A History and 2017-2018 Survey of the Aquatic Fauna of Upper Twin Cave, Lawrence County, Indiana

Final Report to the Indiana Department of Natural Resources,
Division of State Parks and Division of Nature Preserves

By:

Thomas P. Sollman

Indiana Karst Conservancy

3270 E 750 S, Fort Branch, Indiana
Contact: tpsollman@gmail.com

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Abstract

The study was a visual encounter survey of the aquatic macro-fauna of Upper Twin Cave, Lawrence County, Indiana. As part of this study, the cave was surveyed 24 times from May 2017 to June 2018 directly counting selected species. Entry was at Spring Mill State Park entrance proceeding for 3,780’ upstream to entrance 4 in the Indiana Karst Conservancy’s Shawnee Karst Preserve. The largest known population of the Hoosier Cavefish *Amblyopsis hoosieri* with a high of 152, low of 18, average of 88 and a total of 2,059 was observed. The cave also has a large population of the cave crayfish *Orconectes inermis inermis* with a high of 127, low of 7, average of 44 and a total of 1,046. Also noted were the Cave spring crayfish *Cambarus tenebrosus,* the Pickerel frog *Lithobates palustris,* the Bullfrog *Lithobates catesbeianus,* and the Cave salamander *Euryea lucifuga.* Aquatic population counts were most affected by water clarity, followed by whether the dam drain downstream of the cave was open or closed.

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INTRODUCTION

Many studies have been made of the cavefish in Upper Twin Cave in the 122 years since Dr. Carl Eigenmann captured 20 “specimens” there, but actual numbers of fish seen are hard to determine. Observations from the same year have been combined, shown from multiple trips as min/max, shown as part of mark/recapture studies, unpublished then published in reports years later with conflicting numbers and in almost all cases the census Area is unknown.

So, has the population declined, stayed the same, or is it larger compared to previous decades? A simple repeatable visual encounter census could provide a baseline for future comparisons.

Hence this study. The cave was broken up into four study areas based on major landmark features in the cave that could be identified in the future. The light used was explained, the water clarity and height noted, and the time of each census recorded. In short, a researcher in the future should be able to reproduce this census and accurately determine population trends.

So, this study is dedicated to you, future researcher. I hope we have protected these unique creatures.

PART 1: HISTORY

Cave Names

Upper Twin Cave has been documented since the first settlers arrived in Indiana. The cave name, indeed all the caves in the Shawnee System, has a confusing history.

In the early 1800’s, Upper Twin was called Big Springs (McCammon), which slowly evolved to Dalton’s, Dalton’s Spring or Upper Dalton’s by the late 1800’s. (Dalton was a nearby property owner, one account places him also as the operator of the tavern at Spring Mill.) At the same time present day Bronson Cave and the upper entrance to Donaldson Cave (then called Shawnee Cave) were called the Twin Caves. By the early 1900’s it was Upper Spring with a nearby school and later a church to the south west named after it. This was its common name when the state of Indiana acquired it in 1927.

By 1929 the park suddenly was referring to “*…the Twin Caves and the two Bronson Caves*” (Guernsey, 1930). The Twin Caves now became the Bronson Caves and Dalton’s Spring/Upper Spring became the Twin Caves, Upper and Lower. To add a further twist, the upstream entrance in the (modern) Bronson Cave karst window was renamed Schmeltz Cave in 2011 “*to avoid further confusion*” (Vance, 2011).

Karst Window and adjacent Areas

The collapse sinkhole, which contains the dam and boat dock downstream from Upper Twin, was caused by solution enlargement and collapse of the cave roof, probably where a sinkhole was directly above the cave. About 225 feet of stream passage is now exposed lying some 50 feet below the surrounding upland. The collapsed material was slowly removed by solution and erosion. The northern wall (above the Upper Twin dripline) is fairly perpendicular while the other sides, particularly the eastern parking lot side, slope gently up.

The present park road to Upper Twin used to be a county road which proceeded out of the present park to the south. It was surveyed in 1832 and connected Bedford to Beck’s Mill *“…by* *way of Hamer's Mill…"* Part of the description reads: from the *"dug road south of Hamer's Mill*" past the *"Big Cave Spring"* (McCammon).

The area east of the cave was being developed in 1929 by the park: *"Camp stoves and tables have been provided above the entrance to Twin Caves, and road drains have been opened to provide a proper drainage away from the camping area."* (Guernsey, 1930).

Malott (1932) called a collapse such as at Upper Twin a "karst window". W.P. Von Osinski (1935) designated Twin Caves as the type-locality for a karst window.

A horse path used to pass just south above the cave entrance. There is a path above the cave entrance at the 670' elevation mark, perhaps 100' from the cave dripline on the south side of the karst window shown on a 1934 map (Osinski, 1935). This path is identified on a later 1935 CCC (1935) map as a bridal path.

In 1936, the gravel park road to the cave took a curving teardrop path around the area of the present parking lot with space for 25 cars. This was enlarged to 100 cars capacity with the modern-day parking lot being constructed and paved with black-top in 1937 (Simmons, 1938).

Highway 60 was opened in the winter of 1940 passing over about the middle of the study Area of the cave (Guthrie, 1984).

Cave Dams

Dam #1, natural

A photo of the cave entrance from circa 1910 (see fig. 1) shows a low dam at the cave dripline which appears to be natural outwash, perhaps with some human "help". Eighteen years later a photo (see fig. 2) shows an obviously manmade rock dam at the same location. This is the same year the park was organized. Today this rock dam appears largely intact but embedded in sediment backed up from the dam (see fig. 3).

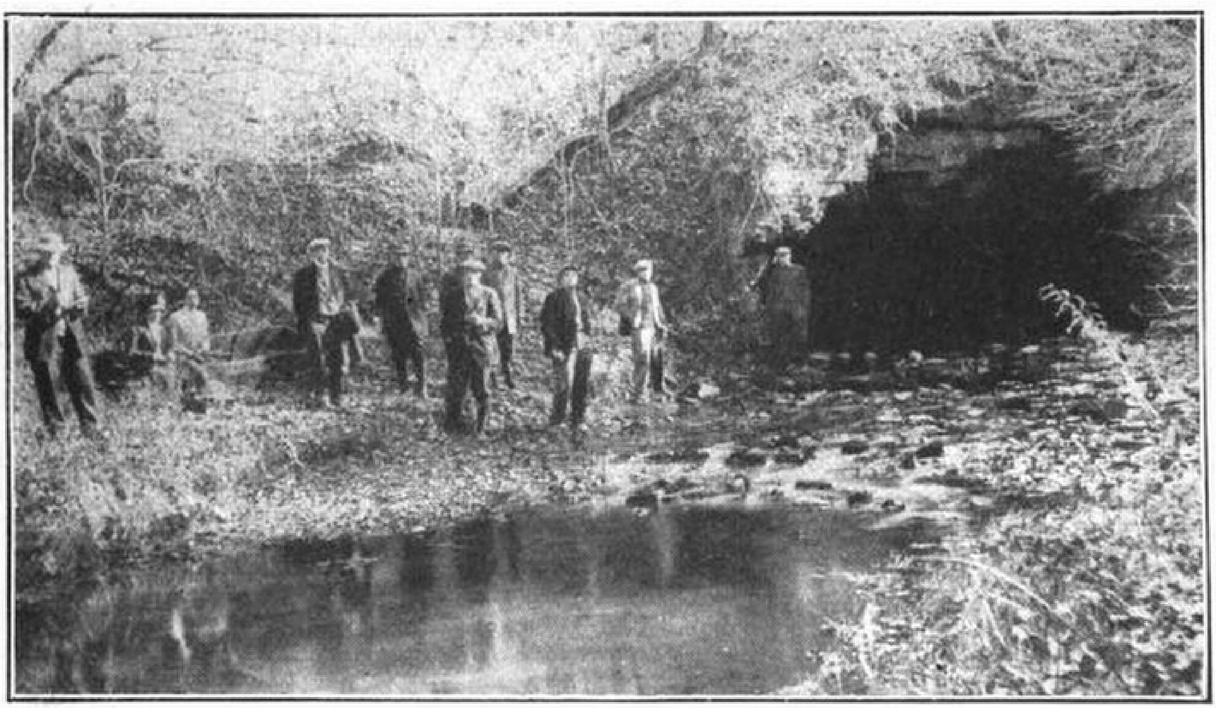


Figure 1. Upper Twin entrance circa 1910. Notice women sitting on boat. (Photo, Breede, 1910)


Figure 2. Upper Twin entrance circa 1928. Manmade rock dam at dripline. (Photo, Mitchell, 1928)


Figure 3. Upper Twin entrance 2017, 1928 rock dam in silt. New, higher, deposits on right.

Dam #2, 1937

A dam was installed in the karst window below Upper Twin in 1937, the year following the first boat tours (see fig. 3). *"Improvements made during the year consisted of the construction of a stone dam in the stream below the mouth of Upper Twin Cave in order to facilitate the use of boats in the cave."* (Simmons, 1938). This dam today is badly weathered but still in place. It is a total of 8' wide and 25' 9" long built of large native limestone rocks mortared together. A series of 3 steps about 1' wide on the lower end lead up to about a 5' wide upper flat area. Centrally located within the dam is a clay drain pipe about 1' in diameter that could be blocked or opened to "open" or "close" the dam.

Dam # 3, 1984

In 1984, a new dam was constructed on the upstream side of and in contact with the original dam (see fig. 4) due to dam deterioration and silt buildup interfering with boat tours (McGurk, 1985). The new dam is poured concrete with a lower flat area about 3' wide that is even with the height of the original dam with a 1' wide section that is 16" higher than the original. It is faced with a 1' thick layer of small natural stones mortared together for aesthetics. This stone facing is badly deteriorated today. A ½" thick flat steel plate is welded to a steel pipe with an inner diameter of 17 ½" that fits into the original dam clay pipe drain. It was equipped with a steel handwheel that operated the dam, but today the mechanism is broken. Park personnel remove the blocking plate in front of the pipe with a jack and chain each fall to prevent silt accumulation.

Figure 4. Dam in Upper Twin karst window in 2017. The 1937 natural stone dam is to the right, and the 1984 concrete dam is to the left. Dam is in the "open" or free-flowing position. The drainpipe runs under the center of the dams.

Cave Maps

The cave was first mapped circa 1908 by Greene and McIndoo giving a horizontal length of 4,674' (Scott, 1909). The next unpublished map was made in 1978 by the Indiana Speleologial Survey showing 7,012' length. The modern-day unpublished map was surveyed from 1989 to 1991 by the Spring Mill Project, giving 16,353' of passage with a vertical elevation of 36'.

Boat Tours

Historic Tours

Boat tours through Upper Twin Cave started in spring of 1936. The tours were immediately popular with over 2,000 people taking the tour in the first year of operation (Simmons, 1937). The first-year tours were launched from the dripline of the cave. The following year, after construction of the dam, they were launched from a flagstone landing (Simmons, 1938). Early boats were of wooden construction. Early photos show smaller boats with 6 to 8-person capacity (see fig. 5). In the 1970's they appear larger with a 10-person capacity. Photos from the 1930's thru 1970's show guides using paddles or poles to move the boats with illumination by gas lantern.

Figure 5. Boat tour circa 1939. The boat is about at the tour's turn around point in the cave. Picture taken from another boat implies a two-boat tour. Note 8-person plus guide capacity and gas lantern for illumination. (photo, Outdoor Indiana, Jan. 1940)

Aluminum boat use started circa 1995 (Catlin, 2017). The original flagstone landing was covered with a wooden landing, at some point, which is still visible below the current wooden dock constructed in 1984.

Upper Twin boat tours competed with boat tours in Donaldson Cave until that cave's tours were discontinued circa 1976 (Keith, 1976). Due to cuts in funding, the boat tour program was out-sourced to the management of the Spring Mill Inn at the park in 2002 for some period.

Present Day Tours

Currently boat tours are conducted every half hour from 9am to 5pm from Memorial Day to August. Tours are on weekends only for some period after that. A tour consists of two aluminum boats closely following each other with up to 8 tourists in each boat. The boats go 640' through consistently deep water and turn around. The guide pulls the boat through the cave by hand from the ceiling and walls. A paddle will be used to get to the dripline, but no paddles or poles enter the water in the cave. In high water levels, tours continue running until water floods over the dock.

Two lights in the front of each boat along with a handheld light provide illumination. A long-time tour guide said in 2017 that the boat-mounted lights had not been used "*the last couple years*" because of the weight of the lead-acid batteries that had to be carried up to the charger in the parking lot frequently. Guides used heavy-duty portable lights that could be set in the boat with the beam angled (Catlin, 2017). In 2017, the boat lights were converted from incandescent to LED and put back in service. Generally, the tours are very quiet with the guide giving a narration and tourists only whispering.

Recent tours are down from their peak of over 30,000 tourists annually in previous decades. In 2016 and 2017, there were between 11,000 and 12,000 tourists annually (Williams, 2018) out of the total annual park attendance of about 600,000 visitors; thus, less than 2% of park visitors tour the cave.

Historical References of Aquatic Cave Life

19th Century

1873:

Cox gives a list of animals found in Donaldson Cave, mentioning that the cave is known to extend through Dalton's Spring (Upper Twin). The list includes the cavefish *Amblyopsis speleus* (= *Amblyopsis hoosieri*) and crayfish *Cambarus pellucidus* (= *Orconectes inermis*) (Collet, 1874).

1882:

Hovey (1882), talking of Donelson's Cave (Donaldson's Cave) and Dalton's Springs (Upper Twin), says "*Both these caves contain eyeless fish, crawfish, and insects*".

1899:

Blatchley (1899) described capturing 24 cavefish in Shawnee Cave (Donaldson Cave) but might have been referring to the stream in Upper Twin (Big Springs at that time) *"In one place where a stream flows out of a cave and through a deep ravine for about 200 yards, and then enters another cave, the blind fish were captured in both caverns within 100' of the openings…"*.

1899 to 1903:

Eigenmann and his students in the Indiana University Cave Farm, located in the present Spring Mill State Park, may have collected thousands of crayfish for classroom use in experiments on cave adaptation from *"the Mitchell Caves"*, which would have been modern day

Donaldson, Bronson, and Upper Twin (Eigenmann, 1899, 1903, 1909; Banta, 1907; Myers, 1952).

20th Century
1907:

Payne (1907) describes a series of experiments with *Amblyopsis.* His number one conclusion was "*Amblyopsis is negatively phototropic.*" While actual numbers of cavefish used were not given, it had to have been dozens. He wrote: *"All of the material used was caught in the caves at Mitchell*".

Banta (1907) describes and compares *Cambarus pellucidus* (= *Orconectes inermis*) to crayfish in Mayfield's Cave. He also talks of the crayfish collected in the Indiana University Cave Farm in the Twin Cave karst window (modern Bronson Cave in the same cave system as Upper Twin) saying:

"On several occasions as many as 200 large individuals were collected at this place for class use at Indiana University. These included the largest and finest individuals of C. bartoni I have ever seen, some of them measuring over 100 mm. in length.".

(Taxonomy of the crayfish of the genus *Cambarus* in the midwestern U.S. has been in a state of confusion, and the workers in the 20th century identified them variously as *Cambarus bartoni*, *Cambarus tenebrosus, Cambarus laevis* or related names.)

1908:

Hahn (1908) gives an important, unique description of the fauna in the Indiana University's "farm", present location of Spring Mill Park. The university had established a fellowship in zoology with the incumbent as resident care-taker. Walter Hahn was the first to hold this position, living there from Sept. 1906 to Sept. 1907. In the paper, he gives extensive lists of animals found in the Shawnee Cave System.

