

# **Phosphorus influence of Fisheries Literature Review**

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October 26, 2006

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1. Allan, D. J. 1995. Stream ecology: Structure and function of running waters. Chapman & Hall, London.

In algal tissue, the C:N:P ratio is 106:16:1. Therefore, when N:P ratios fall below 16:1 nitrogen becomes the limiting factor for algae instead of phosphorus.

2. Allen, M. S., M. V. Hoyer, and D. E. Canfield, Jr. 1998. Factors related to black crappie occurrence, density, and growth in Florida lakes. North American Journal of Fisheries Management. 18:864-871.

This study looked for correlations of white and black crappie occurrence, density, and length with aquatic macrophyte density, lake size, chlorophyll-a concentrations, chlorophyll-a concentrations adjusted for macrophytes, and zooplankton abundance. They found that black crappie occurrence was positively correlated with lake size and chlorophyll-a concentrations. High macrophyte density resulted in lower chlorophyll-a concentrations and greater water clarity. YOY black crappie densities were positively related to zooplankton and adjusted chlorophyll-a concentrations, but explained only 22% of the variation. CPUE and was positively related to chlorophyll-a concentrations and lake surface area.

3. Bachmann, R. W., B. L. Jones, D. D. Fox, M. Hoyer, L. A. Bull, and D. E. Canfield, Jr. 1996. Relations between trophic state indicators and fish in Florida (U.S.A.) lakes. Canadian Journal of Fisheries and Aquatic Sciences 53:842-855.

This study was designed to examine trophic indicators and fish populations to determine the relationships between trophic state, biomass, species richness, species composition, and standing crop of fish. Lakes from all trophic states were selected for the study. Gizzard and threadfin shad were the only fish that increased in standing crop as more eutrophic lakes were studied. Regression analysis showed that lake area best explained the variance of fish species richness. Centrarchids increased in biomass with trophic state, but did not show any statistically significant changes. Largemouth bass populations reflected a higher proportion of large fish as lakes became more eutrophic. The proportion of piscivores to other fish groups declined when looking at lakes undergoing eutrophication.

4. Bayne, D. R., M. J. Maceina, W. C. Reeves. 1994. Zooplankton, fish and sport fishing quality among four Alabama and Georgia reservoirs of varying trophic status. Lake and Reservoir Management 8(2): 153-163.

Four mainstem impoundments, ranging from mesotrophic to highly eutrophic, were examined to determine the response of zooplankton and fish to trophic gradient. Rotifer and total zooplankton densities increased with increasing trophic status, but crustacean zooplankton densities and biomass did not. Estimates of fish abundance and biomass were positively related to trophic state. Shad comprised a higher percentage of the forage fish community in the eutrophic lakes. Crappie grew faster in the more eutrophic reservoirs; however, black bass growth rates were similar in all lakes. Larger fish were

caught in the eutrophic lakes than in the mesotrophic lake; however, angler-caught black bass size was similar among the three eutrophic lakes. The author suggests that improvements of water quality from a near hypereutrophic condition to a moderately eutrophic state (10 - 15 $\mu$ g/L chlorophyll-a) may not be detrimental to sport fisheries.

5. Bunnell, D. B., R. S. Hale, M. J. Vanni, and R. A. Stein. 2006. Predicting crappie recruitment in Ohio reservoirs with spawning stock size, larval density, and chlorophyll concentration. *North American Journal of Fisheries Management* 26:1-12.

In this study, spawning stock size, larval density, and chlorophyll-a were used to predict white and black crappie recruitment in 11 Ohio reservoirs. The results of this study indicated that chlorophyll-a was positively correlated with larval density and recruitment to age 2. An explanation for this relationship is that chlorophyll-a increased the amount of zooplankton, which in turn, resulted in less probability for crappie starvation and enhanced growth.

