Keynote Symposium

Trends in Freshwater Sport Fisheries of North America

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". . . . there I sat and watched the fishes, and kept spinning the bait with the rods. And one of the fish nibbled, a fat one, for in sleep dogs dream of bread, and of fish dream I. Well he was tightly hooked and the blood was running, and the rod I grasped was bent with struggle. So with both hands I strained and had a sore tussel for the monster. How was I ever to land so big a fish with hooks all too slim?"

Aside from minor differences in diction this fish story might have come from a contemporary outdoor magazine; actually it is from the 21st idyll of Theocritus, written in the third century B.C. The passage reflects vividly the fascination, anticipation, and challenge of a sporting experience which consists essentially of two parts: the quest—an adventure in angling methodology; and the attainment of a tangible reward for effort—only a fish-in-hand will do (Figure 1). But this core of the angling experience may be enjoyed in such a variety of natural and social environments, and through such a variety of techniques and conventions that—aside from the inevitable involvement of fish and men—the sport must mean very different things to different people. Because of this, sport fishing has been able to serve the recreational needs of a heterogeneous human population through eras of rapid social and economic change. But, though we may be pleased with the viability of the sport to date, have we any basis for expecting it to survive through, say, the next half-century in a form useful to man? Do we have enough water, enough fish, and enough know-how to preserve the values unique to recreational fishing? To answer these questions it is necessary to consider some of the factors which will influence trends in sport fishing or which may ultimately set a limit to its expansion, and some ways in which we can influence the nature and magnitude of sport fisheries of the future.

A résumé of the predictions of Outdoor Recreation Resources Review Commission Study Report Number 7 (1962) and recent projections of human population growth (U.S. Department of Commerce, 1967) provides a useful point of departure. For convenience, consideration is limited to the public waters of the contiguous 48 states of continental United States, which include 22,120,000 acres of freshwater lakes, streams, and reservoirs. Assuming that loss of public waters (for example by pollution or lack of access) will be balanced by creation of new waters by impoundment, this acreage figure is used as a measure of the sport fishery base.

The population of the U.S. has grown from about 5 million in the year 1800 to 76 million in 1900; to 196 million in 1966; and is expected to reach 286.5 million by the year 1990 (Figure 2), based on the assumption that the average number of children per woman at the end of child bearing will move gradually toward 3.1. The predictions, of course, are vulnerable to vagaries such as economic fortunes, power grid failures, and Papal encyclicals. Projections based on alternative assumptions place the population of year 1990 at 256,000,000 to 300,100,000. The intermediate projection chosen above extrapolates linearly to a population of about 325,000,000 at the turn of the century. Actually, in the U.S. the rate of increase is declining, but there are so many of us doing it that the trend line continues to rise sharply. This situation is something like a spruce budworm outbreak—Figure 2 wouldn't look so bad on a logarithmic scale.

Of the 325,000,000 people of the year 2000, it is estimated that 18 percent will be fishermen, that they will fish an average of 20 times per year, and that 70 percent of this fishing activity will take place in freshwaters

FIGURE 1.—The thrill of possession—scientific studies verify the belief that an essential element of the angling experience is securing a tangible reward for effort (Brown, 1968).

FIGURE 3.—More and more Americans are competing for the use of recreational fisheries. How do we divide a limited sportfish harvest?

of the United States. Thus 819,000,000 fishing trips will be logged on our freshwater lakes, streams, and reservoirs annually. If, in deference to the present salmon boom, we assume that the Great Lakes will absorb twice the fishing activity predicted in ORRRC Report No. 7 and subtract this from the total for freshwater fishing, the remainder of 747,000,000 angling trips is projected for the year 2000 for freshwaters of the U.S. exclusive of the Great Lakes. Assuming next that public waters will support 88 percent of this activity (present levels exceed 75 percent) it is estimated that 657,400,000 fishing trips will be made to public freshwaters exclusive of the Great Lakes. For the 22,120,000 acres of public lakes, streams, and reservoirs in the contiguous 48 states, where most of this fishing will be done, this averages 30 trips per acre annually, or assuming a trip to average 4 hours in duration, 120 hours per acre. Present levels of intensity are about half this (57 hours/acre). Clearly we face a monumental task in dividing limited fishery resources among an increasing number of new Americans (Figure 3).

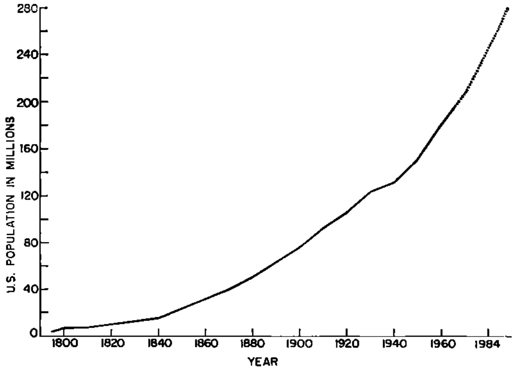

FIGURE 2.—Growth of the human population of the United States, with a projection to the year 1990.

It is not very satisfactory to talk of fishing intensity or yield from a continental fishery of great diversity in terms of average per unit area. The productivity of the water, length of season during which fishing is attractive, and the capacity of waters to absorb intensive use by fishermen and competing recreational groups vary tremendously. At present some waters are very lightly fished while others are subjected to fishing intensities in excess of 2000 hours per acre (McFadden, 1961). Considering first the large areas of water included in the continental total which are relatively unproductive because of extremes of depth, unfavorable water chemistry, or domination by unattractive species of fish, and secondly the premium put on solitude in some forms of angling, the projected average of 120 hours of fishing per acre of water represents intensive use indeed.

Ultimately, the intensity of sport fishing in our freshwaters could be limited by (a) technological inability to increase yield; (b) refusal of human beings to tolerate further crowding while fishing; (c) lack of money to manage the resource at maximum capacity.