Of fishes, he lists only the cavefish *Amblyopsis speaeus* (= *Amblyopsis hoosieri*) as stygobitic and four other species seen as accidentals: the sunfish, catfish, miller's thumb, and minnows.

Several catfish were taken in the "upper cave" (Upper Twin) "*at a point where the light is very dim*" and mentions that ponds in the cave's watershed, which overflow to the cave through sinkholes, had been stocked with them. Several sunfish were taken 80' within the upper cave. The miller's thumb (a sculpin) was taken in the lower cave (Bronson Cave).

The cave salamander, *Spelerpes maculicaudus* (= *Eurycea lucifuga*), were "*very abundant*" near Hamer Cave in the summer where "*Human feces near the mouth of the cave formed a favorite feeding ground*." In the winter, they were found at the large room at the lower entrance to modern Donaldson's cave and "*about a half a mile*" in from its upper entrance.

He identifies frogs seen hibernating in a cave "*not far from the mouth of the cave during March and they seemed to be moving towards the outside*" (probably Upper Twin from the cave description) as Leopard frogs, *Rana pipiens*, describing them as having "*spots scarcely, or not at all, bordered by pale color*". These were probably Pickerel frogs, *Lithobates palustris*, commonly misidentified as Leopard frogs. A bullfrog, *Rana catesbeianus* (= *Liothobates catesbeianus*), was seen washing out of the lower entrance of modern Donaldson Cave.

The water snake was mentioned to have once been found "*some distance within a cave*". Snapping turtle remains were found in an unspecified cave "*some distance from the entrance*". Box turtles were found inside an unspecified cave "*in sexual congress*". White-footed mice were seen numerous times in "*the cave*" (probably modern Donaldson Cave). Cottontail rabbits were frequently seen entering sinkholes and caves, and the remains of three were found in an unspecified cave. A Gray fox's tracks were seen nearly every night, while snow was on the ground, entering Twin Cave (modern Bronson Cave). Red foxes inhabited "*a small cave on top of the hill*". Numerous species of bats were also observed in Upper Twin by Hahn, but bats are specifically not to be covered in this study.

1909:

Eigenmann (1909), commenting on Dalton's Spring (modern Upper Twin) wrote: *"At Dalton's Spring the cave-stream runs above ground for about 100 yards when it enters its subterranean course. Within sight of the lower opening of the "spring" I saw two blind fishes swimming in a quite pool. I secured about 20 specimens and had found the stream which in its varying reaches has furnished me with an unlimited supply of specimens which have enabled me to give the complete history of the eye of this species, Amblyopsis spelaeus De Kay. More material has been obtained from this cave than from all others put together*". Continuing he writes: *"The only place where this species is known to be abundant is in the caves of the Donaldson farm of Indiana University."*

Eigenmann also describes *Amblyopsis* habitat: *"Amblyopsis is found in pools in the cave stream it inhabits. I have secured as many as 12 from a pool perhaps 10 by 50 foot in size. Very rarely they are to be found in the riffles connecting the pools."*

Scott (1909) writes primarily of the plankton washing through the cave. What is fascinating is on page 407 his map of Upper Twin has "*point # 63, obstruction past which boat cannot be taken"*. It is amazing that they managed to get a boat this far into the cave. This is well past the Indiana Karst Conservancy (IKC) entrance, and the boat had to have been dragged over rocks in several places and through some passages about 32" high.

1911-1912:

Spurgeon (1915) collects thirty-three *Cambarus pellucidus* (=*Orconectes inermis*) from "*Shawnee cave, Indiana University farm*" during the fall and winter of 1911 and 1912 ranging in size from 9mm (.35") to 60mm (2.4"). It appears some of the cavefish came from modern Upper Twin Cave. His studies were of the eyes of various blind crayfish, and he concluded that the eyes are instances of *"…arrested development rather than examples of degeneration*".

1924:

Two of the Paratypes used to describe the modern day *Amblyopsis hoosieri* are collected from "Twin Caves". 1)*"Twin Caves, near Mitchell, Lawrence County"* from May 17, 1924 taken by "Hubbs & party", 2) "*Twin* Cave, *Mitchel, Lawrence County"* from June 18, 1924 taken by Blanchard. These may have been from modern Bronson Cave as the caves names were swapped circa 1927 (Charkrabarry, 2014).

Circa 1934 - 1938:

Swanson (1939) in his position as a forester for the Emergency Conservation Works and the Resettlement Administration received many specimens of amphibians from across Indiana; most of which were given to the Carnegie Museum. Two *Eurycea lucifuga* Cave salamanders were collected from "*Under stones between Twin Caves, Lawrence County*.

1944:

Gerking (1945), in his monograph on fishes in Indiana, cites Banta (1907) and Eigenmann's (1909) work adding: *"Our only recent information (1944) is that it is still abundant in Shawnee Cave in Spring Mill State Park"* (Shawnee was used as name for the entire system, including Upper Twin).

1957:

Woods and Inger (1957) mention commercial sales of cavefish in Indiana and Kentucky: *"…continuous collecting of the fishes for sale over the last hundred years…"* and *"…any blind, white cavefish is eagerly sought by the commercial interests."*

1958:

Berg (1958) reported "*a solitary catfish … in a small pool"* in Upper Twin.
Concerning the cavefish population, he writes: *"The number of blind fish that a person sees on different trips to Spring Mill varies considerably…it appears not to be a case of great variation in population numbers, but a variation in the number of fish observed.*" Continuing he says*: "It does, however, appear to the author that there has been a somewhat decline in population number of the past several years."*.

Keith and Poulson (1979), in their report of investigation of Broken Back Syndrome, included some unpublished previous counts by Poulson. (Data interpreted from a table in figure 37.) 1958: 20 cavefish observed.

Poulson (1958) speculated that cavefish population may be drastically reduced from reported levels in 1900 due to later wholesale collection of cavefish from caves in Kentucky and Indiana, including Upper Twin and surrounding caves, for commercial sales.

Writing of the cavefish population he says: *"The low estimates of population are understandable since census of deep water areas is impossible except under semi-drought conditions when clear water occurs. For example, estimates of Spring Mill populations during most of the year differ by a factor of 2 ½ to 3 from time of crystal clear water."*.

1958-59:

Poulson (1960), in his landmark Ph.D. dissertation provided little actual census data except for one date, Aug 25. (The year was not given but was probably 1958 or 1959.) when he *observed* 131 cavefish (capturing and measuring 86 of them), 106 *O. pellucidus* (= *Orconectes inermis*), and 7 *C. bartonii* (= *Cambarus tenebrosus*). (However, when adding up the listed sizes of *O. pellucidus* it totals 116 not 106.)
Poulson made one comment on cave conditions during his census (p10 of thesis) *"…fish and crayfish were directly counted when the water was clear and low…"*.

No reference was made to how many fish were collected for his experiments, but he did mention that an epidemic of Saprolegnia or Ichthyophthirius occurred to his *initial* collection and that *"Small anblyopsids* [sic] *occasionally served as prey for the larger ones."* (p11-12 of thesis).

1962:

Poulson (1963), in a journal article, blurs cavefish censuses by combining two trips in 1957 together (3/7 and 11/2 for a total of 56 cavefish) and three trips in 1958 together (4/7, 8/20, and 11/2 for a total of 146) but does give one firm census result in Upper Twin: 56 cavefish observed on 8-25-1962. He mentions he did collect species from Upper Twin for experiments but doesn't say how many.

Regarding predation on cavefish he says: *"…Amblyopsis cave fish have no predators other than themselves. The most apparent source of mortality before senescence is density dependent cannibalism."*

In discussion of cavefish behavior Poulson observed "*…amblyopsis often swim upstream foraging and passively drift downstream until they contact some obstacle or reach their initial starting point*".

1963:

Keith (1988), in a review of cavefish sightings includes a report by Poulson in 1963 of 220 cavefish in the Donaldson-Twin System *"…confirmed in 1977"*.

1964:

Keith and Poulson (1979), in their report of investigation of Broken Back Syndrome conducted a census that included unpublished previous counts by Poulson in Upper Twin. It's unknown how many trips were made in 1964. (Data interpreted from a table in figure 37.) 1964: 48 cavefish observed.

Poulson (1964) in a journal article discussing cavefish populations refers to Upper Twin Cave: "*The most favorable habitat for A. spelea has 130 cavefish…"*

1966:

Mohr and Poulson (1966) review Poulson's work in the cave: *"about 120 fish make up the population here"* and *"During the seven-year study of Upper Twin Cave* (by Poulson), *there were never less than 81 fish, nor more than 130…"*.

1977:

The Spring Mill Park Naturalist's field journal entry for March 2, 1977 reports that while on a trip with the State Board of Health studying Broken Back Syndrome *"…only healthy cave fish were seen*" also *"…one sculpin seen in the cave"* (Gray, 1977).

1978:

Keith (circa 1978a), in a proposal to study Broken Back Syndrome in the park caves reported a trip circa 1976 with the park naturalist observing 38 cavefish and collecting two that exhibited the classic symptoms of looking "*bruised"* and "*swimming oddly.*" He also reported that in Sept. of 1977 he counted 51 cavefish.

Keith (1978b), writing in the *Proceedings of Indiana Academy of Science* speaking of Broken Back Syndrome says: *"Five visual censuses of the fish population were implemented to note any changes in the incidence of the syndrome over a two-year period."* Continuing: *"A comparison of recent census data from Upper Twin Cave with data taken from the same cave by Poulson* *(unpublished) in 1958 and 1964 does not demonstrate an adverse impact on the population at this time.”*.

1979:

Keith and Poulson (1979), in their investigation of Broken Back Syndrome report, *“Approximately 6% of the population was found to have the Syndrome each year.”* Continuing, they conducted visual census trips in Upper Twin during 1975 and 1979. Their results, which are given in chart form in their figure 37, show only a total of cavefish seen for a year. However, in their report in the *Proceedings of Indiana Academy of Science,* the same year they reported they conducted five census trips over a two-year period, so the yearly total reported seen appears to be a combination of trips during the year. (Data interpreted from table in figure 37.) 1975: 47 cavefish; 1978: 60.

1982:

Culver (1982), in *Cave Life* clarifies and presents unpublished data from Poulson’s census work describing it as: “*The population was sampled once a year for five years.”* Table 3-4 which shows Poulson’s observed cavefish varied from 84 to 130 with a mean of 111.

1985:

Carmelita McGurk (1985), in her report *Caves of Spring Mill State Park,* describing the standard boat tour includes this: *“Blindfish and crayfish are best seen in the shallow water of the turnaround room, after the stalactites.”*.

1989 – 1991:

Sheldon (2018) reported that during survey trips from 1989 to 1991 *“It was common to count over 100 cavefish in Upper Twin…”* This figure is used as a reference in several other publications. Note that included Areas outside this study’s 3,780’ of passage.

1998:

Pearson (1999) reported a survey trip on December 16, 1998 of approximately 4,400’ observing 419 cavefish. Continuing, he compared his observations to Poulson’s saying: *“In the 1960’s Tom Poulson reported seeing about 200 fish in Upper Twin. We believe his estimates, using carbide lights and without the benefit of wet suits for surveyors, produced about half our numbers using dive lights and wet suits. We base this on comparisons with his numbers in very stable populations at Mammoth Cave. Therefore, it appears that the density of the cavefish population in Upper Twin Cave has been relatively stable for at least the last thirty years.”*.

1999:

Louis (1999) reported *capturing* 32 fish in her one trip in Upper Twin during work on her thesis which was largely done in Donaldson. Numbers of cavefish observed were not given.

Summarizing her mark/recapture work in Donaldson’s Cave she said the population estimate was 185 plus or minus 25 individuals, then compared this to Upper Twin Cave: *“This estimate was in agreement with Poulson (1963), and Mohr and Poulson (1966), who obtained a slightly lower population estimate of 67 to 175 individuals in Spring Mill State Park (Upper Twin Cave) in their studies in the late 1950’s and early 1960’s. Our findings were also generally in agreement with Sheldon’s report (1994), of seeing 100+ individuals in Upper Twin Cave.”*.

21st Century

2010:

Nimbler and Poulson (2010) discuss several aspects of the cavefish in Upper Twin. Concerning Broken Back Syndrome, they write: *"A recent trip to Donaldson Cave (Niemiller, unpublished data) revealed no evidence of the syndrome, and Broken Back Syndrome was noted for only three years in perhaps 10% of the fish from this site"*

The distribution of cavefish in Upper Twin and Cave Springs Cave, Arkansas was mentioned: *"As one goes upstream in both these caves the number of cavefish drops to none as the water gets shallower and faster flowing with no refuges in floods."*

Also commenting on any possible effect of commercial exploitation of caves on cavefish they write: *"At Upper Twin Cave, no differences in apparent abundance of A. Spelaea exist between times when tours are conducted and times when tours are not in operation (Poulson, personal observation). And the continued abundance of fish in Upper Twin Cave since Eigenmann's studies suggests that pole boat tours in the downstream part of the cave, starting in the 1950's, have not compromised the populations."*.

2011:

The author conducted a preliminary census of the cave going downstream from the IKC entrance (ent. 4) to the Spring Mill Park entrance in an approximately two-hour trip on December 10, 2011. Twelve cavefish and 2 *Orconectes inermis inermis* were seen in muddy, high water.

2011 to 2015:

Lewis (2016) conducts sampling providing a complete faunal list of the cave. As part of his work, he conducted a census going downstream from the IKC entrance (ent. 4) to the Spring Mill Park entrance on May 2012 observing 98 cavefish.

2012:

Niemiller et al. (2012) postulates that Pleistocene ice ages and the Ohio River formed a barrier that isolated *A. spelaea* long enough for genetic divergence to cause two distinct species to emerge.

As part of their study, one sample (fin clip) was taken from Upper Twin and three from Donaldson Cave.

2014:

Charkrabarry et al. (2014) splits this species from *Amblyopsis spelaea* based primarily on genetic evidence. Two of the paratypes appear to have been from Upper Twin.

2017:

Tour guides conducted a census of every half-hour trip from June 5 to Oct. 22, 2017 during the entire roundtrip, both in and out of the cave. Results ranged from 0 to 22 cavefish seen with the average number generally decreasing as the day progressed. A snapping turtle was also reported on two occasions (Catlin, 2002). Note this may include sighting of the same fish twice.

2018:

Lewis (2018) includes census results with graphs of the cavefish and crayfish inventoried during this study in the 2018 Natural Areas Conference karst ecology fieldtrip guidebook.

Comments on Historic Observations of Aquatic Cave Life

It is impossible to determine population trends in Upper Twin from published accounts. The major study of cavefish was Poulson's work in the late 1950's and 1960's, but his study was primarily one of cavefish behavior. Few actual numbers of cavefish observed were provided or multiple dates were combined. Later reviews of his work include unpublished data, but the numbers given are a combination of trips during the year and conflict from one account to the other.

A shortcoming of almost all censuses is that the length of the surveys is not provided (Pearson 1998 and Lewis 1999, in above list, being the exceptions). Poulson, on page 72 of his thesis, provided a clue of his census range when he wrote: *"… my direct counts from 1957 to 1959 (130 fish in the total one mile length of the cave) …".* Note: The map of the cave at that time showed 4,674'.

Exacerbating this is the conditions under which observations were made are lacking in almost all cases: water clarity and depth, light source used (the exception is Pearson 1998 above), and survey time.

Vague references are made to exceptionally large cavefish populations in the early 1900's that might have been depleted by collecting, either for scientific studies (see Blatchley 1899, Eigenmann 1899 to 1903 and 1909, Banta 1909, and Poulson 1962 above) or commercial sales (see Woods & Inger 1957 and Poulson 1958 above), but there are no references or data given by any author to support this fabled "exceptionally large" pristine population of cavefish.