6. Carlson, R. E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 22:361-369.

The author creates a trophic state index for lakes that can be calculated using Secchi disk readings, total phosphorus concentration, or chlorophyll-a concentration. The scale of the index is from 0 to 100 where algal biomass is doubled at every interval of ten.

7. Drenner, R. W., S. T. Threlkeld, J. D. Smith, J. R. Murnmurt, and P. A. Cantrell. 1989. Interdependence of phosphorus, fish, and site effects on phytoplankton biomass and zooplankton. *Limnology and Oceanography* 34:1315-1321.

The independent and cumulative effects of fish and phosphorus additions on plankton and water quality were observed in tanks. It is suggested that fish and nutrient interactions have only slight effects on plankton populations and that suppression of zooplankton by fish has a greater effect on plankton in oligotrophic lakes than eutrophic. It was found that fish effects on plankton were dependant upon site.

8. Dubuc, R. A. and D. R. DeVries. 2002. An exploration of factors influencing crappie early life history in three Alabama impoundments. *Transactions of the American Fisheries Society*. 131:476-491.

One objective of this study was to identify age-0 crappie limitations. They found that the catch of postlarval juvenile crappie was higher in the more productive lakes studied. Adult fecundity was not found to be related to chlorophyll-a concentration. Fecundity variation was also not found to explain the variation in larval fish abundance, while chlorophyll-a concentration explained the variation in larval crappie density. Chlorophyll-a concentration was found to be related to larval crappie abundance for the more productive section of the lakes, but was inversely related to lake trophic state. Larval growth was directly related to chlorophyll-a concentration but inversely related to

larval density. They found lower age-0 crappie densities in systems with higher chlorophyll-a concentrations.

9. Hanson, J. M. and W. C. Leggett. 1982. Empirical prediction of fish biomass and yield. *Can. J. Fish. Aquat. Sci.* 39:257-263.

Total phosphorus concentration and benthos-biomass/mean depth indices were compared to indices of the morpoedaphic index and total dissolved solids. Total phosphorus concentration was found to be correlated the closest with fish yield ( $r^2=0.84$ ). This correlation is seen in the best fit line,  $Y=0.072X + 0.792$ .

10. Hendricks, A. S., M. J. Maceina, and W. C. Reeves. 1995. Abiotic and biotic factors related to black bass fishing quality in Alabama. *Lake and Reserv. Manage.* 11:47-56.

The objective of this study was to describe the interrelationships between limnological factors, climate, genetic features, and quality of a black bass fishery. Tournament results were used as a sampling method for black bass. The authors suggest that differences in trophic state were not related to catch rates, but were associated with smaller fish in the angler catch and greater effort to catch memorable size fish. Angler catch rates were similar in reservoirs ranging in trophic state from oligotrophic to eutrophic. It was observed that greater weight averages and higher catch rates of memorable size black bass occurred in lakes with higher chlorophyll-n levels.

11. Jones, J. R., and M. F. Knowlton. 1993. Limnology of Missouri reservoirs: an analysis of regional patterns. *Lake and Reservoir Management* 8:17-30.

This paper provides an overview of the limnology of Missouri reservoirs and their water quality and trophic states. They found that reservoirs in the Ozark Highland region generally have lower algal chlorophyll concentrations, nutrient content, suspended solids, and greater Secchi depth readings. They attribute these findings to the land cover of the region. Forest and pasture dominate the watersheds of these lakes opposed to regions where cultivation is more abundant. Agricultural fertilizer is used less in the Ozark Highland region. The paper states that nitrogen can be a limiting factor in some Missouri reservoirs, although Table Rock's N:P ratio was found to have a mean value 40:1 in the years 1978 through 1984. TN:TP in turbid waterbodies may overestimate the importance of nitrogen because phosphorus binds to sediment particles: making it relatively less available for algal growth than nitrogen. Trophic state criteria based on chlorophyll, total P, and total N, are suggested and used to characterize select Missouri lakes.

