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THE DEVELOPMENT OF POPULATION ESTIMATE PROCEDURES IN SMALL TROUT LAKES

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Introduction

At the Pigeon River Trout Research Station, Michigan, the evaluation of various experimental management programs employing a complete, permit-type creel census has been undertaken. Included among these programs are several involving small trout lakes which, in recent years, have received annual plantings of sublegal brook trout. Although data obtained from the creel census--such as total catch, pressure, and catch per unit effort--are indispensable in a thorough evaluation of experimental management, in some instances it was also desired to obtain data on population size. More specifically, it was desired to measure the size, in numbers, of each year class present (identifiable by a distinguishing fin-clip mark made at the time of planting) at two times during the year: immediately before, and after the close of, the trout fishing season. With these data, and also total anglers' catch obtained from the creel census, the fate of each year class could be ascertained; starting with a known number at time of planting (autumn), the following could be determined: mortality

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during the first winter in the lake, angling and natural mortality during the first summer, mortality during the second winter, and so on until the entire year class had disappeared.

Recognizing that, for the above purpose, estimates that were both accurate (lack of systematic error) and precise (small sampling error) would be necessary, considerable effort was applied to the development of a desirable procedure.

Two fortunate circumstances combined to permit an intensive attack on the problem. These were (1) the small size of the lakes (10 acres and less), which permitted intensive sampling, and (2) the very high degree of activity of the brook trout, and consequent ease of capture, at the two times of year at which population measurements were desired.

Since such an intensive effort was applied in favorable circumstances, confidence intervals were usually narrow enough that systematic errors could be demonstrated. It is the purpose of this report to present descriptions of these systematic errors so that, for general application, they may be recognized in future population estimations where such favorable circumstances may not be present or where sampling, for practical reasons, cannot be done as intensively. Not included here is any attempt at evaluation of the experimental management itself, nor many adjunctive data which are applicable only to the Pigeon River lakes; rather, only findings that pertain in general application are presented.

Necessary assumptions

Ricker (1958) has discussed in detail the several assumptions which must be made in a mark-and-recapture procedure of population estimation. Most of these assumptions may be made in the case of the Pigeon River lakes with considerable assurance: (1) there is no recruitment problem since the trout populations are maintained only by plantings of marked fish in known numbers and

sizes; (2) marked fish (fin-clipped) would not lose their mark over the short period of time involved; (3) non-random distribution of the fish, or sampling that was not proportional to fish density, would be unlikely considering the high degree of fish activity and intensity of fishing effort; (4) recognition of all marks would be likely since only technical personnel were involved.

One of the assumptions which could not be accepted without considerable suspicion, however, is "that the marked fish are as vulnerable to the fishing being carried on as are the unmarked ones" (Ricker, 1958, p. 86). Among other things, this means that the method of original capture and marking must not impose any physical or psychological effects on the fish which change their vulnerability, and also that there are no initial differences in susceptibility to the method of capture, for which corrections cannot be made, among the individuals of the population. As Ricker points out, this is an assumption which is extremely difficult to evaluate. Unfortunately, the systematic errors which may be in the estimate as a result of the assumption not holding true may be considerable. The virtual absence of tests of this assumption in the fishery literature appears to bear out the suggested difficulty.

It has been frequently suggested that a means of overcoming some of the possible systematic errors involved in differential vulnerability between the marked and unmarked fish, particularly when passive methods of capture are used, is to obtain the recapture samples by a method of capture different from the method of original capture--thus avoiding sampling bias due to effects imposed by the original capture.

Several instances have been reported where estimates obtained by such a "mixed" procedure (i.e., capture by one method and recapture by another) have been compared to estimates obtained by a "pure" procedure (i.e., capture and recapture by the same method) (Ricker, 1942; Lawrence, 1952; Cooper, 1952;

Cooper and Schafer, 1954; Carlander and Moorman, 1956). In most of these instances the estimates have differed, sometimes considerably, but there was little to indicate which was the better estimate nor any identification of possible systematic errors. Lawrence (1952) compared an estimate of a bluegill population in an Iowa farm pond made by marking fish captured by a seine and recapturing in traps with an estimate made by traps only; the former was about twice that of the latter. The traps were baited, however, so there is reason to suspect that the trapped fish may have been attracted to them for another meal. Lagler and Ricker (1942) reported that marked crappies which had been trapped in fyke nets apparently appeared in recapture samples in a higher proportion than they were present in the lake. Several other workers have reported estimates obtained by trapping which have been too low compared to the return from subsequent poisoning. On the other hand, Loeb (1958) reported "pure" estimates which he considered acceptable using seining alone and also electrofishing alone; however, he points out that a method such as electrofishing does not depend on fish behavior, as does trapping, and a procedure involving different methods of capture would not be as necessary.

