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EFFECTS OF SEDIMENT ON AQUATIC LIFE

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for the
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Illinois Task Force on Agriculture Nonpoint Sources of Pollution

Reduction of Light Penetration

Primary production is the production of organic material from carbon dioxide and water by green plants and is the basis for all food chains in both aquatic and terrestrial environments. Primary production is the result of a process called photosynthesis, which is dependent on sunlight. In aquatic environments, primary production occurs only in the euphotic zone, as the result of photosynthesis by both floating and attached algae and by higher plants. Below the euphotic zone, there is not enough light to permit green plants to produce more food by photosynthesis than they consume in the process of respiration, so there is no primary production. The euphotic zone extends down to the depth at which the light intensity is approximately 1 percent of what it is at the surface. In a shallow lake, the entire lake may lie within the euphotic zone. One effect of suspended sediment is to reduce the euphotic zone, thereby reducing primary production. Claffey (1955: 24) used a spectrophotometer to measure light penetration in waters of various turbidities. In water having a turbidity of 25 JTU, only 24.9 percent of the original light

of the red wave lengths (the most penetrating) was visible at a depth of 4 inches; at 50 JTU, only 6.3 percent; and at 150 JTU, no light was available at a depth of 4 inches.

In farm ponds, lakes, and large impoundments primary production within the water itself can be the major source of food for the entire aquatic ecosystem. Waterfowl feed directly on many species of aquatic macrophytes. Few species of fish feed directly on phytoplankton or macrophytes. Some fish, such as gizzard shad, feed on the zooplankters (microscopic animals) which in turn feed on phytoplankton. Many of the gamefish consume zooplankton when they are small, then graduate to insects and forage fish as they become larger. The effect of turbidity on plankton was measured by Claffey (1955: 43), who used a Wisconsin-type plankton net with No. 25 mesh silk bolting cloth to sample 20 farm ponds of varying turbidity in Oklahoma. Zooplankton probably comprised the bulk of the material collected by the net. Turbid ponds contained much less plankton in the surface waters (0 to 2 feet) than clear ponds:

Turbidity Class	Volume (ml of plankton per liter of water)	Reduction of plankton, in comparison to clear water
Clear (25 JTU)	0.0187	-
Intermediate (25-50 JTU)	0.0037	80%
Muddy (51-350 JTU)	0.0019	90%

Primary production can be a nuisance when it is in the form of algal blooms which are unsightly or cause taste and odor problems in drinking water. Suspended sediment can limit or prevent such blooms by reducing light penetration and adsorbing nutrients, such as phosphorous, which stimulate plant growth. Such blooms might occur in many bodies of water in Illinois if suspended sediment levels were reduced without also reducing levels of plant nutrients.

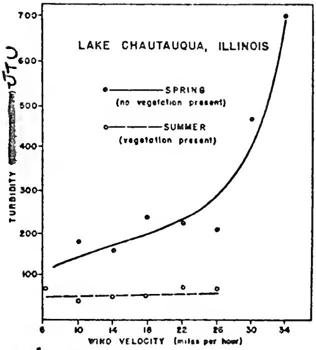


Fig. 1 Turbidities of Lake Chautauqua occurring at various wind velocities (average maximum one hour preceding collection time) in the absence and presence of vegetation. The graph shows that wind has little or no effect upon turbidity of Lake Chautauqua when vegetation is present.

Plant nutrients enter water from many sources, in addition to agricultural sources. For example, phosphorous is used in detergents and contributes to high phosphorous levels in effluents from sewage treatment plants.

In streams and rivers, primary production in the terrestrial environment is a major source of organic material, which is dropped, blown, or washed into the aquatic environment.

In aquatic environments, higher plants have other functions in addition to the function of producing food. Their roots can anchor the bottom against wave action and against the rooting activities of bottom-feeding fish such as carp. The stems and leaves of floating and emergent plants dampen waves. Therefore plants can reduce turbidity by preventing resuspension of bottom sediments by waves or fish. Figure 1, taken from Jackson and Starrett (1959: 162) shows that wind had little effect on the turbidity of Lake Chautauqua when vegetation was present, and a marked effect when vegetation was absent.

