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EVALUATION OF FOUR RAINBOW TROUT—WARMWATER SPECIES FISHERIES IN SOUTHEASTERN OHIO[1]

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ABSTRACT. Four southeastern Ohio lakes that receive annual trout stockings were studied to determine: (1) the extent of available trout habitat in summer, (2) presence or extent of overlap in habitat and diet between trout and native warmwater fishes, (3) harvest of stocked trout, (4) recreational benefits attributable to trout stockings, and (5) the geographic areas that benefited from this management program. The lakes had little or no trout habitat during midsummer. Trout and warmwater species occupied the same habitats, even after thermal stratification, but did not appear to eat the same prey. Very few "carryover" trout (stocked in previous years) were caught. Average annual percent return of stocked trout was 83; 98% of the estimated harvest occurred within 7 wk after stocking. Trout did not grow significantly until after wk 7. The primary beneficiaries of the stocking program were anglers living within 32 km of the lakes. There appeared to be no economically feasible way to prolong the period of trout harvest nor to improve the trout fisheries.

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INTRODUCTION

In the late 1950s and early 1960s, numerous deep impoundments were created in Ohio for water supply, flood control, and recreational use. Because many of them appeared to contain suitable trout habitat throughout the year, the Ohio Department of Natural Resources, Division of Wildlife (ODW), managed some as "two-story" lakes. This management technique involves creation of a coldwater fishery in the deep, cool waters of a lake, while a warmwater fishery is maintained in shallower areas. Such two-story fisheries have been successful in Wisconsin (Jesien 1977), Arizona (Otte 1975), Kentucky (Axon 1974), California (Butler and Borgeson 1965), and many other states. Forked Run Lake became Ohio's first two-story lake when it was stocked with 11,130 rainbow trout (*Salmo gairdneri*) in 1964, and by 1975, 10 Ohio lakes were being stocked each spring with a total of 50,000 rainbow trout (total length 200–300 mm).

The ODW set 3 goals for this management program: (1) to increase angling during early spring, when fishing pressure has been traditionally light, (2) to provide a return of more than 50% of the stocked trout within 6 months after stocking, and (3) to create two-story fisheries without harming native warmwater fish populations.

As of 1975, no comprehensive evaluation of Ohio's two-story fisheries had been attempted. To facilitate future management decisions, ODW needed information on the limnology of the lakes, success of the fisheries, and the type and extent of ecological interactions occurring between trout and indigenous warmwater fish populations.

Six specific questions were addressed by this study: (1) Are the ecological requirements of rainbow trout met during summer thermal stratification? (2) Do the stocked trout and native warmwater fish

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eat the same prey? (3) Do "carryover" trout (trout remaining from stockings in previous years) make an appreciable contribution to the fisheries? (4) What percentage of stocked trout is harvested by anglers? (5) What recreational benefits, in terms of angler trips and angler-hours, are provided by trout stocking? and (6) How extensive is the geographical area served by each fishery? We conducted the study on 4 lakes in southeastern Ohio from July 1976—June 1978.

STUDY SITES

The 4 study lakes were Wolf Run, Belmont and Monroe lakes, and New Lexington City Reservoir. These 4 impoundments had a range in surface areas corresponding to the overall range for Ohio's 10 two-story lakes, and were sufficiently separated geographically to represent all portions of the region in which the 10 lakes were located.

Wolf Run Lake, in Wolf Run State Park, Noble County, is a multi-purpose impoundment used for flood control, water supply, swimming, boating, and camping, with a surface area of 89.1 ha and a maximum depth of 17.4 m. The watershed area (1477 ha) is primarily agricultural land (42%) and woodland (27%).

Belmont Lake, in Barkcamp State Park, Belmont County, used only for recreation, has a surface area of 47.4 ha and a maximum depth of 13.1 m. The 1218-ha watershed is primarily agricultural land (46%) and woodland (30%).

Monroe Lake is part of the 540-ha Monroe Wildlife Area, Monroe County. The lake serves as a flood control reservoir and is open to boating and fishing. It has a surface area of 16.2 ha and a maximum depth of 10.8 m. The 1148-ha watershed is primarily wooded (50%) and agricultural (40%) land.

New Lexington City Reservoir, Perry County, is about 3.2 km north of New Lexington. It is a water/supply reservoir and use is restricted to boating and fishing. It has a surface area of 6.9 ha and a maximum depth of 10.8 m. The surrounding area is mostly woodland and rural residential land.

