RESERVOIR MANAGEMENT PROGNOSIS: MIGRAINES OR MIRACLES

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ABSTRACT

There are about 500 reservoirs (larger than 500 acres), totalling 4.3 million acres, in the 14 States of the Southern Division. Angling demand is predicted to double on Southern waters by the year 2000, and most of the increase is expected to be satisfied by man-made lakes. Southern reservoirs are typically below average in basic fertility, but long growing seasons foster high annual production rates, resulting in above average sport fish yield potentials.

The steady accumulation of reservoir environmental and biological data during the past quarter century has greatly increased our ability to predict standing crops and angler harvests and to devise management practices based on production potentials. Production is primarily controlled by available nutrients, basin morphometry, water exchange rate, climatic cycles, eutrophication rate, and species composition. Future management plans for individual reservoirs should be based on detailed models of environmental factors and calculated optimum production and yield levels.

Manipulation of controllable environmental factors (e.g., water level fluctuation, water exchange rate), intensive cultivation of exposed lake bottoms in the fluctuation zone to enhance survival and growth of sport fish young, and improvement of the forage base through introductions of threadfin shad and other species should receive increased management emphasis. The increasingly successful practice of stocking striped bass, walleye, and other predators should be thoroughly evaluated in terms of angler harvest and effects on existing fish populations. The prognosis for reservoir management is good.

INTRODUCTION

There are now about 500 reservoirs larger than 500 acres in the 14 states within the Southern Division of the American Fisheries Society; they encompass 4.3 million acres at mean annual pool levels. Collectively, they account for one-third of all the fishing water in the South and 47 percent of the reservoir area in the United States. Ten percent (50) of these reservoirs are larger than 25,000 acres, and make up 60 percent of the total area.

Texas has 1,130,000 acres in reservoirs, followed by Oklahoma, 496,000 acres; Tennessee, 477,000 acres; Alabama, 434,000 acres; South Carolina, 352,000 acres; and Arkansas, 325,000 acres. Three-fourths of the Divisional area lies in those six states. In numbers of reservoirs larger than 500 acres, Texas leads with 152, followed by Arkansas, 61; Oklahoma, 50; Alabama, 35; North Carolina, 32; Tennessee, 31; and Louisiana, 30. Collectively, three-fourths of the total are in these seven states.

On the basis of use estimates supplied by State fishery agencies 6 years ago (Bureau of Sport Fisheries and Wildlife [BSFW], U. S. Department of the Interior [USDI], 1968), and by the 1970 National Survey of Fishing and Hunting (BSFW, USDI, 1972), the fishing effort on southern reservoirs this year will total about 68 million angler-days, or 16 angler-days per acre. Fishing pressure should average about 10 days per acre on waters larger than 25,000 acres and about 25 days per acre on smaller reservoirs.

By the year 2000, angling pressure is expected to double in the South, and it is predicted that new impoundments will increase the available fishing water by 4.7 million acres (BSFW, USDE, 1968). However, recent rates of impoundment construction suggest that no more than 2 million acres will be added by that time. Therefore, average pressure could increase from 15 to 30 angler-days per acre on all waters in 27 years — a possibility that poses a formidable challenge to the skill and resourcefulness of fishery managers. With fewer new reservoirs in prospect to provide angling bonanzas for the first 5 to 10 years after construction, the challenge assumes even larger proportions. In the absence of effective, economical, broad-scale tools and techniques, these big waters now pose some of the most vexing management headaches. They also represent the greatest potential for meeting greater angler demand if some minor miracles can be wrought through research and development.

In this panel discussion, I propose to emphasize relatively recent findings on reservoir fish standing crop and harvest in relation to environmental variables, hypotheses concerning sport fish production potential, and how these findings might be applied to current and future management practices. My remarks are directed to reservoirs larger than 500 acres, but many of the precepts could apply to large natural lakes and oxbows as well.

