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The Impact of Voluntary Catch and Release of Legal-Sized Fish on Recreational Fisheries

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Fisheries Research Report No. 1903

June 30, 1982

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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THE IMPACT OF VOLUNTARY CATCH AND RELEASE OF LEGAL-SIZED FISH ON RECREATIONAL FISHERIES[1]

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Abstract

Catching and releasing fish, even though they may be of legal size to keep under prevailing fishing laws, is a widespread practice among recreational fishermen. However, fisheries managers usually concentrate on estimating fishing effort and number of fish harvested when assessing a fishery, and simply assume that the impact of this voluntary release of legal fish is negligible. The purpose of this study was to examine how the release of legal fish might affect a fishery. The approach was to develop a general population dynamics model for addressing voluntary release and to use the model to study its impact on four fisheries with widely different characteristics of growth, mortality, and fishing: a brook trout (Salvelinus fontinalis) fishery in a small stream, a largemouth bass (Micropterus salmoides) fishery in a 400-ha reservoir, a brown trout (Salmo trutta) fishery in a 30-m-wide river, and a northern pike (Esox lucius) fishery in a typical lake. Results for all four fisheries were similar in showing that the voluntary release of fish can have a substantial impact on a fishery if more than 10% of the legal fish caught are released. By altering the effective fishing mortality rate, it caused changes in fishery statistics to occur even though fishing effort and catch rate remained constant. More field studies are needed to understand the nature and extent of voluntary release of legal fish. Also, fisheries managers need to estimate voluntary release of fish, along with harvest and fishing effort, if they want to assess a fishery accurately.

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan

Introduction

In recent years, organized fishing clubs and many popular outdoor writers have promoted the idea of catch-and-release fishing. They have encouraged anglers to release the fish they catch, even though the fish may be large enough to harvest under the prevailing fishing regulations. They argue that catching a fish is the most valuable component of the recreational fishing experience, and if fish are released unharmed, they might be available for recapture in a future fishing trip. This idea has gained considerable support among sportfishermen, and presently, the practice, of releasing legal-sized fish is widespread. However, quantitative data documenting the extent of the practice are scarce. Fisheries managers usually concentrate on harvest of fish in their creel census designs and simply assume that the impact of voluntary release of legal fish is negligible.

During a creel census on the Au Sable River, Michigan in 1976, anglers were asked to report the number of trout they caught and released that would have been legal to keep under the prevailing minimum size-limit regulations. Thereby, an estimate was made of the number of legal-sized trout caught and released along with the usual estimate of trout harvested. The extent of the voluntary catch and release of fish was rather surprising. Anglers reported releasing from 35% to 56% of the legal fish they caught in different sections of the river restricted to fly-fishing (Alexander et al. 1979). What seemed to be a more typical situation existed in the section of the river under normal fishing regulations (any type of lure permitted). There, only 2% of the legal fish caught were released.

In 1979, Michigan Department of Natural Resources began conducting creel censuses on the Au Sable River on an annual basis for a study of a slot size limit (Clark et al. 1980a). Anglers were again asked to report the numbers of fish they released. The results available through 1981 indicated voluntary release of legal fish by anglers might have increased (Clark et al. 1980b). Anglers reported releasing as high as 85% of the legal fish they caught in the fly-fishing sections and as high as 25% in the section under normal regulations.

It seems unreasonable to assume catch-and-release fishing of this magnitude would have a negligible impact on the fishery, even if hooking mortality is low. Furthermore, the number of fish caught and released is a product with some value. Therefore, from the manager's standpoint, it must be addressed if optimal fishery benefits are the goal.

Release of legal-sized fish is probably higher in the fly-fishing sections of the Au Sable River than in most other fisheries. However, there is little doubt this practice is ubiquitous in recreational fisheries. Goudy (1981) reported creel census results on three largemouth bass (Micropterus salmoides) fisheries in southeastern Michigan. He included an opinion survey, which had questions about catch-and-release fishing, as part of the interviewing process. In the survey 27% of the bass fishermen said they usually released the bass they caught. Also, 36% of the bass fishermen approved of a no-kill regulation if it resulted in their being able to catch and release more large bass.