Trophic State	Chlorophyll-a µg/L	Total P µg/L	Total N µg/L
Oligotrophic	53	510	5300
Mesotrophic	>3-7	>10-25	>300-500
Eutrophic	>7-40	>25-100	>500-1200
Hypereutrophic	>40	>100	>1200

12. Jones, J. R., and M. V. Hoyer. 1982. Sportfish harvest predicted by summer chlorophyll-a concentration in midwestern lakes and reservoirs. *Transactions of the American Fisheries Society* 111:176-179.

An index of the relationship between angler harvest and chlorophyll-a is constructed as a prediction of sport fish yield. Chlorophyll-a and fish yield were found to have a strong correlation ( $r=0.91$ ) while correlations between fish yield and total phosphorus, alkalinity, and the morphoedaphic index were weak ( $r=0.72, 0.23, \text{ and } 0.40$ , respectively)

13. Maceina, M. J., D. R. Bayne, A. S. Hendricks, W. C. Reeves, W. P. Black, and V. J. DiCenzo. 1996. Compatibility between water clarity and black bass and crappie fisheries in Alabama. Pages 296–305 *in* L. E. Miranda and D. R. DeVries, editors. *Multidimensional approaches to reservoir fisheries management*. American Fisheries Society, Symposium 16, Bethesda, Maryland.

Relationships between water quality, crappie, and black bass data were studied in Alabama reservoirs. A total phosphorus level of about  $50 \text{ mg/m}^3$  was found to increase water clarity to 120 cm without having a negative effect on crappie and bass populations. A reduction of chlorophyll-a concentrations to  $10\text{-}15 \text{ mg/m}^3$  in eutrophic waters was also found to improve water quality and aesthetics of the water body without damaging the value of the sport fishery.

14. Maceina, M. J., and D. R. Bayne. 2001. Changes in the black bass community and fishery with oligotrophication in West Point Reservoir, Georgia. *North American Journal of Fisheries Management* 21:745-755.

Tournament and electrofishing catch rate data were compared to water quality data during the oligotrophication of a lake. State-mandated reductions in point-and non-point source phosphorus loadings resulted in a drastic decline in total phosphorus concentrations (TP). Concurrent with the decline in TP, chlorophyll-a concentration declined from more than  $40 \mu\text{g/L}$  to  $9\text{-}17 \mu\text{g/L}$ , which was lower than the established criterion of  $27 \mu\text{g/L}$ . Largemouth bass recruitment, growth rates, and electrofishing catch rates of bass longer than 406 mm declined while spotted bass recruitment increased. Tournament angling effort has more than doubled to catch a black bass weighting more than 2.27 kg. The onset of oligotrophic conditions has restructured the black bass population with largemouth becoming smaller, less numerous, and less robust, while spotted bass became more abundant and smaller.

15. Mericas, C., and R. F. Malone. 1984. A phosphorus-based fish kill response function for use with stochastic lake models.. *North American Journal of Fisheries Management* 4:556-565.

Water quality data were collected and analyzed with the occurrence of fish kills in a six lake system. It was calculated that the probability of a fish kill occurring while total phosphorus levels were under  $0.4 \text{ mg/L}$  was negligible. The probability of a fish kill rose to a steady 3% when total phosphorus levels were above  $0.4 \text{ mg/L}$ . Above  $0.4 \text{ mg/L}$ ,

phosphorus was no longer the limiting factor to algal booms and weather became the controlling factor. The authors suggest that reducing total phosphorus to below the 0.4mg/L threshold is a reasonable management objective.

16. Moyle, J. B. 1949. Some indices of lake productivity. Transactions of the American Fisheries Society, 76:322-334.

This paper looked at many different variables to find a strong relationship with lake productivity. Alkalinity, total phosphorus, nitrogen, sulfates, chlorides, ph, and dissolved CO<sub>2</sub> were all examined. It was found that phosphorus and alkalinity were the most valuable of the tested variables. For fish yield, the proposed ideal range of alkalinity was 41-120 ppm. Total phosphorus levels of 0.2 ppm were not found to increase fish yield while levels above 0.5 ppm were considered dangerous due to a tendency for oxygen depletion.

