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Effects of conservation practices on fisheries management

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Beasley Lake watershed located in the Mississippi River Alluvial Plain was subjected to a series of conservation management practices with the goal of reducing sediment and nutrients entering the lake via agricultural runoff. Concurrent with the application of conservation practices, the lake was renovated and restocked to produce a sports fishery. Conservation practices reduced annual mean total solids from 592 mg/L in 1996 to 66.7 mg/L in 2011 resulting in increased Secchi visibility from an annual mean of 16 cm to 28 cm. Phosphorus was reduced by 95% from 1.75 mg/L to 0.08 mg/L while nitrate was reduced by 58% from an average annual high of 0.69 mg/L in 1996 to 0.29 mg/L in 2011. Recovery of the fishery following restocking was slow until after 2000 when water quality improved. Numbers of fish per unit of effort peaked at 82 / hr. in 2006 while highest combined catch per unit of effort (9.37 kg/h) was reported in 2009. While clupeids and centrarchids were an important component of the catch by number for the duration of the study, there was a shift from a carp-catfish dominated catch in 1998 – 1999 to one dominated by centrarchids and clupeids by 2004. Catch and numbers per unit of effort over time show a cyclic pattern of highs and lows indicating instability within the fish community. The decision not to harvest fish in favor of catch and release and the reduction of nutrient concentrations within the lake likely contributed to reduced catch per effort in 2011.

Key words: Suspended sediments, water quality, agriculture, conservation practices, Oxbow lake, watershed.

INTRODUCTION

Management of warm water fisheries for a maximum sustained yield dates back to at least the 1950's with work begun by Swingle [1-2]. The basic concept was one of establishing a "balanced" community of predators and prey. A balanced fish population is defined as one that provides long term, quality sport fishing where annual reproduction replaces fish that have been harvested or have died. In the southern portion of the United States, the typical predator is the largemouth bass and the prey is bluegill. Newly established lakes or ponds would be stocked to achieve the ratio of predators and prey necessary to eventually provide harvestable size fish of both species.

Once stocked, the fishery was managed by controlling harvest and improving the primary productivity of the ponds with the addition of phosphate fertilizers [3]. By harvesting bass at a rate of approximately 11 to 22 kg/ha/year and bluegill, *Lepomis macrochirus* at a rate of 45 to 56 kg/ha/year balances could be maintained. Ponds that were out of balance were first renovated, that is, the existing community of fishes was removed using a toxin and replaced with largemouth bass, *Micropterus salmoides* and bluegill in the proper ratio. Production of harvestable sized fish could be increased by the addition of phosphate fertilizers which stimulates phytoplankton production [4-5]. This increase in primary productivity in turn increases the production of planktonic invertebrates and benthic macroinvertebrates providing food for bluegill. Other than managing for excessive production of emergent vegetation and shoreline erosion few other management options were available.

While oxbow lakes have historically been some of the nation's most productive fisheries, sediment and associated agricultural pollutants have had a negative impact on the recreational fishery [6-9]. Marinda [10]

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reported that filling by sediment contributed to shallow that exacerbate dissolve oxygen declines. Cooke [11] stated that in disturbed watershed such as those with intensive agriculture, sedimentation was the greatest contributor to lake aging. Transported sediments are often accompanied by other contaminants such as pesticides and nutrients particularly during storm events [12]. Cooper and Knight [13] reported nutrients, persistent pesticides, such as DDT (dichlorodiphenyltrichloro-ethane), and its metabolites, heptachlor, lindane and dieldrin, and metals were transported during storm flows along with high concentrations of suspended solids.