The final assumption to be considered is that of equal mortality between the marked and unmarked fish, which may fall under suspicion. However, when significant differences are noted among two or more estimates of the same population, and the method of original capture was the same in all procedures, the reason for the differences must be assigned to factors other than differential mortality caused by the method of original capture and marking.

In the present study, by comparing "mixed" and "pure" estimates, and by using other data available, some tests of the assumption of equal vulnerability were possible.

Methods of capture and estimation procedures

The two methods of capture employed were traps and angling, both of which are passive methods which depend upon behavior of the fish. By sampling with both methods, and by marking the fish differently for each method, four independent estimates of each population in question could be obtained for comparison. Two of these estimations are by "pure" procedures: (1) "angling and recapture by angling," and (2) "trap and recapture by trap." The other two are "mixed" procedures: (3) "angling and recapture by trap," and (4) "trap and recapture by angling."

The two lakes employed in this study were Ford Lake (about 10 acres) and Hemlock Lake (6 acres). Ford Lake had received annual plantings of 5,850 sub-legal brook trout (age group 0), while Hemlock Lake had received annual plantings of 3,000. All plantings were made in the autumn. A few trout entered the anglers' catch as I-annulus fish during the summer following planting, but the great majority of those entering the anglers' catch did so during the first few weeks of the trout season about 1 1/2 years after planting. Few trout were caught by anglers beyond their second summer in the lake. The study was begun in the autumn of 1956 when the year class of predominance was the 1955 year class--trout approximately 1 1/2 years old. A very few trout (about 1 percent) remained in the lakes from plantings earlier than 1955, and these fish are included in all estimates presented as for the 1955 year class.

Other details of methods, since they varied according to lake and to the stage of the program's progress, will be given in later sections.

Population estimates

Population estimates made in the autumn of 1956 of the 1955 year class (including a very few survivors of the 1954 and 1953 year classes) are presented in Table 1 for Hemlock and Ford lakes. The method of Schumacher and Eschmeyer

Table 1.--Population estimates of the 1955 year class in Hemlock and Ford lakes, autumn, 1956

Procedure	Population estimate	95 percent confidence limits	
Hemlock Lake			
Angling and recapture by angling	1,044	893	1,256
Trap and recapture by trap	471	439	508
Trap and recapture by trap, sum of estimates of separate size classifications	482	...	...
Trap and recapture by angling	528	466	609
Angling and recapture by trap	539	496	591
Angling and recapture by trap, M corrected	524	476	584
Ford Lake			
Angling and recapture by angling	833	492	2,717
Angling and recapture by angling, first period and recapture in second period	633	541	762
Trap and recapture by trap	411	389	436
Trap and recapture by angling	432	395	476
Angling and recapture by trap	500	463	544
Angling and recapture by trap, M constant	465	428	509

(1943) was employed at this time; 95 percent confidence limits were obtained by the method discussed by Ricker (1958, pp. 102-103) using formulas given by DeLury (1958) and Schumacher and Eschmeyer (1943). Field operations were conducted in Hemlock Lake from October 16 to October 30 and in Ford Lake from November 5 to November 20; the traps were lifted, moved, and reset during the morning, and angling was conducted by the research station staff during the afternoon using artificial flies. The traps used were hoop nets with wings. The top corner of the caudal fin was clipped for trap-caught fish and the lower corner for angler-caught fish. All marked fish were released near shore, but not in the immediate vicinity of a trap.