PART 2: 2017-2018 CENSUS

METHODS AND MATERIALS

Equipment

Illumination was a Fenix HP25 headlamp with Cree XP-E LED bulb used with the high beam of 180 lumens. This light was bright and focused more than adequately to light to the far side of the cave passages and in very clear water to the pool bottoms.

Field collected data was obtained with a Barnstead Thermodyne Corp. digital pyrometer model PM20700/series 589 with type J thermocouple for temperature. A Myron L Co. model 6P ultrameter (auto temp compensation, accuracy: ± 1% of reading for conductivity and TDS, ±.01 pH) was used for conductivity, ORP, total dissolved solids and pH measurements. The meter was calibrated at least monthly per manufacture recommendations. The meter cell was twice rinsed with stream water at each use and care was taken not to disturb the substrate.

The Community Collaborative Rain, Hail & Snow Network (CCRHS) station IN-LW-4, was used for precipitation records. Missing observations from IN-LW-4 were filled in with observations from station IN-OR-1.

Techniques

Attempts to record size of the larger fauna proved impractical as frequently they could not be approached close enough for size determination due to pool depths or passage restrictions. When walking in shallow water or riffles, the technique was to take 10 steps looking just at the stream, then stop and scan the rest of the passage behind and ahead.

Cavefish and troglobitic crayfish can be confused at a distance in deeper pools. The only way to tell them apart is to wait. When it does move, a crayfish will suddenly "jump" while a cavefish will languidly move away usually in a curving upward path.

O. i. inermis will commonly be under thin wall ledges if present. If in a pool with ledges, one must stand still and wait till the water ripples smooth out; if possible do not even enter the pool. The crayfish will slowly emerge from under the ledges to investigate the observer. It's not unusual to only see their antenna moving slowly back and forth (*O. i. inermis* antenna are readily differentiated from *C. tenebrosus* with practice). The whole crayfish will not come out. Using this technique will have a major impact on the number of *O. i. inermis* seen (in clear water) compared to steady forward movement.

The troglophillic *C. tenebrosus* population probably is much greater than what was observed because of their dark color which blends in well with the substrate. Many times, the only way one can spot them is when they "jump" as one progresses. A good technique is after entering a pool and having waited for the *O. i. inermis* to appear, make a small disturbance and watch for the *C. tenebrosus* to "jump" as they have been stealthily advancing the whole while.

Pickerel frogs will begin moving into the cave in the fall and will be very exposed, usually at the water's edge. In hibernation, they will be clustered at the mudbank at the start of Moonshiner Holler close to the park entrance. Bend down very low to the water and shine your light slightly upwards into the crack between the top of the mud and the limestone wall ledge to see their eyes reflecting, usually in clustered groups. Viewing from both upstream and downstream angles will greatly increase observations as most of them are deep in the crack.

Variables

Every effort was made to reduce survey variables. All surveys were by the same person using the same light. Trip time varied from 2 hours to 4:05 hours with an average of about 3 hours.

The major variable was the water clarity. The second largest variable, which affected only Areas 1 and 2, was if the dam drain was open or closed (see fig. 6).

Study Area 1 was particularly affected by the dam. With the dam drain closed, the water was suddenly much higher at the cave dripline. With the dam drain open, it was normally chest deep through Area 1. There were only two short lengths that had to be swam. With the dam drain closed perhaps 200' were about 5' deep and swimming was required for perhaps 80'. The closer one's head is to the water, the less one is going to see, and no life at all will be seen while swimming in boots.

Study Area 2's entire length was somewhat affected by the dam. With the dam drain open you would walk long stretches of the cave on gravel bars out of the water with the stream meandering from one side or the other. With the dam drain closed, one is always in water. This did not affect the ability to observe so much as the total area of water to scan was much greater.

Water Depth Measurements

Measurements of water depth were taken in two places:

1) At the new (1984) dam below the cave. The top of the dam is remarkably level after 34 years; water runs evenly across the entire width. In the field, the water was measured down from the top of the dam. This measurement was later subtracted from the distance from the top of the dam to the bottom of the drain pipe in the dam which was 57".

2) At the IKC entrance stream passage. The stream bottom here is not stable as the bottom consists of mud and pebbles. To counter this, a point or "permanent" gauge station was established well above the stream and was measured down to the surface. To measure, the observer should sit on the edge of the stream; below the downstream, climb up to the entrance room. The ceiling directly over the water forms a slight wall in front. A small "X" was marked in pencil on the limestone. The initial distance to the stream bottom from the mark was 40".

Water Clarity

Water clarity (turbidity) was the most important factor in this visual encounter survey. A simple approach measuring clarity strictly by sight was used and characterized as how well you could see your boots in the steam. These were labeled with a point system to enable a chart to be made.

1 Crystal clear:	Can see boots perfectly in waist deep water and exceptional visibility.
2 Clear:	Can see boots clearly in waist deep water or if water clarity was not noted in field notes.
3 Slightly cloudy:	Can vaguely see outline of boots in waist deep water.
4 Cloudy:	Can barely see outline of boots in knee deep water
5 Muddy:	Cannot see boots at all in knee deep water.

DESCRIPTION OF CAVE AND STUDY AREAS

Cave Watershed

The water entering Upper Twin is partly fed from Mosquito Creek, a stream that subsides into sink holes at the end of a long shallow valley about 2 ½ miles southeast of the park in section 15, T. 3N., R. 1E. (Berg, 1958, Malott, 1932). The watershed is about ½ mile wide and 5 miles long from the southeast and is composed of karst terrain on the Mitchel Plain. The water enters small solution-enlarged conduits that gradually form the cave itself. Forty-two percent of the total Spring Mill Lake watershed flows through Upper Twin Cave (Hasenmueller, 2000).

The soil type is Cider-Frederick and is formed from the residuum of limestone (Thomas, 1985). At a depth of 4' to 5' in its uneroded phase, it is a heavy, sticky red clay just above the base limestone (Wiancko, 1928). This is the soil exposed and collapsing into the IKC entrance.

The Cave Today

Upper Twin Cave remains in a mostly pristine condition despite having a written history for at least 186 years (McCammon, no date). This is very unusual and perhaps due to very low visitation because of the necessity to swim in many places. While few speleothems occur, very thin delicate limestone ledges are present along lower walls bordering the stream that would have been broken off in more heavily traversed caves. Vandalism is not apparent anywhere except for a few spray-painted names. No historic signatures were noted, perhaps due to complete periodic flooding.

Overall, the main cave passage is mostly of easy walking height. The cave is joint-controlled with eleven sharp 90-degree bends between the park and IKC entrances, usually with a deep pool of water at each bend. The stream generally flows in a riffle-pool sequence, meandering from side to side of the passage. Eleven side passages, all of a horizonal nature, enter the main passage usually at right angles and directly across from each other.

The small tributary leading to entrance 2 (also on park property) is on the left side of the passage about 80' past the tour boat turnaround or 720' into the cave.

The "Small Room" is reached 1,690' into the cave. It is about 125' long with approximately a 20' tall ceiling and has several piles of breakdown on the right side.

On the left at the end of the Small Room is the passage to entrance 3 which is easily confused with the much more impressive in-feeder about 40' directly ahead. The cave stream backs up into the entrance 3 passage opening. This opening is about 2' wide and 5' tall and continues as a narrow and winding passage. In higher water flow, a waterfall can be heard from the main passage.

In another 1,500', or 3,190' into the cave, is the "Big Room". Across from its 28' tall ceiling on the right side is a remnant of an upper stream level formed before the present cave. This upper passage can be reached by climbing on the upstream side but ends shortly in unconsolidated fill material. The downstream section is not climbable without a ladder.

Stygoxene or accidental species were sometimes found in the Big Room and nowhere else in the cave except for threshold areas, leading to the suspicion that there is some access to the surface from the abandoned upper passages.

After the Big Room on the right is a side passage ending in mud fill. This is directly under the large "sinkhole" in the mud fill of the upper passage at the top of the Big Room.

The first hands and knees crawl is about 3,000' into the cave. There are no "belly crawls" to the IKC entrance.

On hot humid days, air enters at the IKC entrance and exits at the park entrance. This causes a mist in the air starting at the Big Room which gets progressively thicker till in the final crawl near the IKC entrance the visibility is only a few feet. Air temperatures might be up to 12 degrees warmer just 4' up from stream level below the IKC entrance.

On very cold winter days, there is a thermally driven chimney effect where warmer cave air is exhausted out of the higher IKC entrance causing below freezing temperatures and ice crystals in the passage mudbanks as far as 100' into the cave.

At the IKC entrance, the route climbs up on the right into a small room and exits into a sinkhole. The IKC entrance is sometimes choked with red, sticky mud requiring exiting back through the park.

Study Areas

The entire study area starts at entrance 1, the Spring Mill State Park entrance, and proceeds 3,780' upstream to entrance 4 in the IKC Shawnee Karst Preserve. Proceeding upstream was required due to induced siltation by the observer.

The entire 3,780' of the cave surveyed was divided into 4 areas, which are referred to throughout the text by number. The study areas dividing points were chosen according to major stream environment changes or major features in the cave to facilitate census repeatability (see fig.6).

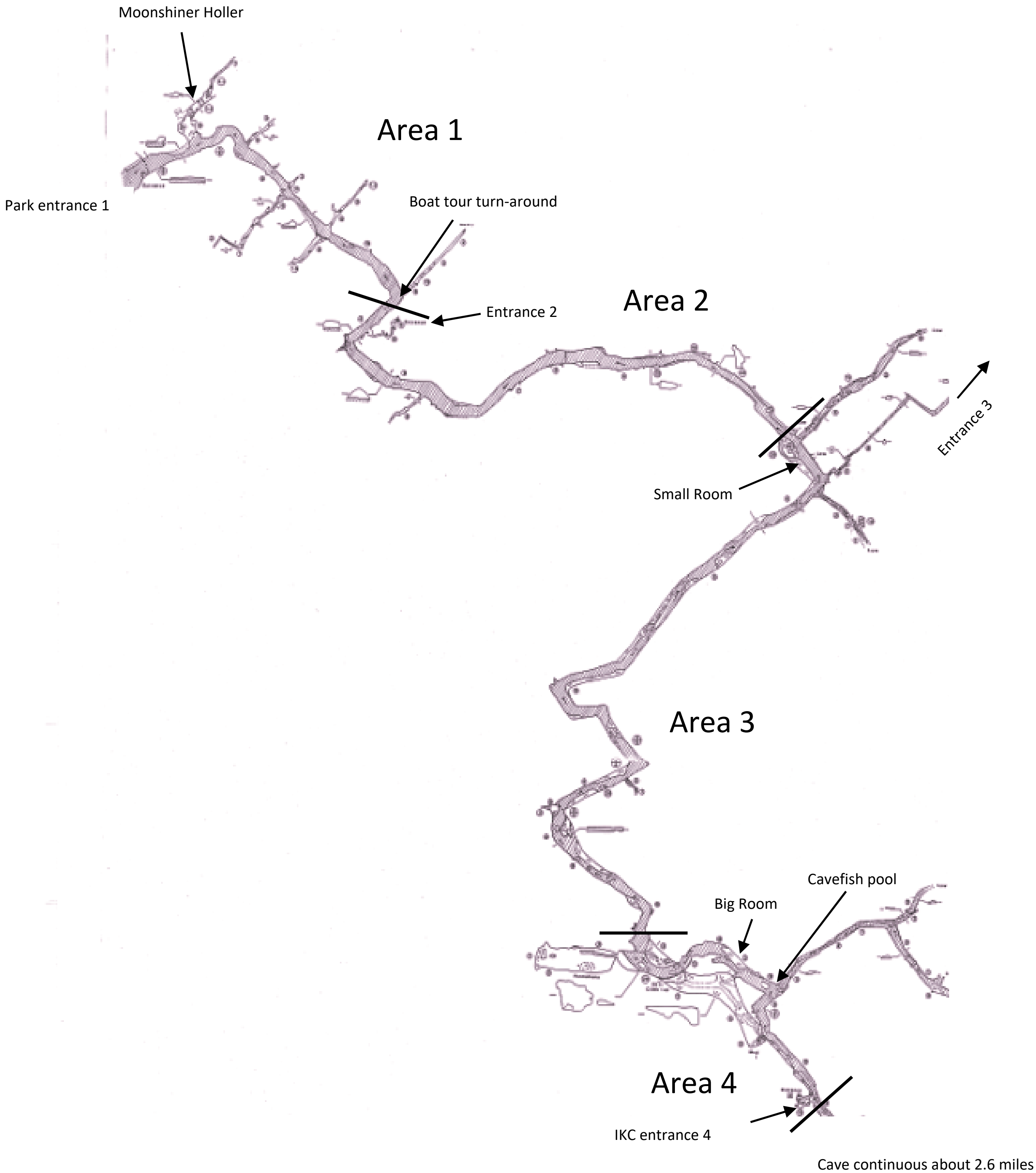
Area 1, (640' long) Starts at the cave dripline; 100' in is Moonshiner Holler on the left. This was entered for about 50'to where it became a crawl. Returning to the main stream and generally staying on the right side of the continuous deep-water passage - the route went to the boat tour turnaround 640'into the cave. No boat was used during the study. Swimming is required in Area 1, especially with the dam drain closed.

Area 2, (1,050' long) Starts at the tour boat turn-around where the loose cobble floor slopes up to the much shallower water passage at a bend to the right. With the dam drain closed, it was about knee-deep water. With the dam drain open, it quickly became a riffle area with a meandering stream. The Small Room is reached 1,050' further which is marked with an 11' long stainless-steel cable across the passage.

Area 3, (1,500' long) Starts at the beginning of the Small Room. About 1,000' from the end of the Small Room is a turn to the left. One may swim to the right through one of two small passes or crawl forward over a short sandbar. The survey route went straight. This is the only area in the cave study area that has a sandbar. Red cave beetles, probably *Pseudanophthalmus stricticollis,* could usually be seen here along with evidence of their prey in the form of worm castings and tracks if the water had been low for a few weeks.

Area 4, (590' long) Starts about 340' after the sandbar area at the entrance to the 130' long Big Room. The route went about 30' to the right to observe the stream at the downstream end of the room then reversed and proceeded up and out of the water on the left to the end of the room. Continuing past the Big Room about 200', in a walking height passage, is a large pool on the left hidden behind ceiling breakdown. The route went to the left just before the breakdown to observe fish in the downstream part of the pool without disturbing them and then around the breakdown to the upstream side of the pool, standing on the large flat rock there to not disturb them. At the IKC entrance climb up, look for cave salamanders and their juveniles which are common here.

Figure 6. Upper Twin Cave Study Areas



AQUATIC SPECIES INVENTORIED

STYGOBITIC

Amblyopsis hoosieri - Niemiller, Prejean and Chakrabarty, 2014, the Hoosier cavefish
Description
Phylum: *Craniata*, Class: *Actinopterygii*, Order: *Percopsiformes*, Family: *Amblyopsidae* Genus: *Amblyopsis*
Global rank: G2 imperiled, Federal rank: C candidate protection, state rank: SE endangered species, state heritage rank: S1 critically imperiled.
References to this species before 2014 will be *Amblyopsis spelaea,* the Northern Cavefish (Chakrabarty, 2014).

Identification
Translucent but appearing to the observer as pinkish white. The largest individual seen was approximately 4 ½" long.

Orconectes inermis inermis - Cope, 1872, the Ghost crayfish
Description
Phylum: *Crustacea*, Class: *Malacostraca*, Order: *Decapoda*, Family: *Cambaridae*, Genus: *Orconectes*
Federal rank: G5 apparently secure, state heritage rank: S3 rare or uncommon
Early records, Blatchley in 1897, refers to this species as *Cambarus pellucidus*

Identification
Slender body shape, elongated appendages, no pigmentation and non-functional eyes. Translucent but appearing to the observer as white, slowing growing darker as they approach molt. Rarely, an individual near molt will be seen appearing very dark, almost black.