Sediment can also have a negative effect on many features of aquatic ecosystems but perhaps the most detrimental effects involve the reduction of primary productivity [14-15]. Knight et al. [16] demonstrated that when suspended sediments in oxbow lakes exceeded 150 mg/L primary productivity, as measured by chlorophyll concentrations, limited due to poor light availability. Further their research showed that this reduction in primary productivity was in spite of sufficient concentrations of phosphorus (1.83 mg/L) and nitrogen (0.82 mg/L). Concentrations of phosphorus and nitrogen far exceeded the water quality criteria established by Mississippi's Department of Environmental Quality. While phosphorus is generally the limiting factor affecting primary productivity in freshwater habitats nitrogen is the primary limiting factor in marine environments. Excessive nutrients in either cause oxygen depletions due to eutrophication and harmful algal blooms. Diaz and Rosenberg [17] and Bianchi [18] have demonstrated the eutrophication responsible for hypoxia in the Gulf of Mexico is associated with excess N and P in agricultural runoff. Additionally, Shields and Knight [19] stated that several aquatic resources including rivers and natural lakes within the Mississippi alluvial plain also experience chronic periods of hypoxic conditions.

Soil conservation practices designed to reduce sediment-laden runoff have been shown to reduce suspended sediment concentrations in the receiving waters of oxbow lakes [20-21]. It was hoped that while reduction in nutrient in-flow may be realized, most oxbow lakes would be sufficiently eutrophic to boost primary productivity and consequently support a sustainable fishery. The research presented here documents the impact of these management practices on the fisheries of oxbow lakes receiving runoff from these managed watersheds.

MATERIALS AND METHODS

Site description, lake and fisheries management

Beasley Lake (33^{o} 23' 52.8", -90^{o} 33.6' 33.6"), located south of Indianola, MS in Sunflower County, is an oxbow lake formed by a meander loop of the Big Sunflower River (Figure 1). The lake is 16 ha in surface area and drains a 404 ha watershed that includes a large wooded riparian zone. According to the landowner the lake was not used for agricultural purposes and only rarely used for recreation; receiving less than five days of fishing effort per year. During the initial years of the study (1995-1996) the watershed was farmed using conventional tilled practices to grow cotton and soybeans. The watershed has undergone several conservation management changes with the intent of reducing nonpoint source pollutants entering the lake. From 1997 through 2000 the additions of slotted pipes, slotted board inlets, grassed buffers, and stiff grass hedges were added to the watershed. In 2001 tillage was converted from conventional to reduced, and in 2003 [22] a portion of the watershed was taken out of production and planted in trees as a part of the Conservation Reserve Program. For further details on crop changes with respect to time on the Beasley Lake watershed see Cullum et al. [23].

Personal communication with the landowner revealed Beasley Lake's low fishing pressure, less than 5 days per year, was in part attributed to poor catch and consistently turbid condition of the water. According to a 2011 survey, anglers in Mississippi expended 7,751,000 days of fishing in the approximately 140,000 lakes and ponds in the state for an average of 55.36 days per water body per year [24 - 25]. Excessive numbers of undesirable fish and the initial "unbalanced" condition of the predator and prey ratio of Beasley Lake made it necessary to "renovated" the oxbow using 5% rotenone solution to remove the existing community of fishes. The lake was re-stocked with largemouth bass, a mix of bluegill and redear sunfish (*Lepomis microlophus*), and channel catfish (*Ictalurus punctatus*) at rates of 123, 1235 and 370 per ha, respectively. The bluegill - redear sunfish mix and channel catfish were introduced in the fall of 1996 followed by largemouth bass in the spring of 1997. Harvest of largemouth bass at a rate 11 to 22 kg/ha per year and bluegill at a rate of 45 to 56 kg/ha per year was recommended to begin in 2000. After property owner changed in 2005, harvest of all species ceased in favor of catch and release.

Research methods

Water quality was measured from February 1995 through August 2011. Water sampling sites were located at three locations one in the middle of the lake and one at each distal end. Surface water was collected at each site at the depth of approximately 0.25 m [23]. Automated water quality monitoring equipment was used to obtain biweekly measurements of temperature, pH, dissolved oxygen and conductivity. Additionally, surface water quality was sampled biweekly for total, suspended, and dissolved solids, total phosphorus, filterable ortho-phosphate, ammonium nitrogen and nitrate nitrogen, chlorophyll, coliform and enterococci bacterial counts and Secchi visibility. More specific details of sampling regimes, physical and chemical parameters measured, and analysis procedures for the project varied with the different