Estimates of the 1956 year class made in the spring of 1957 are presented in Table 2. For these estimates, available time was very limited between the time that the lakes were first ice-free and the opening of the trout season. Field operations before the trout season opened consisted of trapping only, using the Schumacher-Eschmeyer method; trapping was conducted during the periods from April 16 to April 21 in Ford Lake and from April 22 to April 25 in Hemlock Lake. The traps used at this time were constructed of 1/2-inch (or less) mesh hardware cloth, presumably similar to those employed by Lawrence (1952). They were 3 feet long and triangular in cross-section, each side being 2 feet; a funnel was constructed into one end while the other end was closed except for a small hinged door for removing the catch. In Ford Lake the mark used was the removal of an entire pectoral fin (a permanent mark was desired so that an additional estimate could be obtained at a later time for comparison); in Hemlock Lake half the fish were marked by removal of a pectoral fin and half by clipping a corner of the caudal fin. All marked fish were released at a central release point, although, since the lakes were small, the distance from this release point to the nearest trap was not much different than from release points near shore. Recapture samples for the "trap and recapture by angling" estimate were obtained

Table 2.--Population estimates of the 1956 year class in Ford and Hemlock lakes, spring, 1957

Procedure	Population estimate	95 percent confidence limits	
Ford Lake			
Trap and recapture by trap	5,742	4,803	7,138
Trap and recapture by trap, last day's sample	5,041	3,849	6,689
Trap and recapture by angling	4,410	3,840	5,200
Autumn, 1957, check estimate	4,624	4,052	5,333
Hemlock Lake			
Trap and recapture by trap, pectoral clip	3,750	2,055	21,394
Trap and recapture by trap, caudal clip	3,711	2,207	11,659
Trap and recapture by trap, pectoral clip, last day's sample	3,406	2,577	4,425
Trap and recapture by trap, caudal clip, last day's sample	3,206	2,439	4,098
Trap and recapture by angling	2,591	2,449	2,799
Autumn, 1957, check estimate	2,997	2,408	4,034

by angling done by the research station staff after the opening of the trout season; this estimate was made by the direct proportion, or Petersen, method, and 95 percent confidence limits were obtained from tables of binomial confidence limits given by Mainland, Herrera and Sutcliffe (1956).

"Angling and recapture by angling" estimates

The estimates obtained by this method of the 1955 year class in both Hemlock and Ford lakes, 1,044 and 833 respectively, were suspected of being too high, since in both lakes these estimates lay considerably above all other estimates obtained by other procedures.

One possible reason for the estimates being too high was mortality among the angler-caught trout due to fatal hooking. (Some mortality was observed--about 1 percent. All fish hooked badly, or where bleeding occurred, were held in a live cage in the lake for 24 hours, and deaths were recorded and appropriate corrections made in the computations.) However, the fact that the "angling and recapture by trap" estimates did not appear too high confuted the postulate of significant differential mortality.

Another possible explanation for the systematic error was that the trout which had once been caught by the angler's hook acquired a "hook resistance" and subsequently did not appear in the recapture samples in as high a proportion as they were present in the lake. Furthermore, it was observed that after about 40 or 50 percent of the population had been caught and marked, catch per unit effort had decreased greatly; this was probably due to another significant portion of the population acquiring a certain degree of "hook resistance" by being hooked and lost--a result which happened about as frequently as the hooking and landing of a fish.

In Ford Lake the "hook resistance" postulate was evaluated experimentally by ceasing angling after 5 days, permitting the trout to "rest" for a period

of 10 days, then angling again for another period using a different mark. The samples obtained during the second period of angling were then used for the estimation. The result was an estimate of 633, being a reduction from the estimate of 833 for all angling. This procedure is listed in Table 1 as "Angling and recapture by angling, first period and recapture in second period." Apparently during the "rest," the marked trout lost a certain amount, but not all, of their "hook resistance," resulting in a lower estimate.

It was concluded that the "angling and recapture by angling" procedure was not valid because of the differential vulnerability between marked and unmarked fish due probably to a "hook resistance" displayed by the marked fish. (It should be emphasized, however, that the "hook resistance" apparently is lost after some as yet unknown period of time; perhaps valid estimates could be obtained by this method if sufficient time were allowed to elapse between periods of sampling, provided, of course, that the mark used was permanent over the period of time involved.)

"Trap and recapture by trap" estimates, autumn, 1956

In the autumn of 1956 the "trap and recapture by trap" estimates were too low in both lakes (Table 1). As evidence to support this conclusion, the estimates may be compared to the known minimum number present, which was the total number of original captures made with both traps and angling. In Hemlock Lake the minimum number was 515, while the estimate was 471; in fact, the upper 95 percent confidence limit, 508, was lower than the known minimum number. In Ford Lake the known minimum number, 422, although falling within the 95 percent confidence interval, was again higher than the estimate, 411. Furthermore, it would certainly be expected that the true population size would be somewhat larger than the known minimum number, since it was highly unlikely that all of

the fish had been captured. Obviously some systematic error was present in this procedure, producing a low estimate.