FISH PRODUCTION POTENTIAL

What is the fish production potential in Southern reservoirs? Few field measurements of production rate have been attempted and we must rely on indirect measures, such as standing crop, harvest, and age and growth data for estimates of this vital statistic.

Sport fish production.

The accumulation of standing crop data by State fishery agencies in the past 25 years has enabled us to identify some of the most important environmental factors influencing fish crops and, presumably, production (Jenkins, 1968, 1970). Our latest correlation and regression analyses (National Reservoir Research Program [NRRP], 1971, unpub.) based on standing crop data from 172 reservoirs (740 years of record, including about 2,000 samples), corroborate earlier findings that highest crops of sport fishes occur in moderately hard waters (total dissolved solids [TDS], 100-350 ppm) where ionic concentrations of carbonate-bicarbonate exceed those of sulfate-chloride.

In addition, studies have shown that high turbidity suppresses sport fish crops (e.g., see Buck, 1956). Reasoning that combinations of these three factors (TDS, chemical type and turbidity) should identify areas of optimum sport fish crops, I prepared a map of the Nation (Figure 1) using overlays of hydrologic maps depicting these factors (Rainwater, 1962). Lacking sufficient data on turbidity, I used average annual discharge-weighted mean concentrations of suspended sediment in rivers (Rainwater, 1962). Optimum sport fish crop is defined as one which includes a variety of species as well as above average biomass. Black basses, walleye, sauger, northern pike, chain pickerel or trout and other salmonids are important components of such populations, overriding in importance, for example, high crops of catfishes, sunfishes, or yellow perch.

Geographical areas which meet all three water quality criteria and hypothetically produce optimum sport fish crops (Figure 1) are positively related to nonresident fishing license sales — a reasonable indicator of angling excellence. The top 10 states in nonresident license sales in fiscal year 1972 were Wisconsin, Minnesota, Oregon, Tennessee, Michigan, Arkansas, Colorado, Florida, Missouri, and Montana.

Figure 1. Potential areas of optimum production of sport fish (salmonids, pike and pickerel, serranids, black basses, crappies, and sauger and/or walleye) in U. S. reservoirs, lakes and streams, based on the following selected water quality criteria. Criteria are 1) mean annual concentration of total dissolved solids is 120-350 ppm; 2) dominant ions in inflowing streams are calcium-magnesium and carbonate-bicarbonate rather than sodium-potassium and sulfate-chloride; and 3) mean annual suspended sediment load of inflowing streams is less than 2000 ppm. Areas meeting all three criteria are indicated in black; areas meeting two of three criteria are indicated in gray. Derived from hydrologic maps prepared by F. H. Rainwater (1962).

In the South, principal areas of optimum sport fish crops include the Appalachian Mountain area west of the Blue Ridge Mountains, middle Kentucky and Tennessee, south and west Florida, the Ozarks, the alluvial plain of the Mississippi River, and the Edwards Plateau in Texas (Figure 1). Above average crops are postulated in most of the remaining area except western Oklahoma, Texas, Mississippi, and Tennessee, and areas in the Atlantic and Gulf Coastal Plains. There are, of course, numerous exceptions to this categorization, resulting from local anomalies and man-induced changes (e.g., pollution, land use), but the approach should be of value in identifying production potentials and problems. The precept could be used in preparing detailed management maps on a statewide basis and in invoking the cliche' about the creation of a silk purse from a sow's ear when applicable.

Rough fish production.

Similarly, probable areas of above average total standing crops and relatively high crops of rough fish in reservoirs can be broadly described by the criteria a) TDS content greater than 120 ppm and b) mean suspended sediment load of inflowing streams greater than 2,000 ppm. On the basis of our most recent analyses of predominantly Southern reservoirs, the calculated total fish crop would be 210 pounds per acre at a TDS level of 120 ppm (NRRP, 1973, unpub.). The arbitrary average of 210 pounds per acre is influenced by the comparatively low

TDS waters in the South; the nationwide average might be higher, as 50 percent of the prevalent concentration of TDS is greater than 230 ppm Nationally (Rainwater, 1962). However, it should apply to reservoirs generally, as one-half of the U. S. reservoir area is in the South.