All 4 lakes are dimictic impoundments with clear water; Secchi disk readings commonly exceed 3 m. Water chemistry is typical of impoundments in unglaciated portions of southeastern Ohio; hardness ranges from 85 to 154 mg/L as calcium carbonate ($\bar{x}$ = 110 mg/L) and pH from 7.0 to 9.0, most often about 8.2 (G. Billy, ODW, pers. comm.). Trap netting and shoreline seining conducted by ODW during the early 1970s found 14 species of game fish and 7 other fish species in the study lakes. The most common species were largemouth bass (*Micropterus salmoides*), white crappie (*Poxomis annularis*), bluegill (*Lepomis macrochirus*), green sunfish (*L. cyanellus*), yellow perch (*Perca flavescens*), bullhead (*Ictalurus* sp.), and white sucker (*Catostomus commersoni*). Gizzard shad (*Dorosoma cepedianum*) were abundant in Wolf Run Lake.

METHODS AND MATERIALS

We measured vertical changes in temperature and dissolved oxygen (DO) with a Yellow Springs Instruments temperature and oxygen meter to determine the extent of available trout habitat. Measurements were taken twice monthly in spring and summer of 1976 and 1977. In 1976 temperatures and DO were measured at 1-m intervals at 4 or more stations on each lake. Because the 1976 profiles varied little among stations, we sampled only the deepest station on each lake in 1977. We also measured temperatures and DO whenever we set vertical gill nets.

We used an electrofishing boat with 220-volt, pulsed, direct-current gear to sample fish populations in littoral areas of the study lakes and to determine the degree of habitat overlap between trout and warmwater species. We sampled all 4 study lakes in spring 1977, and Wolf Run and Belmont lakes in spring 1978. Electrofishing collections were made before and after surface waters reached 22.5 C, the temperature we accepted as the upper tolerance limit for trout.

After the lakes stratified thermally, we used vertical gill nets to determine the vertical distributions of fish and the extent of habitat overlap between trout and warmwater species. We used 3.6 × 15.2-m, multiple-strand nylon nets of 1, 1.5, or 2-in bar mesh. We hung the nets in a straight line from 4.2-m boards, which served as floats and spreaders. We set net arrays of various mesh combinations from June to September in 1976 and 1977, and generally pulled them at 24-h intervals.

We measured fork lengths and weights of trout taken by anglers and gill nets during spring and summer of 1977 and 1978 and compared them to those of random samples of 50 trout taken on stocking days at each lake. Condition factors (K) were calculated from the formula $\underline{K} = \underline{W}/\underline{L}^3 \times 1000$, where $\underline{W}$ is the weight in grams and $\underline{L}$ is the fork length in mm. Data from trout captured by electrofishing were unsuitable for growth analyses, because electrofishing was selective for smaller trout. We used an F-test to determine whether observed differences were statistically significant.

We calculated the annual survival rate of stocked trout by recording the contribution of carryover trout to each year's sport fishery (Ricker 1975:29, 39). In applying this method, we assumed that each year-class of trout was equally vulnerable to anglers because angler baits (e. g. corn, cheese) were the most abundant items in stomachs of both recently stocked and carryover trout caught by anglers and gill nets.

We removed the adipose fins of all trout stocked in 1977 so they could be distinguished from trout stocked in 1976. Adipose fins seldom regenerate (Mears 1976), and their removal has little effect on long-term survival (Horak 1969, Shetter 1967). Trout stocked in 1978 were not marked, because it was unlikely that any trout stocked in 1976 would survive to 1978, and if they did, the 1976 and 1978 groups would be easily distinguished by their relative sizes.

We evaluated the extent of diet overlap between trout and the most numerous warmwater game fish species during spring 1977 by collecting stomachs from trout and largemouth bass taken by anglers on Wolf Run and Belmont lakes. In April 1978 (2-3 weeks after trout stocking), we collected stomachs from trout, largemouth bass, and sunfishes captured during 4 nights of electrofishing on Wolf Run and Belmont lakes. Stomachs were removed in the field and preserved immediately in 10% formalin. Stomach contents were examined and relative importance of each prey type was determined by its numerical abundance. We compared the diets of trout with those of concurrently captured largemouth bass and sunfishes by using the modification of Morisita's index of overlap suggested by Horn (1966).

We analyzed additional stomachs from 64 trout and 202 centrarchids taken from all 4 lakes during April and May 1977 by angling, electrofishing and gill netting, but only with regard to the numerical abundance of each type of prey. No analysis of overlap was attempted between these groups, because the trout and warmwater species were not captured concurrently.