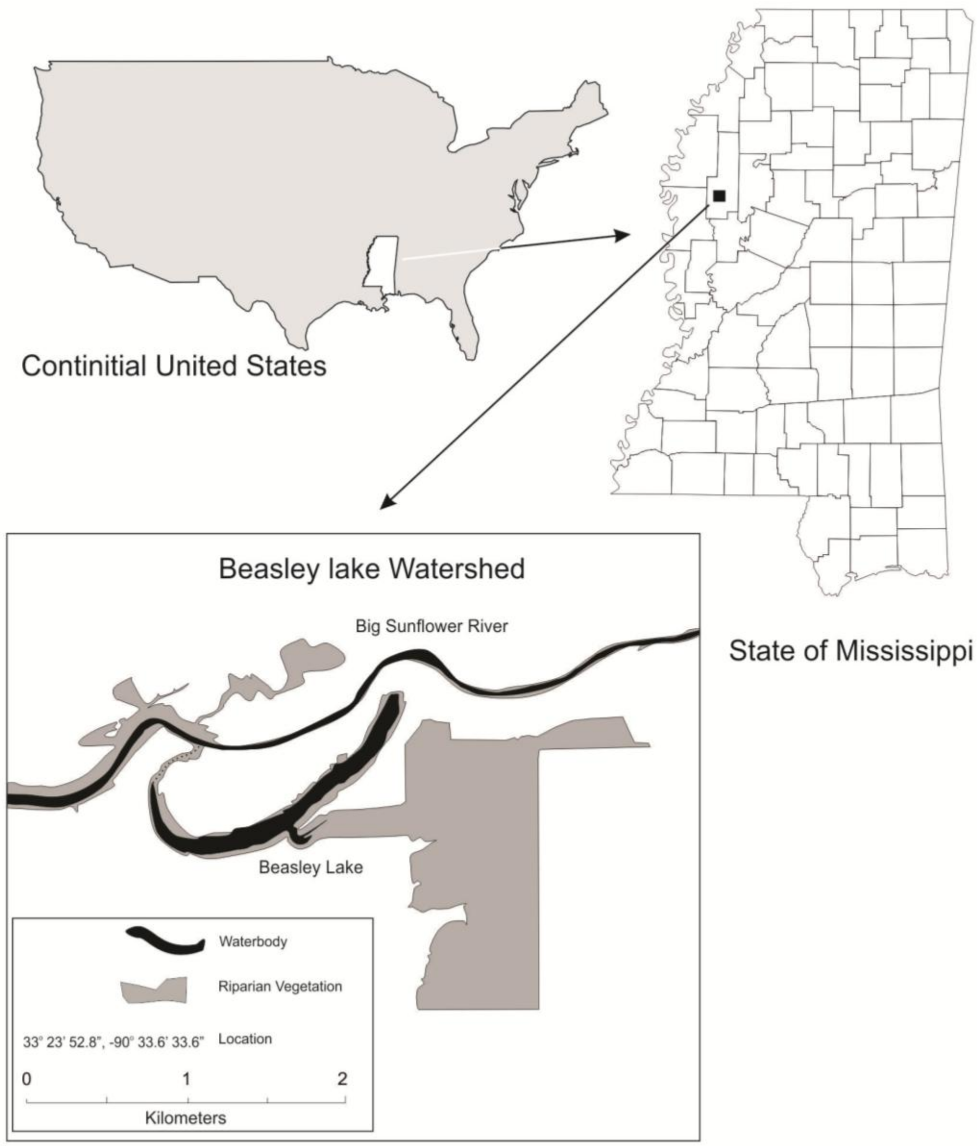

Figure 1. Map of Beasley Lake, MS, USA.

aspects of the project and are in Rebich and Knight [26].