Catch and release of fish always involves a concern about hooking mortality. Many studies have been conducted in recent years to measure rates of hooking mortality caused by different types of terminal fishing gear, such as artifical flies or natural bait. In a review of the subject, Wydoski (1980) listed 161 references. However, few studies have gone beyond a cursory analysis of the possible impact of catch-and-release fishing and hooking mortality at the population level. The traditional population dynamics models, such as those developed by Ricker (1945), Beverton and Holt (1957), and Schaefer (1954), do not address these factors. The only model available that calculates the number of fish caught and released is that of Clark et al. (1980 a), but the model is limited because it assumes all legal-sized fish are harvested. Thus, it only calculates the number of illegal-sized fish caught and released. This is a serious limitation considering the results of the Au Sable River creel cenus.

The purpose of this report is to examine how the voluntary release of legal-sized fish might affect a fishery. The approach was to develop a general population dynamics model which addresses the phenomenon and to use the model to study its impact on four sport fisheries with different characteristics of growth, mortality, and fishing.

Model Development

The model was developed using the same general approach as Allen (1955 a, b), Beverton and Holt (1957), and Jensen (1981). The change in catch from a cohort and the change in numbers in the cohort with respect to age was given by Jensen (1981) as:

$$
(1) \qquad
\begin{aligned}
\frac{dC}{dx} &= FN, && x > x_c, \\
\frac{dN}{dx} &= -MN, && x_r < x < x_c, \\
\frac{dN}{dx} &= -(F+M)N, && x > x_c,
\end{aligned}
$$

where: F = instantaneous fishing mortality, M = instantaneous natural mortality, N = size of cohort in numbers, C = harvest in numbers, x_c = age at entry into the exploited stock, and x_r = age when fish first become vulnerable to the fishing gear.

This general model must be modified to incorporate the important elements of catch and release. Some fish die after being caught and released, so another mortality component must be added. It can be defined as the instantaneous hooking mortality rate (H). Also, fishing mortality must be defined in a different way. Let:

(2) $$F_s = Q \cdot (1 - p_s),$$

(3) $$H_s = Q \cdot p_s \cdot h,$$

(4) $$F_L = Q \cdot (1 - p_L),$$

(5) $$H_L = Q \cdot p_L \cdot h,$$

where: Q = instantaneous catch rate for all fish vulnerable to gear, p_L = probability that a legal fish is released when captured, h = probability that a caught and released fish will die, F_L = instantaneous harvest rate of sublegal fish, H_L = instantaneous hooking mortality rate of legal fish, and p_s, F_s, and H_s have the same meaning for sublegal fish.

The model now becomes:

$$\frac{dC_L}{dx} = Q\,(1 - p_L)\,N, \qquad x > x_c,$$

$$\frac{dC_s}{dx} = Q\,(1 - p_s)\,N, \qquad x_r < x < x_c,$$

(6) $$\frac{dJ_L}{dx} = Q\,p_L\,N, \qquad x > x_c,$$

$$\frac{dJ_s}{dx} = Q\,p_s\,N, \qquad x_r < x < x_c,$$

$$\frac{dN}{dx} = -[M_s + Q\,(1 - p_s) + Q\,p_s\,h]\,N, \qquad x_r < x < x_c,$$

$$\frac{dN}{dx} = -[M_L + Q\,(1 - p_L) + Q\,p_L\,h]\,N, \qquad x > x_c,$$

where the variables J_L and J_s are the numbers of fish caught and released that are legal and sublegal, respectively. Notice that these equations could also be used to study the impact of illegal harvest (C_s) on a fishery, but that is not the focus of this paper.

Integrating, combining, and substituting appropriate equations gives:

$$(7) \quad C_L = \frac{F_L \cdot R \cdot EXP[-(M_s + F_s + H_s)\ (x_c - x_r) - (M_L + F_L + H_L)\ (x - x_c)]}{M_L + F_L + H_L}$$

$$(8) \quad J_L = \frac{Q \cdot p_L \cdot R \cdot EXP[-(M_s + F_s + H_s)\ (x_c - x_r)\ - (M_L + F_L + H_L)\ (x - x_c)]}{M_L + F_L + H_L}$$

Where R is the number of recruits of age x_r.

