Restocking after Fishkills as a Fisheries Management Strategy

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ABSTRACT

Research on stocking the New River with channel catfish (*Ictalurus punctatus*) following a partial fishkill showed restocking to be unsuccessful and of no measurable benefit to the fishery. Only an estimated 50 of the 3,000 channel catfish stocked were recovered by anglers. Cost of each recovered fish was $18.00, based on the initial stocking cost. Factors contributing to the failure of the restocking program probably include the considerable time between the fishkill and restocking (16 months), natural repopulation from unaffected areas, and the relatively small size of the "catchable" stocked fish. A survey of state fisheries agencies (43 replies) regarding restocking policy following a fishkill showed that: (1) twenty states do not restock as a normal policy; (2) fourteen states said they did not restock following fishkills; (3) twenty-seven state agencies replied that they had methods for economic evaluation of fishkills (ranging from a constant price per pound or number, regardless of species, to the Southern Division, American Fisheries Society, method which gives costs per inch and/or per pound of a species or family); and (4) a consensus existed that no detailed evaluation of the effectiveness of restocking after fishkills has been made.

In 1971, the Environmental Protection Agency received reports on 860 pollution-caused fishkills in the United States (Dodson et al. 1972). Fish killed in streams and rivers accounted for 55% of the total fish killed and affected nearly 6,700 km of streams and rivers. Lotic fishkills were responsible for over 40 million dead fish of which 12% were game fish. Municipal operations (sewage and water systems, refuse disposal, and power systems) caused the greatest number of fish to be killed. Almost 86% of the fish mortalities occurred during warm weather months (May through September).

Most state fisheries and/or water pollution control agencies are empowered to collect fines from the party legally responsible for a fishkill. Because of the concentrated numbers of highly visible dead fish resulting from a kill, many people demand a restocking program as the best solution for rapid restoration of the fishery. When a particular party is judged to have caused a fishkill, the court may suggest or designate fine money be used to alleviate damage to that particular fishery. Such a management strategy poses a key question of whether these fines are effectively utilized in financing restocking, especially in the area of the kill.

In areas affected by fishkills, repopulation from unaffected areas may be hastened by lack of competition in the affected area, assuming that water quality and productivity have been restored. Gunning and Berra (1969) studied the repopulation of two experimentally decimated stream populations of chubsuckers, *Erimyzon tenuis*. The study section (33 m) on one stream was repopulated to levels (by weight) greater than originally present during decimation for two successive years. A second stream section (77 m) was repopulated to 68% of the original number and 52% of the original weight after one year. However, a census conducted one year and six weeks after decimation showed repopulation to be 107% of the original number and 95% of the original weight. Similar studies (Gunning and Berra 1970) with longear sunfish, *Lepomis megalotis,* showed repopulation in one year to levels the same as, or greater than, those removed on a weight basis in four of six stream sections. The absence of large predatory species was thought to be the most important factor for repopulation in the longear sunfish study. The authors noted that because fish only were removed, re-entering fish did not face adverse environmental conditions as they might in a typical fishkill situation (low productivity and/or poor water quality).

Studies have also been undertaken to determine natural repopulation rates of streams in typical fishkill situations where water quality and bottom fauna and flora, as well as fish, were affected. Krumholz and Minckley (1964) found rapid increases in diversity and abundance of fishes after temporary pollution abatement in an area with chronic water quality problems. The influx of "clean-water fishes" appeared to come from nearby clean backwaters and creeks. Cairns et al. (1970, 1971a, 1971b) studied the recovery of damaged streams following introduction of various toxins. Six months after a spill of an ethyl benzene-creosote mixture, which killed over 13,000 fish (4,300 trout) in an 11 km section of the Roanoke River, Virginia, they found only a suppressed population of minnows immediately below the spill site. The trout population in this river was entirely supported by stocking because natural reproduction is nonexistent.

Dodson et al. (1972) classified 44% of the reported fishkills in 1971 to be "complete" or "heavy." In the other 56% of the cases, restocking would place stocked fish in varying degrees of competition with surviving native individuals. Stocked fish may also be competing with native fish from adjacent areas moving to fill a partial ecological void.

This study was undertaken to evaluate the effectiveness of restocking after a partial fishkill in an area which did not exhibit chronically degraded conditions. Angler success and changes in fish populations were used as primary determinants of restocking success. In addition to the restocking program, a mail survey was conducted to determine the policies of state fisheries agencies regarding restocking after fishkills.