Whether the money required to produce maximum yields and maximum fishing intensity will be made available to management agencies in the future is a difficult question to answer. The traditional belief that sport fishing is a right to be enjoyed at token cost restricts expenditures for management at the present time. But attitudes toward natural resources are changing away from the primitive exploitative view toward one of responsible husbandry. From an ecological point of view, man has no feasible alternative. However, an ecologically sound social order of the future may or may not include an important place for sport fishing. It seems inevitable that society will in generations ahead make a value judgment which leads either to elimination of sport fishing as an important form of outdoor recreation or to unprecedented expenditures for its maintenance. Under the assumption that society will make the kind of unbiased, level-headed value judgment in favor of the preservation of recreational fishing that we of today would urge upon it, let us consider limitations of yield and human crowding as factors possibly limiting the growth of sport fishing.

PRODUCTION OF SPORT FISH

Production of fish (in the technical sense of elaboration of new fish flesh by birth of new individuals and by growth) varies greatly in the diverse natural waters of the north temperate zone. Hickling (1962) cites a range of 13 pounds per acre in alpine lakes to 400 pounds per acre in shallow eutrophic lakes. Frequently the more productive waters contain a large number of species, many of which are not highly valued as sport fish, and management of such complex populations is extremely difficult at our present level of biological knowledge. For the more manageable case where natural waters are dominated by a single species, production has been estimated in the range of 18 to 161 pounds per acre (Chapman, 1967). Because natural losses take place more or less continuously in fish populations, it is possible to harvest only part of the annual production; yields reported by Chapman (1967) range from 6.7 to 50 percent of production.

Yields of desirable sport fish exceeding 200 pounds per acre are attainable under very favorable conditions. However, the average attainable yield for all the freshwaters of the United States, in the absence of intensive management, must be well below this level considering the restricted number of species and range of sizes valued by fishermen, the high trophic level occupied by many of these preferred species, and the large acreage of relatively unproductive water in the national total. I venture a guess that the upper limit of average yield of acceptable quality sport fish from the freshwaters of the United States is around 30 pounds per acre, in the absence of management of an intensity heretofore not approached in public waters.

Present yields average about 1.4 pounds of fish per trip (20 pounds per acre). If a reduced yield of one pound per trip is assumed to be an acceptable average for the future, our waters must yield 30 pounds per acre at the turn of the century to meet predicted demands. If the guess that 30 pounds per acre is the maximum attainable yield is near the mark, increases in fishing intensity beyond the level forecast for the turn of the century threaten the onset of steadily declining fishing success. This decline will coincide with an erosion of esthetic values due to pressures of intensive resource use. Halting these trends will be an extremely complex problem, and whether we will save much of the quality recreational fishing we have known to the present is most realistically viewed as a challenging, but open, question.

It has already been suggested that the yield available from our natural waters under existing approaches to management may be fully realized by the turn of the century. Intensive aquiculture can produce much greater poundages of fish per unit area than occur in most natural waters and this technology could be used in sport fishery management to the extent that costs and changes in the nature of the fisheries were tolerated by the public. Cultural practices include various methods of fertilization, supplementary feeding, stocking, predator control, water level manipulation, and so forth. None of these procedures is new to contemporary sport fishery managers, but their intensive application has not been considered compatible with the "natural" environment in which our sport fisheries are usually set.

Annual production of the order of 500 to 5000 pounds per acre can be achieved in fishponds through fertilization and crops of 10,000 pounds of trout per acre can be obtained from ponds through intensive feeding (Hickling, 1962). Will increasing demands for sport fishing lead us in the future to sacrifice presently valued characteristics of some of our fisheries in order to obtain high yields? If we are willing to make such tradeoffs, attainable yields will not set a limit on the growth of freshwater sport fishing in this century or the foreseeable part of the next.

FISHING INTENSITY

Those waters in which we employ our biological capability to increase yields by, say, one or two orders of magnitude beyond natural levels, can support very intensive sport fishing in the future. Perhaps a superabundance of fishermen rather than a limited abundance of fish will eventually set an upper bound on the availability of the sport. In quantitative terms, what might be such an upper bound to fishing intensity?

Consider a fisherman with a rod 8 feet long holding a fixed location on a lake or stream. If he is bounded by a square so that the perimeter is nowhere closer than eight feet (a reasonable requirement since his rod is eight feet long) the fisherman is allocated 256 square feet. An acre of water surface will accommodate at any instant 170 fishermen under these conditions. Assuming that two shifts of fishermen use the same water each day, an acre will support 340 fishing trips per day. For a 150-day fishing season and an average trip length of four hours this constitutes a fishing intensity of 204,000 hours per acre annually—one hundred times what would be called extreme intensity today—and over 3500 times the present average.

Such calculations may be ridiculed on the basis that human beings would not voluntarily submit to anything approaching the level of crowding described above. However, consider the following. The state of Pennsylvania some years ago operated a project poignantly named "Fisherman's Paradise" in which fly fishing was permitted for large trout in a heavily stocked stretch of stream with intensive in-channel habitat improvement. During one season, an average of 154 fishing trips per acre per day was recorded (McFadden 68: 1961). This fishing intensity is 45 percent of the "ridiculously" high level described in my calculations above. The fishermen were not evenly spaced throughout the stream, but rather shoulder to shoulder along the banks, for no wading was permitted. On crowded days a second tier of anglers fished over the shoulder of those in the front row.

Vehicular and pedestrian traffic jams that would make a strong city traffic planner weep are endured by fishermen routinely at many access sites. Fishing piers and party boats are often jammed to maximum physical capacity. Even on areas of Lake Michigan, the number of salmon fishing boats is such that they must be forced to conform to a set pattern of navigation to make trolling possible.

To fishing pressure is added that from competing recreational use of water. On the Au Sable River in Michigan, for example, accompanying 325 hours of fishing per acre during the summer season is an additional 691 hours of canoeing per acre (Alexander and Shetter, 1967). Crowding has reached such dangerous proportions that a state conservation warden, while fishing, had the crotch ripped out of his waders by a passing canoe. Clearly, where fishing is good enough, at least a substantial element of the public will tolerate (perhaps not enjoy) crowding up to the physically possible maximum.