STYGOPHILIC

Cambarus tenebrosus- Hay, 1902, the Cavespring crayfish
Description
Phylum: *Crustacea*, Class: *Malacostraca*, Order: *Decapoda*, Family: *Cambaridae*, Genus: *Cambarus*
Federal rank: G5 Secure
Referred to as *Cambarus laevis* before 1977 (Taylor, 1997).

Identification
Darker and larger than *Orconectes*.

TROGLOXENEIC

Eurycea lucifuga- Rafinesque, 1822, the Cave salamander
Description
Phylum: *Craniata*, Class: *Amphibia*, Order: *Caudata*, Family: *Plethodontidae*, Genus: *Eurycea*
State Status: S4 apparently secure   Global Status: G5 secure, state heritage rank: S4

Identification

Very distinctive, bright orange with black spots.
Juveniles are black, up to 2 1/2” long.

STYGOXENEIC

Lithobates palustris, LeConte, 1825, the Pickerel frog
Description
Phylum: *Craniata*, Class: *Amphibia*, Order: *Anura*, Family: *Ranidae*, Genius: *Lihobates*
Global Status: G5 Secure

Identification

Medium to smaller sized with rectangular tan to grey spots on its back, oriented generally in two columns that may blend together to form long rectangles. The most distinguishing feature of the pickerel frog is the bright yellow splash of color on the inner surface of its hind legs that is thought to warn predators of toxic skin secretions (see fig. 7). Pickerel frogs are often mistaken for Northern leopard frogs which have more circular spots. Leopard frogs are not seen in caves.

Figure 7. Pickerel frog, 3-2018, at top of mud crack at Moonshiner Holler, displaying normally concealed classic yellow color on hind leg

Lithobates catesbeianus, Shaw, 1802, the American bullfrog
Description
Phylum: *Craniata*, Class: *Amphibia*, Order: *Anura*, Family: *Ranidae*, Genius: *Lihobates*
Global Status: G5 Secure

Identification

Larger than a Pickerel frog, green or brown with randomly scattered dark spots. Lacking the ridge along the back and patches of bright yellow on inside of thighs like pickerel frogs have.

ACCIDENTALS

Epigean fish, unidentified, were observed three times during the study; on 9-21-2017, 6” long, close to IKC entrance; 10-19-2017, 5” long, near the park entrance; 11-2-17, near the park entrance.

A box turtle shell was seen in the stream just below entrance 2 on 2-12-2018. It appeared to have washed in from that entrance passage.

Single snapping turtles were reported by tour guides on 6-26-17 and 8-6-17 (Catlin, 2017).

Raccoon (*Procyon lotor*) tracks were extremely common on the mudbank below where entrance 2 enters the main passage. The tracks always led into the water. On several trips, the tracks were deliberately rubbed out in the mud with them reappearing the next trip proving continuing visitation. Infrequently, raccoon tracks were noted on the mud at Moonshiner Holler in Area 1. No raccoon tracks were noted elsewhere. Lewis (2011) reported several areas of raccoon scat along the breakdown slope inside the IKC entrance.

RESULTS AND DISCUSSION

Amblyopsis hoosieri

Location in cave

Study Area 4 had the highest density of observed cavefish per hundred feet at 39% of the total observed population followed by Area 2 at 26%, Area 3 at 23%, and Area 1 at 11% (see chart 1 and table 2).

Area 1 perhaps had the best habitat for cavefish with continuous deep water throughout its length but had the lowest density of cavefish. Two factors may have contributed to this: 1) The continuous deep water throughout Area 1 prevented an accurate count. Most of Area 1 was chest deep or swimming depth, nothing will be seen while swimming in boots. During the winter, with the dam drain open and subsequent lower water levels, the percentage of population seen increased 5% in Area 1 and; 2) The stream water had noticeable less clarity in Area 1 in the fall. The water was almost tea colored from tannins from decaying vegetation and leaves, until the first riffles in the cave at the start of Area 2. The dam would trap surface debris causing tree leaves to be floating over a hundred feet into the cave. Even with the open drain pipe, tree leaves would typically be trapped by the dam.

The observer did not notice any difference between where larger or smaller cavefish were observed as reported by Poulson (larger cavefish in deep pools and smaller cavefish in *"silt-bottomed backwater pools and in seepage inlets with silt bottoms*" p. 60 of his thesis). Certainly, cavefish were not grouped close to seepage inlets or in feeders to the cave.

The one exception to this is a unique long, shallow pool at the start of a large in feeder behind a section of four-foot-high cave ceiling collapse about 340' upstream from the start of the Big Room and 250' downstream from the IKC entrance. This is just before the duck-under to continue upstream on the right. The pool in this walking height passage is usually full of cavefish very close together. It's normal to see 10 to 15 cavefish in this pool and common to see 6 to 8 within 2 feet of each other (see fig. 8).

Figure 8. *Amblyopsis hoosieri* in pool (photo: Jerry Lewis, Sept. 2012, IKC *Update* # 107 front cover)

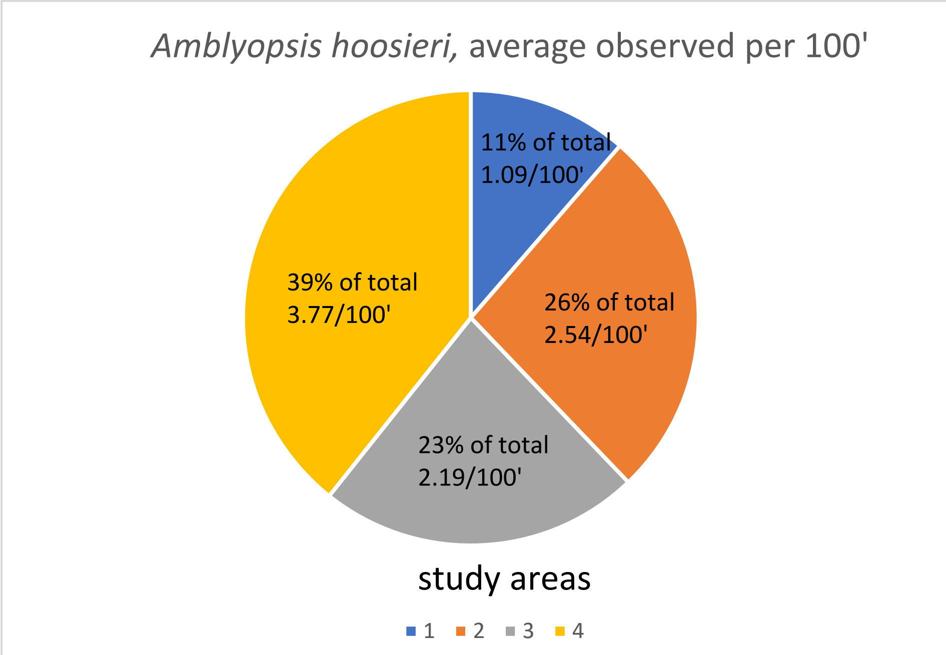


Chart 1. *Amblyopsis hoosieri* observed per hundred feet of cave passage.

Bacterial fin disease/Broken Back Syndrome

No evidence of bacterial fin disease as reported in Donaldson Cave (Pearson, 1995) or Broken Back Syndrome reported in Upper Twin Cave (Keith,1979) was noted. All *A. hoosieri* appeared healthy with no discolorations or fin erosion and were swimming normally. No dead *A. hoosieri* were seen.

Reaction to light and vibrations

Poulson reported that cavefish in Upper Twin always moved away from light directed on them, and multiple studies support this. This observer found that entering (or approaching rapidly) a pool, caused the fish to scatter and dart away. But if the observer stayed a distance away from the pool holding the light beam on them, their typical response was to ignore or even slowly move closer in a meandering, curving path.

A. hoosieri dart away from major disturbances, such as wading in the water or even walking but are *attracted* to very small disturbances, such as standing still. This attraction to very small disturbances may be their investigating possible prey and appears to overcome aversion to light.

Behavior

On some surveys *A. hoosieri* were in very exposed, open locations such as in the middle of the stream and pools, but on other trips they were in more concealed locations such as the edges of pools and hiding under ledges. The census results do not reflect this, but it was very apparent. The census trips were taken about every two weeks and on some trips obvious signs of recent flooding since the last trip were noticed. It was after recent flooding that the cavefish acted more secretive. Poulson (1964, p.751) noted this behavior also during floods: "*Scale growth rings of amblyopsid cave fish, and probably other cave fish, form during floods while plankton and organic matter are being replenished but the fish are secretive, inactive, and not feeding." A. hoosieri* require weeks after a flood to return to normal behavior.

One unusual observation occurred when climbing up and out of a steeply sided pool in Area 2 during high rapid water. The stream running over the riffles into the pool was of considerable speed, and a cavefish, perfectly calm and stationary, was directly below this rush of water facing *downstream* in a calm eddy underneath the rapid current.

Orconectes inermis inermis

Location in cave

Study Area 3 had the highest normalized population per 100' of observed *O. i. inermis* at 35%, followed by Area 4 at 27%, Area 2 at 24%, and Area 1 at 14% (see chart 2 and table 3).

Area 1 having the lowest population of observed *O. i. inermis* may be caused by two factors: 1) As in the case of the low cavefish population in this area, the deep water interfered with observation and 2) continuous deep water does not appear to be the optimum habitat for *O. i. inermis.* They seem to prefer a shallow riffle/pool environment.

Weingartner (1977) also noted more *Orconectes* in shallow riffle/pools than deeper pools in a study of Shiloh Cave, Lawrence County, Indiana and attributed it to prey capture of isopods being more efficient in riffle areas. Hobbs (1973) in his study of Mayfield Cave, Monroe County, Indiana reported *Orconectes* were "*…more often observed in pools than in the shallow faster flowing sections."* Mayfield's Caves pools, however, are intermittent and much shallower compared to the continuous deep water in Area 1 of Upper Twin.

Orconectes in *most* Indiana caves, when in shallow pools, will be found on the black "lens" of organic matter usually present in pool bottoms. In Upper Twin an *O. i. inermis* is rarely found at the bottom of a pool even if the water is very clear. This could be due to the pools being much deeper than normal for Indiana caves. *Orconectes* will be higher along the edge of the pools. If there are thin limestone ledges along the pool edges, they will usually be hidden *underneath* the ledges. This behavior of clinging underneath rock shelves was also noted by Hobbs (1973) in Pless Cave, Lawrence County, Indiana.

One interesting location for these crayfish is on the right side of the Big Room between the large rocks. Here is a shallow pool about 2' by 6' that is above normal variations of the cave steam and sheltered from flood current perhaps providing a refuge during floods. This seems to be a favorite of the crayfish, with 3 to 5 usually seen here. An unusually high proportion of the crayfish were darker and close to molt in this pool.

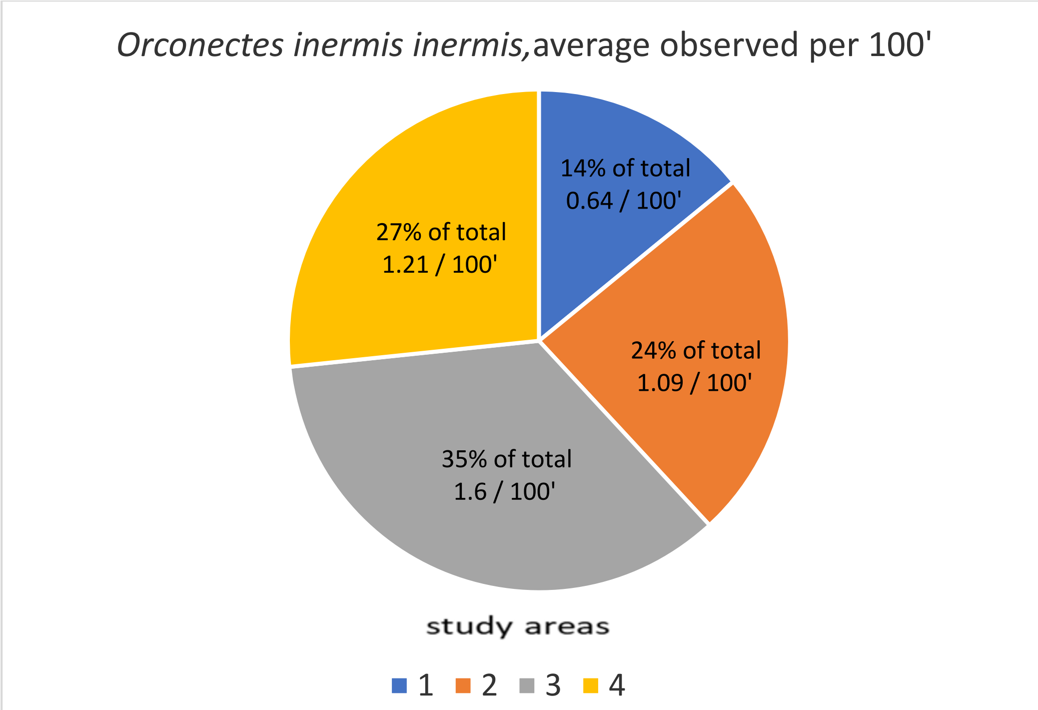


Chart 2. *Orconectes inermis inermis* observed per hundred feet of cave passage.

Mortality

Only two dead *O. i. inermis* were observed during the study, or .0017% of the total observed population. The very low observed mortality rate might be attributed to their being instant food for other organisms upon death.

This can be compared to another study by the author of 3,528' of passage in Shiloh Cave of a mortality rate of 0.0085% (5X higher) during observations of 4,339 individuals during 63 trips from 1993 to 2016.

In another study by the author of the New Discovery section of Marengo Cave, Crawford County, Indiana a mortality rate of 0.00415% (2.4X higher) was found during observation of 3,616 individuals during 39 trips from 1995 to 2017.

There is likely ongoing predation upon *Orconectes* by the raccoons entering the main stream passage from entrance 2. Raccoons are known for their predilection for crayfish and have long been known to prey upon Cave crayfish (Banta, 1907). Frequently traveling long distances in caves, raccoons serve as the top predators in many caves.

A smaller possibility exists of predation by the small population of Pickerel frogs in Area 1 upon *Orconectes*, but the frogs were usually in a torpid state and in the lightless environment probably ineffective in prey capture.

No *O. i. inermis* were observed in "berry" or with young.

Missing chelae

Observations and studies of troglobitic crayfish losing appendages have long been made. Putnam (1877) published an article concerning lost appendages and habits of *Cambarus pellucidus* (= *O. inermis*) and Banta (1907) describes in detail the activity and behavior of *Cambarus pellucidus* (= *O. inermis*) and *C. bartonii* (= *C. tenebrosus*).

Loss of chelae is mainly a result of struggles with rapid currents associated with floods, followed by territorial battles. Another cause for chelae loss was proposed by Hobbs (1973) who observed in Pless Cave that 8% more males than females had missing chelae which he suggested might be accounted for by his observation that males do not always limit their copulation attempts to females.

Totaling all trips and areas, .0411% of the observed population of *O. i. inermis* had one or more chelae missing (0.0240% right, 0.0137% left, 0.0034% both). Undoubtedly the actual number with missing chelae is larger because in the large passages and deep pools (especially of Area 1) of Upper Twin crayfish far away could not be closely observed.

This is less than *O. inermis* observed with missing chelae found in a previous study by the author of 0.072% (1.8X higher) of the total observed population of 4,339 individuals (0.0276% right, 0.0369% left, .007% both) (see chart 3) in 3,528' of passage in Shiloh Cave during 63 trips from 1993 to 2016. The smaller percentage of crayfish with missing chelae in Upper Twin Cave compared to Shiloh Cave can probably be attributed to the passages in Upper Twin being wider with deeper pools which preclude close examination of the crayfish.