Aquatic macrophytes provide habitat for fishes and for a group of invertebrate animals called the "weed fauna." Yellow perch may have disappeared from the bottomland lakes along the Illinois River due to the loss of plant beds the perch use for spawning. Smith (1971: 8) indicates that populations of the bigeye shiner, the bigeye chub, and the pugnose minnow have been decimated in Illinois streams primarily because of the disappearance of aquatic vegetation. The "weed fauna" consists of snails and insects which graze o the macrophytes themselves or on the "scum" formed by bacteria and algae on the larger plants. Predatory insects such as dragonfly and damselfly nymphs hunt their prey among the leaves. The "weed fauna" is important because it furnishes food for members of the sunfish family, such as largemouth bass

and bluegill. In bottomland lakes along the Illinois River, the biomass of the weed fauna once averaged 2118 lbs. to the acre (2374 kg/h) and was eight times greater than the biomass of bottom fauna (Richardson, 1921: 431-432). Since the late 1950's and early 1960's there has been no weed fauna in these lakes because the weeds cannot gain roothold in the soft bottom which is constantly disturbed by wind-generated waves and also because light penetration has been reduced by turbidity. The turbidity and degraded bottom are caused by sediment.

The source of the sediment in the Illinois River cannot be attributed to municipal and industrial effluents originating in the Chicago-Joliet area, because the upper Illinois River is less turbid than the lower Illinois. In fact, beds of sago pondweed grow in the Des Plaines River below the entrance of the Chicago Sanitary and Ship Canal. The Des Plaines and Kankakee Rivers join to form the upper Illinois River. It is only further downstream where tributaries which drain extensive agricultural areas begin to join the Illinois that the turbidity increases and no submerged vegetation occurs.

Reduction of Visibility

Aquatic organisms use a variety of senses to locate food and mates and to avoid danger. The game fishes rely heavily on sight in hunting their food, and it is this attribute which contributes to their desirability as game fish, for they will strike at artificial lures.

If the turbidity of water is increased due to suspended sediment, the ability of game fish to find food (or strike at lures) is reduced. The distance at which a fish will sight and react to prey or bait is called the

reactive distance, and depends on both the size of the prey and the turbidity of the water. Vinyard and O'Brien (1976: 2846-2847) found that the larger the prey size, the greater the effect of turbidity in reducing the reactive distance of bluegills. A turbidity increase from 6.25 to 30 JTU reduced the reactive distance from 8.5 to 2.5 cm for prey 1 mm in size and from 37.5 to 6.0 cm for prey 2.5 mm in size. Thirty JTU appeared to be an upper limit for a turbidity effect. Turbidities greater than 30 JTU did not further reduce the reactive distance presumably because the fish stopped relying on sight to locate their prey and were forced to rely on another sensory system, such as the lateral line system, which is sensitive to water pressure waves generated by movements of prey.

Reduction in reactive distance due to turbidity can have a major impact on the feeding of game fish. Prey that move out of a fish's reactive distance have in fact escaped, and the predator must begin a search for food again. Reduction of reactive distance greatly limits the volume of water a fish can search in a given time. For example, a 50 percent reduction in reactive distance reduces the actual volume searched by a factor of 4, if the fish is assumed to be searching a cylinder, and by a factor of 8, if the fish is assumed to be searching a hemisphere or a sphere (Vinyard and O'Brien, 1976: 2848).

The significance of the laboratory findings of Vinyard and O'Brien (1976) is that turbidity can reduce the feeding of game fish even if there is an abundance of food available in the water.

The reduction in reactive distance of game fish due to turbidity also has a marked impact on angling success, as shown below for Fork Lake, in Macon County, Illinois during the March through September, 1938 fishing season (Bennett, Thompson, and Parr, 1940: 22):

Secchi Disk Visibility, Feet	Number of Fish Caught Per Man-Hour	Reduction of Catch in Relation to Catch When Secchi Disk Visibility = 3.5 to 4.5
3.5 to 4.5	6.53	-
2.0 to 2.5	2.86	56%
0.5 to 2.0	2.04	69%

Many species of game fish exhibit complex reproductive and social behavior which depends on visual cues. For example, male sunfishes build nests in shallow water at the beginning of the breeding season. Since the number of males may exceed the number of favorable nesting sites, and since the fish seem to nest in colonies, each male must aggressively defend his nest against other males. At the same time, the male must be prepared to accept ready females into his nest for spawning. The distinction between a rival male and a ready female is based on visual cues. A female appraoches the nest slowly in a submissive posture, with fins clamped, and her skin assumes a characteristic washed-out color pattern. A rival male generally moves rapidly, raises his fins, and exhibits a bold color pattern. A reduction in visibility interferes with these visual cues. Heimstra et al. (1969: 5-8) found that the activity levels of largemouth bass were reduced and normal social behavior of green sunfish was altered in moderately turbid water (14-16 JTU). The fish also coughed and scraped themselves against the sides of the tanks more frequently in the moderately turbid water (Heimstra et al., 1969: 8).