The inescapable conclusion is that we possess the technical capability to produce yields of fish that will attract fishermen in densities that by present standards are nothing short of fantastic. Neither potential yield nor intolerance of crowding by fishermen constitute foreseeable limits on sport fishing intensity in freshwaters.

VALUES

Managerial capability to produce yields of great magnitude, and tolerance of extreme crowding by at least some fishermen, pose as many problems as they solve. The social product of sport fishing is the aggregate of value which accrues to the participants from an enriching use of their leisure time. But alternatives among old values which can be maintained or new values which can be secured are almost unlimited in number. Fishing can be an escape to solitude or a social enterprise, a vigorous physical challenge or an occasion of relaxation. The physical setting and species of fish sought influence the recreational experience tremendously. People select from this broad spectrum of opportunities according to individual tastes and abilities.

As fishing becomes more intense, management activities come to have more importance relatively, and the original natural characteristics of our waters less in determining the values available from a fishery. Yet we lack objective social criteria for making choices among management alternatives because it is not known precisely or quantitatively what values people seek from the wealth of varied opportunity potentially available in sport fishing. With this socioeconomic problem now in focus, hopefully we can proceed with some long overdue empirical work, carried out or supported by the agencies charged with decision making. Our objective should be to resolve questions of value on the basis of knowledge no less objective than that demanded in the natural sciences upon which fishery conservation is based.

The research done to date indicates generally that the "value" problem is tractable. For example, study of a trout fishery in western U.S. (Brown, 1968) showed that anglers perceived the quality of their fishing experience in terms of size, number, fighting ability, eating quality, and particular species characteristics of the fish, in descending order of importance. It was possible to quantify, on an arbitrary scale of satisfaction, the importance of catch-per-hour and average size of fish caught. A number of different groups of fishermen could be identified on the basis of differing fishing objectives. The penetration of value questions achieved in this single study is encouraging enough to suggest the feasibility of ultimately obtaining a profile of the North American angling public based on a detailed hierarchy of values sought from sport fishing. When human needs and desires are known, the manager can design appropriate biological programs to serve them.

I have emphasized the value which accrues to the individual participant from recreational fishing because I believe this to be the sport's most important benefit. If this value can be expressed in economic terms, much the better, so long as the dollar is recognized as a quantitative unit and not a primary objective. Subject to restraints imposed by the primacy of social value, management of sport fisheries for economic gain to society is a sound secondary objective. At a practical level, social and economic gain are closely intertwined, and it might be hoped that conflicts between the two in fisheries management would be infrequent. The rigor of economic analysis is certainly to be welcomed in recreational fishery management; it is not implied that any value cannot or should not be expressed dollar-wise, but merely argued that the definition of value should be kept as broad as possible.

FISHERY TRENDS AND MANAGEMENT DECISIONS

In sport fishery management, as in so many other endeavors, we possess a technical and economic capability which drastically outpaces our social wisdom. We respond to what we perceive as a recreational need of society with a management program which changes the character of sport fishing. This change has an impact upon the desires and needs of the public which in turn influence future management. And so we track through history, trying to manage our resources to match social trends and, often inadvertently, generating new trends in the attempt. The chain process which sets the destiny of sport fishing is largely out of control. This suggests some weakness in our approach, which I believe to be lack of a broad conceptual

TABLE 1. *An example of a statistical summary of the life history of a fish population. The initial abundance of an average brood is arbitrarily set at unity; l_x is the population surviving at the end of year x; m_x is the number of female eggs produced by a female of age x; $l_x m_x$ is the egg production at age x as a fraction of the initial abundance of the brood. The sum of the $l_x m_x$ values is the multiplication of the population over successive generations, here differing from unity (population stationary) by rounding error.*

Age in years (x)	l_x	m_x	$l_x m_x$	$\Sigma l_x m_x$
0	1.00000	0.0	0.0	
1	0.0086	0.0	0.0	
2	0.0041	0.0	0.0	
3	0.0023	159.5	0.3637	
4	0.0013	240.7	0.3033	
5	0.0007	447.0	0.3129	0.9799

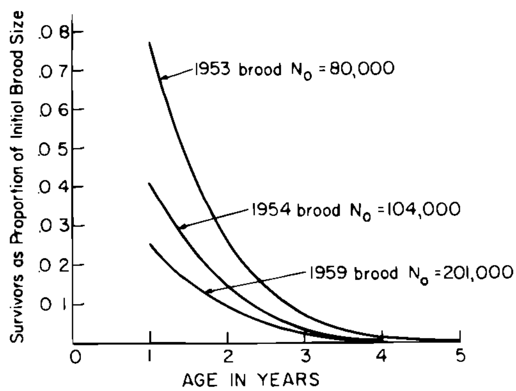

FIGURE 4.—Survival curves for broods of fish of different initial densities (N_0). Data selected to provide an ideal example of population regulation.

base. Not only must values be identified and quantified, and a sound philosophy generated in the appropriate sectors of society, but these must be integrated with biological technology in effective, foresighted planning and management. Clawson (1963) assigns this job to the conservation professionals when he says: "In publicly provided outdoor recreation opportunity, the public agencies can not escape the responsibility for the quality of the experience, for their actions largely determine it."

The problem of sport fishery management, in a broad context, can be made clearer by attempting to set it forth formally. Such attempts, it is hoped, will eventually lead to complex decision-making models which combine biological, social, and economic parameters. In the meantime even primitive efforts in formal problem statement will raise questions which, for lack of answers, cast grave doubt on the efficacy of management efforts. This bit of professional flagellation should, in the long run, do much to purify our management concepts.

An appropriately biological point of departure in fishery problem definition is a statistical summary of the life history of a fish population (Table 1). In this example, an average brood of fish, arbitrarily set at an initial abundance of unity, survives over successive years of life as shown in the l_x schedule (for example, 0.4 percent survive to the end of the second year). The fish first mature at 36 months of age, 160 female eggs being produced on the average by each female (m_3 column). Thus in the first year of spawning the brood has replaced 36 percent of its initial abundance in the population ($l_3 m_3 = 0.36$). In this example the brood about exactly replaces itself during its reproductive life ($\Sigma l_x m_x \simeq 1.0$). Each survival and reproduction statistic can be thought of as a function of many environmental variables—food, predation, population density, weather, natural cover, and so forth—so that the statistics in this table, along with their complex of determinants, can represent much of the biological knowledge of a sport fish population.