STUDY AREA

The New River orginates in Ashe and Watauga Counties, North Carolina and flows generally northward through Virginia, draining 2,000 km^2 in North Carolina and 8,000 km^2 in Virginia. Three sampling stations were established on the New River near a cellulose acetate fiber plant in Narrows, Virginia to evaluate the success of restocking an area receiving treated industrial wastes (Fig. 1). A partial fishkill occurred below the plant in July, 1970, when over 16,000 fish were killed in a 13 km section of the New River (Virginia State Water Control Board 1970). Station I, a control, was located at the A. E. Shumate Bridge, approximately one km above plant discharges. An island divided the river immediately upstream from station I, resulting in higher velocity flows on each side. Below the island, the flow moderated, and the lower section consisted of a deep (2m) run. The substrate of station I consisted of cobble and large rocks. Station II, the affected zone, was located immediately below the last plant discharge. A long rapids extended the width of the stream at staion II; below the riffle was a deep (8m), countercurrent pool near the north bank. The substrate of station II consisted of cobble and large rocks. Station III, the recovery zone, was approximately 5 km below the plant. Nonnavigable rapids delimited the upstream end of station III and was followed by a long run. The substrate at station III was cobble, large rocks, and bedrock. Each station was approximately 400 m in length and 75 m to 110 m in width. Stations were chosen because of habitat similarity and

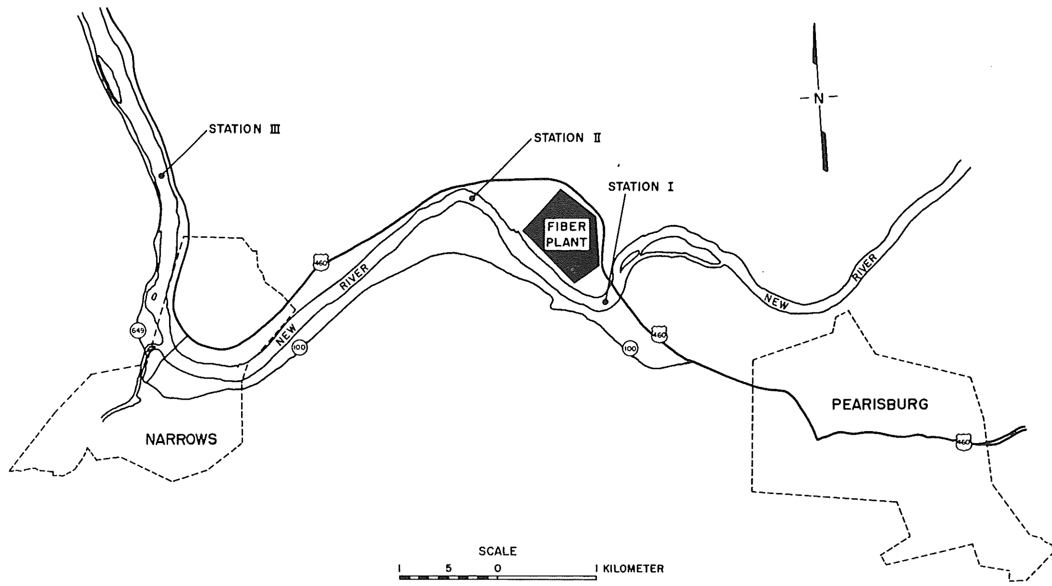

FIGURE 1.—New River in the vicinity of Narrows, Virginia, showing location of sampling stations.

because of accessibility and use by anglers.

METHODS

Mail Survey

Letters were sent to inland fisheries agencies of all 50 states asking for a statement of their policy regarding restocking after fishkills and requesting copies of research reports concerning such restocking.

New River Sampling

Bi-weekly measurements of temperature, dissolved oxygen, and pH were made at each station with portable field units. Measurements at station II were taken on both sides of the river to determine the extent of effluent dispersion. Previous studies (Hydroscience, Inc. 1966, 1967, 1968) showed depressed dissolved oxygen levels at station II (north bank) below the discharges. Installation of secondary treatment facilities and a diffuser pipe at the plant has largely corrected the depressed dissolved oxygen situation.

