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Comparative Sport Fish Performance of Bonneville Cutthroat Trout in Three Small Put-Grow-and-Take Reservoirs

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Abstract.—Field trials using two forms of Bonneville cutthroat trout *Oncorhynchus clarki utah* were conducted in three small put-grow-and-take reservoirs located in southern Utah and performance of these forms was compared with nonnative trout traditionally stocked in Utah. For more than 2 years we conducted poststocking assessments of relative abundance, growth, body condition (K_{TL}), sexual maturity, and return to the creel among fishes subjected to a variety of environmental conditions. Study fish included Bonneville cutthroat trout native to southern Utah; Bonneville cutthroat from Bear Lake in Utah and Idaho; an introduced subspecific hybrid (Yellowstone cutthroat trout *O. clarki bouvieri* × Colorado River cutthroat trout *O. clarki pleuriticus*), commonly stocked in the past for sport fish management; and rainbow trout *O. mykiss*, which have been traditionally the most frequently stocked species in Utah. Rainbow trout had the fastest growth, highest condition, and highest returns (39–60%), except when marginal winter conditions at one reservoir resulted in winterkill. Winter losses of cutthroat trout were not evident, and relative abundance was high in all reservoirs at the time sport fishing was initiated. Returns to the creel among cutthroat trout were highest for the Bear Lake stock (36–60%), intermediate for the southern stock (23–42%), and lowest for the hybrid (15–24%). There were distinct differences in body condition among study fish, and southern Bonneville cutthroat trout had the highest condition among the cutthroat trout tested. Mean lengths among cutthroat trout were greater for the Bear Lake and hybrid stocks than for the southern stock. Higher body condition for southern Bonneville cutthroat trout, however, resulted in nearly equivalent weights among cutthroat trout, and southern Bonneville cutthroat trout were more acceptable to anglers at smaller sizes. Although all study fish exhibited traits that could be beneficial in certain management situations, overall performance of southern Bonneville cutthroat trout was most similar to rainbow trout for stocking in small reservoirs.

Stocking of hatchery trout historically has been an important part of sport fish management in Utah. Rainbow trout *Oncorhynchus mykiss* have been the most frequently stocked species; an introduced subspecific hybrid (Yellowstone cutthroat trout *O. clarki bouvieri* × Colorado River cutthroat trout *O. clarki pleuriticus*, hereafter referred to as the Y×C hybrid) and other nonnative trout species have been stocked less frequently. Most stockings occur in artificial irrigation storage impoundments where trout populations generally are not self-sustaining.

Recent emphasis on management of native fishes and the development of broodstocks of genetically pure Bonneville cutthroat trout *O. clarki utah* (Nielson and Lentsch 1988; Hepworth et al. 1997) have allowed incorporation of native trout into sport fish management programs. Bonneville cutthroat trout are the only trout native to the Bonneville basin in Utah (Behnke 1992). The potential exists to replace or supplement stocking of nonnative trout with native fish in many Utah locations, but sport fish characteristics of Bonneville cutthroat trout are not established. As a taxon, cutthroat trout are genetically diverse, having evolved in a large geographic area and in many different habitats. Different forms of cutthroat trout offer a variety of potential management applications (Behnke 1988; Gresswell et al. 1994). Segregation in diet and differences in catchability were found between fine spotted Snake River cutthroat trout, an undescribed and unnamed subspecies (Behnke 1992), and Pikes Peak cutthroat trout (derived from *O. clarki stomias*) when stocked in a Colorado lake (Trojnar and Behnke 1974). Different cutthroat trout harvest rates were reported for the Snake River, Yellowstone, and Colorado River subspecies stocked in small ponds in Montana (Dwyer 1990). Differences also were found in growth, survival, and natural reproduction when

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two strains of Yellowstone cutthroat trout were used in Montana stocking programs (McMullin and Dotson 1988). Even within Yellowstone Lake, Wyoming, a wide range in life histories was found among different spawning populations of cutthroat trout (Gresswell et al. 1994; Gresswell et al. 1997).

The origin of Bonneville cutthroat trout is probably polyphyletic, ancestral fishes invading ancient Lake Bonneville during different prehistoric times. Although classified as a single subspecies, several distinct forms of Bonneville cutthroat trout are recognized (Martin et al. 1985; Behnke 1992; Shiozawa and Evans 1994). Of particular management interest, Bonneville cutthroat trout in Bear Lake, Utah and Idaho, are a form that evolved as a top-level predator, attaining large sizes and using endemic fishes as forage. Advances in culture of Bear Lake cutthroat trout, attractive sport fish attributes, and interest in using this form in other locations led to sport fish evaluations comparing Bear Lake cutthroat trout to other cutthroat subspecies (Nielson and Lentsch 1988; Berg and Hepworth 1992).

In contrast to the other forms of cutthroat trout used in our study, Bonneville cutthroat trout were derived from stream environments in the southern end of their range in southern Utah and only recently have been available for sport fish management. Southern Bonneville cutthroat trout were present in all suitable habitats that remained after the desiccation of Lake Bonneville about 8,000 years ago and became restricted to a few isolated populations after their widespread decline during the early part of this century (Cope 1955; Hickman and Duff 1978; May et al. 1978; Duff 1988). These remnant populations were used in southern Bonneville cutthroat trout recovery efforts and for broodstock development (Hepworth et al. 1997).