Several reasons are suggested to explain why the "trap and recapture by trap" estimates were too low in the autumn of 1956.

The first of these is that the traps permitted some escapement of smaller sized fish and thus the procedure estimated only a portion of the population. That some escapement occurred was known to be true, since small fish were sometimes gilled in the mesh of the traps and some were even observed to escape. However, the estimate (of the portion available to both methods of capture) made by the "trap and recapture by trap" procedure appeared to be lower than it should have been, when it is considered that the basis for judging the estimates to be low was a comparison with the known minimum number captured by both methods, and that the size ranges and means of total captures by both methods were very similar (Table 3). T-tests indicated no significant difference (above 80 percent level) in either lake between the means for angling and trapping. In other words, some other source of systematic error should be sought to explain why the estimates were less than the known minimum number.

One explanation for this may have been that the release point of the fish, after being removed from the traps, was near shore, approximately mid-way between two adjacent traps. (Note, in a later section, that the "trap and recapture by trap" estimates in the spring of 1957, where a central release point was used, were too high.) This remains a possibility, but it is probably not the principal cause of the error because (1) the release of angler-caught fish was also near shore, and the "angling and recapture by trap" estimates were higher, and (2) the lakes were small and the distances that the fish would have to travel back to the traps, whether a central release point or release points near shore were used, were not much different.

Table 3.--Number of total captures made by angling and traps, Hemlock and Ford lakes, autumn, 1956

Total length (inches)	Hemlock Lake		Ford Lake	
	Angling	Traps	Angling	Traps
6.0 - 6.4	0	3	1	0
6.5 - 6.9	7	23	0	0
7.0 - 7.4	70	127	6	39
7.5 - 7.9	99	216	50	121
8.0 - 8.4	125	244	98	250
8.5 - 8.9	69	146	95	212
9.0 - 9.4	22	37	39	97
9.5 - 9.9	3	8	10	24
10.0 - 10.4	5	8	4	5
10.5 - 10.9	0	3	1	2
11.0 - 11.4	0	0	0	3
11.5 - 11.9	0	0	0	0
12.0 - 12.4	0	0	1	0
Mean (inches)	8.05	8.04	8.47	8.42

Cooper (1952) has suggested the possibility that estimates based on trapping may be too low because of the failure of the "effective fields" of the traps to completely overlap. It is highly unlikely that this factor would be important in Ford and Hemlock lakes, however, considering the intensity of the trapping relative to the size of the lakes and also the very high degree of activity of the fish.

Another possibility was that systematic errors were introduced by combining all sizes of fish, errors which tend to produce an underestimate (Cooper and Lagler, 1956). To test this, estimates in Hemlock Lake were computed for separate size classifications, using the following categories: (1) 6.0 to 7.9 inches in total length, (2) 8.0 to 8.9, and (3) 9.0 and longer. The summed estimate, 482, is given in Table 1 for the "trap and recapture by trap, sum of estimates of separate size classifications" procedure. When this is compared to the combined estimate, 471, and to the known minimum number, 515, it appears that combining the sizes was not the factor causing the estimate to be too low. Actually, a large error due to combining sizes would probably not be expected, since the size range was narrow and most fish lay between 7.0 and 8.9 inches in length (see Table 3).

Finally, the explanation which was tentatively accepted as most probable was that there was a variation in trap susceptibility among the fish in the lake when used with the hoop-net type of trap. In other words, some individuals were displaying a greater trap susceptibility than others and were captured repeatedly in the traps at a higher rate than others, resulting in a proportion of marked fish in the trap samples that was higher than the proportion of marked fish in the lake.

It was concluded that the "trap and recapture by trap" procedure was not valid when used with hoop-net traps, because it produced estimates which were too low.

"Trap and recapture by trap" estimates, spring, 1957

In the spring of 1957, the "trap and recapture by trap" estimates of the 1956 year class (Table 2) were judged too high in both lakes. As evidence to support this conclusion it may be pointed out that, in both lakes, the estimates started at levels well above the numbers planted the previous autumn, then decreased progressively to level out at the figures presented in Table 2. In fact, in Hemlock Lake the final estimates, over 3,700, were considerably higher than the number planted the previous autumn, 3,000.