Initial sampling of fish populations began in July, 1971. Several sampling techniques were compared to determine which would provide good estimates of catfish abundance, but none proved totally satisfactory. Electrofishing was ineffective because of the low electrical conductivity of the water. Nets and traps were unsatisfactory because swift currents and water fluctuations caused by upstream hydroelectric discharges hampered their use. Wire fish traps were the most effective method for capturing and maintaining catfish in good condition. Traps were constructed on a 1.0 × 1.0 × 1.8-m rectangular steel frame covered with 2.5-mm poultry netting. One end consisted of a 1-m diameter cylindrical funnel with a 20-cm diameter opening. Two traps were operated at each station for one week each month to obtain estimates of the percentages of marked fish present in the river.

Creel Survey

A creel survey, similar to that of Hansen (1971), was used to determine changes in catch-per-unit effort and to estimate total yield, effort, and the percentage of marked fish recovered at the different stations. Condition factors of stocked and native fish were also recorded. From May through September, the survey was conducted on one-half weekday and one-half weekend day each week. From October through April, the survey was conducted 2 half weekend days and 2 half weekdays each month. The morning period was from daylight until 1:00 p.m. and the evening period from 1:00 p.m. until dark. Sampling days and times within days were selected using a table of random numbers. Days were not sampled a second time until all other weekdays or weekend days were sampled. A total angler count was made on each survey day. As many anglers as possible were then interviewed to obtain number in party, hours fished, and total length, weight, and mark of each channel catfish creeled. Those parties not interviewed were assigned averages for that day's survey to estimate total angling pressure and catch.

Restocking

Preliminary creel surveys indicated that, by far, the most sought after sport fish in the area was channel catfish. Therefore, catchable-size catfish were desirable for restocking. Channel catfish were obtained in November, 1971, from a commercial hatchery and placed in holding ponds (temperature 10 C) for three days prior to marking. Fish were marked by removal of either the right pelvic, left pelvic, or adipose fin, corresponding to station I, II, or III, respectively. Catfish were held 48 hours after marking (with no observed mortality) before stocking at the rate of 1,000 fish per station. Hatchery temperature, truck temperature, and river temperature were each 10–11 C. A subsample of 50 fish had a mean length of 282 mm and a mean weight of 144 g.

RESULTS

Mail Survey

Personnel from 43 of the 50 state fisheries agencies provided information on restocking after fishkills. Thirteen responses did not state whether restocking after pollution-caused fishkills was a normal management policy. Four responses concerned controlled chemical reclamation projects rather than pollution-caused fishkills. Of the remaining 26 states, 12 did restock to some degree, although six did so only infrequently and/or after severe kills. The remaining 14 states did not restock following fishkills.

Twenty-seven of the reporting state agencies had methods for economic evaluation of fishkills, although several had not yet been tested in court. These methods ranged from a constant price per pound or number, regardless of species, to the method adopted by the 14 states of the Southern Division, American Fisheries Society (1970), which gives costs per inch and/or per pound of a species or family. These prices were based on cost and availability from hatcheries, scarcity (as with endangered fishes), and ecological role of those species not available from hatcheries. Fines in other states had variable bases, including cost of replacement fish only, cost of investigation only, or cost of fish and investigation. Cost of fish was based on hatchery costs, commercial costs, or undisclosed sources. Very few states included aesthetic values in their prices. Investigative costs also varied among states and included labor, clean-up costs, equipment, transportation etc. Four states had not yet developed any economic guidelines for fishkill assessment and the remaining 12 failed to make it clear whether or not they had economic guidelines.

New River Sampling

Measurements taken near the north bank of station II, approximately 300 m below the lowest plant discharge, gave higher temperatures (mean difference 4.8 C) and lower dissolved oxygen (1.6 mg/liter mean difference) than measurements near the south bank. The pH was slightly lower near the north bank than measurements near the south bank (0.1 pH units). Measurements at station I, II (south bank), and III showed little difference on any given day. The highest monthly average temperature recorded at station II (north bank)

TABLE 1.—*Estimated number of anglers, fishing pressure, catch, and catch/effort of channel catfish by month*

Time period	Estimated Values				
	Anglers	Hours fished	Channel catfish caught	Marked channel catfish caught	Catch/hour
August (1971)	100	380	70	0	0.18
September	190	460	55	0	0.12
October	100	400	5	0	0.01
November	0	0	0	0	0
December	0	0	0	0	0
January (1972)	0	0	0	0	0
February	0	0	0	0	0
March	160	260	20	20	0.08
April	390	600	45	0	0.08
May	390	1200	85	23	0.07
June	480	1600	10	0	0.01
July	500	1900	550	7	0.29
August	640	1900	630	0	0.33
September	440	1000	100	0	0.10
October	0	0	0	0	0
November	0	0	0	0	0
Aug–Oct (1971)	390	1200	130	0	0.10
Aug–Oct (1972)	1100	3000	740	0	0.25

was 28 C which occurred in August and September, 1971, and September, 1972. Dissolved oxygen during these months never averaged less than 7.2 mg/liter. The lowest oxygen measurement recorded was 4 mg/liter in June, 1972. Higher temperature and lower dissolved oxygen values at station II (north bank) existed for only a few hundred meters (depending on river flow volume) downstream along the north bank until mixing with the much larger river volume.