Abrasion and Clogging

Most aquatic organisms can tolerate sediment in water for a period of time. Wallen (1951: 18) found that the following turbidity levels (in JTU) were required to kill fish:

Rock bass	38,250
Pumpkinseed	69,000
Channel catfish	85,000
Largemouth bass	101,000
Black crappie	145,000
Green sunfish	166,500

Fish exude a protective mucus on their skin and gills which traps and continually flushes away particles. Mussels have a protective mucus on their gills and can close their shells. There is a group of caddisflies which feed by spinning nets into which particles of food are washed by water currents. These caddisflies then eat the net, food and all. If one net becomes clogged with sediment, the caddisflies presumably can spin another.

However, all of the above protective mechanisms are temperary measures. Continual production of mucus by the fish requires metabolic energy and constitutes a stress on the fish at the same time that its ability to find food is reduced by turbidity. If the net of the caddisfly is continually clogged with sediment of little or no nutritional value, the caddisfly will eventually starve. Clams can resist temporary unfavorable conditions by closing up, but then they cannot carry on normal activities such as feeding, aerobic respiration, growth, and reproduction.

Therefore, while some adult organisms can withstand enormous amounts of sediment in water for several days or weeks, the population may eventually die out due to starvation, failure of reproduction, or cumulative stress.

For example, Ellis (1936) found that the defenses of mussels against excessive sediment were eventually overwhelmed after a long period of exposure.

Silt interfered with the feeding of the mussels and caused mortality:

> These experiments, extending over some fourteen months, showed that most of the common fresh-water mussels were unable to maintain themselves in either sand or gravel bottoms when a layer of silt from one-fourth of an inch to one inch deep was allowed to accumulate on the surface of these otherwise satisfactory bottom habitats, although other individuals of these same species held in the lattice-work crates a few inches or feet above the bottom thrived in this same water. Daily analyses of the water at various levels in these raceways showed that the high mortality of the mussels on the bottom was induced by the silt covering and was not due to low oxygen, pH, carbonates or other water conditions. The Yellow Sand-shell (Lampsilis anodontoides), a sand inhabiting species was the most readily killed by silt deposits, and the Three-horned Warty-back, Obliquaria reflexa, the Maple Leaf, Quadrula quadrula, and the Monkey-face, Quadrula metanevra, were among the more resistant. However, the mortality rapidly approached 90 percent or more for all species when the silt layer began to permanently cover the sand or gravel. On the other hand the mortality of the mussels in the crates was very low.
>
> Laboratory experiments with fresh-water mussels in water carrying heavy loads of erosion silt (this material being kept in suspension by automatic glass stirring devices) showed that erosion silt interfered with the feeding of fresh-water mussels. The mussels in the muddy water remained closed a large percent of the time, 75 to 95 percent, while mussels in silt-free water but subject to the same current influences as those in the erosion silt tests were closed less than 50 percent of the time. When mussels opened in water carrying large amounts of erosion silt an excessive secretion of mucus was produced and this served in part to remove the silt which tended to settle into the mantle cavity. Mussels dying in silt-laden water always contained deposits of silt in the mantle cavity and frequently in the gill chambers. (Ellis, 1936: 39-40. Material in parentheses inserted by Sparks.)

It is noteworthy that the yellow-sand-shell was most readily killed by silt deposits in Ellis's experiments, and that it has apparently disappeared from the Illinois River, probably due to increased silt loads (Starrett, 1971: 334). The silt-resistant maple-leaf and three-horned warty-back were still found in the Illinois River in 1966 (Starrett, 1971).

Habitat Alteration and Destruction

Sediment deposits can cover gravel and sand bottoms which many organisms

require for carrying on normal activities such as feeding and reproduction. In extreme cases, sediment can completely fill, and thereby destroy, an aquatic habitat.

Smith (1971: 8) states that "the gravel chub, Ozark minnow, weed shiner, western sand darter, banded darter, and slenderhead darter have reduced ranges because they have lost extensive gravel- and sand-substrate habitats to silt."