The model was coded in FORTRAN, and the program was designed with several useful features. First, it uses the von Bertalanffy growth curve (Ricker 1975, Beverton and Holt 1957) to relate length and age of the cohort. This allows the analyst to express the size limits corresponding to ages x_r and x_c in units of length. Second, the program permits the use of age specific natural mortality rates, if such data are available. This was accomplished by evaluating each of the equations in a stepwise fashion, where each step corresponds to one year of life. This feature complicates the program, and the added detail would not change the results of most analyses. However, it was considered advantageous because age specific natural mortality data are available for many fisheries. Often these natural mortality rates vary considerably with age, especially for very young and very old fish. Thus, using age specific rates may improve the accuracy of the calculations, and the manager's faith in them.

Third, the numbers of trophy-sized fish havested (C_{tr}) and caught and released (J_{tr}) were added to the model in the same manner as

Jensen (1981). This was done by evaluating the catch equations for fish over an age where they are considered trophies (say x_{tr}). That is:

$$(10) \qquad \frac{dC_{tr}}{dx} = Q\,(1 - p_L)\,N, \qquad x > x_{tr},$$

$$\frac{dJ_{tr}}{dx} = Q\,p_L\,N, \qquad x > x_{tr}.$$

Trophy catch is always inversely related to total harvest in a model in which growth remains constant (Clark 1981), and both of these quantities are important to fishermen. Therefore, regulations can be optimized in this model by balancing the relative values of trophy catch and total catch as was done by Jensen (1981).

Fourth, the program allows the use of unconventional size limits, such as inverted or slot size limits. It calculates catches below or between specified limits. For example, the catches for an inverted size limit would be:

$$(11) \qquad \frac{dC}{dx} = Q\,(1 - p_L)\,N, \qquad x < x_d,$$

where fish must be below age x_d to be harvested. The catch under a slot size limit would be calculated with the same equation, but it would be evaluated between two ages (say x_c and x_d).

And finally, the program was designed to be used in an interactive mode, so it can easily be executed from a desk-top terminal or mini-computer. The program questions the analyst for the input data it needs.

All calculations are made on a per recruit basis, so the model requires the usual assumptions of a typical yield-per-recruit model. The fish population is at equilibrium with its environment. Natural mortality, growth, and recruitment are constant and not affected by fishing. Mortality and growth occur continuously and simultaneously. Also, this model assumes that the instantaneous catch rate and the probability a fish will die after catch and release are constant for all fish older than x_r.

The computer program can be obtained from the author.

Analysis of Voluntary Catch and Release

Four sport fisheries with contrasting mortality and growth rates were chosen for study with the model: 1) a brook trout (*Salvelinus fontinalis*) fishery from a small stream, Hunt Creek, Michigan (McFadden et al. 1967); 2) a largemouth bass (*Micropterus salmoides*) fishery from a 400-ha reservoir, Kent Lake, Michigan (Goudy 1981); 3) a brown trout (*Salmo trutta*) fishery from a 30-m-wide river, the Au Sable River, Michigan (Clark et al. 1980a); and 4) a typical northern pike (*Esox lucius*) fishery for Michigan (Latta 1972).

The analysis of voluntary catch and release was very simple. The references listed were used to obtain the rates of growth, mortality, and fishing for each fishery. These rates were kept constant in the model, and the only parameter changed was the probability a legal fish was released when caught (p_L). It was varied over the full extent of its range from 0.0 to 1.0, or in other words, from the point where all legal fish are harvested to the point where all are released. Resulting changes in the catch of all fish and the catch of trophy-sized fish were used to gauge the effects of voluntary catch and release.

The growth equation of von Bertalanffy was fitted to data available for each species using an interactive procedure (Rafail 1973). Growth was considerably different among the species, with brook trout growing slowest and northern pike growing fastest (Table 1). Natural mortality differed a great deal between species also, with brook trout sustaining exceptionally high natural mortality and largemouth bass sustaining exceptionally low natural mortality (Table 2).

Fishing mortality, regulations, and methods varied widely among the four kinds of fish (Table 3). No information was available on the voluntary release of legal fish for brook trout, largemouth bass, or northern pike. For the sake of argument, it was assumed that few fishermen released any legal fish in these fisheries. In the context of the new model this means $p_L = 0.0$, and from equation (4), $F_L = Q$. Thus, the instantaneous fishing mortality rates (F as defined by Ricker 1975) taken from the respective references for these species were equated to the instantaneous catch rates (Q). Data on voluntary release were available for the brown trout fishery of the Au Sable River. As reported earlier, it varied from 35% to 85% of the legal fish caught, so a value of 50% was assumed for this analysis (or $p_L = 0.50$). The instantaneous fishing mortality (F) reported for the brown trout was 0.36, so the instantaneous catch rate (Q) from equation (4) was 0.72.