Several sources of systematic error are suggested. First, a central release point was used, but for reasons discussed in the previous section this was considered not to be an important source of error.

Another possibility was that, for a mark at this time, an entire pectoral fin was removed, suggesting differential mortality due to the fin removal. To test this postulate, in Hemlock Lake half of the trap-caught fish were marked by removal of a pectoral fin, while the other half were marked by clipping a corner of the caudal, the latter mark obviously not as potentially lethal as the former. The two estimates obtained were nearly identical, 3,750 and 3,711 respectively for the two marks, indicating that the source of the systematic error was not in the fin removal.

Finally, it is suggested that the trout, once caught in the hardware cloth traps, acquired a "trap resistance" similar to that observed with the angler-caught fish the previous autumn. To personify a bit, the fish apparently found the wire traps more objectionable after once having been caught in them. The fact that the estimates started at very high levels and then progressively decreased suggests that the "trap resistance" was being lost over a period of time. A final test of this hypothesis was possible by using the Petersen method with the samples captured on the last day of trapping, since the samples were very large, after

the fish marked earlier had had a "rest." The results for both lakes, given in Table 2, show lower estimates (and considerably narrower confidence intervals), indicating further that the "trap resistance" had been lost to some degree.

In Ford Lake the estimate obtained in this way, for the procedure entitled "trap and recapture by trap, last day's sample," was 5,041 which was a considerable reduction from the estimate of 5,742 for all trapping. Similarly, in Hemlock Lake, the estimate for the pectoral clip was 3,406 and for the caudal clip was 3,206, or reductions from 3,750 and 3,711, respectively, for all trapping. It should be pointed out, however, that these reduced estimates in Hemlock Lake are still higher than the number originally planted (3,000).

It was concluded that the "trap and recapture by trap" procedure, where the wire traps were used, included a systematic error which produced estimates that were too high, and the procedure was judged invalid.

It should be emphasized that while the use of one type of trap (hoop net) produced an estimate known to be low, the use of another type (wire trap) produced an estimate known to be high. The difference apparently is due to the type of trap, and it would be just as unsafe to predict the direction of error in still another type of trap (or these types in another situation) as it would be to assume the procedure to be without error. No suggestions are offered to explain the difference in the behavior of the fish with the two types of traps.

"Mixed" procedure estimates

In Hemlock Lake the estimates of the 1955 year class made in the autumn of 1956 by the two "mixed" procedures--"trap and recapture by angling," 528, and "angling and recapture by trap," 539 (Table 1)--compared well; furthermore there was no error identifiable by judgment against other information such as known minimum number present or numbers planted. However, one systematic error was soon recognized in the "angling and recapture by trap" procedure tending to

produce a high estimate. This was due to the fact that while angling and marking were being done in the afternoon, the traps which had been lifted and reset in the morning, were fishing; in other words, the number of marked fish (by angling) was increasing during the afternoon while the traps were fishing for these marked fish. The number of marked fish used in the calculation for the "angling and recapture by trap" procedure in Table 1 was the number present at the time the traps were lifted (morning), which was the number present at the close of the previous day's angling. The "effective number" present during the total time that the traps were fishing (afternoon to following morning) would be something less. In an attempt to correct for this, the median number was used; that is, a number midway between that present at the time angling began and that present at the close of angling was used in the calculation for the following day's estimate by the "angling and recapture by trap, M corrected" procedure. (An obviously better procedure would be to postpone resetting the traps each day until angling was completed for the day.) The resulting estimate was 524, which was rather strikingly close to the estimate obtained by the other "mixed" procedure, "trap and recapture by angling," 528.

However, both methods of capture apparently discriminated against fish 6 inches in length and shorter, and consequently all estimates made in the autumn of 1956 were probably only of a portion of the 1955 year class. Sampling done with hardware cloth traps and ice fishing a few months later in the winter, where both methods captured many smaller, unmarked fish, provided a check on the autumn estimates since the caudal-clip marks were still easily distinguishable. This check estimate was somewhat higher, and later estimates in 1957 indicated that the winter check estimate was more correct. This does not invalidate the conclusions made regarding the identification of systematic errors, since they would apply to the portion estimated as well as to the entire population as long as the size ranges available to both methods of capture were the same, as Table 3

indicates. Additional estimates were computed by all procedures of the population 7.0 inches and longer, against none of which the methods of capture discriminated; the relationships among these estimates were very similar to those which included all sizes. The importance of using methods of capture to which all sizes of fish are available, however, should be emphasized.