The textbook ideal of a stationary population is rarely encountered in nature. Abundance, survival, growth and reproduction vary more or less continuously in response to changes in physical and biological factors of the environment. In the long run an inverse relation between survival or birth rate and density operates to confine the population within some numerical limits. An example of such natural regulation of population size is presented in Figure 4, in which mortality for an initially large brood is seen to be higher than that experienced by an initially small brood. These examples were selected from an empirical study of a wild brook trout population.

The survival pattern of Figure 4, when integrated with the reproductive rate, provides an assessment of the success of each

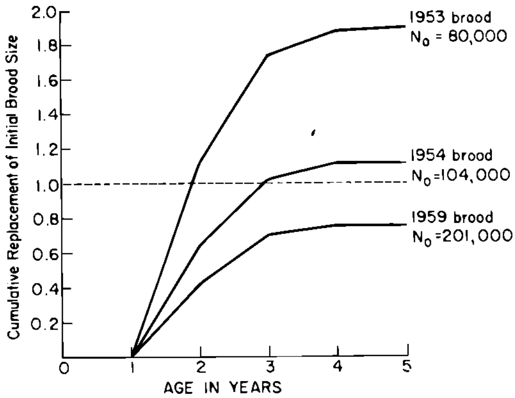

FIGURE 5.—Cumulative lifetime reproductive output of the 3 broods of fish of Figure 4, expressed as a fraction of the initial numbers of each brood. The interrupted horizontal line represents exact replacement of the initial numbers of a brood. Initial brood size is given as N_0.

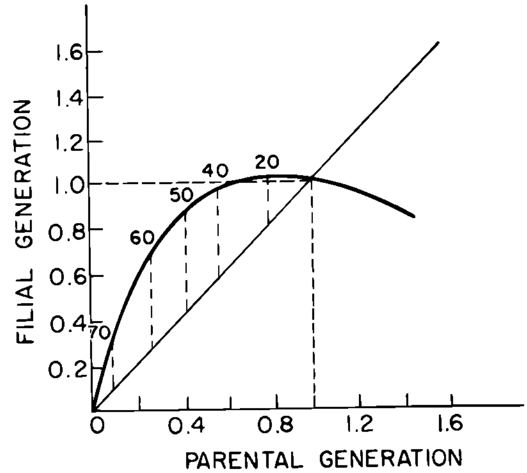

FIGURE 6.—A reproduction curve for a hypothetical fish population, with the exploitation rate required to produce equilibrium yield at several different levels of parental stock density indicated.

brood in replacing its initial numbers during its reproductive span in the population (Figure 5). The cumulative replacement of an initial brood size, used as the ordinate in Figure 5, corresponds to a summation over age of the $l_x m_x$ statistics of Table 1. It can be seen that the initially smallest of these broods (1953) more than replaces its initial numbers during its first reproductive year (age 2). The 1954 brood, one of average initial size, replaced its initial numbers after two years of reproduction; whereas the 1959 brood, initially very large, failed to replace its initial numbers during its life in the population.

Density relations such as demonstrated here can be summarized conveniently through a reproduction curve, a plot of the size of a filial generation as a function of the size of parental generation (Figure 6). Such curves, explained in detail by Ricker (1954), have come to provide a useful conceptual basis for management of a number of important fisheries. A parental generation of less than equilibrium density (represented on the arbitrary scale of the abscissa as unity) is capable of producing sufficient progeny to replace itself and in addition provide a surplus which can be taken as yield. The distance between the curve of Figure 6 and the straight diagonal line which represents replacement reproduction is proportional to the surplus in the filial generation available for harvest. The surpluses available at several different levels of parental stock size are indicated by interrupted vertical lines each labeled with a two-digit number indicating the percentage of the filial generation which can be harvested as surplus. For example, if the stock is held at 0.8 equilibrium density, 20 percent of the filial generation can be cropped on a sustained basis. As the rate of exploitation is increased, stock density decreases continuously and harvestable surplus first increases, then beyond a maximum (at slightly over 60 percent exploitation rate in the example here) declines. This relationship between exploitation rate and equilibrium yield, extracted from Figure 6, is shown graphically in Figure 7.

It is more useful in considering the operation of a sport fishery to express yield as a function of fishing effort rather than of exploitation rate. In studies of commercial fisheries, fishing effort is usually taken as proportional to rate of fishing, which is taken as equal to the natural logarithm of the complement of the exploitation rate, with the sign changed. This may be an excessively crude representation of the relationship between exploitation rate and fishing effort in most sport fisheries, but pending badly

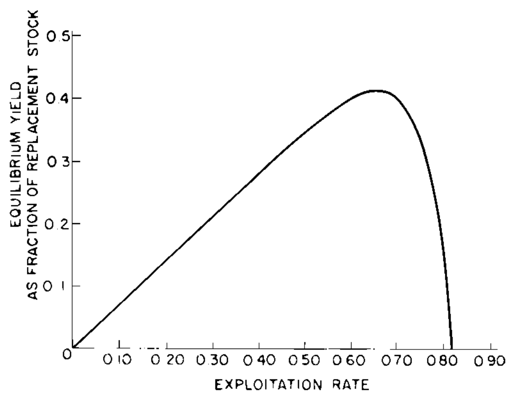

FIGURE 7.—Equilibrium yield as a function of exploitation rate for a hypothetical fish population.