The lakes were stocked soon after ice-out (usually late March), at 1-wk intervals to allow the census clerks to concentrate efforts on each lake for at least 2 days after each stocking. Two clerks censused each lake on the day it was stocked. Thereafter, each angling day was considered to be 15 h, from 0530–2030, and days were divided into morning (0530–1300) and afternoon (1300–2030) survey periods. Both periods were censused for 2 days after stocking. Beginning on the 3rd day, lakes were selected for census at random. Four weekday mornings, 4 weekday afternoons, and all weekend periods were sampled each week until trout harvest dropped to undetectable levels. In 1977, the creel census was continued through September on Wolf Run and Belmont lakes to obtain estimates of the catch of trout and warmwater species during summer.

Total fishing pressure was determined according to Lambou (1961). Census clerks made instantaneous counts of all anglers every 2 h, starting either at 0600 or 1400. Between counts, clerks interviewed anglers. Anglers were asked the time they began fishing, what species they were seeking, how many of each species they had caught, and their places of residence. Trout anglers were asked if they would have come if no trout had been stocked. Anglers being interviewed for the first time during a given season were asked whether they would have bought an Ohio fishing license if no trout had been stocked in Ohio.

Except for the first census day, during which a total count was made, days following trout stockings were separated into strata based on declines in the catch of trout/unit effort. Average daily fishing pressure was computed for 3–6 strata for each lake. Total number of each species recorded in the interviews was divided by the total number of angler-hours to yield catch rates for each species. Catch rates were then multiplied by total angler-hours for that stratum to yield the number of each species taken. The 95% confidence interval for trout harvested in each stratum was computed from the variance of cross products (Lambou 1961).

Total number of trips per stratum was estimated by multiplying the average number of anglers interviewed per survey period by the total number of periods in the stratum. Because census clerks seldom failed to interview anyone who fished on a lake during a survey period, we believed that this method gave a more accurate figure than any other approach.

RESULTS

We have defined trout habitat as water <22.5 C with >3.5 mg/L dissolved oxygen (DO). Several authors (Axon 1974, Mullan and Tompkins 1959) have suggested using criteria of 21.0 C and 4.0–5.0 mg/L DO, but because we gill netted several trout from water of 22.5 C and at DOs <4.0 mg/L, we believed those guidelines to be too stringent. Axon (1974) also reported netting trout at temperatures >21.0 C and at DOs <4.0 mg/L.

According to our criteria, there was at

least one period in each lake during the summers of 1976 and 1977 when the stratum of water suitable for trout was no more than 1 m thick (table 1). New Lexington City Reservoir contained no trout habitat in July and August of both years, but usually in the other lakes the stratum of trout habitat remained <1 m thick no longer than 2 wk. Among all the lakes, the amount of summertime trout habitat tended to be positively related to the surface area and maximum depth.

Our electrofishing and gill netting studies showed that trout utilized only waters ≤22.5 C, but warmwater species utilized waters of all temperatures. When surface waters were <22.5 C, our electrofishing gear captured both trout and warmwater species in littoral areas. After the surface waters warmed to >22.5 C, we continued to take warmwater species by electrofishing, but could capture no more trout. Of the fish captured with vertical gill nets, all 21 trout and the majority of the warmwater fish (70% of the gamefish and 65% of the other fish) were netted from waters of temperatures <22.5 C (table 2).

Trout taken by anglers and gill nets during the first 7 weeks after stocking in 1977 and 1978 were not significantly larger than fish measured at the time of stocking (F-test; $p > 0.05$). In 1977 at Wolf Run Lake, trout taken by gill nets 12–16 weeks after stocking were significantly ($p < 0.05$) longer (by 31 mm) and heavier (by 50 g) than those measured on stocking days. They were also significantly longer and heavier than trout measured 6-7 wk after stocking. Thus, trout did not grow appreciably until they had been in the lakes at least 7 wk.

Condition factors (K) of trout declined gradually after stocking. In both 1977 and 1978, the K of Wolf Run trout declined significantly (F-test; $p < 0.05$) from an average of 1.33 on stocking days to 1.13 after 5-6 wk. Wolf Run trout taken in 1977 after wk 6 showed no further declines in condition.

Angler baits (e. g. corn, cheese, salmon eggs) were the most abundant items in stomachs of trout taken by anglers, electrofishing, and gill netting during the study. By contrast, adult bass contained mostly crayfish and fish, fingerling bass mostly fish, adult sunfish mostly fish larvae and aquatic insects, and fingerling sunfish mostly cladocerans and terrestrial insects.

When we attempted to calculate overlap indices between concurrently captured

TABLE 1

Upper and lower limits (depths in meters) of water strata suitable for rainbow trout habitat in 4 southeastern Ohio lakes, mid-June–September, 1976 and 1977. Trout habitat was operationally defined as water ≤22.5 C with >3.5 mg/l dissolved oxygen.

