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DISAPPEARANCE OF DEAD FISH AND ASSESSMENT OF MORTALITY [1]

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ABSTRACT

Assessing the loss of fish that results from a sudden, extensive kill in a lake or stream usually is a difficult task. The estimate probably seldom approximates the actual number, and it is apt to be low. Disappearance of many of the victims is often responsible for much of the difficulty. Concealment by water depth is one of the main causes of disappearance.

Adult coho salmon that were introduced into a 1.4-mile stretch of the Platte River in Benzie County afforded a test of how completely the introduced salmon could be recovered after they had spawned and died. Twelve hundred coho were released here each fall in three successive years. After the fish began to die, the stream was patrolled to search for carcasses, at least once every 7 days and until spawning activity had ceased. Despite good conditions for retrieval (clear water, mostly shallow depths, large size of the fish), less than 50% of the salmon were found each year. Evidently, the bulk of those not found were hidden in restricted areas of deep water and beneath cover.

Better methods are needed for evaluating fish mortalities. The potentiality for developing such techniques appears to be good. Several approaches are suggested.

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Introduction

Many fish management biologists investigate fish mortalities. Assessment of the size of the kill usually is an essential part of the job, but the investigator is seldom able to obtain a close estimate. A number of researchers (Brown and Ball, 1942; Ricker, 1945; Carlander and Lewis, 1948) have acknowledged the difficulty of the task. The amount of mortality that fishing causes can be quite accurately determined by censusing fishermen's catches; combining census with population inventory is a way to assess accumulated loss from incessant natural mortality. But methods used to evaluate transient mortality are not so systematized as these techniques, and the results usually are far less reliable. The cause of transient kill may be natural (oxygen depletion, as in winterkill, for example), induced (use of rotenone, etc.), or accidental (pollution, etc.).

Disappearance of Fish

Disappearance of many of the victims is a major problem often encountered in evaluating fish mortalities. Some of the conditions and actions that bring about disappearance and concealment are: (1) turbid water; (2) burrowing of distressed fish into soft bottom; (3) submergence of dead fish into deep water; (4) transport from the site of death by current; (5) consumption by scavengers; (6) entrapment in or under vegetation, drift piles, undercut banks, etc.; (7) fungus growth or silt deposit on the carcasses; (8) rapid decomposition.

Turbidity is a handicap that may be insurmountable. However, it is not always a hopeless situation. For example, in a turbid pond in which visibility was limited to 4 inches and from which five species of fish were captured, then marked and returned, Carlander and Lewis (1948) recovered a substantial number of the fish after the pond was treated with rotenone; the rate of recovery ranged between 14% and 91% for individual species, and averaged 60% for all combined.

Entanglement of fish in vegetation (Ball, 1948), burrowing into bottom soil (Rupp and De Roche, 1965), and drifting under cover are among the causes of disappearance. Sometimes scavengers consume many victims of kill. Bacon (1953, 1955) noted that the snapping turtle (*Chelydra serpentina*) probably was the main consumer of dead test fish he observed, but crayfish fed on them also. Bacon found that accumulation of silt and detritus and growth of fungus greatly decreased the chances of the carcasses being detected by anglers who were not aware of their presence in the stream.

Decomposition may either aid or complicate assessment of mortality. Bloating, which may develop soon after death, assists recovery of fish that have sunk into deep water. Parker (1970) experimentally determined the conditions that influence emergence and the extent that surfacing can influence recovery. On the other hand, deterioration may be so rapid that counting or collecting is either very difficult or impossible. Bacon (1953, 1955) found that water temperature controlled the rate of decomposition. At average daily minimum and maximum stream temperatures of 58 F and 64 F, recognizable remains of trout endured as long as 9 days, but on the average lasted only 4.5 days. Faster deterioration would of course be expected in warmer water.

The situation that may most often interfere with accurate assessment of mortality is concealment of killed fish in deep water.