Another comparison is to (the unmapped) Marengo Cave New Discovery Section where 0.136% (3.3X higher) of the total observed population of 3,616 individuals had one or more chelae missing (0.061% right, 0.041% left, 0.033% both) during 39 trips by the author from 1995 to 2017 (Sollman, 2017). Marengo Cave has passages permitting close examination of the crayfish but has a much more violent stream with rapid floods compared to the other two caves which probably accounts for the large difference.

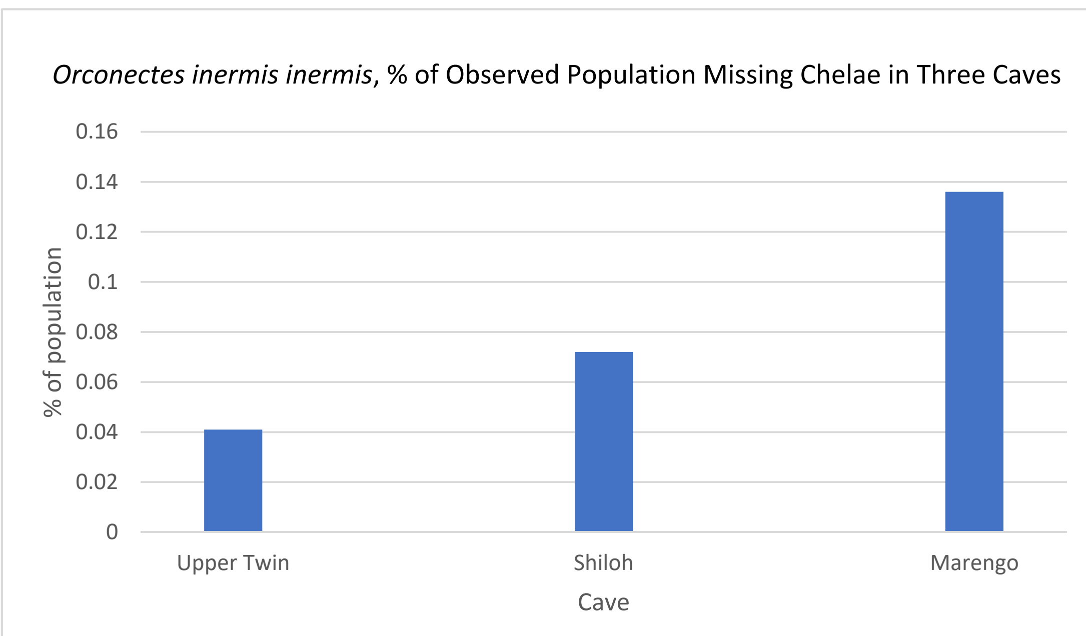


Chart 3. *Orconectes inermis inermis*, % of observed population missing chelae compared in three caves.

Cambarus tenebrosus

Location in cave

The observed *C. tenebrosus* normalized population per 100' was fairly evenly divided among the four study areas: Area 1 at 31%, Area 3 at 28%, Area 4 at 22%, and Area 2 at 19% (see chart

4 and table 4). *Cambarus* crayfish are dark in color and blend in well with the substrate, thus the actual population is probably much greater than observed.

C. tenebrosus will usually be along the sides of the pools or in riffles, rarely along the wall ledges.

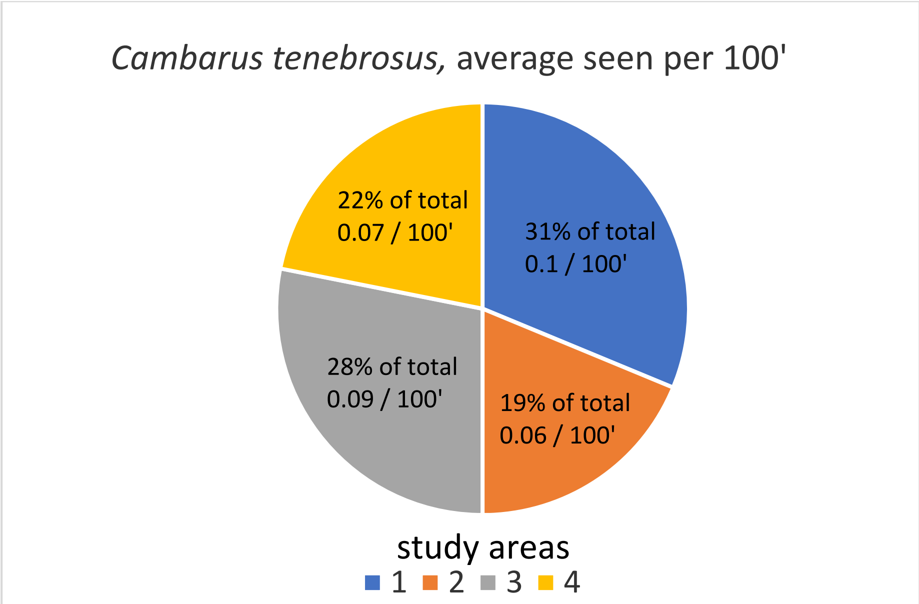


Chart 4. *Cambarus tenebrosus* average observed per hundred feet of cave passage.

Mortality

Twelve dead *C. tenebrosus* were noted during the study or .16% of the total observed population. This is 10 times higher than the *O. i. inermis* population observed mortality. This might be explained by Poulson (1965) who wrote that fluctuations in population sizes of troglophilic species are higher because they are not as efficiently adapted to utilizing the hypogean food resources as troglobites.

This can be compared to a previous study by the author of Shiloh Cave where the *Cambarus* mortality rate was 0.102% (0.6X) and of Marengo Cave where the mortality rate was 0.102% (0.6X) of the 226 individuals observed.

No *C. tenebrosus* were observed in “berry” or with young.

Missing chelae

Totaling all trips and areas 0.04% of the observed *C. tenebrosus* population had one or more chelae missing (0.027% right and 0.013% left). Chart 5 shows the comparison between *O. i. inermis* and *C. tenebrosus* chelae loss.

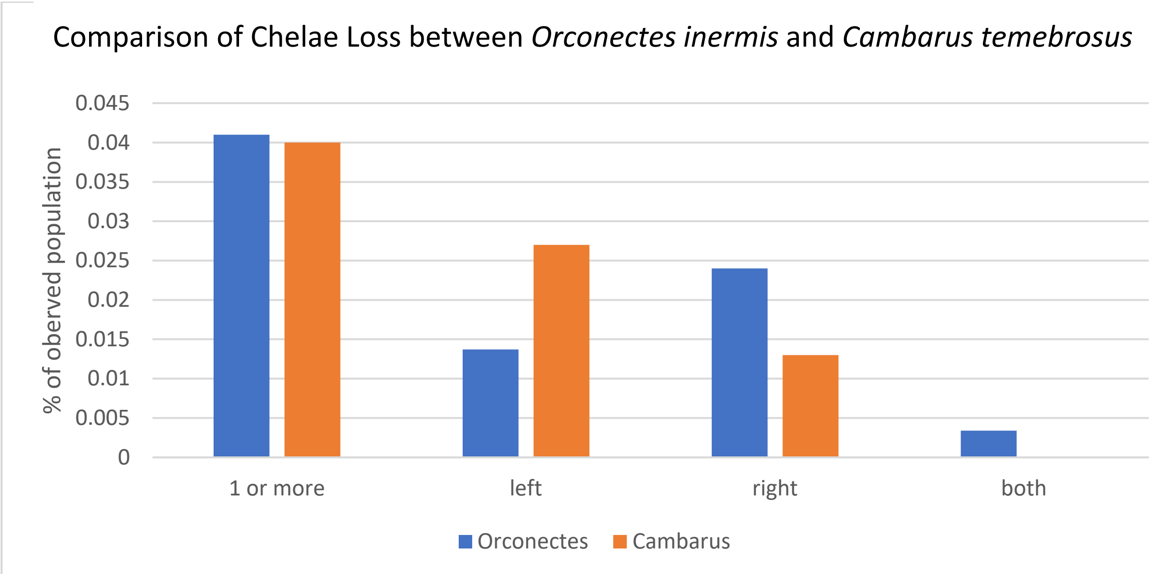


Chart 5. Comparison of chelae loss between *Orconectes inermis inermis* and *Cambarus tenebrosus*.

Behavior

One interesting observation of *C. tenebrosus* behavior was noted by a tour guide on 7-10-2017 on the first tour of the day. He noticed a *C. tenebrosus* on a mudbank in a peculiar highly arched back position which didn't move during the remainder of the day's tours (Catlin, 2017). This behavior has been noted by the author in previous caves, but this crayfish was watched in maintaining this posture and position for over 8 hours! On the same day, another *C. tenebrosus* was observed in this same out-of-the-water, arched back position further in the cave near the middle of Area 2 (I didn't watch him for 8 hours). The water was clear and not of unusual height or flow that day. This behavior was not noted on any other trip.

Eurycea lucifuga

Location in the cave

Cave salamanders will not be far from an entrance. They are seen near the park entrance especially, at the back of Moonshiner Holler, and close to the IKC entrance.

Juveniles were only seen on vertical rocks and walls in the upper room at the IKC entrance, sometimes in large groups. Their spawning pool was not found.

The salamander population is undoubtedly undercounted in Area 1. The author took the commercial boat tour three times, and each time the guide pointed out cave salamanders that were not seen later during the same day's census trip (when the observer was in the water). The salamanders seem to prefer being up high on wall ledges between the dripline and Moonshiner Holler that are visible only from the higher vantage point of a boat.

Mortality

One dead *E. lucifuga* was seen on 12-14-17.

Behavior

Cave salamanders will usually remain stationary if a light is held on them but will sometimes very slowly move in the light and then rapidly dart away when the light is off. Seen on both mudbanks and limestone floors and walls, twice salamanders were observed rapidly swimming.

Lithobates palustris

Location in the cave

Pickerel frogs use of the cave appears to center on hibernation and thus is generally limited to the threshold zone of the cave. Their specific location corresponds to temperatures both outside and in-cave. In the fall when they enter the cave, they are very exposed, usually on the mudbank at Moonshiner Holler (see fig. 9). As winter progresses, they concentrate in hidden thermally sheltered hibernaculum. Observed numbers (see chart 6) peaked while they were still active after entering the cave and varied considerably during the winter as they were hibernating in a deep mud crack just before Moonshiner Holler. This specific location was found to have below freezing temperatures with ice crystals in the mud on the 12-28-2017 census trip.

Figure 9. Pickerel frogs active before hibernation on mudbank at Moonshiner Holler.

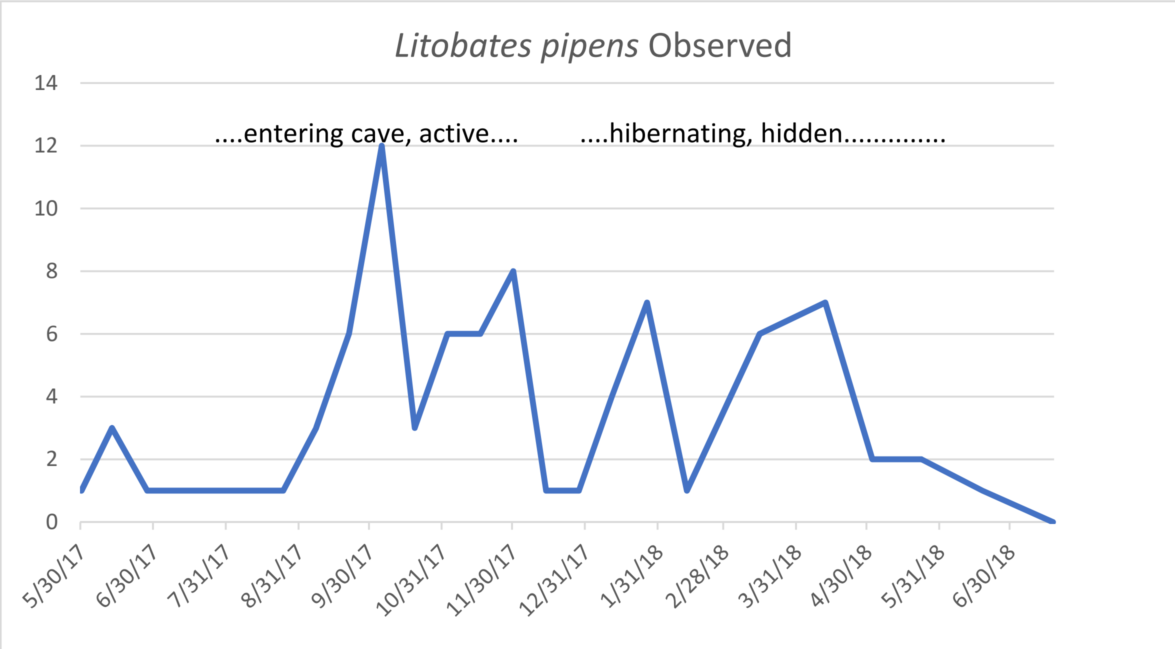


Chart 6. *Litobates palustris* observed.

Lithobates catesbeianus

Location in the cave

Bullfrogs were only seen on the mudbank at the front of Moonshiner Holler and very rarely, the Big Room.

Effect of Water Clarity on Observed Stygobitic Species

Water clarity had a dramatic impact on observed stygobitic species. If the water is turbid not much can be seen. This probably has even more effect in Upper Twin than many other caves in Indiana because of the unusual deep stream water level for an Indiana cave. Chart 7 shows the effect water clarity has on observed cavefish and crayfish populations. The chart uses a polynomial trend line with a very good R squared value of 0.9048 for cavefish prediction and a lower 0.5225 fit for crayfish prediction.

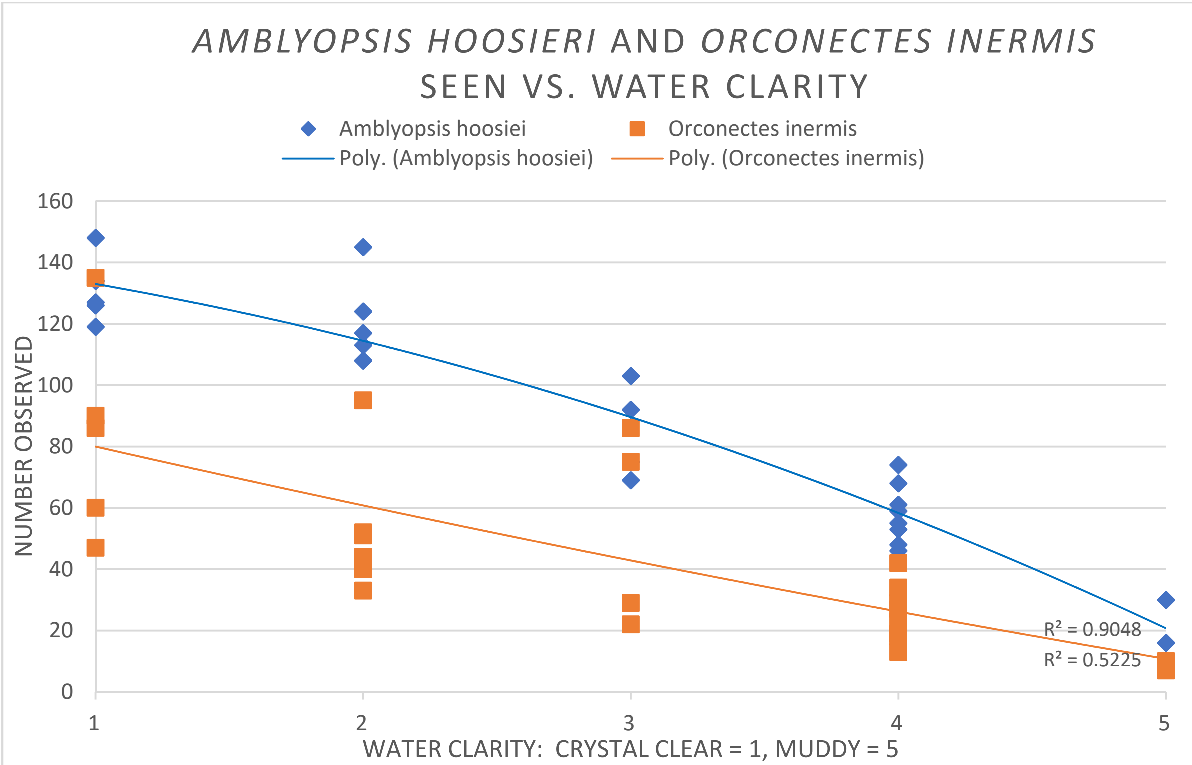


Chart 7. Effect of Water Clarity on *Amblyopsis hoosieri* and *Orconectes inermis* observed.