Yellowstone cutthroat trout were brought to Utah from Yellowstone Lake in the early 1900s (Cope 1955). Yellowstone cutthroat trout are similar to Bear Lake cutthroat trout in that both are derived from large lakes but are dissimilar in other ways. Whereas adult Bear Lake cutthroat trout are primarily piscivorous, cutthroat trout from Yellowstone Lake exist on a diet of invertebrates (Gresswell and Varley 1988; Varley and Gresswell 1988; Gresswell 1995). Strawberry Reservoir, Utah, was stocked with Yellowstone cutthroat trout in 1922 and became Utah's primary source of cutthroat trout eggs for over 40 years. Yellowstone cutthroat trout in Strawberry Reservoir partially hybridized with rainbow trout and Colorado River cutthroat trout native to the Strawberry River watershed, but the Yellowstone Lake cutthroat trout phenotype predominated. Recent testing of the genotype (mitochondrial DNA) indicated that rainbow trout hybridization was minimal, but hybridization with Colorado River cutthroat trout (45%) was more substantial than commonly thought (D. K. Shiozawa, Brigham Young University, personal communication). Electric Lake was stocked with Y×C hybrids, and beginning in 1992 these fish were used as Utah's broodstock. These fish were also used as the source of hybrid cutthroat trout for this study.

We included rainbow trout in our study to compare performance of cutthroat trout to traditional stocking of rainbow trout in put-grow-and-take waters. Rainbow trout used in this study came from a domesticated hatchery stock known as the Sand Creek strain, originally obtained from Wyoming and widely used for routine sport-fish stockings throughout Utah.

Our objective was to compare performance of rainbow trout, the Y×C hybrid cutthroat trout traditionally used for sport fishery management in Utah, and two forms of Bonneville cutthroat trout (southern Bonneville and Bear Lake) stocked into small southern Utah impoundments and managed as put-grow-and-take fisheries. We conducted poststocking assessments of relative abundance (survival), growth, condition, maturity, and return to the creel from 1995 to 1997 at three reservoirs having different environmental conditions.

Study Area

Kolob Reservoir

Kolob Reservoir, at an elevation of 2,147 m, is on Kolob Creek in the Virgin River drainage upstream from Zion National Park. This 101-ha reservoir has an average depth of 6.7 m, a maximum depth of 15.2 m, and a volume of 6.89×10^6 m^3. It is usually full in spring and reaches its lowest level by late fall at the end of the irrigation season. Although the reservoir was full at the beginning of summer in 1995 and 1996, repairs to the dam required total draining at the end of the second summer after study fish were introduced. Downstream escapement of study fish during reservoir releases was prevented by placing a grate over the reservoir outlet. Upstream movement of fish out of the reservoir was limited to 0.5 km of stream because of a barrier waterfall. Sport fish in the reservoir at the beginning of the study included rainbow trout, Y×C hybrid cutthroat trout, and brook trout *Salvelinus fontinalis,* which had been stocked annually. A substantial number of the Y×C hybrid cutthroat trout also are recruited naturally to the reservoir. The study fish were the only fish stocked in Kolob Reservoir during 1995 and 1996. A large population of golden shiners *Notemigonus crysoleucas* also inhabit the reservoir. Public access is by dirt road, which is seasonally restricted by snow.

Pine Lake

Pine Lake, on the Table Cliff Plateau in south-central Utah, is at an elevation of 2,497 m. This 31-ha reservoir has maximum depth of 9.4 m, an average depth of 4.0 m, and a volume of 1.23×10^6 m^3. Water is diverted into the off-stream reservoir from Clay Creek, a seasonally intermittent tributary to the East Fork of the Sevier River, and from springs adjacent to the basin. The reservoir is managed for recreational fishing and attempts are made to maintain the reservoir at full pool. Outflows generally include only surface spillage from the reservoir, although summer evaporation and bank seepage often exceed inflows. Escapement of fish from the reservoir is restricted because of piped inflows and minimal releases. Approximately half of the reservoir surface area is made up of shallow bays with dense growth of rooted macrophytes that caused high pH levels and a partial fish kill during 1 year of the study. Fish populations are limited to stocked trout and included only small numbers of rainbow trout and Y×C hybrid cutthroat trout stocked before introduction of the study fish. Study fish were the only fish stocked in the reservoir during 1995. Additional catchable-size (>230 mm total length or TL) rainbow trout were stocked in 1996 and 1997 to supplement the sport fishery. Public access is by a dirt road that is often impassible during winter.

Upper Kents Lake

The dam for this 11-ha impoundment (elevation of 2,742 m) was constructed in 1995 on a small tributary to the Beaver River in the Tushar Mountains of southern Utah. The reservoir has a maximum depth of 2.9 m, an average depth of 1.8 m, and volume of 0.20×10^6 m^3. Inflows include a small inundated spring and a canal providing water from a neighboring drainage. Irrigation releases are generally in summer and fall, and the reservoir refills during winter and spring. A conservation pool of 50% of the maximum allowed reservoir volume was maintained during our study to provide for a fishery. Maximum reservoir storage was restricted to 1.0 m above the conservation pool because the dam did not pass final construction inspection; this limited summer releases for irrigation and reduced the reservoir to the conservation pool from late fall through much of the winter. The shallowness of the conservation pool (1.9 m maximum depth) and limited winter inflows resulted in low winter oxygen levels and marginal conditions for trout survival. During 1995–1996, fish in the reservoir were restricted primarily to the study groups, but a small number of brook trout migrated into the reservoir from the upstream drainage. Additional stockings of catchable-size rainbow trout and southern Bonneville cutthroat trout fingerlings (<150 mm TL) occurred in 1997 to maintain the sport fishery. Upstream movement of fish was restricted by a waterfall on the inflow canal located about 275 m from the reservoir. Downstream fish movement was limited because of restricted irrigation releases. Public access to the reservoir is by dirt road that is closed during winter.