Year and month	Reservoir			
	New Lexington	Monroe	Belmont	Wolf Run
1976				
June	2.75-6.00	3.25-5.75	2.25-5.75	3.25-11.50
July	*	3.00-5.00	3.50-5.25	4.50-7.00
August	*	2.00-3.00	4.00-5.25	5.00-6.00
September	4.00-4.25	0.00-3.25	1.00-5.50	4.50-5.75
1977				
June	3.25-3.75	1.75-7.00	4.25-5.50	1.00-10.75
July	*	3.25-5.75	4.50-5.50	4.75-8.50
August	*	3.00-5.00	3.75-4.50	4.75-7.75
September	0.00-2.75	1.50-4.00	0.00-3.75	4.50-6.50

* Indicates no trout habitat

TABLE 2

Distributions of fish taken by vertical gill nets during 1976 and 1977 in 4 southeastern Ohio lakes. Data from all lakes were combined.

Species	Total Number Caught	Percentage of Each Species Caught Above or Below 22.5 C	
		>22.5 C	≤22.5 C
Rainbow Trout	21	0	100
Largemouth Bass	8	25	75
Bluegill	23	17	83
Channel Catfish	21	38	62
White Sucker	117	12	88
Gizzard Shad	146	53	47
Others*	12	42	58

* Other species were white crappie, yellow perch, yellow bullhead and brown bullhead.

groups of trout and warmwater species, we found that no overlap existed in 10 of 15 cases. In the remaining 5 cases, 4 of the indices were < 0.05, and the final index, a comparison of adult sunfish and trout taken 17 days after the 1978 stocking at Belmont Lake, was only 0.11. Out of 11 different types of prey observed, only chironomids and caddisflies were common to the trout and sunfish diets. What constitutes an ecologically significant index has not been adequately described, but clearly there was little use of the same foods by trout and warmwater species.

The term "two-story" proved to be a misnomer, because the lakes generally did not have trout and warmwater species fisheries existing simultaneously in the epilimnia and metalimnia. Ohio's trout lakes would be better discribed as supporting "two-stage" fisheries. The first stage, which began when trout were stocked, was characterized by high catch rates of trout, heavy fishing pressure for trout, and rapid trout harvest. During the second stage, which began approximately 7 wk after trout stocking, anglers sought warmwater species, and trout harvest was negligible. Therefore, we have made separate analyses of the 2 stages, that is, wk 1–7 and wk 8–22 after trout stocking.

Most of the angling effort on the study lakes during the first 7 wk after stocking was directed at trout. The percentages of total angler-hours spent pursuing trout during wk 1–7 were as follows:

	1977	1978
Wolf Run	62	88
Belmont	33	61
Monroe	85	74
New Lexington	75	77

In 1977, during wk 8–22, anglers at Wolf Run Lake expended only 6.3% of the total fishing effort seeking trout, and anglers at Belmont Lake only 1.3%. During wk 8–11, these percentages were 4.0% at Monroe Lake and 6.8% at New Lexington City Reservoir. Thus, although trout fishing constitutes a large portion of the recreation provided by the lakes in early spring, it drops to very low levels within 2 months after stocking.

Fishing activity directly attributable to trout stocking was determined from responses anglers made when asked whether they would have come fishing that day had no trout been stocked. An average of 45% of the anglers interviewed on each lake during wk 1–7 replied that they were fishing because trout had been stocked. These anglers contributed an average of 43% of the total hours of fishing pressure on each lake during wk 1–7. However, during wk 8–22 in 1977, only 2% of the anglers on Wolf Run Lake (representing 2% of the total pressure) had come in response to the trout stockings. On Belmont Lake during the same period we found no evidence of any fishing activity attributable to trout.

Percentage returns of stocked trout were consistently high for all 4 fisheries, but most of the harvest took place during the first 7 wk after stocking. In 1977, 77% of all trout introduced into the study lakes had been caught by the end of wk 7, and returns from individual lakes ranged from 58% to 94% (table 3). In 1978, 89% of all introduced trout were harvested by wk 7, and returns from individual lakes ranged from 62% to 99% (table 3). In 1977, during wk 8–22, only 2.5% of the trout stocked in Wolf Run Lake were caught, and no trout were caught at Belmont Lake. During wk 8–11, no trout were taken from New Lexington City Reservoir, and only 1.0% of the trout stocked in Monroe Lake were caught.

Contributions of carryover trout (from previous years' stockings) to the fisheries were negligible. Of the 5,861 creeled trout examined by the census clerks, only 9 were carryover fish. Of those, 6 were caught at Wolf Run Lake, 2 at Belmont Lake, and one at New Lexington City Reservoir. As judged by these returns, mean annual survival of trout in all 4 lakes was 0.0015, ranging from zero at Monroe Lake to 0.0034 at Wolf Run Lake.