Effect of Water Depth on Observed Stygobitic Species

Stream water depths proved a poor predictor of observed stream macro-fauna. Chart 8 shows observed cavefish and crayfish populations compared to water depth at the dam. This chart's polynomial trend lines both have very low R squared values.

Chart 9 attempts to show a correlation between population observations and stream water depth at the IKC entrance. While the R squared values are slightly better, the correlation is poor.

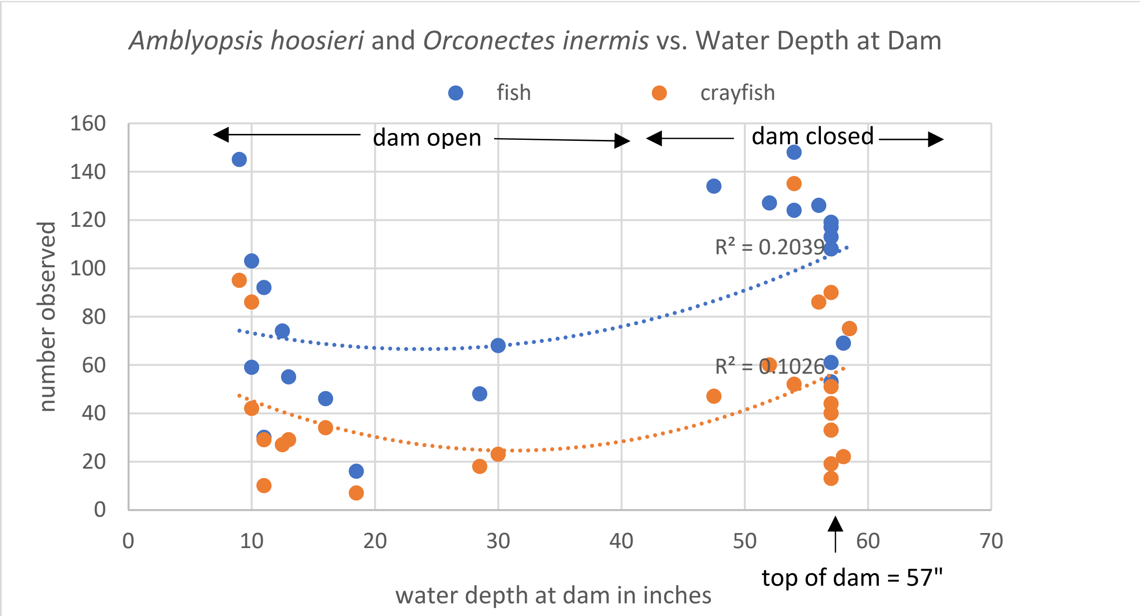


Chart 8. Effect of water depth at dam on *Amblyopsis hoosieri* and *Orconectes inermis* observed.

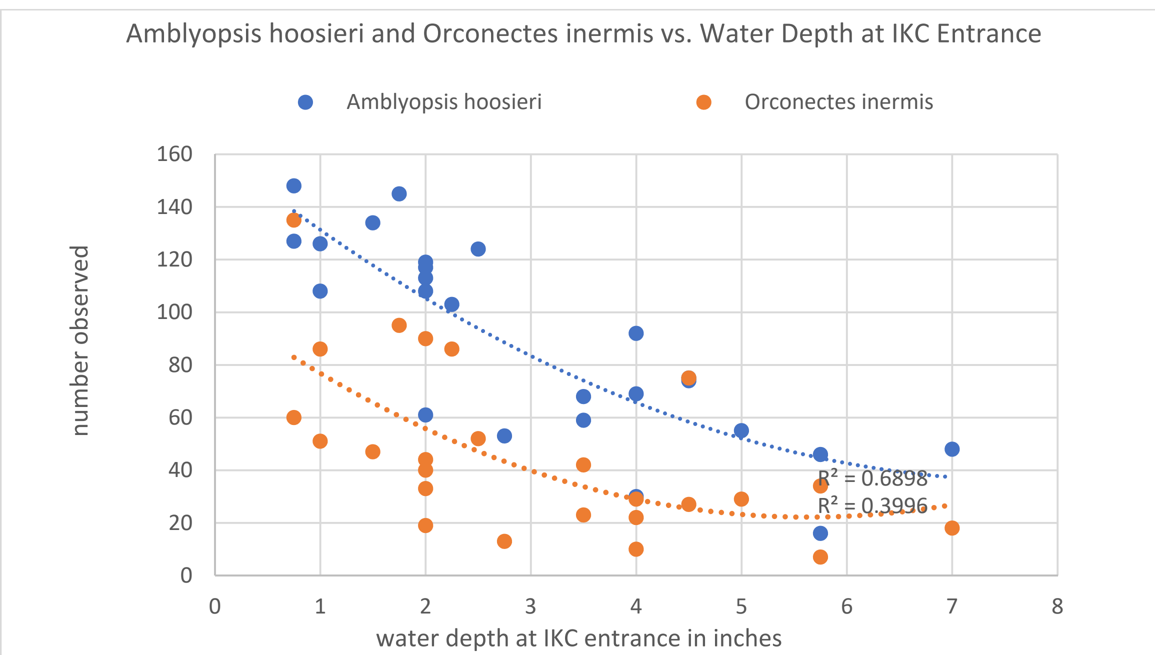


Chart 9. Effect of water depth IKC entrance on *Amblyopsis hoosieri* and *Orconectes inermis* observed.

Effect of Dam on Water Levels

The present dam drain pipe is closed shortly before Memorial Day at the start of the tour season and opened at some point after the season ends in mid to late October to flush accumulated sediment away. In 2017, it was opened the first week in November. Thus, in 2017, the dam was closed for about 42% of the year.

With the dam drain closed, the water is about four feet deeper in normal flow at the dam and backs up water in the cave approximately 1,840' based on actual in-cave measurements of water levels. So, with the dam drain open, the cave is close to its "natural" level and closed about four feet higher initially at the dam then gradually tapers off.

Effect of Precipitation in Watershed on Cave Water Levels

Initial attempts to link precipitation to observed stream levels in the cave using measurements from the National Weather Service showed little to no correlation.

An alternate service; Community Collaborative Rain, Hail & Snow Network (CCRHS) had a better correlation. CCRHS is a non-profit network of volunteers that use 4" manual gauges to record precipitation and is available online at www.cocorahs.org.

CCRHS station IN-LW-4 was used. Missing observations were filled in with observations from the Orleans CCRHS station, IN-OR-1 located 5.2 miles south of the park entrance (see chart 10 and table 9).

Station IN-LW-4, while only 2,300' east of Upper Twin's park entrance, probably does not accurately reflect precipitation entering the cave system as it is on the extreme northeastern boundary of the cave's watershed which is roughly ½ mile wide and extends for 5 miles to the southeast.

Another problem with trying to predict cave stream level with watershed precipitation is that during the "dry" season, ground-water flows do not always increase proportionately to rain-storm events (Hasenmueller, 2000).

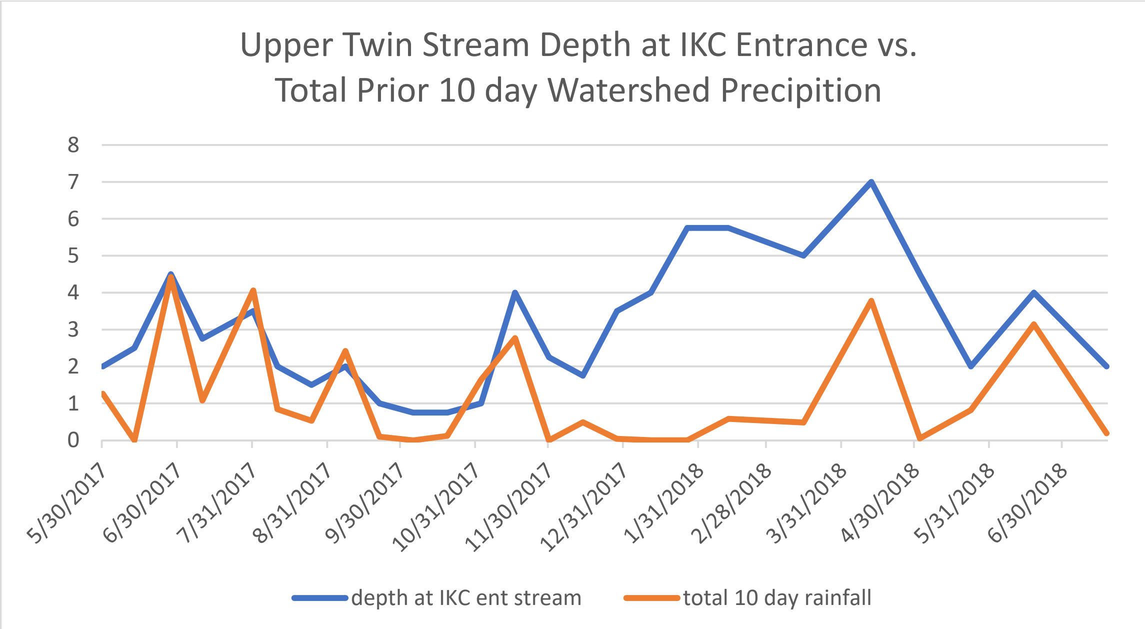


Chart 10. Watershed precipitation compared to cave stream water depth at IKC entrance.

Effect of Boat Tours on Cave Life

The effect of the commercial boat tours on cavefish is a sensitive subject. Poulson (2010) said: *"At Upper Twin Cave, no differences in apparent abundance of A. Spelaea exist between times when tours are conducted and times when tours are not in operation (Poulson, personal observation)"*.

This observation might be offset by some variation of an often-heard comment of tour guides to *"book early if you want to see more fish"*. A census was conducted by Catlin (2017) and others over 30 sample days from June 6 to Oct. 22, 2017. The results (see chart 11 and table 8) appear to support some effect on cavefish behavior as the average number of cavefish seen on every half -hour boat tour decreases as the day progresses during the entire season, regardless of water depth or clarity.

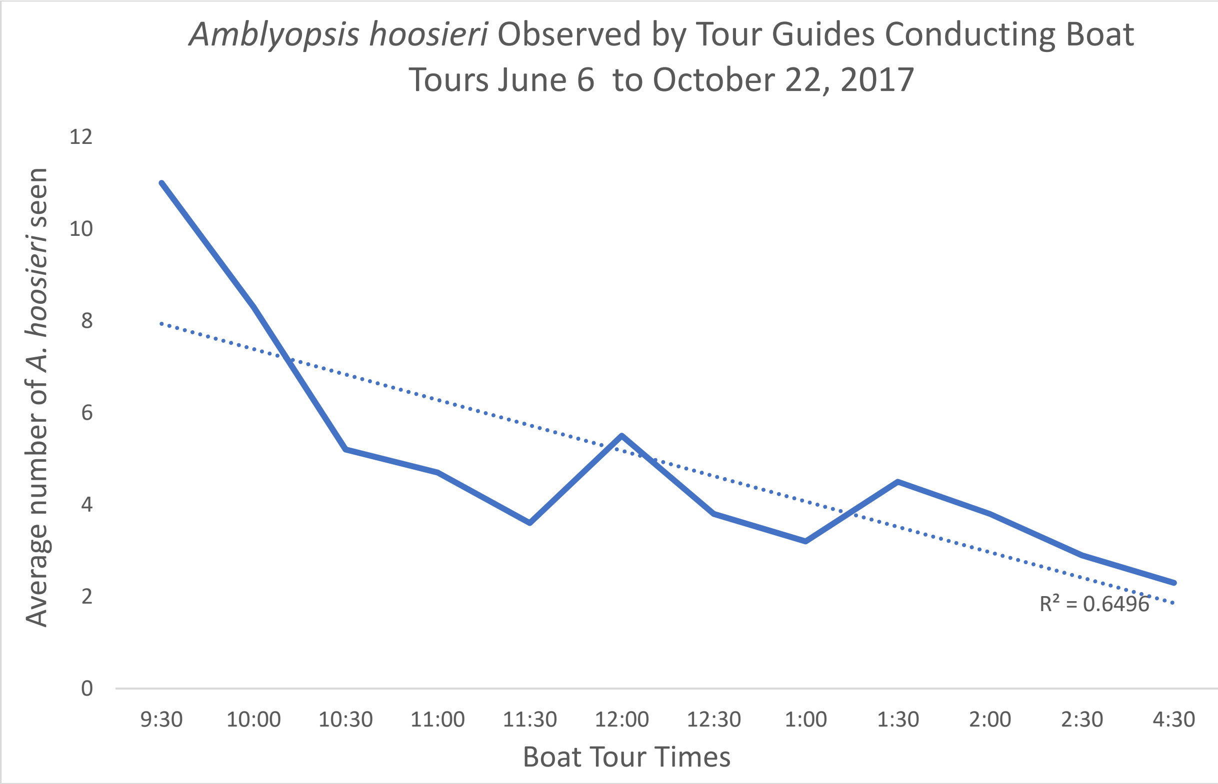


Chart 11. *Amblyopsis hoosieri* observed during boat tours compared to time of day.

It is probable that the cavefish are just moving slowly upstream due to the mild disturbance and drifting back later. Cavefish do this as a normal, natural behavior. One of Poulson's observations mentions this: "*…Amblyopsis often swim upstream foraging and passively drift downstream until they contact some obstacle or reach their initial starting point*" (see Poulson 1962 above). An observation by McGurk (see 1985 above) would seem to further add plausibility: *"Blindfish and crayfish are best seen in the shallow water of the turnaround room, after the stalactites."* Hobbs (1973), in his study of Mayfield's Cave, noted the tendency to move upstream dominates over downstream movement of *O. i. testii*.

Even if the effect is valid, it's doubtful that any harm is being done. Niemiller and Poulson (see 2010 above), two of the world's leading experts on cavefish, wrote "*…the continued abundance of fish in Upper Twin Cave since Eigenmann's studies suggests that pole boat tours in the downstream part of the cave, starting in the 1950's, have not compromised the populations."* (note: Tours in Upper Twin started in 1936.) The review of historic observations in this study seems to support Niemiller and Poulson's position that the cavefish population in Upper Twin is stable.

It certainly is one of the least invasive tours possible. Visitors do not leave the boat, paddles or motors are not used in the cave (as in the two other commercial caves in Indiana featuring cavefish), and the air and water are flowing directly back out of the cave.

The author cannot contribute any personal observations as this study was always started after the last tour of the day in season. The author does believe, however, that any effect by boat tours on cavefish is a demonstration of their normal behavior and is harmless.

Amblyopsis has been noted for a preference for large deep pools with slow moving water (McCandless, 2005) which would lead to an assumption that the densest population would be in Area 1 having the only continuous deep-water environment in the cave. (The balance of the cave consists primarily of a series of pools and riffles).