Methods

Study fish.—Attempts to compare performance of rainbow and cutthroat trout from general management programs in Utah have been confounded because of size differences at time of stocking or because the two species are stocked at different times of year. We made a special effort in this study to culture and stock fish at the same time and at similar sizes to allow comparisons. Eggs were taken during a 4-d period (June 13–16, 1994) to produce study groups of cutthroat trout. Y×C hybrid and southern Bonneville cutthroat trout eggs were taken from wild broodstocks at Electric Lake and Manning Meadow Reservoir, Utah, respectively. Bear Lake cutthroat trout eggs were taken from a captive broodstock at the Egan State Hatchery; the captive broodstock is produced from eggs taken from wild trout at Bear Lake. All cutthroat trout eggs were incubated and reared under similar conditions at the Fisheries Experiment Station in Logan, Utah. Rainbow trout eggs were taken on September 14, 1994, at the Egan State Hatchery, and reared at the Fisheries Experiment Station similar to the groups of cutthroat trout. The egg take date for rainbow trout was scheduled to compensate for differential hatchery growth between cutthroat and rainbow trout in order to produce fish of a similar size at the time of stocking. All study fish were fin-clipped and stocked at similar sizes (146–164 mm TL) in May and June 1995 (Table 1). Southern Bonneville and Bear Lake cutthroat trout were marked with left and right pelvic fin-

TABLE 1.—Statistics for southern Bonneville (SB) and Bear Lake (BL) cutthroat trout, hybrid cutthroat trout, and rainbow trout stocked at Kolob Reservoir, Upper Kents Lake, and Pine Lake during 1995 (TL = total length). An asterisk indicates the mean was significantly different than other means for the same statistic analysis of variance ($P < 0.05$).

Statistic	Fish stocked			
	SB cutthroat	BL cutthroat	Hybrid cutthroat	Rainbow trout
Kolob Reservoir: May 29				
Number	2.400	2,400	2,400	2,400
Number/ha	24	24	24	24
Mean TL (mm)	156	156	164	154
Mean weight (g)	41	33*	41	44
Pine Lake: May 15				
Number	2,900	2,900	2,900	2,900
Number/ha	94	94	94	94
Mean TL (mm)	146	150	155	151
Mean weight (g)	31	30	32	39*
Upper Kents: Jun 12				
Number	1,300	1,300	1,300	1,300
Number/ha	118	118	118	118
Mean TL (mm)	155	156	161	158
Mean weight (g)	34	35	41	49*

clips, respectively; Y×C hybrid cutthroat and rainbow trout were marked with adipose fin-clips. At the time of stocking, there were no significant differences (analysis of variance [ANOVA], $P < 0.05$) in mean lengths among study fish at any reservoir; however, mean weight of one group of Bear Lake cutthroat trout was significantly less than other groups, and in two cases mean weight of rainbow trout was significantly greater than other fish stocked on the same date (Table 1).

Within each reservoir, equal numbers of fish from each study group were stocked on the same date (Table 1). We varied the stocking rates of study fish among reservoirs based on total trout density, including the resident nonstudy trout, so that approximately equal trout densities were achieved at all reservoirs; this assigned density allowed suitable growth and quick recruitment of study fish to the sport fisheries. Approximate trout densities were determined from past stocking records and annual gillnetting data collected over many years to evaluate stocking success at Kolob Reservoir and Pine Lake. Stocking rates were higher at Upper Kents Lake and Pine Lake because there were few other fish in those waters. Kolob Reservoir was stocked at a lower rate because of a relatively large resident trout population. Stocking was conducted with standard hatchery trucks and techniques. At each reservoir a random sample of 20 fish from each study group was held in a live cage for 2 d after stocking to evaluate initial, poststocking survival. No problems were noted with stocking at any of the study waters or with any of the groups of experimental fish.

Gillnetting.—Relative abundance, condition, maturity, mean total length (mm), and mean weight (g) of study fish were determined from gill-net samples collected during spring and fall 1996 and 1997, except that Kolob Reservoir was netted only in spring because of reservoir draining. We used gillnetting to determine relative abundance of study groups and made conservative assessments of poststocking survival of study fish at the time creel surveys were started. Also, we used gillnetting to judge when abundance of study fish became largely depleted and to determine relative abundance when creel surveys were terminated. Gill nets were 38 m long, either floating or diving styles, and had five 7.6-m panels with bar-mesh sizes of 19.1, 25.4, 31.8, 38.1, and 50.8 mm. Floating nets were set to extend 1.8 m down from the surface and diving nets extended 1.8 m up from the reservoir substrate. On each sample date at each reservoir all reservoir habitats were sampled in approximately equal proportion by setting one floating and one diving net near shore and one of each off shore. Netting was repeated on a second sample date during spring sampling at Kolob Reservoir to obtain a larger sample size. Condition (K_{TL}) was calculated as weight $\cdot 10^5/TL^3$. Maturity was evaluated because it could potentially affect growth, survival, and return to the creel (Gresswell 1995). Maturity was determined by calculations of the Gonadosomatic Index (GSI), i.e., the ratio of gonad weight to total body weight (Snyder 1983), and as percent of fish with fully developed gonads.