Harvests of warmwater fish from the study lakes were typical of those in small impoundments. Totals of 7,928 and 10,047 fish were caught from the lakes during wk 1–7 in 1977 and 1978, respectively (table 4). Bluegills and other sunfishes composed an average of 60% of the spring catch, white crappies 24%, and largemouth bass 10%. Yellow perch represented 4%, and yellow bullheads, channel catfish, suckers, and carp the remaining 2%. A total of 19,049 warmwater fish were taken from Wolf Run and Belmont lakes during summer 1977 (wk 8–22). Sunfishes again made up the majority of the catch (76%), followed by bass (14%) and white crappies (4%). Channel catfish, yellow perch, yellow bullheads, suckers and carp made up 7% of the catch (table 4).

TABLE 3

Fishery statistics from 4 southeastern Ohio lakes during weeks 1–7 after they were stocked with trout, 1977 and 1978.

Lake and year	Angler-hours	No. of Trout Stocked	No. of Trout Harvested	Return: Percent	Return: (95% Confidence Interval)
Wolf Run					
1977	24,859	7,200	5,511	76.5	(63.0-90.1)
1978	20,533	8,000	7,850	98.1	(93.0-113.3)
Belmont					
1977	15,486	3,003	1,755	58.4	(50.2-66.6)
1978	18,190	3,003	2,973	99.0	(86.3-111.7)
Monroe					
1977	7,079	2,400	2,255	94.0	(79.3-108.6)
1978	7,738	2,480	1,674	67.5	(55.4-79.6)
New Lexington					
1977	4,745	1,460	1,314	90.0	(72.8-107.1)
1978	5,524	2,000	1,230	61.5	(52.7-70.4)
Totals		29,546	24,562	83.1	

TABLE 4

Estimated catch of warmwater species from 4 southeastern Ohio lakes during weeks 1–7 after trout stocking in 1977 and 1978, and from Wolf Run and Belmont lakes during weeks 8–22 after stocking in 1977.

Period and Lake	Largemouth Bass	Sunfish	White Crappie	Yellow Perch	Other*	Totals
Weeks 1–7, 1977						
Wolf Run	572	471	1272	124	57	2436
Belmont	330	2460	32	0	389	3211
Monroe	281	1155	190	84	0	1710
New Lexington	40	410	29	15	77	571
Totals	1163	4496	1523	223	523	7928
Weeks 8–22, 1977						
Wolf Run	1445	6367	541	478	258	9089
Belmont	1230	8025	142	0	563	9960
Totals	2675	14392	683	478	821	19049
Weeks 1–7, 1978						
Wolf Run	234	409	1970	55	25	2693
Belmont	317	4954	377	193	90	3931
Monroe	93	2339	333	275	14	3054
New Lexington	23	236	48	7	55	369
Totals	667	5938	2728	530	184	10047

*Other species included channel and flathead catfish, yellow and brown bullheads, white suckers and carp.

In 1977 on Wolf Run and Belmont lakes, catch of warmwater species per unit of effort was lower during early spring (wk 1–7) than during summer (wk 8–22). The average catch of warmwater fish per hour was 0.29 during wk 1–7, and 0.41 during wk 8–22. Greater landings of bluegills was primarily responsible for the increase during the summer.

The fisheries at Belmont, Monroe, and New Lexington lakes served limited geographical areas. Fishermen living less than 32 km from the lakes represented over 80% of the anglers during wk 1–7 in 1977 and 1978, and they accounted for an average of 92% of the creeled trout.

The fishery at Wolf Run Lake served a larger geographical area. Over 68% of the anglers on the lake during wk 1–7 in 1977 and 1978 lived farther than 32 km from the lake, and they took an average of 50% of the trout caught.

The geographical areas served by Wolf Run and Belmont lakes during wk 8–22 in 1977 were nearly identical to the areas served during wk 1–7. Apparently the presence of trout had no appreciable effect on the distance anglers traveled to fish in the lakes.

DISCUSSION

None of the study lakes contained ideal trout habitat year-round. Their primary shortcoming was a lack of well-oxygenated water <22.5 C during midsummer. Severe summer conditions can create acute thermal stress or hypoxia in trout, and such conditions have been associated with weight loss (Reimers 1963) and high mortality (Ayles et al. 1976) among stocked trout. The few carryover trout observed in this study may merely be a result of the inevitable genetic variability within a cohort of fish; a few trout are likely to be able to survive at temperatures well above accepted maxima. Well-oxygenated springs may also produce localized pockets of suitable midsummer trout habitat. However, no such springs were found during several thorough explorations of the lakes during summer 1976.