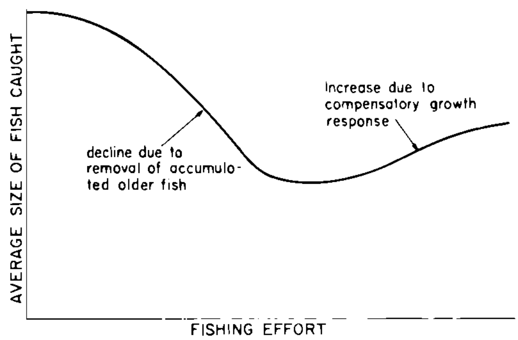

FIGURE 9.—A hypothetical example of the relationship between average size of fish caught and fishing effort.

needed theoretical and empirical work in this area, the foregoing defined relationship has been used to convert Figure 7 into a plot of equilibrium yield against fishing effort (Figure 8). The proximity of the level of fishing effort which produces maximum yield to that which constitutes drastic overfishing is, for the manager, a sobering feature of this graphic analysis. Although empirical data are rarely precise enough to describe the shape of the reproduction curve in detail, the postulates which inevitably lead to a steeply descending right limb in a curve like that of Figure 8 appear reasonable in the light of present knowledge.

In sport fisheries the size composition of the catch is of vital importance to the anglers, and some consideration of the quality of the yield at various levels of fishing effort is necessary. A variety of realistic situations can be hypothesized. In the example chosen here (Figure 9) the average size of fish caught at first declines with the onset of exploitation, as the older and larger fish which have accumulated in the virgin stock are removed. Eventually, stock density may be lowered to a point where a compensatory increase in growth rate more than offsets the decline in size due to decreasing average age, and as fishing effort increases further, a numerically declining yield of increasingly larger fish may be obtained. With this information, yield can now be expressed in units of both numbers and weight, as functions of fishing effort (Figure 10).

Excluding all other aspects of the fishing

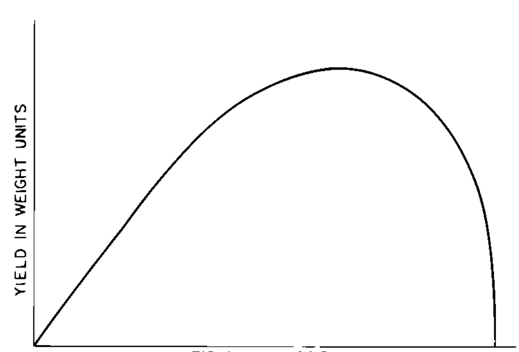

FIGURE 8.—Equilibrium yield as a function of fishing effort, based on Figure 7, and the relationship between exploitation rate and fishing effort set forth in the text.

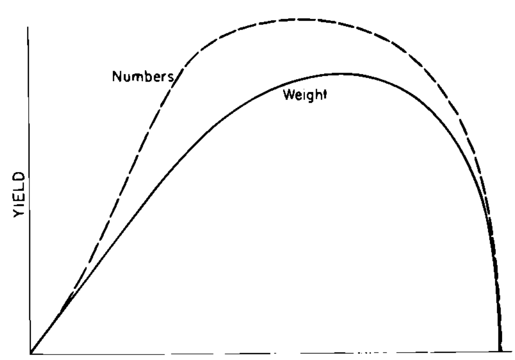

FIGURE 10.—Yield expressed both as number of fish and as total weight, as functions of fishing effort. Based on Figures 8 and 9.

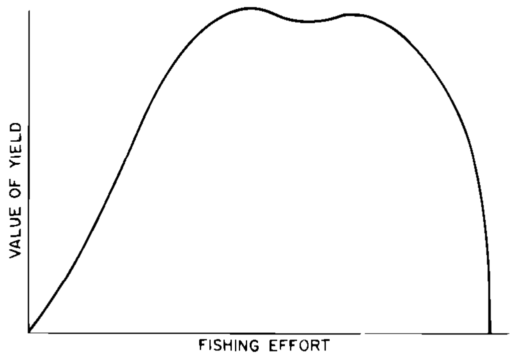

FIGURE 11.—The relationship of value of yield (taken to be a function of both number of fish caught and their average size) and fishing effort. Based on Figure 10, with an arbitrary value scale.

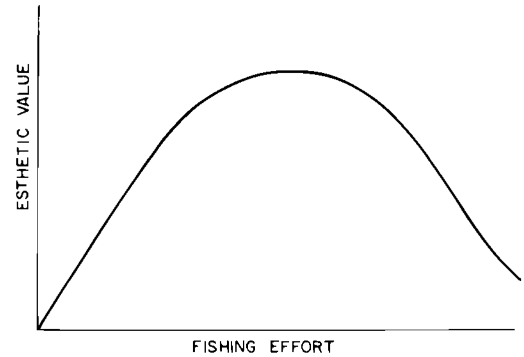

FIGURE 12.—A hypothetical relationship between the esthetic value of the sport fishing experience and fishing effort. Esthetic value, by definition, excludes values associated with the yield of fish.

experience, a particular value accrues to the angling public from the pursuit, catching, keeping, eating, and so forth, of the fish which constitute the yield. This value, being a function of both the numbers of fish caught and of their size, could be related to fishing effort in a very complex manner (Figure 11). Differences among species in the shape and amplitude of the yield-effort curve must be very great indeed, considering the differences in numerical productivity, average size, behavioral pattern, and prestige accorded by fishermen for different species of fish. This subject of comparative value of sport fisheries is virtually untouched by research to date.

In addition to the value generated by the catch, purely esthetic consideration are important in sport fishing. Solitude or social atmosphere, exercise or relaxation, unspoiled wilderness or the beauty of well executed landscape design—all offer broad spectra of values. Although these are in one sense independent of the yield of fish, the fishing experience itself provides prime motivation for the outdoor recreational experience of which they are a part. The reciprocal obviously holds also, for esthetic values help to lure people to fishing sites. Still, it is essential to separate such categories of value for, as will be discussed later, one may not be always compatible with the other.

Little can be said in a precise way about the purely esthetic values of sport fisheries, but it is to be hoped that aggressive action will be taken soon to fill this serious void in our knowledge. Intuitively, it seems that esthetic value must bear some roughly parabolic relationship to fishing effort, one that does not necessarily parallel the relationship between value of yield and effort. An arbitrary curve is drawn in Figure 12.