Probably the best estimate of the portion available to both methods of capture of the 1955 year class in the autumn of 1956 was about 530.

In Ford Lake, in the autumn of 1956, the two "mixed" procedures--"trap and recapture by angling" and "angling and recapture by trap"--produced estimates (432 and 500, respectively) which appeared to reflect the systematic error in the latter procedure, particularly since the confidence intervals did not overlap broadly. The correction made in this lake was to modify the field operation by ceasing angling but continuing trapping, and using only the latter trap samples for the estimate. The corrected estimate, 465, is shown in Table 1 for the "angling and recapture by trap, M constant" procedure, and which compares more favorably with the other "mixed" estimate, 432. Apparently the best estimate would be about 450. (No winter check, as in Hemlock Lake, was made in Ford Lake. However, the fish were larger in Ford Lake [see Table 3], and consequently the error due to the unavailability of small fish was probably not as great in Ford Lake. Later estimates in 1957 indicated that 450 was at least a reasonable estimate.)

In both Hemlock and Ford lakes in the spring of 1957, the "mixed" procedure estimates of the 1956 year class (Table 2) were at a more reasonable figure, considering the numbers planted the previous autumn. These were both "trap and recapture by angling" procedures where the trapping was done first and the recapture samples obtained after the trout season opened, the estimates being made by the Petersen method. In Ford Lake the number planted was 5,850,

and the "trap and recapture by angling" estimate was 4,410. The "autumn, 1957, check estimate" was obtained by recaptures made the following autumn for estimating the population as it was in the spring, employing fish given a permanent mark in the spring by complete removal of a pectoral fin. The autumn check estimate in Ford Lake (4,624) was somewhat higher, perhaps because of differential mortality due to the fin removal, and consequently the estimate of 4,410 was considered the better. Similarly in Hemlock Lake, the "trap and recapture by angling" estimate, spring, 1957, was 2,591 (planting was 3,000 the previous autumn), while the "autumn, 1957, check estimate" was higher, namely, 2,997. The latter was felt to be highly unlikely considering the number planted, and the estimate of 2,591 was accepted as the better.

Additional estimates of the 1955 and 1956 year classes were made the following autumn (1957) using only a "mixed" procedure, and since these data do not add to the methodology under consideration here, they are not reported. However, two checks on the procedure were made, and although the results were neither very extensive nor conclusive, mention should perhaps be made of them.

In Hemlock Lake, in the autumn of 1957, the new planting, consisting of the 1957 year class, was made following the population estimation work on the 1955 and 1956 year classes. Immediately after the planting was made, a "mixed" procedure estimate of it was conducted as a check on the method since the number planted was known. The result was an estimate that was much too high--849 (95 percent confidence limits: 618, 1,295)--compared with the number planted, 600. Apparently the behavior and reaction of newly planted hatchery stock is such that capture and handling by any method decreases their activity or in some other manner makes them less vulnerable.

The second check on the procedure, however, was more fruitful. During the estimation of the newly planted 1957 year class it was possible to estimate a known number of the 1956 year class fish marked during the previous operation (estimation of the 1956 year class). The known number was 172, and the estimate of this number was 163, which agreed reasonably well, and which lent further support to the desirability of using a "mixed" procedure.

Synopsis of procedure comparison

Generally, the "pure" procedures were inferior to "mixed" procedures. "Trap and recapture by trap" estimates, when the hoop-net type of trap was used, produced estimates which were known to be low when compared to known minimum numbers present. "Trap and recapture by trap" procedures, when hardware cloth traps were used, produced estimates which were too high, in some cases higher even than the known number planted 6 months previously. "Angling and recapture by angling" procedures produced estimates that were considered too high, presumably due to a "hook resistance" acquired by the fish after once being caught.

In all cases (except with newly planted hatchery fish), "mixed" procedures of "angling and recapture by trap" and "trap and recapture by angling" produced estimates which were compatible with information on planting and known numbers present, and which agreed favorably with each other.

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