"Above average" reservoir fish crops are predicted in the Tennessee and Mobile River drainages, middle Kentucky, parts of Florida and most of Oklahoma and Texas (Figure 2). Except in western Oklahoma and Texas, high crops of rough fish are not predicted in the South, at least in comparison with the crops of suckers, buffalofishes, carp, chubs, freshwater drum, and large gizzard shad produced in waters of the Corn Belt, the Great Plains, the Great Basin and the Desert Southwest. Again, there are local exceptions to this categorization, usually attributable to pollutants, artificial nutrient enrichment, reservoir operation, or soil type anomalies.

Fishery agencies of Oklahoma, Texas and the Tennessee Valley Authority are currently working on similar, but more detailed categorizations of reservoirs within their purview to provide additional direction and set realistic goals in both research and management. Other States have completed (e.g., Kentucky, Virginia) or are developing parallel schemes of classification of waters which will be of widespread, long-term benefit to management.

Species-environment Correlations.

In addition to making predictions of total and sport fish standing crop, the relation of crops of species or species groups to selected environmental variables

Figure 2. Probable areas of above average total standing crop of fish (>210 pounds per acre) and areas of high crops of rough fish (e.g., suckers, buffalofishes, carp, chubs, freshwater drum, large gizzard shad) in U. S. reservoirs, lakes, and streams based on selected water quality criteria. Criteria are a) mean annual concentration of total dissolved solids is greater than 120 ppm; and b) mean annual suspended sediment load of inflowing streams is greater than 2000 ppm. All shaded areas meet the TSD criterion. Areas in black meet both criteria. Derived from hydrologic maps prepared by F. H. Rainwater (1962).

have been explored through partial correlation analyses to aid in management planning (Jenkins, 1970). Examples of significant correlations (0.20 confidence level) found include: with an increase in reservoir area, an increase in northern pike crop and a decrease in bullhead and "true" sunfish crops; with increase in mean depth, an increase in sunfish and a decrease in channel catfish, largemouth bass, and white crappie; with greater water level fluctuation, an increase in flathead catfish, black bass and white crappie and a decrease in northern pike and sunfish; with decreased water exchange rate, an increase in channel catfish, largemouth and smallmouth bass, and white crappie, and a decrease in flathead catfish, bluegill, and longear sunfish; with increased relative shoreline length, an increase in sport fish crop, except redear sunfish and black crappie; with increase in growing season length, an increase in bluegill, redear, black bass and black crappie crops; with increase in reservoir age, an increase in channel catfish, white bass and walleye and a decrease in northern pike, pickerel, bullheads, and sunfish crops.