17. Ney, J. J., C. M. Moore, M. S. Tisa, J. J. Yurk, and R. J. Neves. 1990. Factors affecting the sport fishery in a multiple-use Virginia reservoir. Lake and Reservoir Management 6:21-32.

Catch rates of the sport fishery in Smith Mountain Lake has declined since 1970. This decline was previously attributed to three probable factors: expanded hydroelectric operation, reduced nutrient loading, and fish species interaction. The influence of these factors on the fishery was studied and reviewed. Expanded hydroelectric operation and species interaction were found to have an insignificant effect on the sport fishery. However, phosphorus concentration was positively correlated with planktivorous fish biomass, while there was no strong relationship found with piscivorous fish.

18. Ney, J. J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. Pages 285-295 in L. E. Miranda and D. R. DeVries editors. American Fisheries Society, Symposium 16, Bethesda, Maryland.

This paper concludes that the reversal of eutrophication can hurt fisheries. The author also concludes that eutrophication vs. oligotrophication can only be resolved on a case by case basis. Regression analysis is used between phosphorus, the principle limiting nutrient, and fishery productivity. Ney suggests that sport fish biomass probably does not peak at a phosphorus concentration less than 100  $\mu\text{g/L}$  although eutrophication status is achieved at 40  $\mu\text{g/L}$ . Prevention of oligotrophication through top-down manipulation has potential to promote clean and good fishing lakes, but not in large eutrophic impoundments. The most promising approach is to prevent oligotrophication through informed decision making between fisheries scientist and limnologist. The author points out that phosphorus is usually the limiting nutrient for primary production and the focus of nutrient reduction programs. The central causes of oligotrophication are point-source nutrient abatement programs on tributary rivers and construction of upstream impoundments. Standing stock of planktivores was highly correlated with total phosphorus while biomass of piscivorous sport fish was not, possibly due to game fish regulations. The author claims that a total phosphorus concentration between 80 and 100

$\mu\text{g/L}$  will support the greatest biomass of sport fish, although these concentrations are associated with "green lakes".

19. Perrin, C. J., M. L. Rosenau, T. B. Stables, and K. I. Ashley. 2006. Restoration of a montane reservoir fishery via biomanipulation and nutrient addition. *North American Journal of Fisheries Management* 26:391-407.

Nutrient addition and biomanipulation was applied to an aging reservoir in trophic decline. The populations of salmon and trout were declining because of fewer nutrients and competition with illegally introduced sticklebacks. The reservoir was fertilized for five years with phosphorus additions of  $225 \text{ mg/m}^2$ . Both trout and salmon were stocked leading to a 4% decrease in sticklebacks. Annual phosphorus loading increased from  $103 \text{ mg/m}^2$  to  $225 \text{ mg/m}^2$ , altering N:P ratios from 25:1 to 13:1. Total phosphorus load was raised from  $202 \text{ mg/m}^2$  in 1993 to  $450 \text{ mg/m}^2$  in 2000. In the end, the fishery was restored to a point that sport fish were numerous and a greater proportion were of quality size.

20. Stockner, J., G. E. Rydin, and P. Hyenstrand. 2000. Cultural oligotrophication: causes and consequences for fisheries resources. *Fisheries* 25:7-14.

This article looked at the current state of knowledge of oligotrophication and gave a historic perspective on human caused oligotrophication. Causes include: removal of anthropogenic nutrient loading (sewage), creation of reservoirs and impoundments, logging (vegetation removal), diversion of rivers from one drainage basin to another, drainage of wetlands, channelization of streams, loss of migratory fish populations (dams), acidification and liming of lakes, and climate change. Reduction in fish yield in many lakes over the last 20-30 years has been attributed to oligotrophication. It is suggested that returning over-enriched systems to a mesotrophic condition would be a middle-ground approach that would increase the aesthetics of a system without hurting the fishery.