Creel surveys.—Angler surveys were conducted to make direct observations on angling returns of study fish and to make expanded estimates of total harvests (Robson 1960). Surveys included angler interviews and instantaneous counts of fishermen. Surveys began at Pine Lake and Kolob Reservoir in August 1995, about the time that study fish had grown to a catchable size. Surveys at Upper Kents Lake were started in June 1996, when the reservoir was first opened to public fishing. At all reservoirs, surveys were conducted seasonally, May or June through October, when vehicle access was possible. We assumed that fishing pressure was negligible at other times of year. Surveys were terminated at Kolob Reservoir in 1996 after the reservoir was drained and discontinued at Pine Lake and Upper Kents Lake in 1997 after study fish were largely depleted. Surveys were stratified by month, weekday and weekend days, morning and afternoon shifts, and by boat and shore anglers. Each reservoir was surveyed 6–8 d per month, and angler counts were made at five random times within a work shift. Angler interviews included data on hours fished and number of study fish harvested. Surveys were conducted by trained technicians. The same technician conducted surveys at all three reservoirs during the same year.

Other field observations.—Oxygen and pH measurements were taken at Pine Lake and Upper Kents Lake when water quality became marginal for trout survival. Dead trout were collected and identified after a partial fish kill at Pine Lake and after Kolob Reservoir was drained. Data were used to supplement gillnetting and creel surveys. General observations also were made on a winter fish kill at Upper Kents Lake, but identifying marked fish was impossible.

Statistical analysis.—Confidence intervals (95%) for estimates of angler harvests were determined as ±2 standard errors of the estimate (Robson 1960). Differences between estimates of mean length, weight, K_{TL}, and GSI among study groups were tested by one-way ANOVA, and paired comparisons were made by least-significant-difference tests (Ostle 1963). Chi-square analysis was used to evaluate observed versus expected angling returns of study fish relative to the percentage stocked. Differences were considered significant at an alpha level of 0.05 for all statistical tests.

Results

Gill nets set in April and May 1996, approximately 1 year after stocking, caught all groups of study fish in relatively large numbers in each reservoir, except Upper Kents Lake where only four rainbow trout were collected (Table 2). This small catch of rainbow trout followed a winter when March oxygen levels were less than 1.0 mg/L for all water depths measured at three areas of the reservoir and after numerous dead trout were observed at ice-out. Numbers of the three cutthroat trout groups remained relatively high in gill-net samples through spring 1997. By fall 1997, numbers of southern Bonneville and Bear Lake cutthroat trout were largely depleted at Upper Kents Lake, and gill-net catches consisted primarily of Y×C hybrid cutthroat trout. At Kolob Reservoir, where stocking rates of the study fish were lowest, the overall gill-net catch also was lowest, but fish from all study groups were present. When the reservoir was drained in September 1996 (17 months after stocking), the 37 fin-clipped trout collected from the shoreline were 70% Y×C hybrid cutthroat trout, 16% Bear Lake cutthroat trout, 11% southern Bonneville cutthroat trout, and 3% rainbow trout. At Pine Lake, numbers of study fish declined rapidly in the gill-net samples after the first summer, and Y×C hybrids predominated the catches after the initial netting. Low water levels, low inflows, and associated increases in growth of aquatic macrophytes during the summer of 1996 produced pH levels exceeding 9.8 in some parts of the reservoir during July. For about 2 weeks a few dead fish were found each morning in shallow weedy bays where pH levels were highest, but survival of fish remained largely unaffected in the main body of the reservoir where pH ranged from 9.0 to 9.3. Of 62 fin-clipped trout collected, 44% were rainbow trout, 37% Y×C hybrids, 14% southern Bonneville cutthroat trout, and 5% Bear Lake cutthroat trout.

Estimated percent return to the creel at Kolob Reservoir was 60% for rainbow trout, 36% for Bear Lake cutthroat trout, 23% for southern Bonneville cutthroat trout, and 15% for Y×C hybrids (Table 3). Estimated percent returns to the creel at Pine Lake also were greatest for rainbow trout (39%), followed by southern Bonneville cutthroat trout (33%), Bear Lake cutthroat trout (32%), and Y×C hybrids (19%). In contrast, we estimated a return to the creel for rainbow trout of only 19% at Upper Kents Lake compared with approximately 60% Bear Lake cutthroat trout, 42% southern Bonneville cutthroat trout, and 24% Y×C hybrids. By 1997, harvests of study fish were negligible because they had been depleted by anglers and natural mortality. Even at Kolob Reservoir, which was drained at the end of the second summer, sufficient time had elapsed that most of the study fish remaining at the time of draining were Y×C hybrids. Considering all three reservoirs, returns of rainbow trout were highest and Y×C hybrid cutthroat trout lowest, except at Upper Kents Lake where overwinter survival of rainbow trout was poor. Percent returns for Bear Lake cutthroat trout were highest among the groups of cutthroat trout at Kolob Reservoir and Upper Kents Lake. Southern Bonneville cutthroat trout had the highest returns for cutthroat trout at Pine Lake.