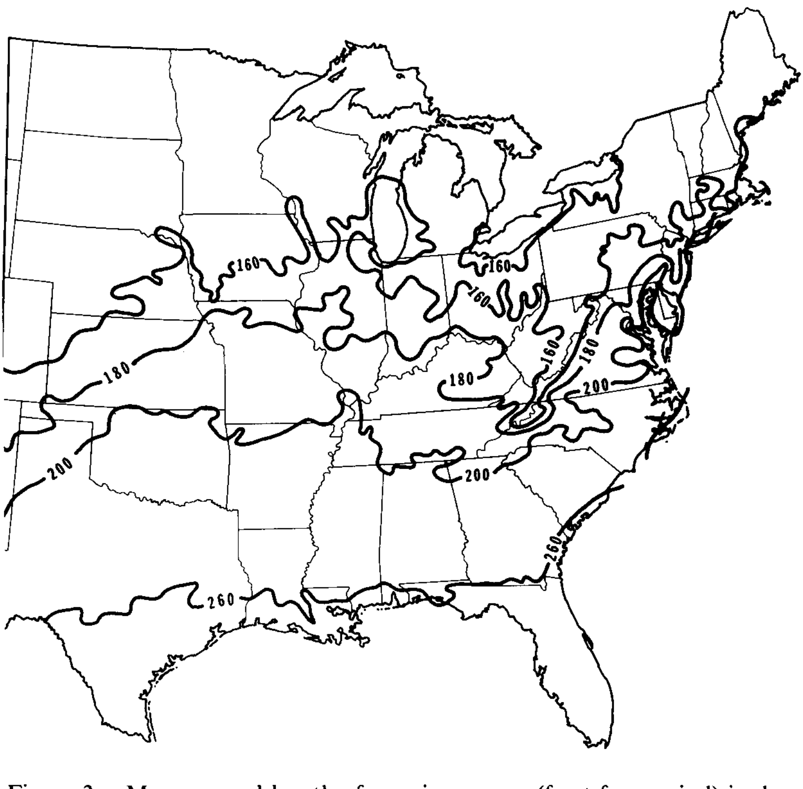

Figure 3. Mean annual length of growing season (frost-free period) in days for the eastern United States. Isolines indicate growing seasons of 160, 180, 200 and 260 days. Data derived from Climates of States; Climatography of the United States Nos. 60-1 thru 60-50. 1959-72. Environmental Data Service, Environmental Science Services Administration, U. S. Department of Commerce.

We are attempting to quantify some of these species vs. environment relations through multiple regression analyses with the additional data acquired in the past 3 years. However, it now appears that more data will be required to produce predictive regressions which explain more than 50 percent of the variability in the crops of most species.

Production vs. length of growing season.

Most of the impounded water in the South is classified as soft (TDS = 120 ppm) and below average in fertility, but this deficit is offset by long growing seasons. Physiological research has established that basic metabolic rates of fish double with each 10°C (18°F) rise in water temperature. D. H. Thompson (1941) postulated that since fish yield may be expected to be proportional to total digestion, it should be possible to express the relation of yield to carrying capacity at different latitudes. Using digestion rates described by Markus (1932), he derived values of maximum annual yield as percentage of carrying capacity, based on mean monthly air temperatures, which varied from 21 percent in Vilas County, Wisconsin, to 118 percent at New Orleans.

Highly positive correlations between length of growing season (Figure 3) and sport fish harvest (Jenkins and Morais, 1971), prompted us to explore the utility of Thompson's hypothesis in relation to reservoir fish crops and yields. A curvilinear relationship derived from growing season (frost-free period in days) versus Thompson's latitudinal yield estimates (Figure 4) approximated the relationship noted between standing crop of sport fishes (as measured by mid-summer sampling with rotenone) and harvest in 15 reservoirs where data on both were available for two or more years (NRRP, unpub. data).

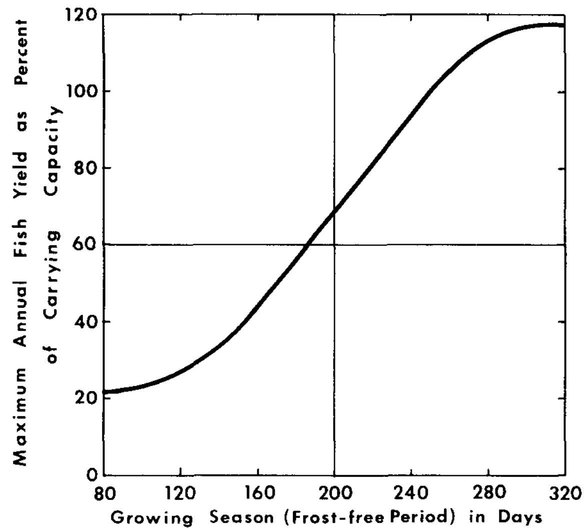

Figure 4. Hypothetical relationship of average annual length of growing season (frost-free period in days) to maximum annual fish yield as percent of carrying capacity (standing crop at most critical period in late winter or early spring), based on a theory advanced by D. H. Thompson (1941). The regression formula, where X is growing season in days and Y is maximum yield as percent of carrying capacity, is $Y = 81.73 - 1.516 X + 0.01099 X^2 - 0.00001845 X^3$.

