North American Journal of Fisheries Management 10:106–110, 1990

The Effect of Illegal Harvest on Recreational Fisheries

LARRY M. GIGLIOTTI[1] AND WILLIAM W. TAYLOR

Department of Fisheries and Wildlife
Michigan State University, East Lansing, Michigan 48824-1222, USA

Abstract.—The degree of compliance with a fishing regulation can have a significant impact on the regulation's effectiveness. In this paper, we use a yield-per-recruit simulation model to evaluate the effect of poaching on legal harvest in sport fisheries. Two types of illegal harvest were considered: harvest of fish below the legal size limit and harvest of fish from catch-and-release fisheries. The results depict the degree of reduction in legal harvest in minimum-size fisheries with 0–100% (in 10% increments) illegal harvest. For brook trout *Salvelinus fontinalis*, the reduction in legal harvest ranged from 11% at 10% illegal harvest to 72% at 100% illegal harvest; these reductions ranged from 10 to 66% for northern pike *Esox lucius*, 8 to 57% for brown trout *Salmo trutta*, and 2 to 22% for largemouth bass *Micropterus salmoides*. In catch-and-release fisheries, illegal harvest reduces the number of fish caught and released. Most of the benefits of catch-and-release regulations, in terms of increased numbers and sizes of fish, are lost when approximately 20% of large-sized fish (i.e., fish that would be legal in a minimum-size fishery) are harvested illegally. When all sizes of fish that can be caught by the fishing gear are illegally harvested, the benefits of the catch-and-release regulation are lost when illegal harvest reaches approximately 15%.

Since Swingle's (1950) early research on balance in fish populations, fishery managers have realized the importance of size structure of fish populations in producing good yields of sport fish. The key to providing balanced fish populations lies in maintaining sufficient numbers of larger-sized fish because these individuals are the effective predators and reproducers. Because anglers are generally interested in catching these large fish, balanced fish populations can usually only be achieved through regulations (e.g., creel limits, size limits, restrictions on gear, and seasons) that control the sport harvest.

One of the most common regulations imposed on anglers is the minimum-size limit, which requires anglers to release fish below a specified size that they may otherwise have harvested. One of the premises of releasing undersized fish is that the fish will survive and contribute to the fishery by being available for harvest at a larger size. According to Hunt (1970), "the size limit, if wisely applied, is the best single regulation for preventing excessive angler harvest of brook trout [*Salvelinus fontinalis*] populations."

With increasing demands on fisheries resources, even size limits may not adequately protect fish populations and provide good angling opportunities (Weithman and Anderson 1977). Some anglers have become quite vocal in their demands for quality fishing opportunities, with "quality" loosely defined as more large-sized fish. Catch-and-release regulations have been one tool used by fishery managers (Cordes 1977) to provide this quality angling. These regulations are based on the logic that released fish will be available to be caught several more times at increasingly larger sizes (Wydoski 1977).

Even the best regulations will be inadequate if illegal harvest is too great. Noncompliance with regulations, whether they are minimum-size restrictions or specialized catch-and-release regulations, could block the goal of providing larger fish for recreational fishing. For this reason, fishery managers need an understanding of the effect that noncompliance with regulations can have on recreational fisheries.

The purpose of this paper is to demonstrate the usefulness of a yield-per-recruit simulation model for evaluating the effect of illegal harvest (poaching) on the four specific sport fisheries described and modeled by Clark (1983). We do this by evaluating the effects of poaching on harvest in minimum-size fisheries and on catch rate in catch-and-release fisheries.

Methods

The biological model for estimates of fish abundance used in this paper was described in detail by Clark (1983). This model is a modification of the yield-per-recruit model (Beverton and Holt 1957) and was used by Clark for evaluating the biological consequences of voluntary catch and re-

[1] Present address: Department of Natural Resources, 126 Fernow Hall, Cornell University, Ithaca, New York 14853, USA.

lease. Clark partitioned total instantaneous mortality (Z) into three components: natural (M), fishing (F), and hooking (H) mortality; hooking mortality accounts for fish that die after being caught and released. Another parameter (p), representing the probability that a legal-sized fish was released after capture, was added to modify the levels of fishing and hooking mortality. The model predicts the numbers of legal, sublegal, and trophy-sized fish that are captured. Size structure of the sublegal harvest was proportional to the population size structure. The calculations in Clark's model are made on a per-recruit basis so that the following assumptions of the yield-per-recruit model are necessary (Clark 1983).