The formerly productive bottomland lakes along the Illinois River are almost completely filled with sediment. In February, 1976, the Illinois Natural History Survey made a survey of the water depths of Lake Chautauqua, a bottomland lake along the Illinois River at Havana in Mason County. The maximum depth of the southern 2/3 of this large lake (2000-3000 acres, depending on water levels) was 18 inches. The findings were analyzed by the Illinois State Water Survey, and compared to their earlier studies of sedimentation in Lake Chautauqua (Stall and Melsted, 1951). In the period from 1926-1976, Lake Chautauqua has lost 34.7% of its original capacity.

The loss in terms of fish habitat is much worse than the capacity loss indicates, because the deeper areas of the lake have filled much faster than the shallow areas, and the lake is now uniformly shallow. It once contained areas which were 7 feet deep during low water stages. A diversity in the topography of the bottom is important in maintaining a diversity of plant and animal life. The deeper the water, the less the light penetration, and different species of aquatic plants are adapted to different light intensities. In very deep areas, there are holes in the mat of vegetation because plants are absent or their growth is reduced. As many fishermen know, large gamefish often inhabit the edge of these holes. The deep areas also

offer a refuge for fish both in winter, when shallow water freezes solid, and in summer, when the water temperature in shallow areas can approach lethal levels.

In the summer of 1975, the Illinois State Water Survey measured sediment deposition in Lake DePue, a 500-acre bottomland lake along the Illinois River in Bureau County. Their findings were as follows (Lee and Stall, 1976:11):

> (1) From 1903 to 1975 the capacity of Lake DePue has been reduced from 2837 ac-ft to 778 ac-ft, a 72.6% capacity loss. In terms of annual deposition rate, the lake lost 28.6 ac-ft or 1.01% per year.
>
> (2) The change of lake volume is due to the rising of the lake bed. It was estimated that the annual rate is 0.57 inches per year. The expected time to reach the current normal lake level is about 33 years.

The latter finding indicates that there will be no lake at all in 33 years. As to the source of the sediment in the Lake, Lee and Stall (1976: 29) conclude that it comes from the suspended sediment load carried by the Illinois River. According to local residents, the former depth of Lake DePue was about 18 or 20 feet (Lee and Stall, 1976: 2) and annual speedboat races and regattas were held there. The last annual speedboat race was in 1973, and the 1974 race was cancelled because the water was too shallow (Sparks, 1975: 62).

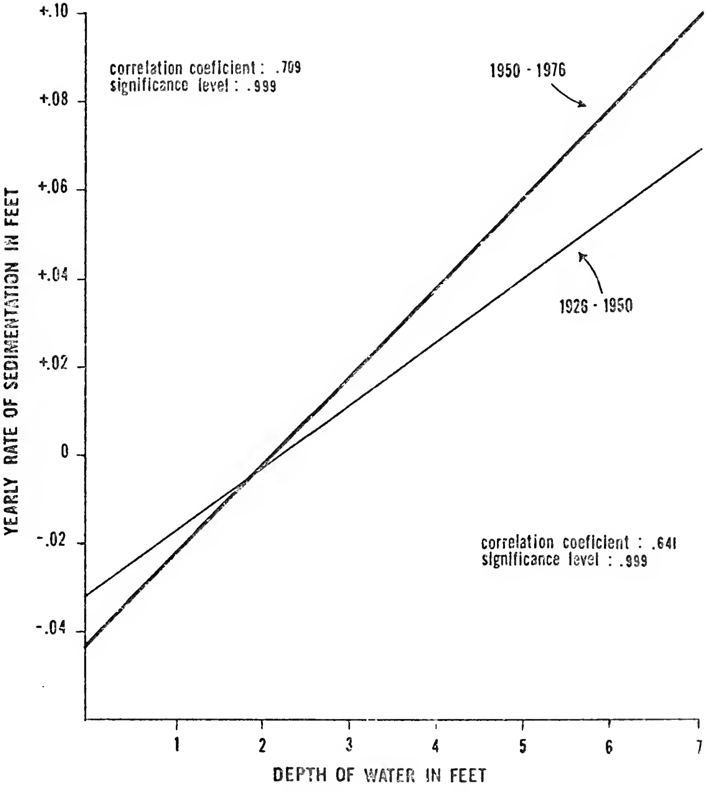
Lake Meredosia, a 1400-acre lake along the Illinois River in Morgan and Cass Counties, has lost 46% of its capacity since 1903 (Lee, et al., 1976: 7).