As example of the applicability of this hypothesis as a predictor is provided by 10 years of data on largemouth bass standing crop and harvest on 28,000-acre Beaver Reservoir, Arkansas (South Central Reservoir Investigations, unpub.). Carrying capacity (defined as the minimum standing crop at the most critical period in early spring) was estimated as follows: standing crop in terms of biomass recovered from cove sampling, divided by 0.60 (60 percent recovery of marked bass) equals biomass present in mid-August. Biomass equals carrying capacity plus 41 percent of carrying capacity (percent of growing season completed by mid-August [60 percent], multiplied by yield as percent of carrying capacity with a 200-day growing season [68 percent]). In Beaver Reservoir, with a growing season of 200 days, biomass recovered following rotenone sampling, multiplied by 1.25, equals estimated early spring biomass. Through 10 years of impoundment, the accumulative angling yield was 80 percent of estimated carrying capacity (Figure 5); the calculated mean annual carrying capacity was 11.1 pounds per acre and mean yield of 9.0 pounds per acre.

The "Thompson growing season regression" (Figure 4) predicts a maximum yield of 68 percent of carrying capacity, compared with the angler harvest of 80 percent of calculated carrying capacity.

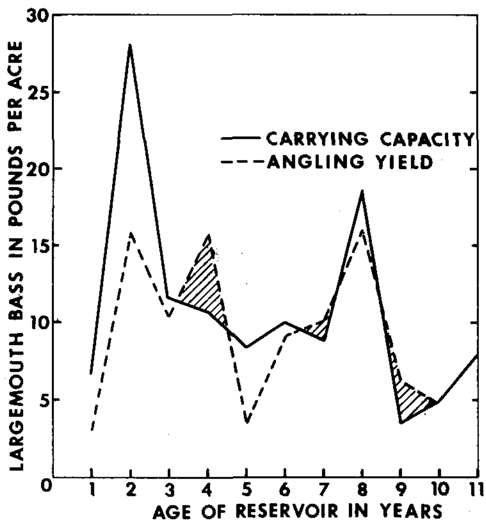

Figure 5. Comparison of the calculated carrying capacity and angling yield of largemouth bass in Beaver Reservoir, Arkansas, through the first 10 years of impoundment, 1964-73. Hatched areas indicate years in which yield exceeded calculated carrying capacity. The 1973 harvest estimate is extrapolated from known harvest in the first 5 months of that year. Carrying capacity in the first year of impoundment, 1964, was estimated from rotenone samples taken in the 500-acre dead storage pool present in summer 1963, prior to final dam closure in December 1963. (Based on unpublished data, South Central Reservoir Investigations, BSFW.)

New reservoir conditions (inundation of new land, higher fertility and turnover ratios) apparently sustained slightly higher yields in Beaver Reservoir than that predicted by growing season length and calculated carrying capacity. However, in older, more stable reservoirs, the postulated relationship should hold. On the basis of August 1973 rotenone samples we predict a 1974 largemouth bass angler harvest of about 8 pounds per acre in 11-year-old Beaver Reservoir (Figure 5).

The mean standing crop of black bass in 156 southern reservoirs, weighted by reservoir area, was 9.8 pounds per acre. The mean annual area-weighted angler harvest of black bass in 47 southern reservoirs was 4.4 pounds per acre, or about 45 percent of average crop.

Bennett (1962) cautioned that "in the production of fishes of above average size, a large source of available food per individual fish seems to exceed in importance the length of the growing season." The guiding premise in most southern reservoir management schemes, however, is that available food is not a limiting factor. If the hypothesis that we have advanced is not defensible, perhaps we should reexamine our management precepts concerning the adequacy of the forage base and the advisability of stocking striped bass, walleye, and other predators into existing predator populations.