The potential for long-term trout survival is further lessened by scarcity of suitable forage. Although chironomids and *Chaoborus* larvae were present, these lakes lack the large cladocerans and amphipods known to be important items in trout diets (Brooks 1968, Galbraith 1967, Calhoun 1966:204, Johannes and Larkin 1961, Leonard and Leonard 1946, Hazzard 1935, Atkinson 1932). Soft-rayed forage fish species suitable for trout also appear to be lacking. Young bluegills and perch were abundant, but these species are seldom eaten by trout (Stocek and McCrimmon 1965, Leonard and Leonard 1946). The trout stomachs examined during the study contained no cladocerans, amphipods, minnows, or perch, and only one bluegill. A scarcity of certain prey items in trout diets may only indicate low use by trout, which are opportunistic feeders, but the absence of normally important prey items suggests that these items simply were not available.

The issue of potential competition between introduced trout and native fish has not been completely resolved. It is nearly impossible to prove that no competition exists, but our diet studies showed little overlap between the food of trout and that of other species. Possibly the domesticated, opportunistic trout simply did not use available forage, preferring to feed on relatively abundant angler baits, which resembled their hatchery fare. Ware (1971) reported that wild trout exposed to unfamiliar prey in laboratory studies did not eat it for several days; domesticated trout may have similar problems.

Trout surviving until thermal stratification occurs may be forced to compete for food with fish other than centrarchids. Suckers, whose diet often overlaps with that of trout (Harkness and Ricker 1929), are present in the deeper waters of all 4 lakes. Percent return of stocked trout was lower in Ontario lakes containing suckers than in lakes without suckers, suggesting competition (Fraser 1972). Juvenile gizzard shad, abundant in Wolf Run Lake, may also eat prey utilized by trout (Cramer and Marzoff 1970). The ODW recently stocked all 4 lakes with yellow perch, a coolwater species that may compete with trout for the scarce planktonic and benthic forage available (Galbraith 1967). Percent return of stocked trout from a small Ontario lake dropped drastically after the introduction of yellow perch (Fraser 1978).

Low annual survival of trout was primarily due to fishing mortality. Over 80% of the stocked trout were creeled during wk 1–7. Additional harvest during summer months plus fall and winter fishing (when no creel census was taken) could bring the total return to 85%. The remaining 15% probably succumbed to hooking mortality, thermal stress, or native predators. Hatchery trout are highly susceptible to hooking stress (Wydosky et al. 1976), and as noted above, suitable trout habitat was scarce. Native predators such as largemouth bass (present in all 4 lakes) and esocids (in Belmont and Monroe lakes) are known to prey on stocked trout (Keith and Barkley 1970, Axon 1974), and their contribution to trout mortality could have been significant.

Observed declines in trout condition factors were similar to declines noted among trout of similar size stocked in California (Reimers 1963). The average condition of Ohio trout 6 months or more after stocking was comparable to those of trout studied under similar circumstances in Ontario and the eastern U. S. (Stocek and McCrimmon 1965, Klak 1940). However, growth rates of trout in the Ohio lakes were well below those noted for trout in lakes in Arizona (Otte 1975), Kentucky (Axon 1974), and Michigan (Alexander and Shetter 1969). Low growth rates of Ohio trout were probably due to a lack of planktonic forage and scarcity of suitable habitat.

The study lakes provided acceptable return rates of stocked trout. Average annual return per lake (81%) equals or exceeds percentage returns of catchable-trout fisheries in Pennsylvania (Hartzler 1977), Wisconsin (Jesien 1977), Arizona (Otte 1975), Kentucky (Axon 1974), and California (Butler and Borgeson 1965). Returns on the study lakes easily surpass the ODW management goal of 50%, and exceed the 75% return suggested by the U. S. Fish and Wildlife Service as acceptable for reservoir trout fisheries (Sport Fishing Institute 1979).

Unfortunately, the trout harvest is brief. About 98% of the trout caught are taken during the first 7 wk after stocking. Similar brevity of harvest was found in all the fisheries mentioned above, and is considered a chronic problem in catchable-trout fisheries. The fishing period can be prolonged by using staggered stocking dates (Butler and Borgeson 1965), but transportation costs are usually considered prohibitive.