In order to enjoy sport fishing, the public incurs costs for tackle, travel, subsistence, licenses, etc., these have been the subject of considerable study in recent years. As the total amount of fishing effort increases, the total cost for all the participants in sport fishing increases also. On any broad regional scale, at least, it is assumed that competition among fishermen, leading to greater unit expenditures for such items as travel, will produce a more than proportional increase in cost as fishing effort increases (Figure 13).

The foregoing considerations of yield, value, and cost can be integrated in a model through which trends in sport fishery intensity and management can be examined (Figure 14). Although a number of intermediate steps separate this graph from our point of departure, it should be recalled that we have proceeded from the biological basis of the fishery and inputs from all environmental sources are implicitly incorporated into this diagram.

At any level of fishing effort the value accruing from the catch (unshaded area) has been added to the esthetic value accruing from the fishing experience (cross-hatched

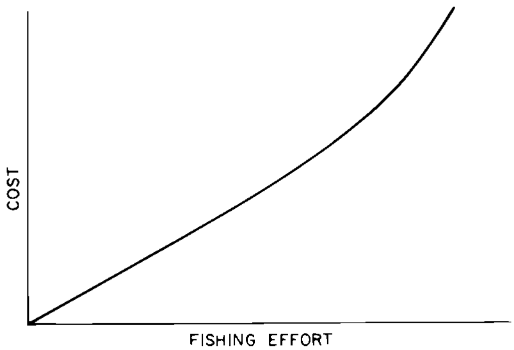

FIGURE 13.—Aggregate costs incurred by sport fishermen as a function of total fishing effort.

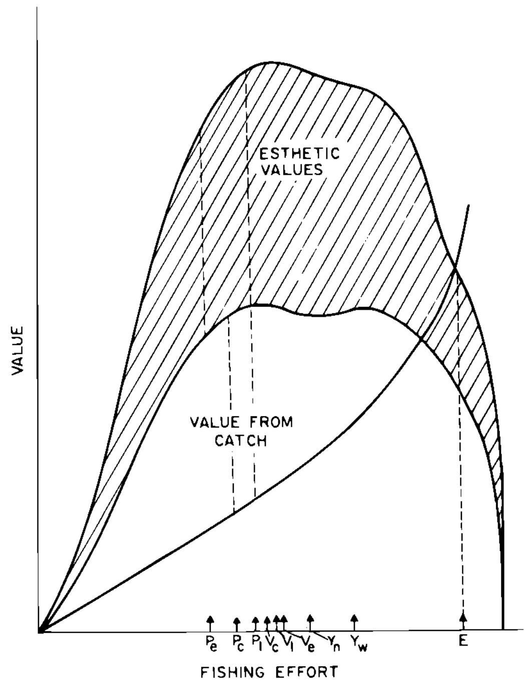

FIGURE 14.—Esthetic value, value of catch, and cost of participation in relation to fishing effort, based on the hypothetical relationships of the preceding figures. Arrows indicate magnitude of effort at which various characteristics of the fishery are maximized. Interrupted vertical lines indicate the magnitude of the maxima for different types of value.

area), the uppermost curved line representing total value. Superimposed on the roughly parabolic value curves is the ascending curve of cost. For any given level of fishing effort the profit gained by the participants can be measured as the value minus the cost.

Catering to the vocational compulsion of the resource manager to maximize something, nine different candidates have been indicated by labeled arrows along the abscissa. From left to right these are: $P_e =$ profit from esthetic experiences alone; $P_c =$ profit from the catch of fish alone; $P_t =$ total profit from all sources; $V_c =$ value generated by catch alone; $V_t =$ value generated from all sources; $V_e =$ value generated by esthetic experience alone; $Y_n =$ numerical yield of fish; $Y_w =$ yield in weight; $E =$ fishing effort. It would be possible for the maxima of some of these quantities to coincide in some situations, but the point is made here that this need not be the case. If value were broken down into more categories (which would be highly desirable) the choice of quantities to maximize, and hence the decision making dilemma of the manager, could be enlarged considerably.

Suppose that Figure 14 represents an important local single-species fishery or even our continental mixed-species sport fishery. What quantity should be maximized? It is in vogue in recreational fishery management to scorn the old commercial-fishery-tainted objective of maximum sustained yield and to pledge loyalty instead to such concepts as optimal value or maximum public benefit, which never, to my knowledge, have been defined. It would be ironic if, upon definition, the maxima for these "new" concepts turned out to coincide closely with the old and vulgar maximum sustained yield. At any rate, sport fishery management currently lacks a *defined* objective and hence the effectiveness, in a long term sense, of most present programs is open to question.

What would be the consequences of taking a very business-like view and considering society to be a monopolistic owner of sport fisheries? Following an analogy to the usual argument for commercial fisheries, the difference between participants' aggregate costs and value attained could theoretically be captured as a rent. In order to maximize this rent, the number of participants in sport fishing would have to be limited. "Undemocratic," you say, "discriminatory; politically inexpedient?" Numerous examples exist of entry to public outdoor recreation being limited—by the luck of the draw in lotteries; by temporal or spatial zoning; by an individual's ability to drag himself out of bed at an unreasonably early hour to stand at the head of a long line. In fact, society has, in many cases, chosen to limit participation in sport fisheries to those who live in or have access to rural areas and to ignore the wants of those many citizens confined to urban environments. This is accomplished by lavishing management expenditures on outstate waters while lathering pollutants on urban waters.

The substantial rents available from this scheme could be invested in raising the value attainable from the fishery, and thus either increasing future rents or eventually allowing increased participation at submaximum rents. Society plays an awkward dual role of monopolistic owner and fisherman, but can we rule out, *a priori*, the possibility that this strategy might benefit the greatest number of people in the long run?

