cut- back cutthroat rado River
throat trout trout cutthroat trout

Age 1979 1980 1979 1980 1979 1980

0 1.18 2.40 1.96 1.54 1.49
1 1.26 0.96 1.61 0.25 1.58 2.42
2 0.82 0.74 0.64 0.40 1.02 1.08
3 0.62 0.54 0.65 0.51 0.84 0.87
4 0.40 0.16 0.65 0.61 0.37 0.33
5 and older 0.03 0.03 0.11 0.12 0.06 0.06

All ages 0.47 0.33 0.35 0.23 0.56 0.79

duction of young of the year increased in 1980 and
that of old, slow-growing fish decreased (Figure 2).
In 1980, the ratios for Right Fork decreased be-
cause reproduction was poor and production of

young of the year was scant. The ratios were higher
in Roaring Creek than in Right Fork (where den-

sity of old fish was higher SCAi76(9m64 410.4 Tm (in)Told)Tj 1 9 17.0eased

PRODUCTION OF HIGH-ALTITUDE CUTTHROAT TROUT 389

ROARING CREEK

•z 2o

• ,o

o

RIGHT HANO FORK ROARING CR[[K

50

40

LITTLE GREEN CREEK

20

0

z o

FIGURE 3.--Percentage composition ofsubstrates in RoaringCreek, RightFork, and LittleGreenCreek in 1980. No plant detritus or claywas detected in any samples.

rose to 29% and 43%, respectively, of total pro-
duction in these streams, despite the high snow-
pack. The abnormally low snowpack in 1977 did
not appear to coincide with unusually strong year
classes of age-2 fish in 1979 or age-3 fish in 1980 in any of the streams.

Discussion

The production of cutthroat trout in Little Green Creek, Roaring Creek, and Right Fork varied from 1.5 to 3.6 g/m 2, which is low compared with that reported for salmonids in most rivers studied (Le Cren 1969; Chapman 1978; Mortensen 1979). Overall ratios of production to biomass, which ranged from 0.23 to 0.79, were also lower than ratios for resident brook trout in Quebec (0.70- 1.65: O'Conner and Power 1976), anadromous and resident brown trout in Denmark (0.7-1.8: Mor-tensen 1977), or brown trout in the United King-dom (1.5-3.0: data from Mann 1971; production calculated by Chapman 1978). The low produc-tion in our study streams probably results from the late emergence and subsequent scarcity of young cutthroat trout and the slow growth of large fish, among which angling and natural mortality are low. These biological factors are related, in turn, to the cold winters and short growing seasons at high elevations in northern Colorado. Chapman (1978) noted that production: biomass ratios usu-ally are in the range 0.9-2.4, but that production and ratios may be lower in cold streams. Crisp et al. (1975) found lower production of brown trout in high-elevation headwater sections of the River Tees than in most English lowland streams. The low production in the present three streams is con-sistent with these investigations.

The three streams differed markedly from each other in relative biomass and production of young of the year, which were both highest in Little Green
Creek where fine gravel and slow flows were most prevalent. Rinne (1980) reported that Gila trout
Salmo gilae spawned preferentially in gravel 0.2-
3.8 cm in diameter, which corresponds to the fine
gravel and lower half of the coarse-gravel cate-
gories in the modified Wentworth scale we Wentwo1 19.2 0

390 SCARNECCHIA AND BERGERSEN

in Right Fork, few exceeded lengths of 30-35 mm
before winter. Emergence in Right Fork, where
young of the year were scarcest, was later than for
similar species of Salrno in more southerly waters.
Harper (1978) reported that Apache trout emerged
mainly from August 1 to 15 in Big Bonito Creek, Arizona; Rinne (1980) observed young-of-the-year Gila trout as early as June 25 in New Mexico. Although genetic differences between the species undoubtedly exist, key physical environmental factors such as water temperatures may result in life history differences between these species. Eggs may be deposited later and develop more slowly in Colorado streams such as Roaring Creek and Right Fork than in New Mexico and Arizona be-cause water temperatures are lower. If so, in years of above-average snowpacks such as 1979 and 1980, spring runoff would be protracted, spawning and emergence would be later, and year classes may be weaker. Drummond (1966) showed that annual recruitment of age-0 fish from Cabin Creek into Trapper's Lake, Colorado, was inversely related to water content of the snowpack in that winter (over the normal range of snowpacks), and directly related to eventual success of anglers in catching adult fish of this age group. Nehring and Anderson (1983) subsequently found that the strength of year classes of brown trout in the South Fork of the Rio Grande was inversely related to snowpack levels and summer rains.
Although our data were limited, abundance and production of young of the year were high in 1980 in Roaring Creek and Little Green Creek (Figure 2), despite high snowmelt. However, heavy sum-mer rains may have depressed water temperatures and reduced year-class strengths in 1979, as Nehr-ing and Anderson (1983) concluded for the South
Fork of the Rio Grande. We observed that the summer was much drier in 1980 than in 1979 in