In the summer of 1976, a Natural History Survey crew attempted to sample 7 additional bottomland lakes along the Illinois River. It was impossible to float a canoe in more than about 1/3 of the surface area of each of these lakes, due to extensive sediment deposits.

There is evidence that the rate of sedimentation in these lakes is greater in recent times than it has been in the past. Figure 2 shows that

Figure 2

THE RATE OF SEDIMENTATION IN LAKE CHAUTAUQUA IN TWO PERIODS, 1926 - 1950 AND 1950 - 1976



correlation coeficient : .709
significance level : .999

correlation coeficient : .641
significance level : .999

In August 1974, dissolved oxygen levels in Meredosia Lake were 3 mg/l, while oxygen levels in the river on the same date were 6 mg/l. The readings were taken in the middle of the afternoon on an overcast day, and waves produced by a strong wind were resuspending bottom sediments in the lake. In the lake, a die-off of gizzard shad was occurring, and almost all the fingernail clams maintained in plastic cages on the bottom of the lake had died since they had last been checked in mid-July.

Metals are known to accumulate in sediment. For example, Mathis and Cummings (1973: 1580-1581) found that most metals in the Illinois River occurred in sediment at levels several orders of magnitude greater than levels in water. Organisms which lived in the sediment, such as oligochaete worms and clams, contained higher levels of the metals than organisms such as fish. Since the chemical environment in the gut of a worm or at the gill surface of a clam is different than it is in the sediment or water, it is possible that metals and other toxicants can be mobilized from the sediment and taken up by organisms which ingest sediment or live in contact with sediment.

Sediment can serve as either a source or a sink for nutrients such as phosphorus, depending upon conditions such as pH, temperature, oxidation-reduction potential, and the amount present in water.

Ecosystem Effects

The plants and animals living together in a certain habitat form a characteristic assemblage of species called an ecosystem, and one dramatic effect of excessive sediment can be to cause a shift from one type of ecosystem to another. For example, sediment very likely contributed to the

at depths greater than 2 feet below an arbitrary reference point of 435 feet above mean sea level (MSL), the rate of sedimentation in Lake Chautauqua has been greater in the period 1950-1976, than in the period 1926-1950. For example, at a depth of 5 feet, the 1926-1950 rate was .04 inches per year, while the 1950-1976 rate was approximately .06 inches per year. It is necessary to compare rates for the two periods at the same depth, because as was mentioned earlier, the rate of sedimentation increases with depth. The reason that there is a negative rate of sedimentation in water depths less than two feet is that shoreline and islands in these lakes have eroded as a result of wave action. The wave action has probably been more severe since the aquatic vegetation in these lakes disappeared in the 1950's (see Figure 1).

Six other bottomland lakes along the Illinois River showed much the same pattern as Lake Chautauqua: the rate of sedimentation has increased in recent periods compared to older periods going as far back as 1903. While the navigation dams installed on the Illinois River in the 1930's have slowed the current and increased sedimentation and while boats using the navigation channel resuspend bottom sediments, the input of sediment to the river may also have increased in recent times, because sedimentation rates have increased in lakes such as Chautauqua which are upstream from the influence of the dams and which are connected with the river only during high water.

Backwater areas along the Mississippi River bordering Illinois are also filling in noticeably, although the process seems to be taking longer than it has in the Illinois River, perhaps because the Mississippi is a much larger river than the Illinois.

The loss of bottomland lakes along the Illinois and Mississippi Rivers represents loss of the majority of natural lake habitats available in Illinois.

The only natural lakes in Illinois are Lake Michigan, the lakes in the glaciated lands of northeastern Illinois, and the bottomland lakes along the Illinois and Mississippi Rivers.

Sedimentation rates for reservoirs in various parts of the state are given in the summary report of the Soil Erosion and Sedimentation Subcommittee. The rates range from 0.28 to 7.7 tons of reservoir sediment per year per acre of watershed. The useful life span of these reservoirs, in terms of producing fish and aquatic life, is shortened in proportion to the rate of sedimentation, just as the useful life span for water supply is shortened.