Late spring to early summer fish sampling was accomplished using a boat mounted electroshocker according to Reynolds [27]. Electricity was applied as pulsed direct current. Voltages were varied to compensate for differing lake conductivity over the several years of the study. Sampling effort was limited to a maximum of one hour of electrofishing that provided adequate survey coverage while minimizing damage to recovering populations. Captured fish were placed in holding tanks until they could be identified to species, weighed, and measured for total length, and released. Capture mortality was generally limited to smaller individuals.

Analytical and chemical methods were based on procedures from APHA [28]. Calculation of means and statistical analysis was completed using SigmaStat for Windows version 2.03 statistical software. All parameters were tested for differences at the 5% level of significance. Log transformed data were subjected to simple linear regression to determine relationships between total phosphorus, total sediment and chlorophyll a concentrations [29].

RESULTS AND DISCUSSION

Water quality changes

The conservation practices employed in Beasley Lake watershed were primarily based on methods designed to reduce the velocity of runoff water. Reducing velocity reduced the energy available for both erosion and

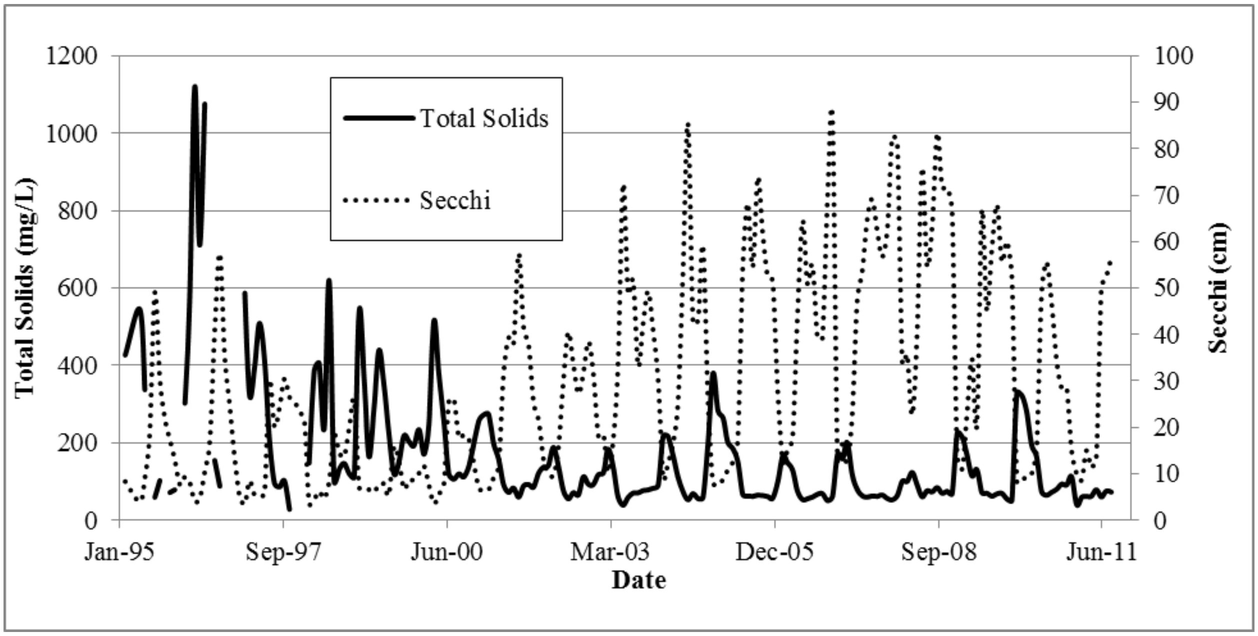

Figure 2. Monthly mean Secchi depth and total solids concentration from Beasley Lake, MS, USA from January 1995 through June 2011.