Many interviewed anglers believed that the harvest period could be lengthened by prohibiting fishing for several days after stocking, to allow the trout to disperse, or by reducing the daily bag limit of 10 trout. In effect, Monroe Lake was "closed" to fishing by an ice cover for several days after stocking in 1978. No prolongation of harvest was noted, but percentage return of stocked trout fell by almost 40% compared to 1977. Natural mortality of catchable cutthroat trout (*Salmo clarki*) in Munsel Lake, Oregon, was greatest when anglers were not able to fish immediately after stocking, and natural mortality was the dominant factor determining the number of fish available to anglers from that fishery (Hansen 1971). Likewise, reduction of the daily limit of trout from 10 to 5 did not substantially alter the distribution of catch on Strawberry and Allen lakes, Minnesota (Johnson 1978). Hence, neither delaying the start of fishing nor reducing bag limits appears to be an effective method of prolonging harvest.

The negligible contribution of carryover trout to the fisheries of the study lakes is consistent with the findings of Jesien (1977), Hartzler (1977), Otte (1975), Axon (1974), Butler and Borgeson (1965), and many others. Trout do not thrive in waters with native populations of percids, centrarchids and catostomids (Fraser 1972), and all 4 study lakes contain such populations.

Trout harvested and hours of recreation provided are the major benefits of any catchable-trout program. Based on a cost of $0.912 per trout stocked (T. Goettke, ODW, pers. comm.), in 1977 and 1978, 2.45 h of recreation were provided and 0.88 trout were caught per dollar the ODW spent rearing and stocking trout. The primary beneficiaries of stocking programs were anglers living within 32 km of the lakes, who accounted for 65% of the trout fishing pressure and creeled 64% of the trout taken.

Other potential benefits of the stocking programs include increased campsite usage and increased fishing license sales. Of the anglers we interviewed, 2% reported that they would not have bought an Ohio license if no trout had been stocked. We could not estimate the total numbers of different anglers that fished the study lakes, hence increased license sales could not be quantified.

Increased expenditures within the state are another tangible benefit. The U. S. Fish and Wildlife Service (1977) reported that, nationwide, average expenditures by anglers fishing upland reservoirs were $9.00 per trip. If expenditures by Ohioans approximate the national average, the 9,330 extra angler-trips generated by trout stockings on the study lakes in 1977 and 1978 represented increased expenditures of $83,970, most of which was presumably spent in Ohio.

The trout stocking program accomplished all of the major management goals set forth by ODW. It provided an additional sport species, increased angling activity during early spring, provided >50% return, and did not adversely affect native warmwater fish populations. Drawbacks of the program included the brevity of the effective fishing period, slow trout growth, virtually total mortality of unharvested trout, and the limited geographical areas served by the fisheries.

Brevity of the effective fishing period is a chronic problem of catchable-trout fisheries. Poor trout growth and high mortality of unharvested trout are apparently caused by limnological conditions, and cannot be economically remedied. Somewhat larger geographical areas could be served if statewide publicity (including stocking dates) were given to the public, but publicity would inevitably lead to congestion of anglers on stocking days and would probably further attenuate the period of trout harvest. Thus, there appear to be few management options that could alleviate any one negative aspect of the fisheries without exacerbating another.

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LITERATURE CITED

Alexander, G. R. and D. S. Shetter 1969 Trout production and angling success from matched plantings of brook trout and rainbow trout in East Fish Lake, Michigan. J. Wildl. Mgmt. 33: 682–692.

Atkinson, M. J. 1932 A study of comparative results from stocking barren lakes with rainbow trout. Trans. Amer. Fish. Soc. 62:197–201.

Axon, J. R. 1974 Evaluation of the "two-story" trout fishery in Lake Cumberland. Bull. Kentucky Fish. No. 60. 60 p.

Ayles, G. B., J. G. Lark, J. Barica and H. Kling 1976 Seasonal mortality of rainbow trout (*Salmo gairdneri*) planted in small eutrophic lakes of central Canada. J. Fish. Res. Bd. Canada. 33: 647–655.

Brooks, J. L. 1968 The effects of prey size selection by lake planktivores. Syst. Zool. 17: 273–291.

Butler, R. L. and D. P. Borgeson 1965 California "catchable" trout fisheries. Bull. Calif. Fish. Game No. 127. 47 p.

Calhoun, A. (ed.) 1966 Inland fisheries management. Calif. Fish. Game 546 p.

Cramer, J. D. and G. R. Marzoff 1970 Selective predation on zooplankton by gizzard shad. Trans. Amer. Fish. Soc. 99: 320–332.

Fraser, J. M. 1972 Recovery of planted brook trout, splake, and rainbow trout from selected Ontario lakes. J. Fish. Res. Bd. Canada. 29: 129–142.

——— 1978 The effect of competition with yellow perch on the survival and growth of planted brook trout, splake, and rainbow trout in a small Ontario lake. Trans. Amer. Fish. Soc. 107: 505–517.