(1) The fish population is at equilibrium with its environment.
(2) Natural mortality and growth are constant and not affected by fishing.
(3) Mortality and growth occur continuously and simultaneously.

Also, the assumption is made that the instantaneous catch rate and the probability that a fish will die after its release are constant for all fish older than the age at first vulnerability to fishing gear.

We analyzed the same four Michigan sport fisheries used by Clark (1983). These four fisheries, which had contrasting mortality and growth rates, were

(1) brook trout in Hunt Creek, a small stream (McFadden et al. 1967);
(2) largemouth bass *Micropterus salmoides* in Kent Lake, a 400-hectare reservoir (Goudy 1981);
(3) brown trout *Salmo trutta* in the Au Sable River, a 30-m-wide river (Clark et al. 1980); and
(4) northern pike *Esox lucius* in a lake (Latta 1972).

We evaluated two types of regulations for each of the four fisheries: a minimum-length limit (brook trout, 178 mm; brown trout, 203 mm; largemouth bass, 305 mm; northern pike, 508 mm) and catch and release only. For each of these cases, the poaching rate ($1 - p$) was varied from 0 to 100% (by manipulation of p in the model) by 10% increments to define the relation between poaching and legal harvest. Results of the analyses were based on 1,000 recruits starting at age of first vulnerability to fishing gear (Clark 1983).

TABLE 1.—Relation between poaching rate (probability that a sublegal-size fish will be kept), the number (N) of legal-sized fish harvested per 1,000 recruits, and the percentage reduction (R) in the legal harvest. Minimum-length limits used for these simulations were 178 mm for brook trout, 203 mm for brown trout, 305 mm for largemouth bass, and 508 mm for northern pike.

Percent illegal harvest	Brook trout		Brown trout		Largemouth bass		Northern pike	
	N	R	N	R	N	R	N	R
0	79	–	256	–	415	–	73	–
10	70	11	235	8	405	2	66	10
20	61	23	216	16	396	5	59	19
30	54	32	199	22	386	7	53	27
40	47	41	183	29	377	9	48	34
50	42	47	168	34	368	11	43	41
60	36	54	155	39	359	13	39	47
70	32	59	143	44	350	16	35	52
80	28	65	131	49	342	18	31	58
90	24	70	121	53	334	20	28	62
100	22	72	111	57	325	22	25	66

Results

Minimum-Length Limits

The effect of poaching on legal harvest was greatest for brook trout; the reduction in the number of legal-sized fish caught per 1,000 recruits ranged from 11% at a 10% poaching rate to 72% at a 100% poaching rate (Table 1). Over this same range of poaching rates, reductions in legal harvest were 10–66% for northern pike, 8–57% for brown trout, and 2–22% for largemouth bass. The effect on the largemouth bass fishery was low because of the relatively low instantaneous catch rate (Q) used for this species in the model ($Q = 0.22$ versus 1.90 for brook trout, 0.72 for brown trout, and 0.52 for northern pike).

Catch and Release

We considered two types of illegal harvest from a catch-and-release fishery: illegal harvest of fish that would be legal in a minimum-size fishery (large-sized fish) and illegal harvest of all sizes vulnerable to fishing gear. The effect of poaching rate on the total number of fish caught and released was similar for each species (Figure 1). In catch-and-release fisheries, illegal harvest (both types) can have a substantial effect on the numbers of large-sized fish legally caught and released. This is because, in a catch-and-release fishery, the total number of fish caught and released (the product from such a regulation) goes to zero at 100% illegal harvest.