the vicinity of all three streams--as reflected by the high maximum temperatures in Right Fork and Little Green Creek in 1980 (Table 4). Survival and production of young of the year were also higher in Roaring Creek and Little Green Creek in 1980 than in 1979. We also believe that year-class strength in these streams was depressed by high abundances of large trout in the sections. For example, a 63% reduction in biomass of fish of age 4 and older in Little Green Creek in 1980 corresponded to a sixfold increase in production of young of the year. Reductions in cannibalism, crowding, or both, may have led to this increased production of young fish. Rinne (1980) observed cannibalism on small Gila trout by larger ones,

but Bulkley (1959) found that greenback cutthroat trout ate aquatic and terrestrial invertebrates, not fish. Although more thorough feeding studies are needed on greenback and Colorado River cut-throat trout in small streams, Bulkley (1959) con-cluded that much of the mortality of age-0 fish must result from factors other than predation. We believe that crowding is a main cause of this mortality of age-0 fish. In late summer, when the young of the year emerge, streamflows are low and
habitat is scarce. The reduction in the number of older fish in Litfie Green Creek in 1980 reduced

intraspecific crowding, which in turn led to in-creased overall production and a higher turnover ratio, and may have allowed higher survival of age-0 fish. The depressing effects of older fish on production may be more severe in small streams, where fish of all ages are closer together, than in larger streams (Nehring and Anderson 1983) and streamfed lakes (Drummond 1966), where more segregation of the age groups is likely.
Although genetic differences between the stocks undoubtedly exist, physical factors also exert a strong influence on production and biomass of cut-
throat trout in these three stream sections. In ad-

dition, at least three other biological factors affect the abundance and production of young-of-the-year cutthroat trout: the time of emergence of ju-veniles; growth rates of juveniles prior to their first winter; and the abundance of large resident adult
fish.

Acknowledgments
A National Wildlife Federation fellowship and
a Sport Fishing Institute research grant provided additional valuable support for this research. We
thank S. Horak and M. Giossi for field assistance.

We also thank R. B. Nehring, R. F. Raleigh, R. J.
Behnke, and anonymous reviewers for comment-
ing on the manuscript. ti8fW512 0 Td (4w.4 fiTd (theHA5.44 0 Td (R.)Tj(A (also)Nj 33 agRees

abunda84j 13.92 0 d96 251.04 Tm (thank)Tj6 0 Td175Td (troW

PRODUCTION OF HIGH-ALTITUDE CUTTHROAT TROUT 391

by the Bureau of Sport Fisheries and Wildlife on Rocky Mountain National Park. U.S. Bureau of Sport Fisheries and Wildlife, Washington, D.C.
Chapman, D.W. 1978. Production in fish populations. Pages 5-25 in S. D. Gerking, editor. Ecology of freshwater fish production. Blackwell Scientific Pub-lications, Oxford, England.
Crisp, D. T., R. H. K. Mann, and J. C. McCormack. 1975. The populations of fish in the River Tees system on the Moor House National Nature Re-serve, Westmonland. Journal of Fish Biology 7:573-
593.

Drummond, R.A. 1966. Reproduction and harvest of cutthroat trout at Trapper's Lake, Colorado. Colo-rado Division of Wildlife, GFP-R-S-3, Fort Collins. Drummond, R. A., and T. D. McKinney. 1965. Pre-dicting the recruitment of cutthroat trout fry in Trapper's Lake. Transactions of the American Fish-eries Society 94:389-393.
Groves, A. B., and A. J. Novotny. 1965. A thermal marking technique for juvenile salmonids. Trans-actions of the American Fisheries Society 94:386-
389.

Harper, K. C. 1978. Biology of a southwestern sal-monid, $almo apache (Miller 1972). 1 37.92 421.lUE