An attempt was made to choose values for the probability of death after catch and release (h) which corresponded to the gear types used in each fishery and the characteristics of each species. For example, a value of 0.05 was used to represent fly-fishing-only regulations for brown trout. This value and the others (Table 3) may be somewhat arbitrary, but they are certainly reasonable values judging from the literature on the subject (Shetter and Allison 1955, 1958; Wydoski 1980). The most important consideration for this analysis was that a fairly wide range of hooking mortality was represented.

The sizes of first vulnerability to the fishing gear were chosen based on experience (Table 3). Ages corresponding to these lengths are model parameters (x_r), and they were computed from the von Bertalanffy growth equations for each species. Likewise, the minimum size limits for each fishery (Table 3) were used to compute the ages of entry into the exploited stocks (x_c). The sizes and ages at which each kind of fish becomes a trophy were chosen subjectively (Table 3). They were not meant to be representative of trophy fish on the world scale, but only to represent the larger fish in the respective fisheries.

Results of the analysis were based on 1000 recruits starting at age x_r. The effect of varying the percent of legal fish released on the total catch of fish was similar for each species (Fig. 1). As voluntary release of fish increased, total harvest decreased and total catch-and-release frequency increased. Since the catch-and-release frequency increased at a faster rate than the harvest decreased, the total catch (harvest plus catch-and-release) increased. Total catch was maximum when all fish were released.

The effect of voluntary release on the catch of trophy fish was similar for brook trout, brown trout, and northern pike (Fig. 2). Harvest of trophies increased as voluntary release of fish increased until it reached a maximum value where 40% to 60% of the legal fish caught were released. All of these harvest curves were rather flat until about 80% of the legal fish were released. Thus, the harvest of trophy fish in these fisheries was not very sensitive to the voluntary release of fish. However, there was a tremendous impact on the catch-and-release and total catch of trophies, both increased rapidly in exponential fashion and reached a maximum when all fish were released.

The effect of voluntary release of fish on the harvest of trophy largemouth bass was slightly different from the others. It was maximum when all legal fish were harvested and decreased continuously as release of fish increased (Fig. 2). One might speculate that largemouth bass behaved differently due to the combined effects of their low natural mortality rate, high hooking mortality rate, young age of attaining trophy status, and low catch rate (Tables 2 and 3). However, further analysis with the model, in which each of these variables were varied separately, showed that the low catch rate (Q = 0.22) was the one and only reason for the unique trend in trophy harvest. As the catch rate increased, the maximum value of the trophy-harvest curve decreased and shifted toward higher release rates (Fig. 3). The trends in trophy catch and harvest for largemouth bass at the higher catch rates were similar to those of the other three species.

Discussion

Releasing legal-sized fish has the effect of reducing the fishing mortality, and therefore the total mortality, sustained by the population. The catch rate will not change unless fish learn to avoid capture from experience. It is then inevitable, under the assumptions of this analysis, that when voluntary release increases: 1) the total catch of all fish and the total catch of trophy fish will increase; 2) the harvest of all fish will decrease; and 3) the harvest of trophy fish may either increase or decrease depending on the catch rate.

What this means in more practical terms can be seen by examining the results of the analysis for the brown trout fishery of the Au Sable River. This was the only fishery used for which field data were available to document the extent of voluntary release. Under a 203-mm size limit, fishermen of the Au Sable River would catch about 300 brown trout per thousand recruits, and of those, 1.14 would be of trophy size (Figs. 1 and 2). This relatively high catch would be possible only if they continued to release 50% of the legal fish they caught. If the fishermen decided to harvest every legal fish they caught, they would catch 15% fewer fish in total (256 fish) and 64% fewer trophy fish (0.41 trophies). Total harvest was 41% less under the condition of 50% release of legal fish than it was when every fish was kept, but it seems almost ironic that the harvest of trophies was 38% higher. Of course, this was made possible because voluntary release of fish reduced the total mortality between the age of entry into the fishery (x_c) and the age of entry into trophy size (x_{tr}). More fish were then available for harvest at the trophy size.

All real-world fisheries will violate the model assumptions to some degree. The question is whether or not they will violate them enough to change the results of the analysis. Adequate field data are available for trout stream fisheries in Michigan to show that these fisheries will not violate model assumptions to a large degree (McFadden et al. 1967; Clark et al. 1980 a, 1981; Clark 1981). Therefore, the brook trout and brown trout fisheries used in this analysis would probably behave as predicted.