The difference between the catch rate under 0%

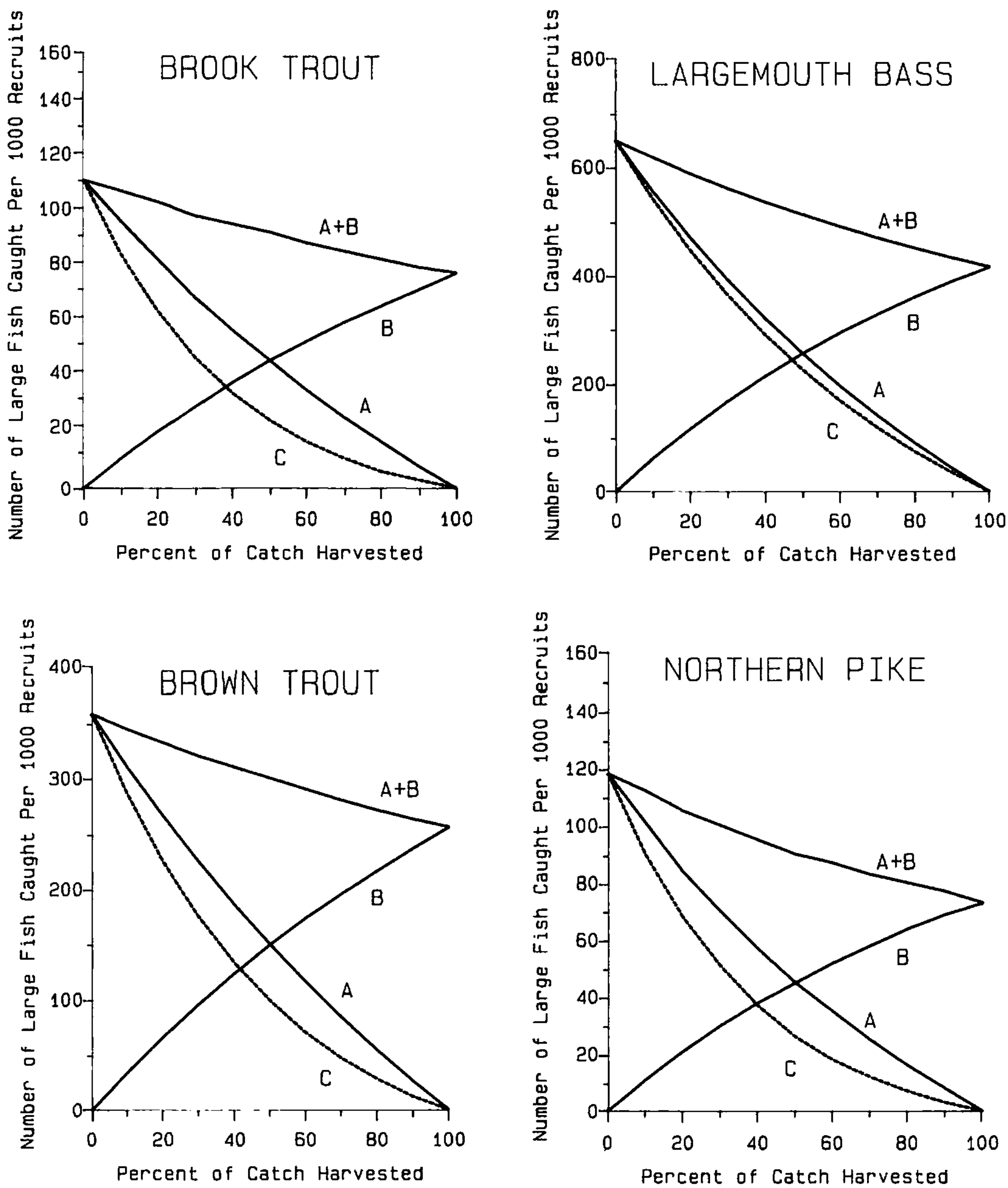

FIGURE 1.—The effects of varying the percentage of large brook trout (>178 mm long), large largemouth bass (>305 mm), large brown trout (>203 mm), and large northern pike (>508 mm) illegally harvested from a catch-and-release fishery for each species on legal catch rate (A), illegal harvest (B), and total catch rate (A + B). Line C in each panel represents the effect of varying the percentage of all sizes of fish illegally harvested from the catch-and-release fishery on the number of larger fish caught and released.

illegal harvest and the catch rate under 100% illegal harvest of only large-sized fish represents the difference between a catch-and-release fishery and a minimum-size fishery with no illegal harvest of sublegal fish. Thus, it represents how many more fish can be caught when a minimum-size fishery changes to a catch-and-release fishery. This permits the estimation of the amount of illegal harvest that eliminates the benefits of the catch-and-release regulation.

Most of the benefits of fishing legally under catch-and-release regulations are lost if between 20 and 30% of the large-sized fish are illegally harvested (Figure 1). With this intensity of illegal harvest, the total number of fish caught nearly equals what the legal harvest would be in a minimum-size fishery. Specifically, the illegal harvest rate that reduced all benefits of catch and release to those of a minimum-size fishery were 22% for brook trout, 24% for brown trout, 26% for largemouth bass, and 28% for northern pike.