Angler returns of observed Y×C hybrids were significantly less than expected (chi-square analysis; Table 4). Returns of rainbow trout were significantly less than expected at Upper Kents Lake and significantly greater than expected at Kolob

TABLE 2.—Gill-net results and statistics for Kolob Reservoir, Upper Kents Lake, and Pine Lake stocked with southern Bonneville (SB) and Bear Lake (BL) cutthroat trout, hybrid cutthroat trout, and rainbow trout, 1996–1997 (TL = total length, K_{TL} = condition, GSI = gonadosomatic index). Mean values across a statistical row without a letter in common are significantly different (analysis of variance, $P < 0.05$).

	Study group			
Date and statistic	SB cutthroat	BL cutthroat	Hybrid cutthroat	Rainbow trout
Kolob Reservoir				
Apr 96				
Number caught	24	7	24	10
Mean TL (mm)	275 z	294 yx	285 y	297 x
Mean weight (g)	198 z	217 z	201 z	283 y
Mean K_{TL}	0.95 y	0.84 z	0.87 z	1.07 x
Mean GSI	0 z	0 zy	0.0111 y	0 zy
Pine Lake				
Apr 96				
Number caught	53	38	38	17
Mean TL (mm)	261 z	274 y	275 y	312 x
Mean weight (g)	176 y	157 z	183 y	328 x
Mean K_{TL}	0.98 x	0.76 z	0.87 y	1.07 w
Mean GSI	0.0012 z	0 z	0.0182 y	0.0059 z
Oct 96				
Number caught	6	1	37	9
Mean TL (mm)	289 z	336 yx	303 zy	320 x
Mean weight (g)	229 z	272 zy	256 z	330 y
Mean K_{TL}	0.93 zy	0.72 z	0.91 z	0.99 y
Mean GSI	0.0111 z	0.0074 z	0.0227 y	0.0262 y
Apr 97				
Number caught	1	0	4	0
Mean TL (mm)	303 z		315 z	
Mean weight (g)	274 z		297 z	
Mean K_{TL}	0.99 z		0.93 z	
Mean GSI	0.0365 z		0.0406 z	
Sep 97[a]				
Number caught	0	0	0	0
Mean TL (mm)				
Mean weight (g)				
Mean K_{TL}				
Mean GSI				
Upper Kents Lake				
May 96				
Number caught	95	40	64	4
Mean TL (mm)	247 z	270 x	259 y	270 yx
Mean weight (g)	153 z	166 z	163 z	209 y
Mean K_{TL}	0.99 x	0.82 z	0.93 y	1.06 x
Mean GSI	0.0144 y	0 z	0.0163 y	0.0115 zy
Sep 96				
Number caught	18	28	57	0
Mean TL (mm)	312 z	344 x	333 y	
Mean weight (g)	345 z	377 zy	383 y	
Mean K_{TL}	1.12 x	0.93 z	1.03 y	
Mean GSI	0.0110 z	0.0106 z	0.0267 y	
May 97				
Number caught	10	17	110	0
Mean TL (mm)	330 z	362 x	350 y	
Mean weight (g)	390 z	425 z	414 z	
Mean K_{TL}	1.08 x	0.89 z	0.96 y	
Mean GSI	0.0549 z	0.0518 z	0.0630 z	
Sep 97				
Number caught	3	2	19	0
Mean TL (mm)	368 z	384 z	359 z	
Mean weight (g)	566 z	588 z	484 z	
Mean K_{TL}	1.13 z	1.00 z	1.04 z	
Mean GSI	0.0081 z	0.0088 z	0.0179 z	

[a] No fish were captured in this month.

TABLE 3.—Numbers of southern Bonneville (SB) and Bear Lake (BL) cutthroat trout, hybrid cutthroat trout, and rainbow trout observed, estimates of expanded harvests, and percent returns from creel surveys at Kolob Reservoir, Pine Lake, and Upper Kents Lake, 1995–1997 (Est = estimated, CI = 95% confidence interval).