On the other hand, largemouth bass and northern pike fisheries are usually part of ecosystems which are more complex than trout streams, and the extent to which they would behave as predicted by a yield-per-recruit model is unknown. There is evidence to show that changes in harvest rates or fishing regulations can cause compensatory changes in growth and natural mortality for these species (Graham 1972; Kempinger and Carline 1978), and this would cause deviations from predictions of yield-per-recruit models. However, there is also evidence that yield-per-recruit models have been successful in predicting the behavior of these fisheries (Latta 1972; Latta 1974; Schneider and Lockwood 1979; Goudy 1981).

Further complicating the matter, there is evidence that the susceptibility of largemouth bass to capture decreases as they gain experience with fishing, and this may also be true of other kinds of fish. Westers (1963), Anderson and Heman (1969), and Schneider (1973) found that largemouth bass with no prior angling experience were highly vulnerable to capture, but their catchability declined rapidly after being subjected to angling.

On the other hand, Hackney and Linkous (1978) found only a slight tendency for conditioning of learning to avoid capture, and only among naive largemouth bass exposed to bait angling for the first time. Largemouth bass which were no longer naive and/or were sought with artificial lures had an equal probability of capture and appeared to strike at random. Many of the bass in their three-month experiment were caught twice per day, and one individual was captured three times in little more than an hour. Weithman et al. (1980) reported similar frequencies of recaptures for largemouth bass in a private impoundment in Missouri.

Even with its shortcomings in proper perspective, results of this analysis have important implications for recreational fisheries managers. First, a judgment: the impact on a fishery of voluntary catch-and-release can be assumed negligible if less than 10% of the legal fish caught are released. The presence of voluntary release of fish at higher than 10% changes the interpretation of creel census estimates of catch and fishing mortality. Also, it means that harvest rate (instantaneous fishing mortality) could change considerably while catch rate and fishing effort do not change. This is a crucial point if one wants to study differences in fisheries between one area and another or differences in a single fishery caused by changes in regulations or other management actions.

For example, voluntary release of fish may be an increasing trend in many fisheries. If so, historical data on harvest and fishing effort under an old regulation may not be directly comparable to data under a new regulation. Furthermore, voluntary release of fish may be size related. If this is true, catch and effort data comparing a 203-mm size limit to a 305-mm size limit may be misleading. The conclusion is that more field studies are needed to understand the nature and extent of voluntary release of fish. Also, sport fisheries managers need to estimate voluntary release of fish, along with harvest and fishing effort, if they want to assess a fishery accurately.

Finally, because voluntary release of fish has the effect of reducing the fishing mortality rate, open encouragement of this practice by fisheries managers may be a viable management alternative. Practically speaking, fisheries managers have few alternatives available to them when it comes to regulating a fishery. They can limit the harvest through size limits, bag limits, gear restrictions, total-annual-catch quotas, controlling the number of fishermen, or limiting the time fished. All these alternatives have only one basic goal, to direct and maintain the fishing mortality at a level which provides optimum societal benefits. Voluntary release of fish has the advantage of reducing fishing mortality, while at the same time, producing positive benefits in return, increased total catch and trophy catch. However, it may prove to be a sociological factor that cannot be influenced by managers. Even if it does, managers should be aware of its effects on the fishery and on their fishery statistics.

Acknowledgments

I am grateful for the reviews I received on this manuscript from G. R. Alexander, H. Gowing, J. C. Schneider, and W. C. Latta of Michigan Department of Natural Resources. B. A. Gould and G. M. Zurek typed several drafts of the manuscript until the final version evolved. A. D. Sutton drafted the figures.

Table 1. Predicted lengths in millimeters at age for the four species of fish studied using the von Bertalanffy growth equation with the parameters listed.

Age	Brook trout	Largemouth bass	Brown trout	Northern pike
1	78	104	104	320
2	145	205	173	402
3	200	283	238	481
4	246	344	297	558
5	284	391	353	631
6		427	404	702
7		455	451	770
8		476	495	836
9		493	535	900
10		506	572	961
PARAMETERS				
K	0.1842	0.2570	0.0780	0.0368
L_∞	475	550	1033	2593
t_o	0.0282	0.1880	-0.3540	-2.5840

Table 2. Instantaneous natural mortality rates by age for the four species of fish studied.