Longer growing seasons and consequent higher annual metabolic and turnover rates inherent in the biota of southern reservoirs appear to decrease the relative importance of closed fishing seasons, size limits and more stringent creel limits as means of improving angling. Hypothetically, maximum annual fish yield exceeds 60 percent of carrying capacity where the growing season is longer than 185 days — which includes all of the Southern Division states except the Appalachian Mountains area. On the basis of available reservoir data, about 35 percent of the carrying capacity of all sport fishes, combined, is harvested annually.

No strong evidence of inadequate spawning stocks of largemouth bass has been reported from large southern impoundments. Year-class strength in older reservoirs is determined primarily by environmental factors such as spring runoff and attendant nutrient inflow and flooding of terrestrial vegetation, which enhance survival and growth of both predator and prey. Maintenance of high water levels throughout the summer is apparently requisite to strong year-class formation (South Central Reservoir Investigations, unpub.).

Reservoir carrying capacity and annual production is primarily controlled by available nutrient levels, basin morphometry, water exchange rate, temperature regime, eutrophication rate, climatic cycles, and species composition. Models of reservoir production and yield need to be strengthened through correlation and regression analyses of long-term ecological data which will enable fishery managers to predict sport fish production and optimum yield levels for all major fishing waters. Management techniques can then be specifically tailored to the needs of a particular fishery on a more timely and economical basis.

The additional data steadily being acquired by Southern fishery agencies are gradually increasing our capability to predict reservoir crop and harvest. For example, additional standing crop estimates acquired in the last 3 years in hydropower reservoirs have significantly increased the percent of variability in total crop explained by only one abiotic variable — mean TDS. Curvilinear regressions of total crop on TDS explain 74 percent of standing crop variability in hydropower storage reservoirs and 70 percent in hydropower mainstream reservoirs (Figure 6). Previous (1970) maximum R^2 values for the regressions applying to these reservoir groups were 62 and 54 percent, respectively (Jenkins, 1970). The promise of future gains in predictive ability is bright.

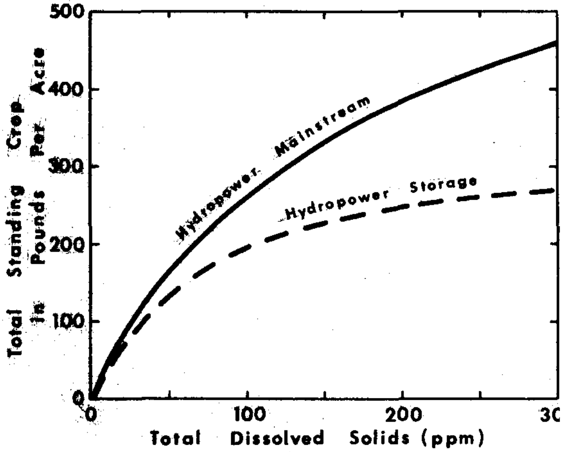

Figure 6. Regressions of total standing crop on total dissolved solids in 52 hydropower mainstream reservoirs (storage ratio 0.165) and 44 hydropower storage reservoirs. Coefficients of determination (R^2) are: mainstream reservoirs = 0.70; storage reservoirs = 0.74. Regression formulas are 1) hydropower mainstream, log(standing crop in pounds per acre) = -0.6150 + 2.252 (log TDS in ppm) -0.3762 (log TDS in ppm)^2; and 2) hydropower storage, log (standing crop in pounds per acre) = -0.6126 + 2.366 (log TDS in ppm) -0.460 (log TDS in ppm)^2.

MANAGEMENT PROGRESS AND POSSIBILITIES

Stocking of sport fishes.

Introduction, or periodic stocking of striped bass, walleye, rainbow trout, and northern pike now commands the spotlight on the Southern reservoir management stage. Much effort has been expended in improving rearing techniques, increasing pond production of fingerlings, and adjusting stocking rates and times for these species during the past decade. These activities will undoubtedly receive growing management emphasis, along with the stocking of catchable channel catfish and blue catfish in smaller impoundments, as economical husbandry techniques evolve.