Although much of the evidence reported for this occurrence is circumstantial, it nonetheless is quite convincing. Rupp and De Roche (1965) have provided direct evidence. These investigators evaluated standing crops in three lakes by capturing, marking, and returning samples of fish, completely destroying the populations with rotenone, and then estimating the populations from numbers of marked and unmarked fish recovered. Besides collecting fish that floated and those that settled on bottom in shallow areas, they picked up others by systematic sampling in deep water with SCUBA. In two of the lakes, 47% and 57% of the total estimated number of fish (which respectively represented 67% and 60% of the total weight) had sunk to and remained on bottom in depths that exceeded 2 feet. In the third lake, the comparative evaluation was applied to individual species, seven of which provided enough recoveries for valid results. The portions of the estimated populations of these species that were found on bottom in the deeper parts of the lake ranged from 7% to 55% for number, and from 6% to 92% for weight.

Streams have received less attention than lakes in regard to problems that accompany evaluation of fish mortality. Such problems can be as complicated in streams as they are in lakes, and sometimes more so.

Platte River Study

I recently had a good opportunity to evaluate recovery of dead fish from a stream while investigating competition between coho salmon (*Oncorhynchus kisutch*) and trout (brown trout, *Salmo trutta*, and rainbow trout, *Salmo gairdneri*) in the Platte River, Benzie County. In the autumns of 1969, 1970, and 1971, we introduced adult coho to achieve reproduction in an experimental section. Barricades prevented these salmon from escaping and other adult salmon from entering the stocked area. Because the coho salmon dies soon after spawning, and as I was to observe the released fish closely through the spawning period to obtain various information, the situation was highly convenient for determining how many of the carcasses could be found.

The salmon were captured in the weir at the Platte River Anadromous Fish Hatchery, and were released upstream from the weir. The introductions of adult coho amounted to 1,208 fish in 1969, and 1,200 in each of the two following years. The numbers of males and females were equal. All of the fish were fin-clipped before release, mainly to differentiate them from any other adult salmon that might escape into the study area. The salmon averaged 27 inches in length and 7 3/4 pounds in weight.

The salmon were confined to a stretch of the river that extended from the dam associated with the weir to a fish barrier that had been installed 1.4 miles upstream. The dam was 4 1/2 feet high and was equipped with a grid of steel bars across the top that obstructed salmon from passing over the spillway either upstream or downstream. The backwater formed by this dam was about 700 feet long and averaged about 100 feet wide. In the lower 500 feet, some depths exceeded 6 feet; the upper 200 feet had depths to 4 feet and sluggish current. The next 1,400 feet of stream averaged 55 feet wide and 2 feet deep, and the rate of flow was approximately 1 foot per second. The following 5,380-foot stretch, which terminated at the fish barrier, averaged 44 feet wide and 1 foot deep, and had a current of 1 foot per second.

The 1.4-mile stretch of stream was patrolled and carefully searched for salmon carcasses at least once every 7 days during the spawning period, and until sometime after it had ended. The patrols were made by walking downstream in the river, except where all of the channel was too deep for wading; broad deep areas were inspected first from one bank, and then from the other. Dead salmon were identified as to sex, examined for fin clips, and tallied. Then they were either distinctly marked or removed from the river and its proximity; either procedure guarded against their being recounted.

The numbers of dead salmon found were 579 in 1969, 549 in 1970, and 583 in 1971 (Table 1). It will be seen that each year recovery was less than 50% of the number released. At the outset of this study I had expected that the rate of recovery would be appreciably higher. The rate that resulted was surprising in view of conditions that favored good recovery, namely, large size of the fish, clear water, and generally shallow depths. As some salmon definitely still survived when the last inventories were made in 1969 and 1970 (Table 2), one may assume that the counts would have been higher had search continued longer; however, it seems unlikely that additional recovery would have amounted to much. In 1971, few (if any) salmon were alive by the time the last inventory was made.