Sampling yielded only 22 channel catfish; none were marked. Rapid water level fluctuations and swift currents frequently shifted or destroyed traps.

Creel Survey

Fishing pressure was essentially nonexistent from November through February (i.e., no anglers were observed on survey days). Effort increased in March, 1972 (Table 1). Twenty-three of these were from station I and 27 from station II. No recaptures were reported from station III. From March through July, expanded creel survey data gave an estimated catch of 710 channel catfish, an estimated 50 of which were marked. No marked fish were observed during the remainder of the study, although an estimated 730 channel catfish were caught during August and September. Comparison of the fishery during the three month period before restocking (August–October, 1971) with the fishery during the same period in 1972 showed that the number of anglers, effort, catch, and catch/effort (C/f) increased during the second summer, although no stocked fish were caught during these months. Much of this increase is attributed to publicity given the restocking program.

Comparison of the fishery by station showed that fishing pressure was similar at stations II and III (anglers and effort) in 1971 while pressure was less at station I (Table 2). In 1972, pressure increased at all stations, with II and III again having similar fishing pressures. Fishing pressure increased at station I but was still less than pressure at station II or III. Catch/effort estimates show that catch at station II averaged higher than catch at either I or III, especially during July–September, 1972. Fishing pressure was very low at all sta-

TABLE 2.—*Estimated number of anglers, fishing pressure, catch, and catch/effort of channel catfish by station*

	Station											
	I				II				III			
Month	Anglers	Effort	Catch	C/f	Anglers	Effort	Catch	C/f	Anglers	Effort	Catch	C/f
August (1971)	0	0	0	0	70	300	65	0.22	30	90	2	0.02
September	10	10	0	0	90	350	35	0.10	90	110	20	0.18
October	0	0	0	0	40	120	5	0.04	70	280	0	0
Nov–Feb (1972)	No anglers observed on survey days											
March	0	0	0	0	80	150	20	0.13	80	110	0	0
April	70	90	15	0.17	90	140	10	0.07	240	380	20	0.05
May	90	390	50	0.13	140	330	25	0.07	160	440	12	0.03
June	30	260	10	0.04	110	200	0	0	350	1200	0	0
July	120	320	0	0	160	640	525	0.82	220	960	15	0.01
August	110	320	15	0.05	330	1250	595	0.48	200	370	25	0.07
September	80	170	20	0.12	140	350	80	0.22	160	510	5	0.01
Aug–Oct (1971)	10	10	0	0	200	770	105	0.14	190	480	22	0.05
Aug–Oct (1972)	190	490	35	0.07	470	1600	675	0.42	360	880	30	0.03
All months	510	1560	110	0.07	1250	3830	1360	0.35	1600	4450	100	0.02

tions in June, 1972, because of high water during most of the month.

Condition factors were computed from mean length and weight data for each station's catch using the relationship, $CF = \frac{10^5 W}{L^3}$ (Table 3). Based on the small number of marked fish returned to the creel, the mean condition factor for all stocked fish was 0.919, while the mean condition factor for native fish caught during the same months was 0.949. Lengths and weights were recorded for only four stocked fish recovered by anglers and one of them had an unusually high condition factor (>1.5). The condition factors of the other three stocked fish recovered were all less than 0.7.

Because of the low numbers of returns, no up- or downstream movement patterns could be determined. One fish is known to have moved from station I to station II, a distance of approximately 1 km. One fish stocked at station II was reportedly recovered 6 km upstream by an angler. All other recoveries were at the station of origin.