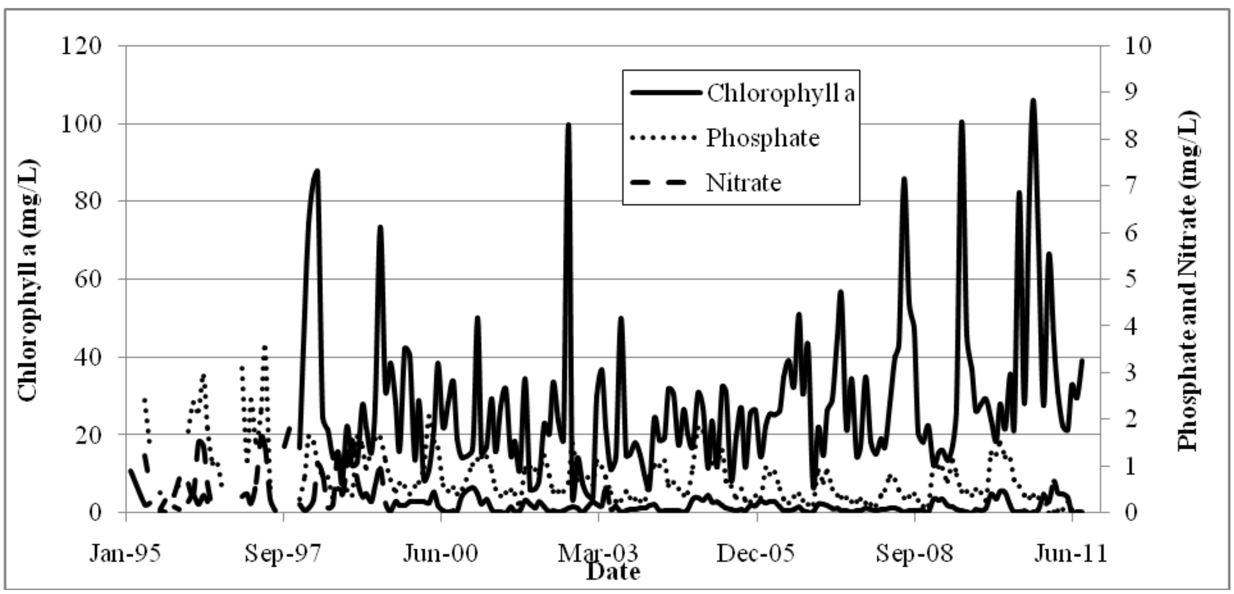

Figure 3. Monthly mean chlorophyll a, phosphate and nitrate concentrations for Beasley Lake, MS, USA from January 1995 through 2011.

transport of soils. Structural practices such as slotted board inlets retained standing water during a portion of the year greatly reducing water velocity. This Allowed sufficient time for suspended soils to settle, while also allowing longer time for water infiltration. While arguably not as effective as slotted board inlets, other methods such as grass buffers and stiff grass hedges also retarded the flow of water and reduced velocities and consequently reduced sediment and associated nonpoint pollutants.

Watershed management practices as expected, reduced total solids in the lake (r = - 0.714). Annual mean total solids were reduced from 592 mg/L in 1996 to 66.7 mg/L in 2011; a reduction of approximately 89 %. This reduction greatly improved water clarity as measured by Secchi visibility which increased with time (r = 0.734) from an annual mean of 15.9 cm to 28 cm for the same time period (Figure 2). Phosphorus was also reduced along with nitrate (r = - 0.733, and - 0.687 respectively) (Figure 3). Annual mean total phosphorus concentration

Table 1. Catch per unit effort (kg/hr) and number per unit effort (number/hr) from Beasley Lake.

	Catch per unit effort (kg/hr)					
	1998	**1999**	**2004**	**2006**	**2009**	**2011**
Amiidae			0.94		3.33	
Catostomidae	0.36				23.34	
Centrarchidae	2.50	0.15	17.02	12.65	54.22	4.48
Clupeidae	2.35	0.21	4.34	13.88	9.52	3.13
Cyprinidae	5.05	0.23	9.90	6.06	10.22	
Ictaluridae		0.50	0.40			
Lepisosteidae	1.23	1.73	1.08	0.41	5.60	0.83
	Number per unit effort (number/hr)					
	1998	**1999**	**2004**	**2006**	**2009**	**2011**
Amiidae						
Catostomidae						
Centrarchidae	62	4	69	166	144	40
Clupeidae	61	4	48	150	104	38
Cyprinidae	17	1	5	10	40	
Ictaluridae		3	1			
Lepisosteidae	3	2	3	2	4	2

was reduced by 95.2 % from 1.75 mg/L to 0.08 mg/L while nitrate was reduce by 58% from an average annual high of 0.69 mg/L in 1996 to 0.29 mg/L in 2011.