Year and month	Statistic	Study group			
		SB cutthroat	BL cutthroat	Hybrid cutthroat	Rainbow trout
		Kolob Reservoir			
1995					
May	Number stocked	2,400	2,400	2,400	2,400
1995					
Aug	Number observed	4	4	2	24
	Est harvest (CI)	39 (±41)	57 (±97)	32 (±63)	277 (±342)
Sep	Number observed	3	4	4	17
	Est harvest (CI)	41 (±55)	45 (±42)	40 (±55)	189 (±119)
Oct	Number observed	4	10	1	37
	Est harvest (CI)	64 (±90)	100 (±130)	8 (±15)	327 (±153)
1996					
May	Number observed	23	16	5	33
	Est harvest (CI)	249 (±166)	196 (±159)	52 (±73)	338 (±176)
Jun	Number observed	10	19	9	15
	Est harvest (CI)	120 (±66)	317 (±158)	132 (±107)	255 (±191)
Jul	Number observed	3	10	5	3
	Est harvest (CI)	46 (±55)	117 (±149)	60 (±65)	31 (±44)
Aug	Number observed	1	8	7	4
	Est harvest (CI)	2 (±3)	42 (±39)	32 (±45)	17 (±7)
Total	Number observed	48	71	33	133
	Est harvest (CI)	559 (±219)	874 (±320)	357 (±174)	1,434 (±473)
	Percent return	23%	36%	15%	60%
		Pine Lake			
1995					
May	Number stocked	2,900	2,900	2,900	2,900
1995					
Aug	Number observed	19	17	7	22
	Est harvest (CI)	141 (±61)	113 (±84)	45 (±51)	117 (±84)
Sep	Number observed	15	28	9	8
	Est harvest (CI)	78 (±55)	241 (±199)	77 (±97)	51 (±58)
Oct	Number observed	34	29	6	27
	Est harvest (CI)	202 (±121)	231 (±213)	37 (±53)	158 (±127)
1996					
May	Number observed	32	18	19	29
	Est harvest (CI)	213 (±177)	135 (±145)	102 (±59)	203 (±137)
Jun	Number observed	19	7	12	32
	Est harvest (CI)	184 (±135)	75 (±74)	112 (±88)	338 (±201)
Jul	Number observed	10	2	7	11
	Est harvest (CI)	90 (±70)	23 (±32)	53 (±65)	121 (±73)
Aug	Number observed	3	6	7	11
	Est harvest (CI)	28 (±40)	45 (±57)	36 (±33)	88 (±113)
Sep	Number observed	1	10	13	7
	Est harvest (CI)	3 (±7)	44 (±41)	64 (±39)	35 (±34)
Oct	Number observed	2	4	2	1
	Est harvest (CI)	5 (±10)	19 (±32)	11 (±22)	6 (±11)
1997					
May	Number observed	0	1	0	0
	Est harvest (CI)	0	4 (±8)	0	0
Jun	Number observed	0	0	0	0
	Est harvest (CI)	0	0	0	0
Jul	Number observed	1	1	1	0
	Est harvest (CI)	3 (±6)	3 (±6)	3 (±6)	0
Total	Number observed	136	123	83	148
	Est harvest (CI)	950 (±279)	936 (±354)	539 (±182)	1,118 (±324)
	Est % return	33%	32%	19%	39%

TABLE 3.—Continued.

Year and month	Statistic	Study group			
		SB cutthroat	BL cutthroat	Hybrid cutthroat	Rainbow trout
		Upper Kents Lake			
1995					
Jun	Number stocked	1,300	1,300	1,300	1,300
1996					
Jun	Number observed	24	58	9	12
	Est harvest (CI)	162 (±75)	497 (±337)	59 (±48)	114 (±169)
Jul	Number observed	15	15	5	13
	Est harvest (CI)	150 (±231)	103 (±112)	45 (±59)	107 (±123)
Aug	Number observed	16	19	4	3
	Est harvest (CI)	52 (±79)	76 (±67)	18 (±18)	10 (±20)
Sep	Number observed	11	10	5	4
	Est harvest (CI)	158 (±198)	32 (±64)	104 (±208)	16 (±32)
Oct	Number observed	6	10	9	0
	Est harvest (CI)	24 (±40)	40 (±43)	42 (±55)	0
1997					
Jun	Number observed	1	0	0	0
	Est harvest (CI)	3 (±6)	0	0	0
Jul	Number observed	0	1	6	0
	Est harvest (CI)	0	11 (±22)	32 (±41)	0
Aug	Number observed	0	1	2	0
	Est harvest (CI)	0	10 (±21)	16 (±24)	0
Sep	Number observed	0	2	1	0
	Est harvest (CI)	0	12 (±18)	3 (±6)	0
Total	Number observed	73	116	41	32
	Est harvest (CI)	549 (+326)	781 (+371)	318 (+234)	247 (+212)
	Est % return	42%	60%	24%	19%

Reservoir and Pine Lake. Results varied for Bear Lake and southern Bonneville cutthroat trout depending on the reservoir. When rainbow trout were included in the analysis, the number of southern Bonneville cutthroat trout observed was significantly lower than expected at Kolob Reservoir, but returns to the creel were as expected at the other two reservoirs. Comparing cutthroat trout, southern Bonneville cutthroat trout returned at a significantly higher-than-expected rate at Pine Lake but returned in about the same proportion as the number stocked at the other two reservoirs (Table 4). When rainbow trout were included in the analysis, Bear Lake cutthroat trout returned at a significantly higher-than-expected rate at one of three reservoirs. Comparing only cutthroat trout, Bear Lake cutthroat trout returned at a significantly higher-than-expected rate at two of the three reservoirs and at about the same proportion as the number stocked at the other reservoir.

When study groups were ranked according to condition factor, the rankings were similar for every gill-net sample at each reservoir (Table 2). Condition for rainbow trout was significantly higher than other study fish, and mean K_{TL} factors were consistently greater than 1.0. Values for southern Bonneville cutthroat trout were consistently near 1.0 and significantly higher than other cutthroat trout whenever sample sizes remained above 10 fish. Condition values for Y×C hybrid and Bear Lake cutthroat trout were generally 1.0 or less. Despite attempts to maintain equal densities, condition and growth were generally higher at Upper Kents Lake compared with the other two reservoirs, where trout populations were already established before stocking of study fish.