All of the Southern states are stocking striped bass fry or fingerlings, either experimentally or on a routine annual basis. Naturally spawning stocks of striped bass now exist in Lakes Marion and Moultrie, South Carolina; Kerr Reservoir, Virginia-North Carolina; and Lake Keystone, Oklahoma.

One-half of the States (Arkansas, Georgia, Kentucky, Maryland, North Carolina, South Carolina, Tennessee) routinely stock rainbow trout in large warmwater reservoirs having a cool, oxygenated hypolimnion. Growth of these fish is usually excellent, and provides an attractive midsummer fishery when angling success for other species is poor.

Walleyes have been stocked in Southern reservoirs for over 20 years, most recently in shallow, turbid, windswept impoundments in Oklahoma and Texas. Surprising success has occurred there in shallow sand and silt-bottomed waters. Spawning is concentrated on rock rip-rap along the face of the earth-fill dams. Sub-impoundments of 5 to 20 acres are now used by some State agencies to produce 4-6 inch walleye for late summer stocking. This technique is relatively expensive, but without the addition of sizable juveniles, adequate year classes are rare in deep, clear, older reservoirs. Pond-rearing efforts will probably increase until methods are developed that will enhance natural reproduction in reservoirs proper.

Northern pike and muskellunge have also been championed as trophy sport fishes and predators on adult gizzard shad. Stocking of pike fry in new reservoirs in the mid-South has often resulted in excellent survival, with growth-rates of 4 pounds per year and maximum longevity of 6 years. Although northern pike mature at age I in some waters, reproductive success has been limited; fry stocking in later years of impoundment has also been relatively unsuccessful. The critical requirements of spawning substrate and water levels and temperature must be available before adequate natural reproduction can be expected. Structures that control water depths in nursery areas when levels change in the reservoir, chemical control of undesirable fishes, and planting of sedges or grasses for egg deposition are probably requisite to sustained northern pike production in southern impoundments.

Other sport fishes which have been introduced include brown trout, kokanee, chain pickerel, flathead and white catfishes, largemouth, spotted, redeye, and smallmouth basses; crappies; various sunfishes, and sauger. Brackish west Texas reservoirs have been planted with flounder, red drum, channel bass and redfish from the Gulf of Mexico. Growth of some species has been phenomenal, but none have reproduced. Transplants of additional North American species will undoubtedly occur, but introductions of exotic species should be approached with extreme caution, following the evaluation procedures recommended by the Exotic Fishes Committee, American Fisheries Society.

Questions concerning the effects of stocking large predators on existing reservoir fish populations have prompted member agencies of the Reservoir Committee, Southern Division, American Fisheries Society, to launch a coordinated 2-year study of 26 reservoirs in 11 States where periodic stocking of striped bass, walleye, rainbow trout or combinations of these species, is in progress. By simultaneous study of the physicochemistry, standing crop and angler harvest in these reservoirs, the Committee hopes to identify environmental factors that influence the success or failure of the introduced predators at various stocking rates, determine angler harvest of the predators, and gain further insight into predator-prey relationships.

Estimates of pelagic forage fishes in Ozark reservoirs have shown that mortality of young-of-year shad typically exceeds 99+ percent by fall due to predation (Houser and Netsch, 1971). Annual production of young gizzard and threadfin shad (combined) in Beaver Reservoir has varied erratically from 40 to 180 pounds per acre, which is theoretically convertible to 15 to 60 pounds per acre of predator fish flesh. Angler-harvest of predators during the study period has varied from 10 to 40 pounds per acre. The forage base is obviously not inexhaustible in reservoirs of this type, and evaluations of the changes in predator populations which may occur when additional predators are added to existing populations rates priority attention.

Stocking of forage fishes.