With the reduction in water column solids and increased water clarity, light was more available for phytoplankton production as indicted by the increase in chlorophyll a from 3.42 mg/L to 33.1 mg/L which represents a 90 % increase (Figure 3). Chlorophyll *a* was positively correlated with time (r = 0.73).

Fisheries

Following the application of rotenone in Beasley Lake, Knight and Welch (2004) reported recovering representatives of 15 species from Beasley Lake. White crappie, (*Pomoxis annularis*), gizzard shad (*Dorosoma cepedianum*) and madtom catfish (*Noturus gyrinus*) were numerically dominant species in Beasley Lake, while gar (*Lepisosteus sp*.), common carp (*Cyprinus carpio*), white crappie and paddlefish (*Polyodon spathula*) were important in the catch by weight. Subsequent sampling for Beasley Lake produced representatives of 19 species over the course of 13 years of sampling. While one might expect the species diversity of Beasley Lake to be low it actually exceeded the pre-renovation diversity of 15 species. This was likely due to failure to eliminate all fish during the renovation process and reintroduction of fish from the adjacent Sunflower River during periods of flooding.

Recovery of the fishery following restocking was slow until after 2000 when water quality improved as reflected in increased Secchi visibility, decreased total solids and increased chlorophyll a concentrations. Numbers per unit of effort peaked in 2006 while highest combined catch per unit of effort was reported in 2009 (Table 1). Clupeids and centrarchids dominated the catch by number for the duration of the study (Table 2); however, there was a shift from a carp -catfish dominated catch in 1998 – 1999 to one dominated by centrarchids and clupeids by 2004.

Catch per effort and numbers per effort over time show a cyclic pattern of highs and lows (Figure 4). As indices of stock abundance these values represent predator prey interactions between largemouth bass and their prey, shad and bluegill; therefore some cycling is expected. In the case of a sports fishery these peaks and valleys would normally be dampened by harvest in a typical fishery. The decision not to harvest fish in favor of catch and release by the land owner allowed the fish community to exceed its carrying capacity which caused a subsequent collapse of the fishery. Additionally conservation practices that reduce the nutrient concentrations within the lake also exacerbated the problem by suppressing the carrying capacity.

Two oxbow lakes, Deep Hollow and Thighman, which are located in the same ecoregion and are of similar size, watershed usage, and management practices may be used to compare the results from Beasley Lake. Beasley Lake’s highest catch per unit of effort of 54.2 kg/hr. exceeded that of Deep Hollow (37.7 kg/hr.) and Thighman Lakes (43.83 kg/hr). All three lakes had been renovated and managed to reduce agricultural runoff. Catch composition as would be expected were similar for all lakes [30].

To protect the Gulf of Mexico from hypoxia and to

Table 2. Percent composition by weight and number from Beasley Lake.

By weight	1998	1999	2004	2006	2009	2011
Amiidae			2.80		3.14	
Catostomidae	3.16				21.97	
Centrarchidae	21.76	5.21	50.54	38.34	51.04	53.06
Clupeidae	20.46	7.31	12.89	42.06	8.97	37.06
Cyprinidae	43.91	8.24	29.39	18.37	9.62	
Ictaluridae		17.66	1.17			
Lepisosteidae	10.71	61.58	3.21	1.23	5.27	9.89
By Number	**1998**	**1999**	**2004**	**2006**	**2009**	**2011**
Amiidae			0.79		0.68	
Catostomidae	0.69				0.68	
Centrarchidae	43.06	28.57	54.33	50.61	48.65	50.00
Clupeidae	42.36	28.57	37.80	45.73	35.14	47.50
Cyprinidae	11.81	7.14	3.94	3.05	13.51	
Ictaluridae		21.43	0.79			
Lepisosteidae	2.08	14.29	2.36	0.61	1.35	2.50