Mean length at all reservoirs was highest for rainbow trout, lowest for southern Bonneville cutthroat trout, and intermediate for Bear Lake and Y×C hybrid cutthroat trout, except in two comparisons when abundance of study fish became reduced to sample sizes of 3 or fewer fish (Table 2). Although growth was slowest at Pine Lake compared with the other reservoirs, study fish attained a catchable size by the end of the first summer after stocking and approached or exceeded 300 mm TL during the second summer. Mean weight was also highest for rainbow trout at all reservoirs and was significantly greater than weights of other study fish, except in one comparison in which only one Bear Lake cutthroat trout was sampled (Table 2). Differences in mean weights among the cutthroat trout were not as great as differences in mean lengths and, among most comparisons, were

TABLE 4.—Chi-square analysis of observed versus expected numbers of creeled southern Bonneville (SB) and Bear Lake (BL) cutthroat trout, hybrid cutthroat trout, and rainbow trout, 1995–1997. Pooled test (all study groups) was performed with $\chi^2 = 7.81$ (3 df, $P < 0.05$). Individual tests were completed with $\chi^2 = 3.84$ (1 df, $P < 0.05$). An asterisk indicates the observed value was significantly different from the expected value ($P < 0.05$).

Study site and group	Number (percent) in creel		
	Observed	Expected	χ^2
Comparison: All study groups			
Kolob Reservoir			
SB cutthroat	48 (17)	71.25 (25)	10.12*
BL cutthroat	71 (25)	71.25 (25)	0.00
Hybrid cutthroat	33 (12)	71.25 (25)	27.38*
Rainbow	133 (47)	71.25 (25)	71.36*
Pooled			81.64*
Pine Lake			
SB cutthroat	136 (28)	122.5 (25)	1.49
BL cutthroat	123 (25)	122.5 (25)	0.00
Hybrid cutthroat	83 (17)	122.5 (25)	12.74*
Rainbow	148 (30)	122.5 (25)	5.31*
Pooled			19.53*
Upper Kents			
SB cutthroat	73 (28)	65.75 (25)	0.80
BL cutthroat	116 (44)	65.75 (25)	38.40*
Hybrid cutthroat	41 (16)	65.75 (25)	9.32*
Rainbow	33 (13)	65.75 (25)	16.31*
Pooled			64.83*
Comparison: cutthroat trout study groups			
Kolob Reservoir			
SB cutthroat	48 (32)	50.67 (33)	0.21
BL cutthroat	71 (47)	50.67 (33)	12.24*
Hybrid cutthroat	33 (22)	50.67 (33)	9.24*
Pooled			14.46*
Pine Lake			
SB cutthroat	136 (40)	114.0 (33)	4.25*
BL cutthroat	123 (36)	114.0 (33)	0.71
Hybrid cutthroat	83 (24)	114.0 (33)	8.43*
Pooled			13.39*
Upper Kents			
SB cutthroat	73 (32)	76.67 (33)	0.18
BL cutthroat	116 (50)	76.67 (33)	20.18*
Hybrid cutthroat	41 (18)	76.67 (33)	16.60*
Pooled			36.95*

not significantly different. Because southern Bonneville cutthroat trout were more robust, their mean weights were nearly the same as the other cutthroat trout, even though Bear Lake and Y×C hybrid cutthroat trout had greater mean lengths. At Kolob Reservoir and Upper Kents Lake all study fish reached mean weights of 300 g during the second summer, whereas all groups at Pine Lake exceeded mean weights of 229 g.

Gonad development was slower for Bear Lake cutthroat trout compared with all other study groups (Table 2). At age 2 (spring 1996), Bear Lake cutthroat trout still had a GSI of zero, whereas most other study fish showed some development. Although most comparisons of GSI values failed to show or had inconsistent significant differences, Bear Lake cutthroat trout had the lowest GSI for each location and each date sampled, excluding the two fish collected on the last netting at Upper Kents Lake. Few, if any, trout survived to age 3 (spring 1997) at Kolob Reservoir and Pine Lake. However, all groups of cutthroat trout surviving to age 3 at Upper Kents Lake had some mature individuals of both sexes, and some fish attempted to spawn in the inlet. Maturity at age 3 for males and females, respectively, was 100% ($N = 2$) and 75% ($N = 8$) for southern Bonneville cutthroat trout, 40% ($N = 5$) and 50% ($N = 12$) for Bear Lake cutthroat trout, and 83% ($N = 30$) and 81% ($N = 31$) for Y×C hybrids.

Discussion

As is typical of many field experiments involving natural systems, a number of factors complicated the interpretation of results from this study. Environmental variables we were not able to quantify obviously had a significant impact on the survival and performance of the different study groups of trout. The draining of one reservoir and seasonally inhospitable environments at two of the reservoirs were additional unplanned variables. In spite of these confounding factors, the results of our study illustrated some differences among the fish studied that were consistent across the three reservoirs. These differences have important implications for management of native trout in small put-grow-and-take reservoirs. In addition, we made some observations and gathered circumstantial evidence indicating differences among study groups that warrant further investigation.