Gizzard and threadfin shad, brook and Mississippi silversides, blueback and Atlantic herring, smelt, needlefish and other fishes have been introduced in Southern reservoirs to improve the forage base. The desirability of the threadfin shad as a manageable forage fish has inspired widespread introductions outside of its original range. Advantages of the species include its small maximum size, prolonged spawning period and short life span. Its susceptibility to winter kill in areas where the mean January air temperature is less than 40° F is a mixed blessing. This characteristic provides an annual population control, but imposes annual reintroduction costs. The techniques of economically obtaining, transporting, and stocking threadfin adults have been refined, and should be used increasingly in the future. The apparent suppression of gizzard shad populations by introduced threadfin shad needs further study.

Habitat manipulation.

In a recent broad-brush effort to model fish communities, Regier and Henderson (1973) concisely expressed the major feature of impounded waters of utmost importance to management, as follows:

"Reservoirs are typically ecologically intermediate between quite unstable reaches of rivers with extensive flood plains, and lakes with relatively more uniform volumes and rates of exchange of materials with the environment. The moderately variable parts of reservoirs are dominated by opportunistic species, from plankton to fish, with higher production than the more constant lake-like parts. The cultivation of seasonally exposed parts of the reservoirs should, other things being equal, enhance production of opportunistic fish..."

Deliberate, long-term management of the fluctuation zone, comprising about 2 million acres of alternately exposed and inundated area in Southern reservoirs, is a critical need. More quantitative measures should be made of natural vegetative production in this zone, along with identification of the plants most suitable for cultivation which would provide optimum spawning conditions, food and cover for desired sport fishes. Recent evidence of increased willingness of some reservoir operating agencies to fluctuate water levels for sport fish production points to the urgent need for improved techniques in managing the fluctuation zone.

The established method of drawing down flood control reservoirs to grow rye, sudan or smartweed on the exposed substrate and to facilitate removal of coarse fishes and concentrate forage fishes for increased predation needs to be expanded. Some practical means of controlling high colloidal-clay turbidity which occurs in some of these flood control reservoirs also needs to be developed to accompany the drawdown technique.

Fertilization of large reservoirs as a feasible management method has been precluded by cost, inability to control water exchange rate and the probability that undesired fishes would benefit more than desired species. Increased nitrogen and phosphorus levels in major water courses stemming from agricultural and domestic sources indicates that accelerated eutrophication may present greater problems in the future than nutrient deficiencies. State water quality standards may prohibit any management technique which will speed eutrophy of public waters.

Fish attractors such as brush shelters and flooded trees have functioned relatively well in bringing fish and fishermen together. Drawbacks include deterioration of standing timber with age and proper placement of shelters to avoid exposure during drawdown and annual maintenance costs. Floating, heated fish docks with brush shelters continue to be popular among winter anglers where extreme drawdown or prolonged ice-cover do not occur. As fishing pressure increases, the need for heated docks as well as fishing piers, jetties and bridge walkways will increase. Satisfactory structural designs and relatively high costs are current bottlenecks to increased development. Better data on reservoir angler-use should enable operating agencies to plan and build optimum numbers of access areas, launching ramps, parking lots, brush shelters, and other conveniences.

Cooling-water reservoirs are appearing rapidly in this region, posing a new set of problems for fishery managers. Although most are privately owned, management by public agencies is ordinarily required. The opportunities for increased fish production as well as the very real possibilities of disaster in these "volatile" waters are now being researched by a few agencies (private and public), and experimental management schemes are being tested. Future fishery conclaves will undoubtedly feature lengthy sessions on hot-water problems.

CONCLUSION

The fishery managers of man-made lakes have been faced with a multitude of unanswered questions and uncontrollable environments in the past 27 years (post World War II), and have often been cast in the role of scientific observers rather than manipulators. But a gradually accumulating mass of data on fish life history, population dynamics and limnology has now provided a backlog of facts on which to base some defensible hypotheses and a number of workable management schemes. Accelerated research and experimentation, growing influence over reservoir operating schedules, pollution abatement, and the development of more sophisticated tools should enable managers to meet the predicted doubling of angler demand in the next 27 years. My prognosis for reservoir fish management is "bullish," with fewer acetyl salicylate tablets prescribed for managerial migraines in the coming years. A minor miracle or two would, of course, be welcomed.

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