Interactions Between Sediment and Other Factors

Ellis (1936) found that organic matter mixed with erosion silt created an oxygen demand in water and that the oxygen demand was maintained 10 to 15 times as long as the oxygen demand created by the same amount of organic material mixed with sand. The oxygen demand can increase many-fold when sediment containing organic material and bacteria is resuspended by waves or currents (Butts, 1974; Baumgartner and Palotas, 1970). For example, Butts (1974) found that under quiescent conditions the sediment oxygen demand in the Illinois River at mile 198.8 in Peoria Pool was 2.8 g/m^2/day, while the demand was 20.7 g/m^2/day when the sediment was disturbed. At three sampling stations in Meredosia Lake (mile 72-78) the sediment oxygen demand under quiescent conditions ranged from 2.58 to 4.32 g/m^2/day, and from 12.92 to 83.0 g/m^2/day under disturbed conditions (Personal Communication, 2 September 1975, Mr. Thomas A. Butts, Associate Professional Scientist, Illinois State Water Survey, Peoria, Illinois). The oxygen demand exerted by sediment in some reaches of the river and in some bottomland lakes is great enough to seriously diminish the oxygen supply in the water.

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The plants and animals living together in a certain habitat form a characteristic assemblage of species called an ecosystem, and one dramatic effect of excessive sediment can be to cause a shift from one type of ecosystem to another. For example, sediment very likely contributed to the

shift in the numerous bottomland lakes along the Illinois River from clear, vegetated waters with abundant game fish populations to turbid, vegetationless waters dominated by species such as carp and buffalo (Sparks, 1975: 54-56).

The presence of sediment brings about these changes in both direct and indirect ways, some of which have been mentioned above. The relationship between sediment and an observed change in an ecosystem is often complex, and some examples of these complex cause-and-effect patterns will be discussed below.

As mentioned above, the reactive distance of predatory fish is reduced by turbidity. In addition, populations of prey used by gamefish generally decline in turbid water. For example, Buck (1956a: 49) found that the ratio of forage fishes (gizzard shad, minnows, and small sunfishes) to the predaceous bass and crappie was approximately 1 to 1 in a muddy reservoir and 13 to 1 in a clear reservoir. As a consequence, the growth of bass, crappies, and other carnivorous species in the turbid reservoir was severely limited. The populations of plankton-feeding forage fish, such as gizzard shad, were limited due to the low level of plankton production in the turbid reservoir (Buck, 1956a: 51).

Sediment can change the species composition of a body of water by changing the habitat, the food supply, and bringing about differential rates of reproduction in different species. For example, the sunfishes, a family which includes largemouth bass, bluegill, and crappies, lay their eggs in nests which are constructed in shallow water. They prefer to construct nests on firm, rather than soft substrates. Buck (1956a: 23) found that largemouth bass and sunfish produced young in new farm ponds with firm, unsilted bottoms, but not in older ponds with soft, silt-laden bottoms. The sunfishes must be able to see their mates to go through the reproductive act, which is mediated by visual

cues. The males fan their eggs to keep away sediment and supply oxygenated water. The eggs can be smothered by excessive sediment. The guardian male must also be able to see in order to keep away suckers and minnows which eat eggs.

Juvenile gamefish take refuge in plant beds and feed on the insects and other "weed fauna" they find there. Older gamefish feed on forage fish, which in turn are dependent on the plankton, which is less abundant in turbid waters than in clear water.

The end result of the complex interactions described above were observed by Buck (1956b), who studied fish production in farm ponds, hatchery ponds, and reservoirs in Oklahoma which had a wide range of turbidities. The farm ponds were rotenoned, then restocked with largemouth bass and bluegills or largemouth bass and redear sunfish. A total of 12 farm ponds was divided into 3 turbidity classes. After two growing seasons, the average total weights of fish were:

clear ponds (less than 25 JTU)	161.5 lb/acre
intermediate ponds (25–100 JTU)	94.0 lb/acre
muddy ponds (100 JTU)	29.3 lb/acre

The redear and bluegill sunfish reproduced more abundantly and grew faster in clear water. Survival of bass was greater in intermediate ponds than in clear ponds, perhaps due to competition with abundant sunfish populations in the clear ponds. However, the surviving bass grew faster in clear ponds:

	average weight gain	average length increase
clear ponds	14.0x	6.9 in.
intermediate ponds	7.1 x	5.1 in.
muddy ponds	2.5x	2.4 in.

The results from hatchery ponds, where turbidities were artificially controlled, and from the reservoirs, generally paralleled the results from the farm ponds.