Galbraith, M. G., Jr. 1967 Size-selective predation on *Daphnia* by rainbow trout. Trans. Amer. Fish. Soc. 96: 1–10.

Hansen, D. J. 1971 Evaluation of stocking cutthroat trout, *Salmo clarki*, in Munsel Lake, Oregon. Trans. Amer. Fish. Soc. 100: 55–60.

Harkness, W. J. and W. E. Ricker 1929 A preliminary study of some trout waters of Ontario. Trans. Amer. Fish. Soc. 59: 256–267.

Hartzler, J. R. 1977 An analysis of angler effort and the catch of one- and two-year old hatchery trout on Spring Creek (Centre County), Pennsylvania. Unpubl. M. S. Thesis, Pennsylvania State Univ., State College, PA. 69 p.

Hazzard, A. S. 1935 A preliminary study of an exceptionally productive trout water, Fish Lake, Utah. Trans Amer. Fish. Soc. 65: 122–128.

Horak, D. C. 1969 The effect of fin removal on stamina of hatchery-reared rainbow trout. Prog. Fish-Cult. 31: 217–220.

Horn, H. S. 1966 Measurement of "overlap" in comparative ecological studies. Amer. Nat. 100: 419–424.

Jesien, R. V. 1977 The contribution of stocked trout to the sport fishery of three small Wisconsin lakes. Unpubl. M. S. Thesis, Univ. Wisconsin, Stevens Point. 69 p.

Johannes, R. E. and P. A. Larkin 1961 Competition for food between redside shiner (*Richardsonius balteatus*) and rainbow trout in two British Columbia lakes. J. Fish. Res. Bd. Canada. 18: 203–220.

Johnson, M. W. 1978 An evaluation of reduced limits and a shorter season on sport fishing in two lakes managed for rainbow trout. Minnesota Dep. Nat. Res. Investigational Rep. No. 348. 27 p.

Keith, W. E. and S. W. Barkley 1970 Predation on stocked rainbow trout by chain pickerel and largemouth bass in Lake Ouachita, Arkansas. Proc. Annu. Conf. Southeast Game Fish Comm. 24: 401–407.

Klak, G. E. 1940 The condition of brook and rainbow trout from four eastern streams. Trans. Amer. Fish. Soc. 70: 282–289.

Lambou, V. W. 1961 Determination of fishing pressure from fishermen and party counts with a discussion of sampling problems. Proc. Annu. Conf. Southeast Fish Game Comm. 15: 380–401.

Leonard, J. W. and F. A. Leonard 1946 An analysis of the feeding habits of rainbow trout and lake trout in Birch Lake, Cass County, Michigan. Trans. Amer. Fish. Soc. 76: 301–314.

Mears, H. C. 1976 Overwinter regeneration of clipped fins in fingerling brook trout. Prog. Fish-Cult. 38:73.

Mullan, J. W. and W. A. Tompkins 1959 Trout pond management in Massachusetts. Mass. Div. Fish. Game. 132 p.

Otte, L. E. 1975 An evaluation of the rainbow trout-warmwater species fishery in Parker Canyon Lake. Unpubl. M. S. Thesis, Univ. Arizona, Tucson, 53 p.

Reimers, W. 1963 Body condition, water temperature, and over-winter survival of hatchery-reared trout in Convict Creek, California. Trans. Amer. Fish. Soc. 92: 39–46.

Ricker, W. E. 1975 Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada No. 191. 382 p.

Shetter, D. S. 1967 Effects of jaw tags and fin excision upon the growth, survival, and exploitation of hatchery rainbow trout fingerlings in Michigan. Trans. Amer. Fish. Soc. 96: 394–399.

Sport Fishing Institute 1979 Bull. Sport Fishing Inst. No. 305. SFI, Washington, DC. 8 p.

Stocek, R. and H. R. McCrimmon 1965 The coexistence of rainbow trout (*Salmo gairdneri* Richardson) and largemouth bass in a small Ontario lake. Canadian Fish-Cult. 35: 37–58.

United States Fish and Wildlife Service 1977 1975 national survey of hunting, fishing, and wildlife-associated recreation. U. S. Fish Wildl. Serv. Publ. 95. 91 p.

Ware, D. M. 1971 Predation by rainbow trout (*Salmo gairdneri*): The effect of experience. J. Fish. Res. Bd. Canada. 28: 1847–1852.

Wydosky, R. S., G. A. Wedemeyer and N. C. Nelson 1976 Physiological response to hooking stress in hatchery and wild rainbow trout (*Salmo gairdneri*). Trans. Amer. Fish. Soc. 105: 601–606.