However, over the entire course of this study, the average *Amblyopsis* observed per hundred feet in Area 1 was the *lowest* in the cave at 11% of the total population. This increased to 18% when the dam drain was open (trips 26 to 35). The dam drain being open also corresponds closely to winter closure of the boat tours (trips 25 to 36).

This 7% increase in observed *Amblyopsis* was probably due to the water level being lower with the dam open in the off season permitting better observations and better water clarity with the dam not trapping surface debris.

Water Quality Analyses

Oxygen Reduction Potential (ORP)

ORP at the dam averaged 166 millivolts (mV) with a range of 101 to 251. At the IKC entrance ORP averaged 149 with a range of 92 to 235 (see table 10).

Generally, the ORP readings rose with higher stream water depth and flow, but this also occurred during the winter which could also indicate less organic input to the cave stream.

ORP might be thought of as a measure of the cleanliness of the water and its ability to break down contaminants. ORP levels indicate the level of bacterial activity of the water as ORP levels and Coliform counts have a direct link. Generally, the higher the ORP the higher the oxygen content and the lower the Coliform count.

Total Dissolved Solids (TDS)

TDS at the dam averaged 344 parts per million (ppm) with a range of 290 to 413. At the IKC entrance, TDS averaged 345 with a range of 257 to 455.

TDS showed a tendency to rise with lower stream levels and slower flows reflecting the greater amount of dissolved minerals.

TDS looks at all dissolved solids in water, both electrical conducting and non-conducting, so is an estimate of the mass of dissolved solids. Suspended solids do not affect TDS readings

Specific Conductivity (Cond)

Conductivity at the dam averaged 492 microSiemens (µS) with a range of 416 to 588. At the IKC entrance, conductivity averaged 493 with a range of 408 to 586.

Conductivity is closely related to TDS and tracked along with it with varying stream levels. Conductivity looks at how well electricity can pass through substances that are in the water and is a good indicator of pollution. Water in its natural state has low conductivity; tap water typically is 50-100 uS/cm.

pH

pH at the dam averaged a slightly alkaline 7.87 with a range of 6.62 to 8.54. At the IKC entrance, pH averaged 7.95 with a range of 7.05 to 8.51.

pH results did not appear to be affected by stream depth or flow and showed a slow, steady rise during the study even though the meter was calibrated per manufacturer suggestion.

pH measures the degree of acidity or basicity of a solution. The value ranges from 0 to 14 pH with 7 being neutral, with lower values acidity and higher values basic or alkaline in a logarithmic scale. Most karst waters are in the pH 7 to 8 range (Sasowsky, 2005).

Previous Studies Included in Water Analysis Chart

Chart 12 below includes water analysis from previous work in the cave. Hasenmueller and Buehler made field measurements seven times from Nov. 1998 to May 2000 at the Upper Twin park entrance. Conductivity and pH were measured each time and Total Dissolved Solids once. The type of meters was not specified (Hasenmueller, 2000, 2006).

The author made one pre-study trip in Dec. 2011 using the same meter as in the study. Note the 2011 trip has an unexplained high reading in ORP compared to readings during the study. Notes were not kept as to calibration of the meter before the 2011 trip.

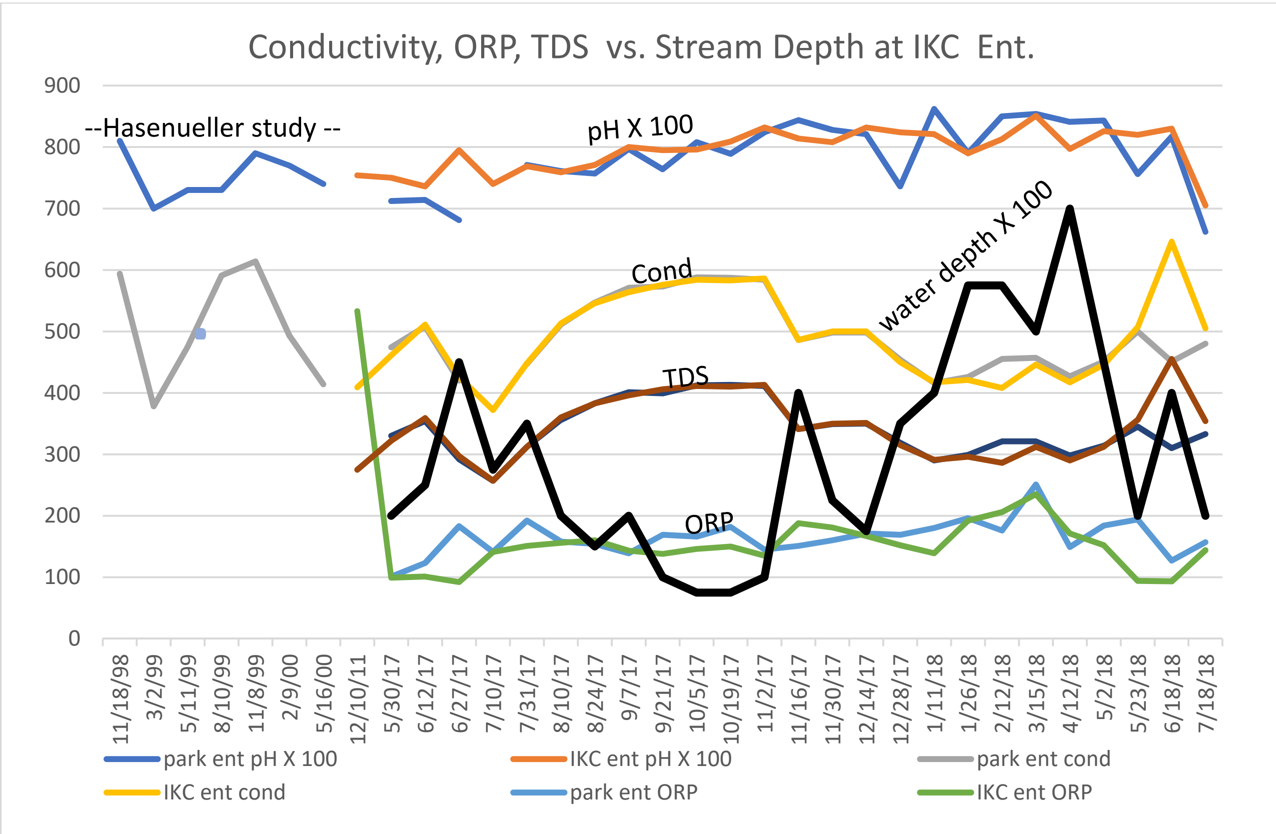


Chart 12. Conductivity, ORP, TDS vs. Stream Depth at IKC Entrance.

CONCLUSIONS

The *Amblyopsis hoosieri* cavefish population appears healthy and historically stable with no disease or mortality observed. The park boat tours may be causing the cavefish to slowly move upstream and leave the area when daily tours are in operation; however, they return each night with no apparent harmful effects.

The *Orconectes inermis inermis* and *Cambarus tenebrosus* crayfish populations appear to be compatible to similar caves in their range in Indiana with similar mortality and chelae loss.

A small population of *Lithobates palustris* Pickerel frogs use the park entrance for hibernation, generally staying within 100'of the entrance.

Occasional accidentals: snapping turtles, bullfrogs, catfish, sculpin and other surface fish are found near the cave park entrance. Raccoons routinely enter from entrance 2, more rarely from the park entrance.

Eurycea lucifuga Cave salamanders were observed near the park and IKC entrances with juveniles only seen at the IKC entrance. Entrances 2 and 3 enter the main passage far enough removed from their surface entrances as to negate expectations of salamander observations.

Predicting cavefish and crayfish populations based on the cave stream water clarity is possible and accurate.

Predictions of cavefish and crayfish populations based on the cave stream water depth at the dam is not possible and will be poor at the IKC entrance stream.

Prediction of cave stream depth from the watershed precipitation has a poor correlation, partly because the monitoring station is not favorably sited in the watershed and partly because of differing soil absorption rates between wet and dry seasons.

The cave stream water quality is good. ORP readings rise (get better) with higher stream flow, TDS and Conductivity readings rise with low flows (reflecting greater amounts of dissolved solids), and stream pH readings are unaffected by stream flow.

RECOMMENDATIONS

An annual census of cavefish should be conducted in all the stream caves in the park. This would seem warranted considering their endangered status and the fact that the Spring Mill Park cave complex has perhaps the largest population of *Amblyopsis hoosieri* in the world. Whistling and Hamer Caves both have large cavefish populations about which almost nothing is known. Incidental accounts speak of large numbers of cavefish within both caves, but there has never been a formal census of aquatic life in them.

An annual census was also a recommendation of Pearson and Boston in their 1995 report to the Indiana Department of Natural Resources (Pearson, 1995, p. 91) and of McCandless in his Ph.D. dissertation. He recommended a census at least every 3 years (McCandless, 2005, p. 178)

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The Indiana Karst Conservancy permitted egress of the cave in its Shawnee Karst Preserve. Dr. Julian Lewis provided direction and crucial guidance; Keith Dunlap gave advice on content, statistics, and charts.

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Marjan LaGrange graciously provided editing and finally my wife Patricia, who let me go caving all the time, for “science”. . . of course.

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Appendix A.

Table 1. Census Overview

trip	date	time since last boat tour	water clarity	dam	water Depth at dam	water depth at IKC Ent	survey time
1	5/30/17	1/2 hour	very cloudy	closed	57"	2"	2:50
2	6/12/17	1/2 hour	clear	closed	54"	2.5"	2:50
3	6/27/17	1/2 hour	clear	closed	58.5"	4.5"	2:35
4	7/10/17	1/2 hour	clear	closed	57"	2.75"	2:30
5	7/31/17	1 day	clear	closed	30"	3.5"	2:25
6	8/10/17	4 days	clear	closed	57"	2"	2:15
7	8/24/17	4 days	crystal clear	closed	47.5"	1.5"	2:10
8	9/7/17	4 days	crystal clear	closed	57"	2"	2:50
9	9/21/17	4 days	crystal clear	closed	56"	1"	3:05
10	10/5/17	4 days	crystal clear	closed	52"	0.75"	2:30
11	10/19/17	4 days	clear	closed	54"	0.75"	3:20
12	11/2/17	winter closure	crystal clear	closed	57"	1"	2:50
13	11/16/17	winter closure	cloudy	open	11"	4"	3:10
14	11/30/17	winter closure	slightly cloudy	open	10"	2.25"	3:25
15	12/14/17	winter closure	slightly cloudy	open	9"	1.75"	4:05
16	12/28/17	winter closure	cloudy	open	10"	3.5"	3:20
17	1/11/18	winter closure	very cloudy	open	11"	4"	2:35
18	1/26/18	winter closure	cloudy	open	16"	5.75"	3:00
19	2/12/18	winter closure	muddy	open	18.5"	5.75"	2:35
20	3/15/18	winter closure	slightly cloudy	open	13"	5"	2:50
21	4/12/18	winter closure	cloudy	open	28.5"	7"	2:50
22	5/2/18	winter closure	slightly cloudy	open	12.5"	4.5"	2:00
23	5/23/18	winter closure	slightly cloudy	closed	57"	2"	2:25
24	6/18/18	1 hour	slightly cloudy	closed	58"	4"	2:00
25	7/18/18	1/2 hour	clear	closed	57"	2"	2:20

Table 2. *Amblyopsis hoosiei*, the Indiana cavefish

	Study Areas	1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	0	0.00	13	1.24	35	2.33	11	1.86
2	6/12/17	4	0.63	57	5.43	37	2.47	26	4.41
3	6/27/17	16	2.50	16	1.52	21	1.40	22	3.73
4	7/10/17	2	0.31	10	0.95	17	1.13	24	4.07
5	7/31/17	3	0.47	13	1.24	27	1.80	25	4.24
6	8/10/17	8	1.25	25	2.38	46	3.07	29	4.92
7	8/24/17	5	0.78	37	3.52	61	4.07	31	5.25
8	9/7/17	4	0.63	26	2.48	60	4.00	29	4.92
9	9/21/17	6	0.94	24	2.29	62	4.13	34	5.76
10	10/5/17	6	0.94	31	2.95	51	3.40	39	6.61
11	10/19/17	20	3.13	38	3.62	62	4.13	28	4.75
12	11/2/17	9	1.41	23	2.19	46	3.07	30	5.08
13	11/16/17	7	1.09	41	3.90	13	0.87	31	5.25
14	11/30/17	14	2.19	35	3.33	24	1.60	30	5.08
15	12/14/17	31	4.84	36	3.43	46	3.07	32	5.42
16	12/28/17	3	0.47	27	2.57	13	0.87	17	2.88
17	1/11/18	0	0.00	10	0.95	2	0.13	18	3.05
18	1/26/18	5	0.78	24	2.29	10	0.67	7	1.19
19	2/12/18	0	0.00	6	0.57	4	0.27	6	1.02
20	3/15/18	8	1.25	20	1.90	20	1.33	7	1.19
21	4/12/18	2	0.31	25	2.38	11	0.73	10	1.69
22	5/2/18	17	2.66	21	2.00	22	1.47	14	2.37
23	5/23/18	5	0.78	44	4.19	56	3.73	15	2.54
24	6/18/18	0	0.00	26	2.48	26	1.73	17	2.88
25	7/18/18	0	0.00	38	3.62	51	3.40	24	4.07
	average		1.09		2.54		2.19		3.77

Table 3. *Orconectes inermis inermis*, the Cave crayfish

	Study Areas	1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	0	0.00	2	0.19	15	1.00	2	0.34
2	6/12/17	6	0.94	13	1.24	23	1.53	10	1.69
3	6/27/17	16	2.50	16	1.52	21	1.40	22	3.73
4	7/10/17	1	0.16	1	0.10	6	0.40	5	0.85
5	7/31/17	1	0.16	2	0.19	9	0.60	11	1.86
6	8/10/17	2	0.31	9	0.86	27	1.80	6	1.02
7	8/24/17	3	0.47	7	0.67	29	1.93	8	1.36
8	9/7/17	4	0.63	23	2.19	58	3.87	5	0.85
9	9/21/17	1	0.16	12	1.14	60	4.00	13	2.20
10	10/5/17	2	0.31	9	0.86	35	2.33	14	2.37
11	10/19/17	17	2.66	34	3.24	67	4.47	17	2.88
12	11/2/17	4	0.63	1	0.10	39	2.60	7	1.19
13	11/16/17	0	0.00	15	1.43	12	0.80	2	0.34
14	11/30/17	9	1.41	29	2.76	36	2.40	12	2.03
15	12/14/17	24	3.75	32	3.05	31	2.07	8	1.36
16	12/28/17	2	0.31	16	1.52	20	1.33	4	0.68
17	1/11/18	0	0.00	5	0.48	4	0.27	1	0.17
18	1/26/18	1	0.16	14	1.33	17	1.13	2	0.34
19	2/12/18	0	0.00	1	0.10	6	0.40	0	0.00
20	3/15/18	1	0.16	10	0.95	14	0.93	4	0.68
21	4/12/18	0	0.00	8	0.76	9	0.60	1	0.17
22	5/2/18	6	0.94	7	0.67	11	0.73	3	0.51
23	5/23/18	2	0.31	4	0.38	19	1.27	8	1.36
24	6/18/18	0	0.00	5	0.48	13	0.87	4	0.68
25	7/18/18	0	0.00	10	0.95	20	1.33	10	1.69
	average		0.64		1.09		1.60		1.21