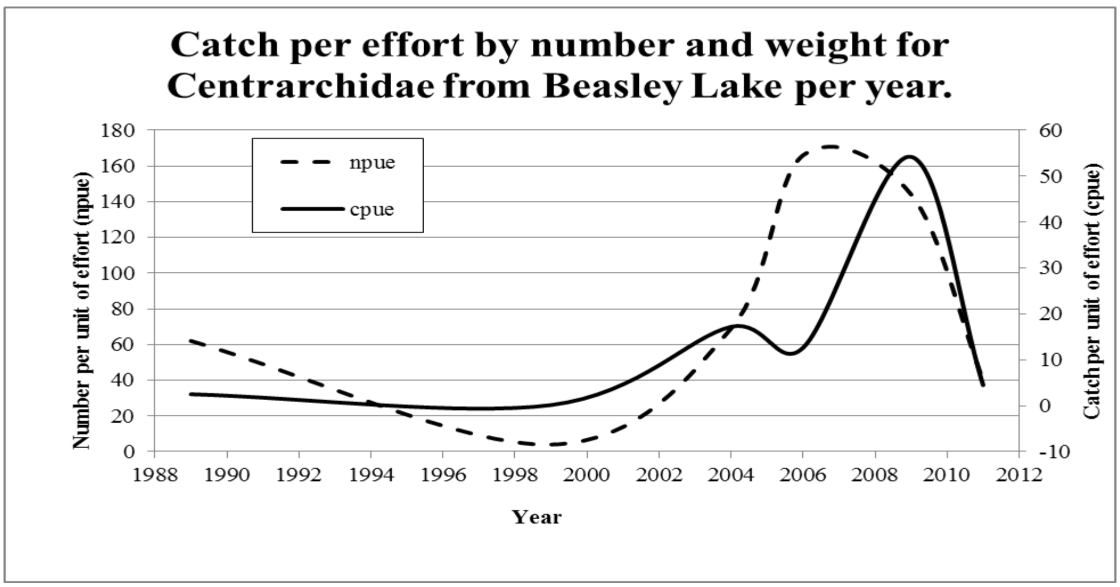

Figure 4. Number and catch per unit of effort for Beasley Lake, MS, USA from 1998 through 2011.

eliminate low dissolved oxygen conditions in the state's rivers and streams, a major goal for the State of Mississippi is to reduce concentrations of phosphorus and nitrogen in its surface waters. However, because nutrients are necessary to maintain secondary productivity of lakes, ponds and impoundments, water quality goals may come in conflict with fisheries management goals. Harvest practices should be implemented based on sound biological reasoning in order to maintain a sustainable fishery. This study demonstrates that well intended objectives of reducing agricultural pollutants and protecting trophy fish can have unintended and detrimental consequences.

Conclusions

Management of a sports fishery involves manipulations of the aquatic ecosystem in many areas including preserving a suitable ratio of predators to prey, maintaining an appropriate concentration of nutrients sufficient to sustain primary productivity and controlling nonpoint pollutants from the surrounding watershed. Conservation practices reduced annual mean total solids, phosphorus and nitrogen while chlorophyll *a* increased water clarity as measured by Secchi visibility greatly improved. Numbers of fish per unit of effort peaked in 2006 while highest combined catch per unit of effort was reported in 2009. Catch per effort and numbers per effort over time show a cyclic pattern of highs and lows. The decision not to harvest fish in favor of catch and release along with the reduction of nutrient concentrations within the lake likely resulted in reduced catches in 2011. While reduction of nutrients is a common goal of state and federal agencies responsible for the protection of water resources, consideration must be given to the management goals of a particular body of water. Because nutrients are necessary to maintain secondary productivity of lakes, ponds, and impoundments, water quality goals may come in conflict with fisheries management goals. Additionally, harvest practices should be implemented based on sound biological reasoning in order to maintain a sustainable fishery.

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