The extreme alternative is to allow unrestricted participation in sport fishing. Under this plan, fishing effort will continue to increase as population grows so long as value sufficient to cover costs (including opportunity costs) can be extracted from the sport fishing experience by new participants. Considering the attainable yield and the impact of users on esthetic values, I would guess that for present intensity and methods of sport fishery management the point of maximum fishing effort (E) may be around 1 billion angler days annually for the 22,120,000 acres of public freshwaters in the contiguous 48 states, or 45 angler days per acre. The profit to society under unrestricted participation comes not as rent but as the sum of the participants' opportunity costs met, an extremely difficult quantity to measure. Because Figure 14 is based on hypothetical biological and value relationships, the other maxima indicated by arrows cannot be quantified on the abscissal scale in relation to the estimated value of point E.

At point E the maximum quantity of recreational fishing occurs. Is this a recreational optimum or might it be a point at which fishing is just slightly better than the next best alternative, but no recreation available is of very high quality? In this model, it is assumed crudely that a curve, a joint function of quantity and quality, can adequately represent value. To locate a true recreational optimum it would be far better to incorporate in a model a response surface with separate quantity and quality axes.

It can be argued that maximization of profit is an inappropriate objective of sport fishery management because too low a level of participation is entailed. It can be argued too that at the level of maximum participation too small an aggregate value is realized from our resources. A further argument over what to maximize might pit the aesthete against the "meat fisherman" (V_e vs Y_w) in a class struggle rivaling in emotional pitch the Bolshevik revolution. The least a decision-making model should be expected to do is to protect the manager from this latter controversy!

But no, the model only sets forth the alternatives, justifying its existence through the argument that a problem well stated is already half resolved, and leaving the actual decision to society or its delegates. And once the complexity of the decisions is appreciated we may, appropriately, come to worry about the utility of present institutional forms for making value judgments and policy decisions. The model generates little peace of mind.

The management practices employed to manipulate fishery resources or use-patterns are viewed in terms of this model as attempts to change the shape or amplitude of the value curves. For example, fertilization or stocking are intended to do this directly by increasing yield. Restrictive regulations attempt to maintain yield and hence value at high levels of fishing effort without the regulations themselves destroying the recreational value of the fishery. Let us examine in turn, as further examples of the application of this type of model, the partly political problem of licensing, a conflict between catch value and esthetic value, a two-species biological problem, and a social problem inherent in sport fishery management.

With regard to the financing of management through licensing, it is well known that existing fees represent a very thin slice of the area under the cost curve. The "value of catch" curve has been drawn with a steeply descending right limb, which has a sound basis in population theory, and the "esthetic value" curve is of similar shape, which seems intuitively reasonable. As a consequence it is theoretically possible in a fishery exposed to maximum effort to raise the cost line, corresponding to a substantial increase in license fees for added management expenditures, without lowering the position of point E greatly, that is, without forcing many fishermen into alternative forms of recreation. This conclusion is reached even without postulating elevation of the value curve as a result of investment of added license revenue in effective management.

For the second example, it is easy to visualize how, as we try to meet rising demand for sport fishing, value accruing from catch might be increased through intensive biological management to a point where the resulting fishing intensity destroyed all esthetic values. Such a situation can be produced easily by indiscriminate stocking of very large fish. Is this an admissible procedure for management? Under what conditions should a natural, self-sustaining stock of fish of, say, only moderate productivity be replaced by a much higher density of artificially propagated fish? An alternative, in the face of increasing fishing pressure, might be to restrict harvest of the natural stock severely, with the probable result, maintenance of a more natural fishery which was used by fewer people. Clearly, management programs can change the shape of the value-from-catch curve and of the esthetic value curve independently, thereby evoking a differential response in fishing effort from groups of anglers with differing value criteria.

Just as one type of value can be destroyed in the mass pursuit of another, so one species of fish may be overexploited in a fishery which includes a more productive or elusive companion species (Figure 15). This could

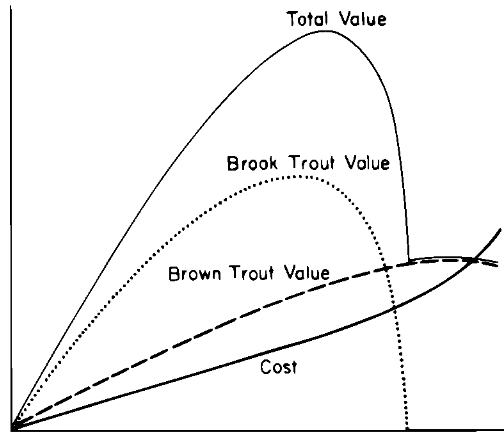

FIGURE 15.—Values and cost versus fishing effort in a hypothetical sport fishery for two species which are exploited together. Dotted line represents value from brook trout alone; interrupted line represents value from brown trout alone.

easily be the case in a fast-growing, mixed population of brook trout (*Salvelinus fontinalis*), which are highly vulnerable to angling, and brown trout (*Salmo trutta*), which are much more difficult to catch. The brown trout, persisting under heavy fishing pressure, may provide sufficient recreational value to generate, ultimately, enough fishing pressure to decimate the brook trout stock. If no brown trout were present, fishing effort would stabilize at the level where value provided by brook trout fishing alone was equal to cost, considerably below the effort at which total value equals cost. It is clear that the more easily exploited species can persist only under reduced fishing pressure, and the conventional cure for the problem is to impose restrictive regulations. When is the additional species saved worth the psychological cost, the enforcement cost, and the loss of fishing opportunity occasioned by more restrictive regulations?