In the turbid reservoir, Buck (1956b: 257) found an unusual preponderance of old bass and a scarcity of young bass -- this was very unusual for a new reservoir:

> For example, of 56 bass collected in 1954, 64 percent were in their fourth year and 32 percent in their third year. This was representative of all samplings. All evidence points to a small population dominated by slow-growing, older bass and with limited recruitment through natural reproduction. It seems doubtful that the bass population will be able to sustain itself in the face of increasing turbidities.
>
> In contrast, young-of-the-year bass were abundant in the clear reservoir both years of the study. To illustrate, the population of fingerling bass in a 10-acre cove rotenoned in 1955 was estimated conservatively at 21,780.

Buck observed the same pattern in the other gamefish. In contrast, catfish and rough fish were favored in the turbid waters (Buck, 1956b: 257):

> Both channel catfish and flathead catfish are abundant in the turbid reservoir. In the clear reservoir, only two adult channel catfish and one adult flathead were taken. In the first year of clear reservoirs, the bass, crappies, and other scaled species apparently out-produce the catfish and then limit them by predation on their young. Turbid waters, on the other hand, offer young catfish protection from these predators. Furthermore, catfish can find food in turbid waters more easily than can species which do not have so highly a developed sense of smell. As a result, the bass and crappies lose ground. Even growth of the channel catfish, however, was slower in the turbid reservoir than in less turbid waters. Flathead catfish exhibited the most favorable growth of any species studied in the turbid reservoir, reaching an average length of 28.3 inches in their fourth year.

The combined weight of rough fish (carp, river carpsuckers, and bullheads) represented 42.4 percent of the population by weight in the turbid reservoir, compared with 7.0 percent in the clear reservoir.

Buck's (1956b: 260) final conclusion was: "The clear reservoir attracted more anglers, yielded greater returns per unit of fishing effort, as

well as more desirable species, and was immeasurably more appealing in the aesthetic sense."

The same causal relationships and end results Buck observed in the Oklahoma ponds and reservoirs have occurred in Illinois. The bottomland lakes along the Illinois River have changed from clear, vegetated waters which supported an abundance of gamefish, commercial fish, and waterfowl, to turbid, vegetation-less waters dominated by carp and buffalo. In some cases the lakes are so filled with sediment the carp, buffalo, and gizzard shad do not survive. The sediment not only fills the lakes, but also exerts an oxygen demand which depletes the dissolved oxygen required by fish and other aquatic organisms.

At one time, special trains brought sport fishermen to towns, such as Havana, along the Illinois River, and freight trains hauled away commercial fish to Chicago and New York (Mills, et al., 1966: 14). Now, Dixon's fee fishing area in Peoria imports carp from Wisconsin, the restaurants along the Illinois River buy channel catfish from Arkansas, and the residents of beach communities, such as Quiver Beach and Baldwin Beach, in Mason County, are no longer able to swim in the bottomland lakes or even to launch their boats from their cottages in mid-summer.

Table 1

Reported Levels of Effect of Sediment and Turbidity on Aquatic Life

Level	Biological Effect	Reference
14-16 JTU	Largemouth bass activity reduced and social behavior of green sunfish altered. Coughing and scraping increase.	Heimstra et al., 1969: 5-8.
20 JTU	Reactive distance of bluegill reduced by 50%, in comparison to reactive distance in clear water.	Vinyard and O'Brien, 1976: 2847
30 JTU	Reactive distance of bluegill reduced by 80%. <u>Upper limit</u> for effect on bluegill reactive distance.	Vinyard and O'Brien, 1976: 2847
25-50 JTU	80% reduction in net plankton, compared to plankton production in clear farm ponds (25 JTU).	Claffey, 1955: 43
51-350 JTU	90% reduction in net plankton, compared to plankton production in clear farm ponds (25 JTU).	Claffey, 1955: 43
84 JTU	Highest turbidity in which largemouth bass were able to spawn.	Buck, 1956a: 19, 23-24
100 JTU	Spawning success of redear and bluegill severely restricted or completely restricted above this level.	Buck, 1956a: 23-24
25-100 JTU	42% reduction in total weight of largemouth bass, redear sunfish, and bluegills produced in farm ponds, relative to total production in clear farm ponds. 49% reduction in average weight gain and 26% reduction in average length increase of young bass after two growing seasons, in comparison to gains by bass in clear ponds.	Buck, 1956b: 249
100 JTU	82% reduction in total weight of largemouth bass, redear sunfish, and bluegills produced in farm ponds, relative to total production in clear farm ponds. 82% reduction in average weight gain and 65% reduction in average length increase of young bass after two growing seasons, in comparison to gains by bass in clear ponds.	Buck, 1956b: 249