If on the other hand, the illegal harvest includes all catchable fish, then the impact on the catch-and-release fishery is even more dramatic for each species (Figure 1). As an example, for northern pike, 28% illegal harvest of only large-sized fish eliminates all benefits of the catch-and-release regulation, but if illegal harvest includes all catchable fish, then about 15% illegal harvest reduces all benefits of the catch-and-release regulation. Also, approximately 15% illegal harvest of all catchable sizes reduces all benefits of catch-and-release regulations for brook trout and brown trout and 24% illegal harvest of all catchable largemouth bass reduces all benefits of catch-and-release.

Discussion

In a fishery, some of the most dynamic components of the system are people and their behavior (Orbach 1980). People have a variety of direct and indirect effects on the fishery and desire a variety of benefits from the fishery resource. The primary goal of sport-fishery management is to provide environments that satisfy human desires for recreation while simultaneously protecting the environment from overuse or misuse that would render natural processes incapable of their normal resiliency (Orbach 1980). Accomplishment of this goal requires that fishery managers have a good understanding of the satisfaction that people seek from a fishery and an understanding of the ways people participate in fisheries, in addition to an understanding of the ecology and biology of fish species. Only then can regulations be used effectively.

Although there are not many reports of illegal harvest, due to the difficulty of obtaining data, the few studies available show that illegal harvest can be substantial in some areas. Gabelhouse (1980) found that sublegal largemouth bass constituted 0–90% of the annual harvest in seven Kansas reservoirs. The harvest of sublegal largemouth bass recorded in a creel survey at Big Creek Lake, Iowa, ranged from 28 to 39% of the total catch, but many sublegal fish were close to legal size (Paragamian 1982). Glass (1984) reported that the portion of sublegal largemouth bass varied seasonally from 8 to 67% of all largemouth bass taken from Sooner Lake, Oklahoma. He also reported that most of the illegally harvested fish were not ones near the length limit, but were obviously sublegal fish.

The extent of illegal harvest in a recreational fishery may very well be the fishery manager's greatest unknown and could easily be the one factor blocking attainment of management objectives for the fishery (Paragamian 1984). For example, Michaelson (1983) reported a case of a district biologist whose sampling indicated a poorly structured fish population in a lake that historically supported excellent fishing. This population improved substantially in a single year after law enforcement efforts on the lake were greatly increased to reduce the number of fishing violations.

Use of Clark's model, with appropriate fishery-specific biological parameters, will enable fishery managers to evaluate the effect of various levels of illegal harvest of sublegal-sized fish on the harvest of legal-sized fish. By collecting information on the level of illegal harvest in various fisheries, managers can direct enforcement efforts to areas where noncompliance has the greatest effect or prevents attainment of a management objective. After all, decreasing illegal harvest is a valid way to increase legal harvest.

Clark (1983) has shown that releasing legal-sized fish can have a significant effect on the fishery by increasing total numbers of fish caught. Thus, catch-and-release regulations have been one tool used by fishery managers to produce quality fishing. However, our research shows that the benefits of a catch-and-release fishery are quickly reduced by illegal harvest. Therefore, when catch-and-release management areas are established, some plan should be included to ensure compliance with the regulations. For catch-and-release fisheries, in addition to knowing the amount of illegal harvest, managers need to estimate the nature of illegal harvest with respect to the size of fish removed because the size of fish illegally removed will affect the total catch rate.

Fisheries managers need to be concerned not only about the effect of illegal harvest on catch or harvest, but also the effect on users. A preliminary field study of angler attitudes towards regulations indicated that most trout anglers fishing in special regulation areas would have their satisfaction lowered "very much" (70.0%, $N = 35$) or "somewhat" (22.0%, $N = 11$) if they saw other anglers violating the regulations (Gigliotti 1989). In general, anglers believed that their fishing area was being neglected by fishery managers if the violation rate was, in their opinion, too high. Thus, the satisfaction of anglers may be increased by reducing illegal harvest, even in areas where the resource is not threatened. Because noncompliance with regulations can affect the satisfaction of anglers, there is a definite need for close cooperation between fishery managers and law enforcement officials.

Acknowledgments

We would like to thank R. D. Clark, Jr., for the use of his model and for his editorial help on an earlier draft. Thanks also to D. B. Jester for his editorial assistance on the final draft and to W. C. Latta for his editorial comments on an earlier draft. D. B. Hayes drafted the figures and provided helpful suggestions on an earlier draft of the manuscript. This research was supported by the Michigan Agricultural Experiment Station.

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