Age	Brook trout	Largemouth bass	Brown trout	Northern pike
1	1.109	0.158	0.261	0.713
2	1.514	0.158	0.494	0.713
3	3.507	0.158	2.408	0.713
4	3.912	0.158	1.609	0.713
5	4.605	0.158	1.609	0.713
6		0.158	2.303	0.713
7		0.158	3.000	0.713
8		0.158	3.000	0.713
9		0.158		0.713
10		0.158		0.713

Table 3. Fishing parameters used for each species. Q = instantaneous catch rate, h = probability of death after catch and release x_r = age at first vulnerability to fishing gear, x_c = age of entry into the exploited stock, and x_{tr} = age when fish are first considered to be trophy size. Lengths (mm) associated with each of the age parameters appear in parentheses.

Model parameter	Brook trout	Largemouth bass	Brown trout	Northern pike
Q	1.90	0.22	0.72	0.52
h	0.30	0.20	0.05	0.10
x_r	1.61 (120)	1.95 (200)	1.23 (120)	1.05 (325)
x_c	2.58 (178)	3.33 (305)	2.45 (203)	3.34 (508)
x_{tr}	4.00 (246)	6.00 (427)	5.00 (353)	7.00 (770)

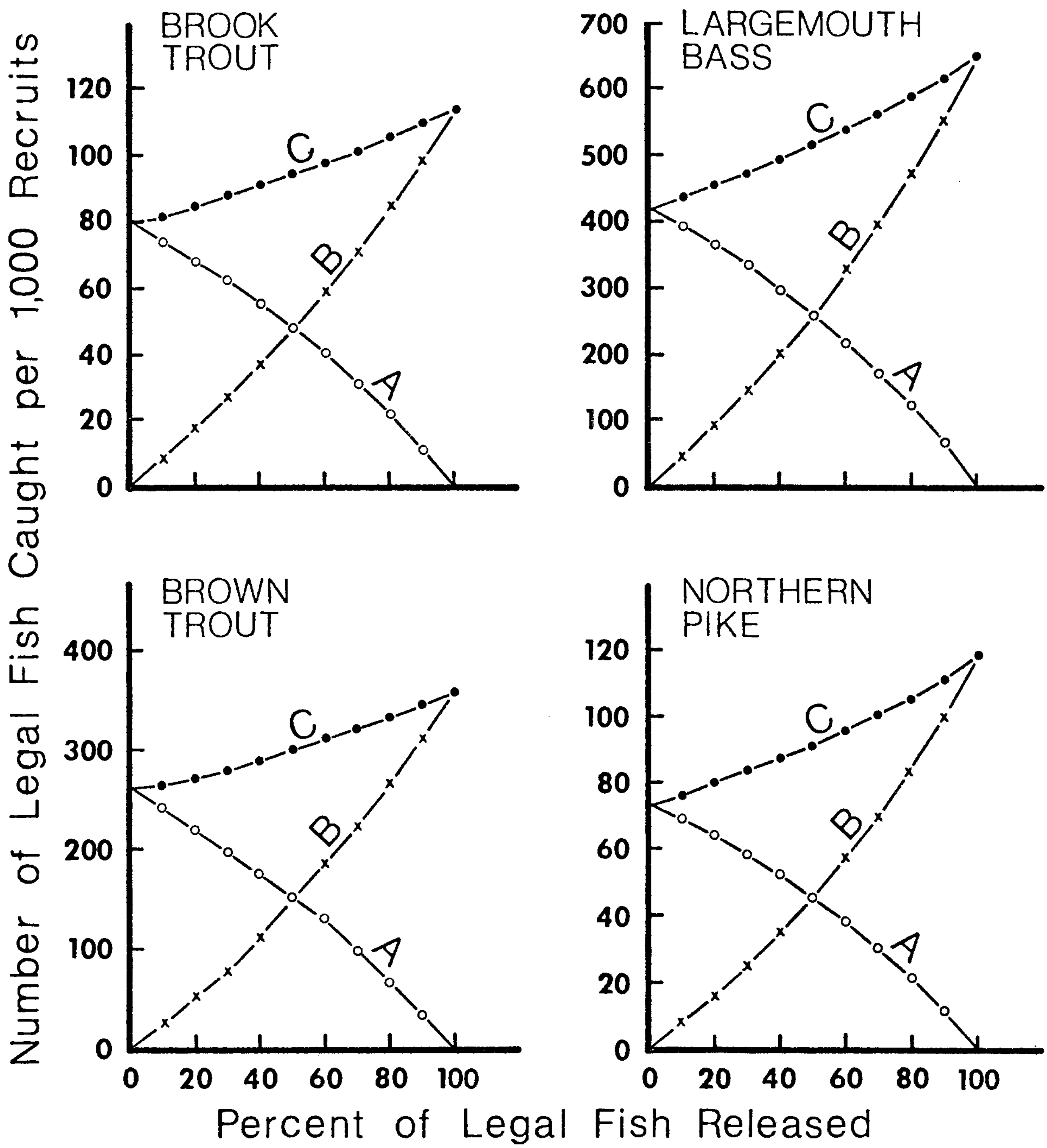

Figure 1. The effect of varying the percent of legal fish caught and released on the number of legal fish harvested (line A), the number caught and released (line B), and the total number caught (line C = A + B).