Table 1 (continued)

Reported Levels of Effect of Sediment and Turbidity on Aquatic Life

Level	Biological Effect	Reference
An increase in suspended sediment (limestone dust) from 9.7 to 28.3 mg/1	26% increase in macroinvertebrate drift.	Gammon, 1970: 68,96
An increase in suspended sediment (limestone dust) from 20.3 to 125.0 mg/1	90% increase in macroinvertebrate drift.	Gammon, 1970: 68, 96
38,250 JTU	Lethal to rock bass.	Wallen, 1951: 18
85,000 JTU	Lethal to channel catfish.	Wallen, 1951: 18
101,000 JTU	Lethal to largemouth bass.	Wallen, 1951: 18

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GLOSSARY

Effects of Sediment on Aquatic Life
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Benthos. The plants and animals living on the bottom of a stream or lake.

FTU. Formazine turbidity units. Turbidity as determined in a nephelometer which has been calibrated with a suspension of formazine as a turbidity standard. Formazine is formed by reacting hydrazine sulfate and hexamethylene tetramine under carefully controlled conditions (Chevalier, 1959: 132-133).

Jackson candle turbidimeter. A turbidimeter which measures "the depth of a column of water sample that is just sufficient to extinguish the image of a burning standard candle observed vertically through the sample." Results are expressed as Jackson turbidity units (JTU) (American Society for Testing and Materials, 1973: 232).

JTU. Jackson turbidity units.

Nephelometer. A turbidimeter which measures "the light-scattering characteristics (Tyndall effect) of the particulate matter in the sample. . . . The measurement of nephelometric turbidity is accomplished by measuring the intensity of scattered light at 90 deg to the incident beam of light. Numerical values are obtained by comparison with the light-scattering characteristics of a known or an arbitrarily chosen material in an equivalent optical system. Comparison may also be made between transmitted light effect and scattered light effect." The results from a nephelometer are sometimes expressed as nephelometric turbidity units (NTU) (American Society for Testing and Materials, 1973: 232).

NTU. Nephelometric turbidity units.

Particulate matter. Same as suspended matter and total suspended solids. The amount of material in suspension, determined by measuring the weight gain of a filter after a known volume or weight of the water sample has passed through it.

Photosynthetic zone. Same as euphotic zone. The depth of water in which there is enough light for photosynthesis to exceed respiration (Odum, 1971: 14). In general, this zone extends down to the depth where the light intensity is 1 percent of full sunlight intensity (Odum, 1971: 301).

Phytoplankton. Microscopic, drifting aquatic plants, mostly algae.

Resuspended sediment. Sediment which is stirred up from the bottom by water currents, wave action, boat traffic, or by the rooting activities of fish such as carp.

Secchi disk. A circular metal plate, 20 cm in diameter, the upper surface of which is divided into four equal quadrants and so painted that the two quadrants directly opposite each other are black and the intervening ones white. The disk is used to measure the limit of visibility in water by lowering it into the water on a graduated line, and noting the depth at which it disappears (Welch, 1948: 159). Secchi disk transparency represents the zone of light penetration down to about 5 percent of the solar radiation reaching the surface and marks the lower limit of the major photosynthetic zone (Odum, 1971: 297).

Sediment. Solid, particulate material which is deposited by water.

Submergent vegetation. Large free-floating or rooted aquatic plants which are entirely submerged in the water, such as coontail, or which have leaves at the surface of the water, such as lotus. In contrast, emergent vegetation refers to plants such as cattail, which can grow in shallow water, but which have leaves above the water.

Suspended sediment. Sediment which is carried in the water column.

Turbidimeter. A device for measuring turbidity.

Turbidity. "Turbidity in water is caused by the presence of suspended matter, such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through [a] sample [of water]. Attempts to correlate turbidity with the weight concentration of suspended matter are impractical because the size, shape, and refractive index of the particulate materials are important optically but bear little direct relationship to the concentration and specific gravity of the suspended matter." (Rand, 1976: 131.)

Zooplankton. Microscopic, drifting aquatic animals.

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