A final problem to be considered reveals the over-simplicity of this type of model and the great complexity of decision-making when social factors are considered. In sport fishing, costs incurred (especially if psychological costs are included) and values obtained vary much more widely among individual participants than is the case in a

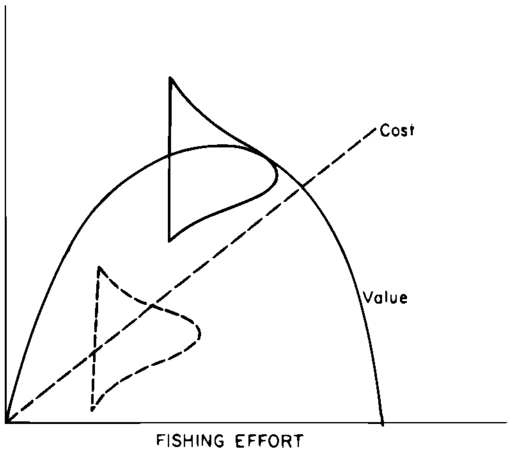

FIGURE 16.—The problem of wide variation in costs and values for individual participants in recreational fisheries.

commercial fishery. This is especially clear in the case of value, which is fixed in the marketplace in the commercial case but which is such a complex and completely individualistic quality in the recreational case that, at present, we are unable even to measure it. If the recreational needs of real, as opposed to hypothetical average, human individuals are to be met, cost in relation to value must be considered separately for various types of people. Consider a fisherman for whom the appropriate cost curve would be much higher than average (an individual from the upper tail of the cost distribution of Figure 16). This may be a person who must travel a great distance to the fishery, one for whom the financial cost is high relative to income, or one whose leisure time is extremely limited. As the value per participant declines with increasing fishing effort, this individual will have more trouble covering the costs of participating than will one with average or low costs, assuming he obtains about average value from his fishing. This is undesirable enough when due to the natural consequences of development of a fishery, but much worse when some participants are forced out of recreational fishing by management procedures which change cost-value relationships to the advantage of one group and the disadvantage of another.

This is merely a graphical restatement of the problem of conflicting resource uses. Since the value that a fishery of a particular type represents to different individuals varies so greatly, socially successful management will consist of reducing the variance about the value curve by providing a wide variety of recreational fisheries, each managed for a narrow range of values, and each to be selected voluntarily, in relation to the individual's costs, by the appropriate participants. The correct mix for this patchwork quilt of recreational opportunity must be determined by quantitative study of the public's needs and preferences. The managerial pattern which results will be administratively complex but biological and sociological problems will be greatly simplified, and after all, it is the fish and people we are out to accommodate.

I have not said specifically whether most of the diagrams shown here represented a single local fishery or our continental freshwater sport fishery as a whole. Ideally each of our important component fisheries should be analyzed, recognizing biological differences among species of fish and different environments, and local variations in recreational demand. Regional problems then would be attacked by joint analysis of all component fisheries.

You may object that these diagrams are just so much sophistry; that they do not solve problems and, in fact, make them seem much worse than they are. Granted, many of the management successes of the past have been achieved with a minimum of intellectual groaning and grunting. But the complexity of problems of even the immediate future is so staggering that commitment to formal definition and quantitative analysis is absolutely prerequisite to their satisfactory solution on a long-term basis. At present we lack a workable conceptual base for management, a definition of values relevant to human society, and a rational system for choosing among management alternatives. As a result of these deficiencies, trends in freshwater sport fisheries are out of control. We look upon them as extrinsic phenomena, and design fishery management programs to run along behind these trends, trying but inevitably failing to keep up. Not until management is viewed as a generator of new trends rather than an answer to trends of the past will it be possible to carry out effective long-range planning.

The present complexion of sport fishing in continental United States in relation to social patterns provides a timely example to support the foregoing critical contentions. In 1920 the population of the United States first became predominantly urban. By 1960, 70 percent of our people were concentrated in 5,000 urban centers. During this period of social change, recreational fishery management became more and more concentrated *away* from the cities. One cause was loss of water resources in urban areas due to pollution, but another important cause, which has led to neglect of many *fishable* waters, was turning of our attention away from the urban environment, in preoccupation with the relatively unspoiled natural landscape. It was a simple enough matter for the fisherman to travel out of his city to a rural fishing hole.

But what of the more than 20 percent of the families in the U.S. who do not have access to an automobile (the figure is 39 percent in New York City)? Changes in the pattern of mass transit facilities have isolated these people in their home neighborhoods. And must the opportunity for young Americans to fish during their day-to-day leisure time be written off forever, to be replaced with an occasional weekend or summer trip by car? Are the costs imposed by the necessity to travel long distances to fish inescapable? Recreational fishing opportunity is now distributed very unevenly over our population, and this has come about partly because trends we have generated in management have accentuated the separation of us people from our recreational friends, the fish.

Forty percent of all leisure time is available after work or after school. Limited access to the outdoors during these times partly accounts for the fact that only 3 to 4 percent of all leisure time is used for outdoor recreation (Clawson, 1963). It seems that imaginative management could bring closer to our cities increased opportunity for recreational fishing, thereby capturing a substantial share of the population's leisure time which is now invested in less rewarding pursuits. Does it not make good sense to enrich the environment in which most North Americans spend most of their living hours?

FIGURE 17.—Effective management can continue to produce high quality sport fishing for generations to come.

Water resources in urban environments are limited in relation to human population density and severe limits on recreational fishing potential must exist in some areas. But many cities are located on substantial bodies of water, and many are complexes of intensive development with greenbelt areas interspersed. The possibilities for intensive fishery development coordinated with urban and regional planning must be great in many localities. An entirely different cost-value scale exists in the urban recreational setting, and management innovations which cannot be justified elsewhere may be entirely appropriate there. Have we, as a profession, directed recreational fishery manage-

FIGURE 18.—Will we earn the wrath of future generations of Americans for allowing fishing to go to pot?

ment along a path not fully relevant to the needs of society—a path which sidesteps the sticky challenge of intensive sport fishery development? Although I would like to hint that we have drifted in this direction we certainly are not guilty of having done so by design. Rather—and this is the brunt of my argument—we have been vulnerable to such misdirection because of *lack* of design in fishery management.

The indignity of this self-criticism need not weigh too heavily upon the profession. Many successes have been achieved to date and I am convinced that we possess the ability to solve the complex management problems of the future. Further, we have chanced to stroll onto the stage of history at a time when adequate recreational resources are still available, but in immediate danger of engulfment, in the absence of imaginative planning, by a rapidly expanding population of users. Under these circumstances we cannot escape either earning the credit for providing quality recreational fishing through the foreseeable future (Figure 17), or earning the blame from future generations of North Americans for letting fishing go to pot (Figure 18).

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