TABLE 3.—*Mean lengths and weights and condition factors for angler-caught channel catfish from New River by station*[a]

Year	Station	Observations	Mean length	Mean weight	Condition factor
1971	1	0	—	—	—
	2	31	468 ± 35	1142 ± 282	0.936 ± 0.043
	3	7	436 ± 53	702 ± 270	0.805 ± 0.145
	Total	38	462 ± 31	1061 ± 241	0.912 ± 0.047
1972	1	12	420 ± 39	692 ± 244	0.848 ± 0.065
	2	65	394 ± 15	621 ± 107	0.915 ± 0.040
	3	14	405 ± 28	671 ± 172	0.947 ± 0.031
	Total	91	398	638	0.911
1971–72	1	12	420 ± 39	692 ± 244	0.848 ± 0.065
	2	96	413 ± 15	789 ± 126	0.922 ± 0.031
	3	21	416 ± 26	682 ± 142	0.900 ± 0.068

[a]The observations in this table are for those fish for which *both* lengths and weights were recorded. More fish had lengths only recorded (scales broken).

The cost/fish for the estimated number recovered (50 of 3,000) was $18/fish based on the cost of the original stocking. This amount reflects only the purchase price of the fish, because all other normally incurred costs (labor, transportation, etc.) were donated.

DISCUSSION

The success of restocking streams following fishkills has not been well studied; however, some generalizations concerning restocking can be made from the survey of state fisheries agencies. The majority of respondents felt that natural repopulation was sufficiently rapid and effective to outweigh restocking benefits. In heavily polluted streams with marginal water quality, game fish populations are generally suppressed and existing fisheries are marginal. Fishkills may be common in these situations and restocking marginal waters would not be beneficial. Charles (1957) found that restocking experimentally decimated streams with game fish to improve the fishery was successful only for a limited time. A gradual reversion to the original population composition was found. In streams with good water quality and fish populations, fishkills are usually the result of an accidental spill. The area would be repopulated naturally, either by immigration or by recruitment from surviving individuals after water quality was restored.

The question of economic assessment must be considered whether or not an agency decides to restock. Although most states had some form of assessment methods, lack of uniformity was characteristic. If the value of the various areas involved (fish, habitat, investigation, transportation, equipment, administrative work, and legal fees) could be somewhat standardized among states, recovery of damages would no doubt be facilitated. Those states adopting the "Monetary Values of Fish" (Southern Division, American Fisheries Society 1970) have at least made the first step toward standardization. A major problem is the lack of a satisfactory method for population estimation which can be utilized on larger streams to determine the percentage of the population affected by a fishkill.

Results from this study show that recovery of the affected stream was well along after one year. The latest fishkill (1970) resulted in the loss of 8,000 channel catfish (including several thousand catchable-size catfish) in the 13 km of river below the plant. This kill was probably incomplete because of the haven afforded by inflowing tributaries and the incomplete toxicant dispersion. Channel catfish probably had become reestablished to some degree in the year between the kill and restocking because they are relatively mobile (Funk 1955). Catch-per-unit effort figures for the time period before restocking indicated a substantial existing population. These highly variable estimates are similar to those reported by Miller (1966) for several streams.

The absence of stocked fish in the river sampling and in creels could be attributed to low survival. Stocked fish were from a commercial strain not adapted to a lotic environment, and may have been unable to compete successfully with native fish or to adapt to the new habitat. Lewis, Summerfelt, and Lopinot (1963) reported an average return of 1.2% for a fall stocking of catchable-size channel catfish subjected to angling the following spring. Various authors have compared the survival of wild and domestic strains of fishes, particularly brook trout. Flick and Webster (1964) found wild strains of brook trout to have a 21%–26% higher over-summer survival than domesticated strains. Mason, Brynildson, and Degurse (1967) also found a higher over-summer survival of wild strains of brook trout. However, over-winter survival was higher in the domestic strains, apparently because of their larger size. Over-winter survival of hatchery-reared trout has been found to be inversely related to the population size of the native population (Shetter 1947; Brynildson and Christenson 1961). Reimers (1963) showed that a decline in condition factor, together with rising temperatures and a breakdown in body vitality in critical late-winter periods, resulted in fish being unable to survive as spring approached. Whether the same situation occurs with channel catfish is open to question.

Emigration of stocked catfish is another possible reason for the absence of fish in the creels, and no doubt occurred to some degree, although periodic checks of anglers as far as 16 km downstream from the plant revealed no marked fish.

The relatively small size of the stocked channel catfish undoubtedly contributed to their poor return to anglers. Unmarked catfish caught by anglers were significantly larger than marked fish. Stocked fish might appear in the anglers' catch in greater numbers as their size increased, although stream sampling yielded no evidence that the marked fish were still present in the study area.

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