Besides the close similarity of the figures for total recovery, the annual pickups of dead salmon were also characterized by these consistencies: (1) Nearly equal numbers of males and females. (2) When transfers were segmented through time (in 1969 and 1970), extent of recovery of salmon was similar among different segments; in 1969, recovery by segment amounted to 51% from the combined total of two separate releases of 404 salmon that were marked the same, and 41% from the 400 in the third release, that were marked differently; in 1970, the rates from two releases of 600 salmon each were 47% and 46%. (3) Considerably more dead coho were found in the lower 2,100 feet of stream than in the adjoining 5,380-foot stretch; recovery in the shorter portion amounted to 62, 71, and 60% of total recovery from the 1.4 miles of river, respectively, in 1969, 1970, and 1971.

What became of the salmon I could not find? Of more than 3,000 sockeye salmon (Oncorhynchus nerka) carcasses that Merrell (1964) marked on several Alaskan streams, he later found little more than 1% of them; he attributed most of the disappearance to scavenging bears and to washing of carcasses into deep water. Scavenging was of little consequence on Platte River. Raccoons occasionally dragged dead coho on bank to feed on them. Such salmon that were seen were

Table 1.--Numbers of introduced, adult coho salmon, recovered after death in a 1.4-mile stretch of Platte River [1]

Part of stream	Year and sex					
	1969		1970		1971	
	♂	♀	♂	♀	♂	♀
Below Section I (2,100 feet of stream)	180	182	175	177	156	131
Section I + 100 feet (5,380 feet of stream)	112	105	78	81	102	116
Total recovered [2]	579		549		583	
Percent recovered	48		46		49	

[1] Numbers of salmon released: 1969--1,208; 1970--1,200; 1971--1,200.

[2] Total for 1970 includes 38 salmon on which sex was not determined, and 1971 total includes 78 of such fish.

Table 2.--Numbers [1] of coho salmon tallied on the later patrols of the 1.4-mile stretch of Platte River that received spawning adults in 1969-71 [2]

Inventory dates	1969 Dead	1969 Live	1970 Dead	1970 Live	1971 Dead	1971 Live
6-8 November	--	--	--	--	30	58
	--	--	--	--	36	11
10 November	--	--	--	--	7	36
	--	--	--	--	24	12
22-25 November	31	56	--	--	21	18
	61	--	--	--	39	1
30 November - 2 December	25	25	17	18	--	--
	41	35	53	20	--	--
14-16 December	10	13	--	--	12	0
	30	7	--	--	9	0
21-22 December	--	--	9	3	--	--
	--	--	24	1	--	--

[1] The upper number of the paired figures is for the upper 5,380 feet of stream, lower number is for the lower 2,100 feet.

[2] Periods during which the salmon were released: (1969) 21 October-5 November; (1970) 20-28 October; (1971) 13-16 October.

listed as recoveries. This part of the stream was closed to fishing when the coho were present, and as far as is known there was no unaccounted removal of salmon by humans. A small number of carcasses may have been overlooked because they were partially or entirely covered with silt; a few that evidently had been bypassed previously were found in this condition.

After carefully considering various possibilities of disappearance, I have concluded that most of the introduced salmon that were not found were in deep water and beneath cover. The first 700 feet of river above the dam probably contained at least 95% of the total area of deep water (depths of at least 4 feet) in the 1.4-mile stretch. I conclude further that most of the salmon concealed by depth lay in this backwater, and mainly in the lower 500 feet of it, because good visibility permitted fairly good recovery of carcasses that were on the bottom in the shallower upper 200 feet. Recovery of chinook salmon following their death after spawning in a Canadian lake, year after year amounted to less than 10% of the numbers known to have been present; the carcasses recovered were in depths less than 3 meters, and it was concluded that the others must have lain in deep water (Ricker, 1945).