21. Tsai, C., M. Wiley, and A. Chai. 1991. Rise and fall of the Potomac River striped bass stock: a hypothesis of the role of sewage. *Transactions of the American Fisheries Society* 120:1-22.

The authors collected and integrated water quality data, sewage treatment discharge events, commercial fishing records, juvenile striped bass research, and zooplankton and phytoplankton research to offer insight into the history of the striped bass fishery of the Potomac River. A transfer function-noise model and a multiplicative decomposition analysis suggest that sewage discharge plays a role in the fishery, particularly the recruitment of striped bass. It is hypothesized that an increase in sewage raised the fertility of the spawning and nursery regions and was responsible for the abundance of striped bass from the 1940s through the 1960s. It is further hypothesized that the improvements in sewage treatment processes, since the early 1970s, have greatly lowered sewage nutrient loading, lowered fertility in the spawning and nursery regions, and contributed to the recent decline of striped bass in the Potomac Estuary.

22. Wetzel, R. G. 1975. *Limnology*. W. B. Saunders Company, Philadelphia, Pa.

Total phosphorus concentrations for most unaltered lakes are in the range of 10-15  $\mu\text{g/L}$  although variation is high. The amount of total phosphorus generally increases with lake productivity.

23. Yurk, J. J., and J. J. Ney. 1989. Phosphorus-fish community biomass relationships in southern Appalachian reservoirs: can lakes be too clean for fish? *Lake and Reservoir Management* 5:83-90.

Nutrient abatement programs have had the perception that all aspects of a reservoir will benefit from clearer water. This view has overlooked the ideas of ecology concerning trophic interaction. In eutrophic systems, fish habitat can be reduced by summer stratification that includes oxygen deficient layers, but food supply is usually the limiting factor for fish biomass. In this study, the relationship between fish biomass and total phosphorus was measured in large southeastern reservoirs (greater than 200 ha). Phosphorus explained 66 percent of the variation of total fish standing stock. When individual species were evaluated, only gizzard shad biomass could be explained by total phosphorus concentrations. When fish were evaluated by diet, planktivores showed a significant relationship to phosphorus concentration while benthic feeders did not. Phosphorus concentration could only explain half of the variation in piscivore biomass. This difference is probably due to insufficient transfer of energy between trophic levels. Gizzard shad rapidly reach a size too large for piscivores to consume and contributed to 90 percent of the planktivore biomass in this study. Therefore, energy is lost in gizzard shad that would otherwise be transferred to piscivores. In the eleven year study, trends in total phosphorus concentration over time were very similar to trends in total fish biomass. In 1973, 1976, 1979, and 1982 the total phosphorus concentration measured about 170, 100, 40, and 20  $\mu\text{g/L}$  and the total fish biomass measured about 1000, 900, 300, and 200 kg/ha, respectively, on Smith Mountain Lake. In other southern Appalachian reservoirs, the total phosphorus concentration and fish biomass were linearly correlated on a log scale. At a total phosphorus concentration of 5, 20, 50, and 100  $\mu\text{g/L}$ , the total fish biomass was about 6, 14, 100, and 200 kg/ha, respectively.

24. Zeller, H. D. 1953. Nitrogen and phosphorus concentrations in fertilized and unfertilized farm ponds in central Missouri. *Transactions of the American Fisheries Society* 82:281-288.

Six farm ponds were studied in Missouri. Phosphorus ranged from .016 to .028 ppm yearly in fertilized ponds and .01 to .016 ppm per year in unfertilized ponds. A good correlation was found between phosphorus and plankton productivity when phosphorus was read daily. Phosphorus added as fertilizer was found to be utilized within one week and as soon as 24 hours depending on biological activity. It is suggested that phosphorus concentration changes are so rapid that daily checks must be made to keep significant changes from passing unnoticed.