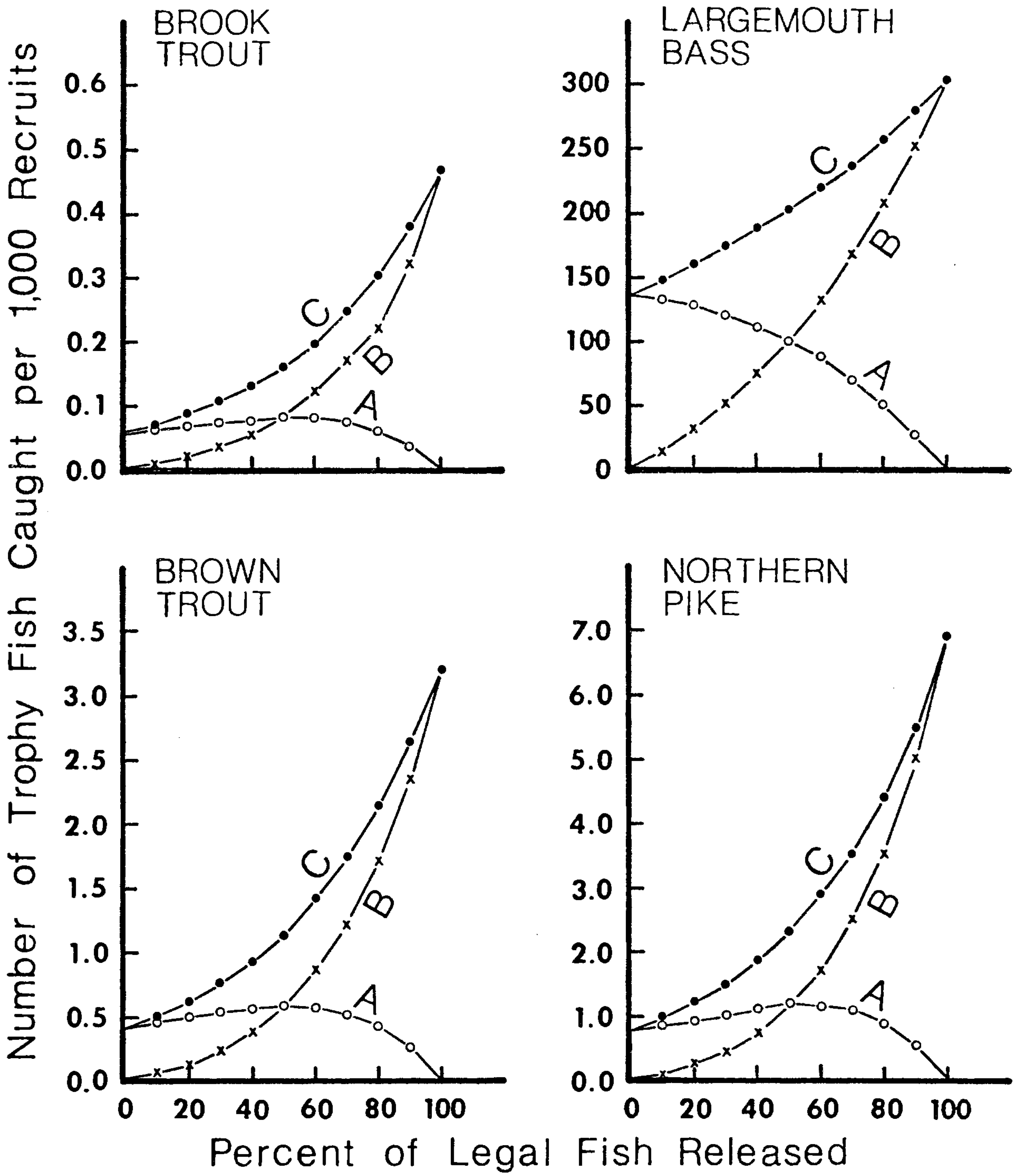

Figure 2. The effect of varying the percent of legal fish caught and released on the number of trophy fish harvested (line A), the number caught and released (line B), and the total number caught (line C = A + B).

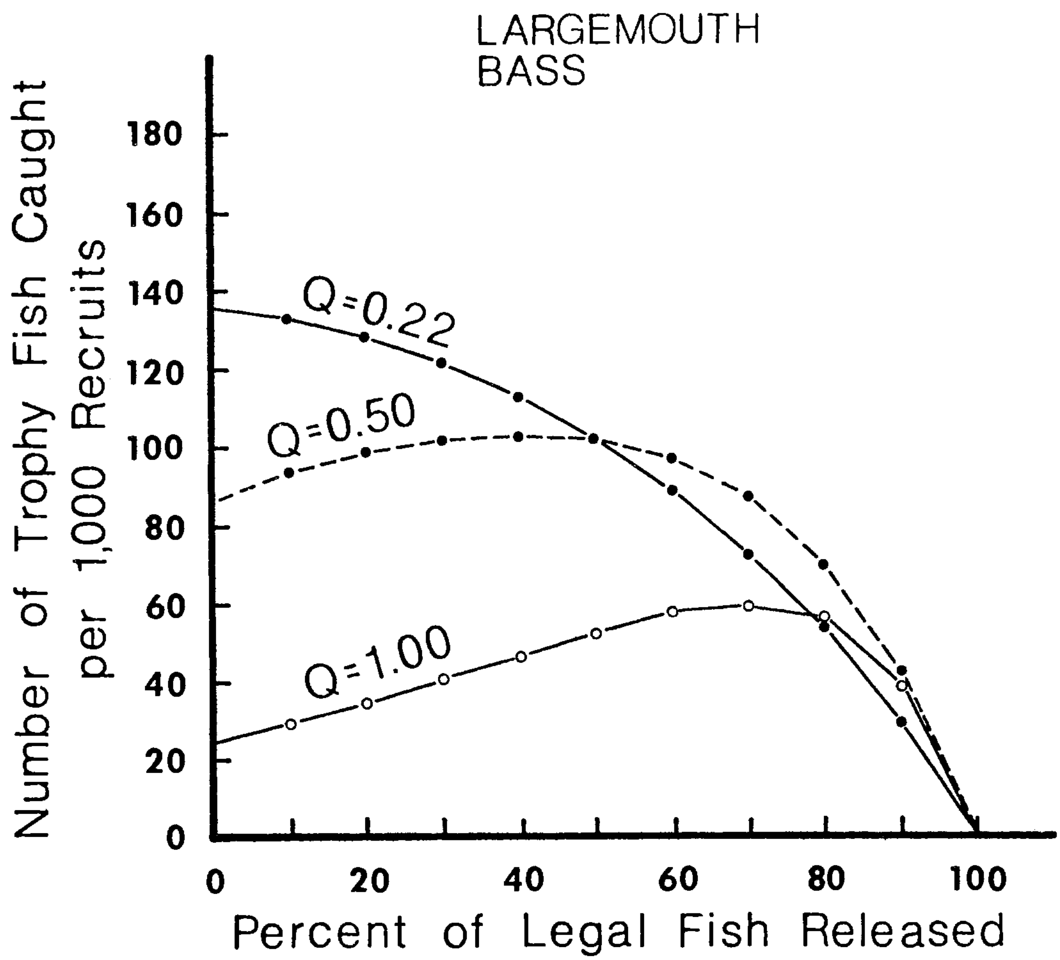

Figure 3. The relationship between the percent of legal fish caught and released and the number of trophy fish harvested for three different catch rates applied to largemouth bass in Kent Lake, Michigan.

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Typed by G. M. Zurek