The most likely location of "lost" salmon in the rest of this 1.4-mile portion of Platte River was beneath cover. The bulk of the cover had been introduced through a stream improvement program completed in 1958. Log rafts and log jams especially favored concealment. Some carcasses were found under the edges of these shelters. Thorough examination of several of the cover structures would have been highly desirable, but lack of time prevented it. A colleague has told me that numerous coho salmon carcasses were found beneath a drift pile on another Michigan stream when the pile was torn apart.

Low temperatures in Platte River in October and November (45-40 F) favored recovery of dead salmon by retarding decomposition. Even at these temperatures, however, the carcasses deteriorated extensively in 2 weeks. In locations where many of them were strewn over the bottom in the fall, only a few bones remained by April. Carcasses disappeared far more slowly when they were out of water. Skin and flesh (as well as foul odor) from some of the stranded carcasses lasted into June.

Recommendations

Better methods are needed for assessing fish kills. Examples of mortality for which reliable estimates are especially desirable are (1) catastrophic kills that require determination of need for restocking, and the amount, in the event that restocking is necessary, and (2) pollution kills for which the responsible parties must make restitution. My impression from personal experience and the literature is that mortalities are most often underestimated.

Rupp's and De Roche's investigation (1965) illustrates that a promising potentiality of improving evaluation does indeed exist. Besides apparently being applicable to other lakes, the methods used in that study may suggest other ways of sampling dead fish in deep water. Another approach toward improvement may be that of establishing probability values for surface-recovery of various species of fish (suggested by Carlander's and Lewis' [1945] basic observations), and including consideration of various sizes, as well as physical factors of the environment (as Parker [1970] did).

An example of improving assessment of mortality on streams is development of guidelines by a series of procedures such as these: (1) capture, mark, and immediately release as many fish as possible, tallying them by species and length groups; (2) destroy the population with a toxicant; (3) recover as many of the dead fish as possible; and (4) determine recovery rates from the numbers of marked fish seen again. These recovery rates would serve as a basis for evaluating mortality in future kills. The consistency of the rates obtained from salmon in Platte River lends support to the belief that the suggested procedures would prove practicable. Quite certainly, whatever guidelines resulted from the procedures would in future practice be best suited to the stream in which they evolved. It seems probable, however, that they would also be useful for other, similar streams.

Literature Cited

Bacon, Edward H. 1953. Studies on the disappearance of dead trout and creek chubs in the Pigeon River. Mich. Dep. Cons., Inst. Fish. Res., Rep. No. 1392, 11 pp.

Bacon, Edward H. 1955. Studies on the disappearance of dead trout in the Pigeon River. Mich. Dep. Cons., Inst. Fish. Res., Rep. No. 1442, 9 pp.

Ball, Robert C. 1948. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Trans. Amer. Fish. Soc., 75(1945): 36-42.

Brown, C. J. D., and Robert C. Ball. 1942. A fish population study of Third Sister Lake. Trans. Amer. Fish. Soc., 72(1942): 177-186.

Carlander, Kenneth D., and William M. Lewis. 1948. Some precautions in estimating fish populations. Prog. Fish-Cult., 10(3): 134-137.

Merrell, Theodore R., Jr. 1964. Ecological studies of sockeye salmon and related limnological and climatological investigations, Brooks Lake, Alaska, 1957. U.S. Dep. Int., Fish Wildl. Serv., Spec. Sci. Rep., Fish. No. 456, 66 pp.

Parker, Richard O., Jr. 1970. Surfacing of dead fish following application of rotenone. Trans. Amer. Fish. Soc., 99(4): 805-807.

Ricker, William E. 1945. Natural mortality among Indiana bluegill sunfish. Ecology, 26(2): 111-121.

Rupp, Robert S., and Stuart E. De Roche. 1965. Standing crops of fishes in three small lakes compared with C^{14} estimates of net primary productivity. Trans. Amer. Fish. Soc., 94(1): 9-25.

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