The return of Bear Lake and southern Bonneville cutthroat trout to anglers was acceptable at all three reservoirs (Tables 3). Estimated returns of Bear Lake and southern Bonneville cutthroat trout exceeded 20% of the number stocked, which is generally considered adequate when fingerling-size trout are stocked (Borgeson 1966; Johnson 1978; Stuber et al. 1985). This occurred even though anglers used angling methods developed largely for rainbow trout, which have been the predominant species used for fishery management in southern Utah. In our study, the Y×C hybrid cutthroat trout were less vulnerable to angling than other study fish, and consequently they were the most abundant of the study fish remaining in all three reservoirs at the termination of the study. The higher vulnerability of Bear Lake cutthroat trout to angling compared with the Y×C hybrid cutthroat trout is consistent with other comparisons from Utah (Nielson and Lentsch 1988; Berg and Hepworth 1992). These authors also found Y×C hybrid cutthroat trout returned to the creel over a longer period compared with Bear Lake cutthroat trout and rainbow trout. Dwyer (1990) found that rainbow trout returned to the creel more quickly in Montana ponds compared with several strains of cutthroat trout, and Stuber et al. (1985) reported that in Colorado most rainbow trout are harvested within a year after stocking.

The differences we observed in condition factors among study fish also were consistent across the three study waters (Table 2), regardless of environmental conditions. These differences have important implications for management in smaller waters where trout are often harvested at small sizes. Southern Utah trout are acceptable to anglers at a size of around 230 mm TL, providing the fish are relatively robust and display high condition factors. In another southern Utah reservoir, Hepworth and Duffield (1987) found that small rainbow trout with K_{TL} factors less than 0.95 were not acceptable to the public. In this study, Bear Lake cutthroat trout less than 363 mm TL consistently had K_{TL} factors of 0.93 or less. We observed instances in which anglers considered Bear Lake cutthroat trout 250–300 mm TL to be less desirable than other study fish of similar lengths because of their slender body shape. Angler harvest is often delayed in larger lakes until most trout exceed 300 mm TL, such as at Bear Lake where condition of cutthroat improves after they convert to a fish diet and attain larger sizes (Nielson and Lentsch 1988).

Bear Lake cutthroat trout consistently had the lowest GSI. From a sport-fish management perspective, late maturity may be desirable if providing large fish is an objective. Maturity at a later age allows a longer time for fish growth before energy is diverted into gonad development and fish are subjected to the rigors of spawning (Gresswell 1995). Early maturity of stocked trout can lead to large losses before substantial angling harvest occurs because of spawning migrations from lakes and associated mortality. We found no distinct differences in age of maturity among southern Bonneville cutthroat trout, Y×C hybrid cutthroat trout, and rainbow trout, but we did observe delayed maturity for Bear Lake cutthroat trout, similar to findings of Nielson and Lentsch (1988).

The draining of reservoirs and poor water quality during winter and midsummer are not typical for most put-grow-and-take waters managed for salmonids in southern Utah. They are, however, problems that managers occasionally face at small irrigation storage reservoirs. Subjecting study fish to extreme conditions was not a planned part of our study but occurred because of uncontrolled environmental variables. In retrospect, these variables provided insight into other differences among study groups that have important management implications. For example, winter losses of trout at Upper Kents Lake were almost entirely rainbow trout. All groups of cutthroat trout survived in comparatively large numbers. It is uncertain if differences in overwinter survival were due to physiological or behavioral differences among study fish or something unique to the reservoir. To our knowledge, there have been no direct comparisons of rainbow trout and cutthroat trout reactions to extremes in hypoxia. Different forms of cutthroat trout and rainbow trout have been used for sport fish management in Utah under the assumption that tolerances for low oxygen were similar. Unpublished laboratory results comparing low oxygen tolerances among cutthroat trout used in this study along with Snake River cutthroat trout did not show any significant differences (E. J. Wagner, Utah Division of Wildlife Resources, personal communication). Further study comparing low oxygen tolerances between native cutthroat trout and rainbow trout may help explain the differential overwinter survival observed at Upper Kents Lake. Confirmation of such an advantage for cutthroat trout would have important implications for managing sport fisheries in similar situations. Although the mechanism for greater overwinter survival for cutthroat trout was not identified, their use in a put-grow-and-take management program at Upper Kents Lake provided an alternative to a more costly put-and-take program, which would be necessary if stocking were limited to rainbow trout.

The differences we found in sport-fish performance among several forms of cutthroat trout have implications for developing future management programs. Specific stocks of fish might be used in addressing specific management needs or problems. For example, southern Bonneville cutthroat trout, with its high condition factor and relatively high return to anglers, would be suitable for stocking in small put-grow-and-take lakes. Considering vulnerability to angling and body conformation, use of Bear Lake cutthroat trout appeared more appropriate in large lakes where they are able to convert to a fish diet and grow to larger sizes. Stocking of Y×C hybrid cutthroat trout appeared most suited to situations where low vulnerability to angling is desired in order to maintain a reproducing population or extend the length of time a cohort of fish will return to anglers.

Building interest and support for native trout is an important component of maintaining and enhancing populations of native fish and protecting their habitats. Conversion from traditional programs to stocking of native fishes should proceed with caution to avoid drastic changes in popular sport fisheries and to avoid creating public opposition to cutthroat trout. Managers should balance these considerations and use native trout where they might best utilize unique characteristics to improve sport fisheries and increase support for native trout.

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