Table 4. *Cambarus tenebrosus*, the Cave spring crayfish

Study Areas		1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	2	0.31	2	0.19	3	0.20	0	0.00
2	6/12/17	0	0.00	0	0.00	1	0.07	0	0.00
3	6/27/17	4	0.63	1	0.10	0	0.00	0	0.00
4	7/10/17	0	0.00	0	0.00	2	0.13	0	0.00
5	7/31/17	0	0.00	0	0.00	0	0.00	0	0.00
6	8/10/17	0	0.00	1	0.10	3	0.20	2	0.34
7	8/24/17	0	0.00	1	0.10	3	0.20	2	0.34
8	9/7/17	0	0.00	0	0.00	2	0.13	0	0.00
9	9/21/17	0	0.00	0	0.00	2	0.13	3	0.51
10	10/5/17	1	0.16	0	0.00	5	0.33	0	0.00
11	10/19/17	1	0.16	2	0.19	6	0.40	0	0.00
12	11/2/17	0	0.00	1	0.10	1	0.07	0	0.00
13	11/16/17	0	0.00	0	0.00	0	0.00	1	0.17
14	11/30/17	2	0.31	1	0.10	0	0.00	1	0.17
15	12/14/17	5	0.78	0	0.00	0	0.00	0	0.00
16	12/28/17	0	0.00	0	0.00	0	0.00	0	0.00
17	1/11/18	0	0.00	0	0.00	0	0.00	0	0.00
18	1/26/18	1	0.16	3	0.29	0	0.00	0	0.00
19	2/12/18	0	0.00	0	0.00	0	0.00	0	0.00
20	3/15/18	0	0.00	1	0.10	2	0.13	0	0.00
21	4/12/18	0	0.00	1	0.10	0	0.00	1	0.17
22	5/2/18	0	0.00	0	0.00	1	0.07	0	0.00
23	5/23/18	0	0.00	0	0.00	1	0.07	1	0.17
24	6/18/18	0	0.00	1	0.10	0	0.00	0	0.00
25	7/18/18	0	0.00	1	0.10	1	0.07	0	0.00
	average		0.10		0.06		0.09		0.07

Table 5. *Lithobates palustris*, Pickerel frog

	Study Areas	1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	1	0.16	0	0.00	0	0.00	0	0.00
2	6/12/17	3	0.47	0	0.00	0	0.00	0	0.00
3	6/27/17	1	0.16	0	0.00	0	0.00	0	0.00
4	7/10/17	1	0.16	0	0.00	0	0.00	0	0.00
5	7/31/17	1	0.16	0	0.00	0	0.00	0	0.00
6	8/10/17	1	0.16	0	0.00	0	0.00	0	0.00
7	8/24/17	1	0.16	0	0.00	0	0.00	0	0.00
8	9/7/17	3	0.47	0	0.00	0	0.00	0	0.00
9	9/21/17	6	0.94	0	0.00	0	0.00	0	0.00
10	10/5/17	12	1.88	0	0.00	0	0.00	0	0.00
11	10/19/17	3	0.47	0	0.00	0	0.00	0	0.00
12	11/2/17	6	0.94	0	0.00	0	0.00	0	0.00
13	11/16/17	6	0.94	0	0.00	0	0.00	1	0.17
14	11/30/17	8	1.25	0	0.00	0	0.00	0	0.00
15	12/14/17	1	0.16	0	0.00	0	0.00	0	0.00
16	12/28/17	1	0.16	0	0.00	0	0.00	0	0.00
17	1/11/18	4	0.63	0	0.00	0	0.00	1	0.17
18	1/26/18	7	1.09	0	0.00	0	0.00	1	0.17
19	2/12/18	1	0.16	0	0.00	0	0.00	0	0.00
20	3/15/18	6	0.94	0	0.00	0	0.00	0	0.00
21	4/12/18	7	1.09	0	0.00	0	0.00	0	0.00
22	5/2/18	2	0.31	0	0.00	0	0.00	0	0.00
23	5/23/18	2	0.31	0	0.00	0	0.00	0	0.00
24	6/18/18	1	0.16	0	0.00	0	0.00	0	0.00
25	7/18/18	0	0.00	0	0.00	0	0.00	0	0.00
	average		0.53		0.00		0.00		0.02

Table 6. adult *Euryea lucifuga*, the Cave salamander

	Study Areas	1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	2	0.31	0	0.00	0	0.00	2	0.34
2	6/12/17	2	0.31	0	0.00	0	0.00	0	0.00
3	6/27/17	0	0.00	0	0.00	0	0.00	0	0.00
4	7/10/17	0	0.00	0	0.00	0	0.00	0	0.00
5	7/31/17	0	0.00	0	0.00	0	0.00	0	0.00
6	8/10/17	0	0.00	0	0.00	0	0.00	2	0.34
7	8/24/17	0	0.00	0	0.00	0	0.00	0	0.00
8	9/7/17	1	0.16	0	0.00	0	0.00	0	0.00
9	9/21/17	0	0.00	0	0.00	0	0.00	0	0.00
10	10/5/17	1	0.16	0	0.00	0	0.00	1	0.17
11	10/19/17	1	0.16	0	0.00	0	0.00	0	0.00
12	11/2/17	0	0.00	0	0.00	0	0.00	0	0.00
13	11/16/17	1	0.16	0	0.00	0	0.00	2	0.34
14	11/30/17	0	0.00	0	0.00	0	0.00	0	0.00
15	12/14/17	0	0.00	0	0.00	0	0.00	0	0.00
16	12/28/17	0	0.00	0	0.00	0	0.00	0	0.00
17	1/11/18	0	0.00	0	0.00	0	0.00	0	0.00
18	1/26/18	0	0.00	0	0.00	0	0.00	0	0.00
19	2/12/18	0	0.00	0	0.00	0	0.00	0	0.00
20	3/15/18	0	0.00	0	0.00	0	0.00	0	0.00
21	4/12/18	0	0.00	0	0.00	0	0.00	0	0.00
22	5/2/18	1	0.16	0	0.00	0	0.00	0	0.00
23	5/23/18	0	0.00	0	0.00	0	0.00	0	0.00
24	6/18/18	1	0.16	0	0.00	0	0.00	0	0.00
25	7/18/18	0	0.00	0	0.00	0	0.00	0	0.00
	average		0.06		0.00		0.00		0.05

Table 7. *Lithobates catesbeianus*, the American bullfrog

Study Areas		1		2		3		4	
trip	date	total	per 100'	total	per 100'	total	per 100'	total	per 100'
1	5/30/17	0	0.00	0	0.00	0	0.00	0	0.00
2	6/12/17	0	0.00	0	0.00	0	0.00	0	0.00
3	6/27/17	0	0.00	0	0.00	0	0.00	0	0.00
4	7/10/17	0	0.00	0	0.00	0	0.00	0	0.00
5	7/31/17	0	0.00	0	0.00	0	0.00	0	0.00
6	8/10/17	0	0.00	0	0.00	0	0.00	0	0.00
7	8/24/17	0	0.00	0	0.00	0	0.00	0	0.00
8	9/7/17	0	0.00	0	0.00	0	0.00	0	0.00
9	9/21/17	0	0.00	0	0.00	0	0.00	0	0.00
10	10/5/17	0	0.00	0	0.00	0	0.00	0	0.00
11	10/19/17	0	0.00	0	0.00	0	0.00	0	0.00
12	11/2/17	1	0.16	0	0.00	0	0.00	0	0.00
13	11/16/17	0	0.00	0	0.00	0	0.00	1	0.17
14	11/30/17	1	0.16	0	0.00	0	0.00	0	0.00
15	12/14/17	0	0.00	0	0.00	0	0.00	0	0.00
16	12/28/17	0	0.00	0	0.00	0	0.00	0	0.00
17	1/11/18	0	0.00	0	0.00	0	0.00	0	0.00
18	1/26/18	0	0.00	0	0.00	0	0.00	0	0.00
19	2/12/18	0	0.00	0	0.00	0	0.00	0	0.00
20	3/15/18	0	0.00	0	0.00	0	0.00	0	0.00
21	4/12/18	0	0.00	0	0.00	0	0.00	0	0.00
22	5/2/18	0	0.00	0	0.00	0	0.00	0	0.00
23	5/23/18	0	0.00	0	0.00	0	0.00	0	0.00
24	6/18/18	0	0.00	0	0.00	0	0.00	0	0.00
25	7/18/18	0	0.00	0	0.00	0	0.00	0	0.00
	average		0.01		0.00		0.00		0.01

Table 8. *Amblyopsis hoosieri* observed by Tour Guides During Boat Tours 6-5-17 to 10-22-17

	tour start time														
	9:30	10:00	10:30	11:00	11:30	12:00	12:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30
6-5-17	8	3	1	1	5			4		2		2	1		5
6-12-17	8		3	1	1			3	3		0	5	4		
6-19-17	2														
6-26-17	2	1	1	1	3			1	1	0	0	0	0	0	1
7-3-17		2	1	1	1		1	2			2	1			2
7-10-17	2	0	0	0	0		0			0	1				1
8-5-17	3	0		1	1				1	0					
8-6-17	8	2					2			3	0			2	1
8-12-17	5	2	1	6	3				2	0	1	3	0	0	
8-13-17	6		6		3			0	0	2	2	4	2		
8-19-17	7	0	6	6	3		0	5	5	3	3	2	3	2	3
8-20-17			2	3				2	1		2	2		3	1
8-26-17	12	10			4		4	4			3			4	2
8-27-17	8	7	8	6	4			2	3	3		0			
9-2-17			17	15				8	7	9			8	5	3
9-3-17	10	15	2				4	5	4		6	5			3
9-4-17	14	12	3	6		6	2	3	4	2					
9-9-17	16		11					1	2	5	7	2	1	3	4
9-16-17	31	23			8				8	12			8		
9-17-17				3	4					5	2				2
9-23-17	19	11		5	3		5	4			3				
9-24-17	13	9			5			6	3			2	3		
9-30-17		8	9	4	4				8	6		6	6		
10-1-17	14	12	6	9	4	5			5			9			
10-7-17	12			9			11	1	6						
10-8-17			2		6					4	8		2		
10-14-17			14	8					16	5			1		
10-15-17	18	23							7		5				
10-22-17	24	18			7		9			7	5				
total seen	242	158	93	85	69	11	38	51	86	68	50	43	39	19	28
total counts	22	19	18	18	19	2	10	16	19	18	17	14	13	8	12
av. seen	11	8.3	5.2	4.7	3.6	5.5	3.8	3.2	4.5	3.8	2.9	2.3	3	2.4	2.3

Table 9. Precipitation in Watershed for 10 Days Before Census

Total and Weighted Precipitation (day 1=100%, day 2=90%, day 3 = 80%, etc.)

From Community Collaborative Rain, Hail and Snow Network

Readings from station IN-LW-4, .45 miles east of park entrance

Missing Readings (in red) from station IN-OR-1, 5.2 miles south of park entrance

census date	trip	day of trip	days before census 1	2	3	4	5	6	7	8	9	10	**total**	**weighed**
5/30/17	1	0	0	0.02	0	0.09	0.91	T	0	0.02	0.07	0.15	1.26	0.66
6/12/17	2	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
6/27/17	3	0	0	0	3.15	0.35	0	0	0	0.86	0.06	-----	4.42	3.04
7/10/17	4	-----	-----	-----	0.46	0.21	0.02	0	0	0	0.39	0	1.08	0.61
7/31/17	5	0	0	0.1	0.42	0.1	0	0	1.4	2.04	0	0	4.06	1.67
8/10/17	6	**0**	**0**	**0.04**	----	----	----	0	0.01	0.79	**0**	0	0.84	0.28
8/24/17	7	0	0.08	T	----	----	----	**0.45**	**0**	**0**	**0**	----	0.53	0.31
9/7/17	8	0	0	0	0	0	1.23	1.03	0	0.12	0.03	0.01	2.42	1.30
9/21/17	9	0	0	0	0	0	0.1	0	0	0	**0**	----	0.10	0.06
10/5/17	10	0.03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
10/19/17	11	0	0	0	0.1	0	0	0	**0**	**0**	0.02	----	0.12	0.08
11/2/17	12	0.29	0.12	0.04	0.01	0	0.3	0	0	0.02	0.83	0.32	1.64	0.55
11/16/17	13	0.41	0	0	----	----	----	0	0	0	0.51	2.26	2.77	0.33
11/30/17	14	0.11	0	0	0	0	0	0	0	0	0	0	0.00	0.00
12/14/17	15	----	----	----	----	T	0	0	T	0	0.49	0	0.49	0.10
12/28/17	16	0	0	0	0	0	0	0	0	0	0	0.04	0.04	0.00
1/11/18	17	----	----	----	----	0	0	0	T	0	0	0	0.00	0.00
1/26/18	18	0	T	T	T	----	----	----	----	----	----	----	0.00	0.00
2/12/18	19	0.23	0.11	0.01	0	0	0.28	T	0.03	0.12	0	0.03	0.58	0.34
3/15/18	20	0	0.21	T	0	0	0.02	T	0.16	0.06	0.03	0	0.48	0.31
4/12/18	21	0	0	0	0	0	0	0	T	0.34	3.44	----	3.78	0.79
5/2/18	22	----	**0**	----	----	----	**0**	**0**	**0.05**	----	----	----	0.05	0.02
5/23/18	23	0	0.66	0	0.06	0.07	T	0	0.03	0	0	0	0.82	0.77
6/18/18	24	0	0	0.01	0.03	1.22	0.16	0.92	0.66	0.14	0	0	3.14	1.75
7/18/18	25	0	T	0.11	0.08	0	0	0	0	0	0	0	0.19	0.16

notes:

1) Snow only reported 3-14-18 (0.8") and 3-8-18 (0.7"). These were added at 1" snow = .2" rain

2) "T" means trace, counted as 0" rain

3) "----" means missing observation from both stations

4) "day of trip" not included in total or weighted calculations

Table 10. Water Quality Analysis

	pH		conductivity		ORP		TDS	
	park ent	IKC ent	park ent	IKC ent	park ent	IKC ent	park ent	IKC ent
11/18/98	8.1		594					
3/2/99	7		378					
5/11/99	7.3		475					
8/10/99	7.3		591				520	
11/8/99	7.9		614					
2/9/00	7.7		493					
5/16/00	7.4		414					
12/10/11		7.54		409		533		275
5/30/17	7.12	7.5	474	461	101	99	330	322
6/12/17	7.14	7.36	508	511	123	101	354	359
6/27/17	6.81	7.95	420	426	183	92	292	297
7/10/17		7.4		372	141	141	257	257
7/31/17	7.71	7.69	447	448	192	151	312	312
8/10/17	7.61	7.59	511	513	158	156	356	360
8/24/17	7.57	7.71	547	546	154	160	383	383
9/7/17	7.97	8	571	564	139	143	401	396
9/21/17	7.64	7.95	573	576	169	138	399	406
10/5/17	8.08	7.96	588	584	166	146	412	411
10/19/17	7.89	8.09	587	583	182	150	413	410
11/2/17	8.24	8.32	584	586	145	135	411	413
11/16/17	8.44	8.14	486	486	151	188	341	341
11/30/17	8.28	8.08	498	500	160	181	349	350
12/14/17	8.21	8.32	498	500	171	167	350	351
12/28/17	7.36		454	450	169	152	319	315
1/11/18	8.62	8.21	416	417	180	139	290	291
1/26/18	7.9	7.9	426	421	196	192	299	296
2/12/18	8.5	8.13	455	408	176	206	321	286
3/15/18	8.94	8.51	457	446	251	235	321	312
4/12/18	8.41	7.97	427	417	149	171	298	290
5/2/18	8.43	8.26	451	446	184	152	314	312
5/23/18	7.56	8.2	500	507	194	94	345	356
6/18/18	8.17	8.3	451	646	127	93	310	455
7/18/18	6.62	7.05	480	505	157	144	333	354