PHOLEOS

Journal Of The Wittenberg University Speleological Society

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PHOLEOS

Pholeos is a biannual journal of the Wittenberg University Speleological Society (WUSS), an internal organization of the National Speleological Society (NSS).

Purpose
The Grotto is dedicated to the advancement of speleology, to cave conservation and preservation, and to the safety of all persons entering the spelean domain.

WUSS web page
www.wittenberg.edu/witt/stud_orgs/wuss/

Subscription rates are $7 a year for two issues of *Pholeos*. Back issues are available at $3.50 an issue.

Exchanges with other grottoes and caving groups are encouraged. Send all correspondence, subscriptions, and exchanges to the grotto address.

Membership
The Wittenberg University Speleological Society is open to all persons with an interest in caving. Membership is $12 a year and comes with a subscription to *Pholeos*.

Meetings
Meetings are held every Wednesday at 7:00 p.m. when Wittenberg University classes are held. Regular meetings are in Room 210 in the Science building (corner of Plum and Edwards – parking available in the adjacent lot), while special meetings are usually held in Room 319. At the conclusion, members usually eat at an area restaurant.

Submissions
Members are encouraged to submit articles, trip reports, artwork, photographs, and other material to the Editor. Submissions may be given to the Editor in person or sent to the Editor at the Grotto address. Guidelines for submitting research papers can be found on the back cover of this issue.

Research at East Twin, Andros Island, Bahamas. Photo by Beth Hagen.

PHOLEOS

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EDITOR'S NOTE

Welcome to another issue of *Pholeos*. This issue sports a face-lift. In anticipation for our 20th anniversary, I believed it was time to give *Pholeos* a new look. The design elements can be found thoughout this issue of *Pholeos*, so why not take a look and tell me whether you like it or not.

Talking about what you like or not, I would like to direct your eyes to the Letter to the Editor found below this article. The editorial section is something we would like to make a regular feature of *Pholeos*. Don't be afraid to write in and give us your opinion on *Pholeos*, WUSS, or caving in general.

As you may or may not have known, next year is the 20th anniversary of WUSS. Hard to believe that we have been a grotto of the NSS for that long, huh? Look for more information to appear later this year in either an upcoming issue of *Pholeos* or through the mail. I would also like to encourage everyone to check out the WUSS web page and sign up for our mailing list. There isn't a better way of keeping up on the happenings of WUSS.

This issue, I hope, will stand out in your minds as one of the best issues of *Pholeos* yet. The main article this issue is a study of blue holes that Katie Gogolin did over the summer in the Bahamas. That is followed by a trip report by Matt Beversdorf describing what it was like for the two weeks that Katie and her helpers were in Andros. This issue also has some of the first cave maps published in a few years. With luck, these will not be the last as we finish up Rose and Canyon caves. We also have some artwork by Samantha Neifer, a crossword puzzle, and some pictures of OTR.

Jason W. Moon

Jason Moon, Editor

LETTER TO THE EDITOR

Congratulations for another fine edition of Pholeos. David Effron is to be commended for his article on histoplasmosis. He has a good grasp of the subject and writes well. I appreciate his citation of my paper. I also enjoyed the cat story. At the risk of being picky, I want to elaborate on two trivial points, so, if you wish, you may pass this on to him.

Also, at about the same time, in 1932, two Iowa City physicians cultivated the organism from the weeping sores on the legs of a Greek cook. This was noted in *The Iowa Grotto Intercom Vol. XI*, No 3, May-June, pp. 33-35, 1975. Histoplasmosis in Iowa, certainly an obscure reference.

As to the disease being endemic in Europe, that is technically correct. It is found in caves in Romania and Malta. It exists in badgers or their dens and in other wild animals in Switzerland and in soil on a chicken farm in Italy. However, several caving expeditions, particularly from England, to Mexico and Central America have had to be aborted because the participants came down with the acute form of the illness. I think it fair to say that most European cavers show very little immunity on their first contact in this hemisphere.

Warren Lewis

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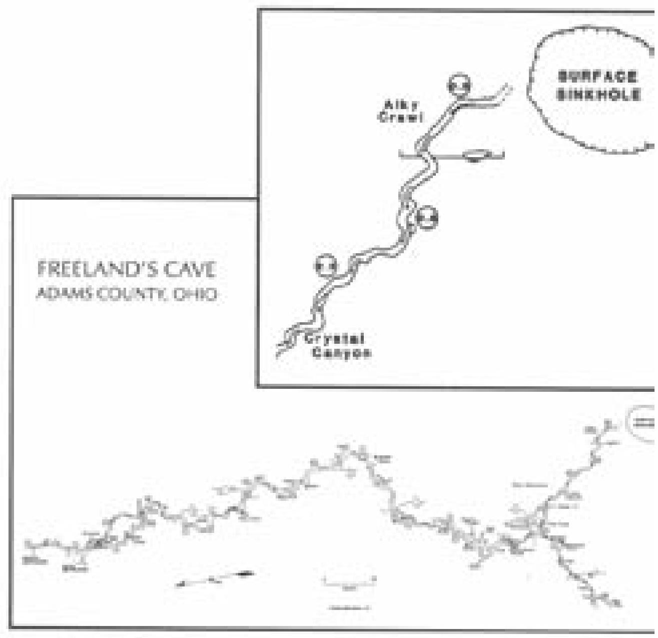
Freeland

Members of W.U.S

Article by Erin Athy
Photos by Don Conover

Overlooking the work left.

Every last piece of trash must go.



Detail of Freeland's Cave showing location of sinkhole.

What do two toilets, several large household appliance a trampoline, hundreds of old bottles and rusty cans and fifty cavers have in common? They all could be found in the Freelands Cave Sinkhole on November 12, 1998. This sinkhc had been filled to the brim with debris. It is believed to connect directly with Freeland's Cave, the only known home of *Pseudanophthalmus ohioensis*, a small red beetle. In addition Dr. Horton Hobbs reported seeing two metal drums, unload by someone in 1986, that possibly could be leaking unknown contents into the cave system. For these reasons, a much needed sinkhole clean-up was coordinated. The work began 8 am and with the help of area cavers, grotto and individual donations, and cooperation from the landowner who supplie a tractor, two industrial sized dumpsters were filled with deb from the sinkhole. Items that could be recycled, such as glass and metal, were separated from the non-recyclable. After fou

Cleanup

clean up Freeland's Sinkhole

hours of hauling out twelve years worth of junk, the barrels finally were uncovered. The good news is that both drums were open-ended, hopefully indicating they were never full. So one mission had been accomplished. The work continued until sunset when the dumpsters could no longer be stuffed with any more trash. Still, after a full day of hard work, the bottom of the sinkhole—and perhaps another entrance into Freeland's—had not been found. But on the other hand, three-fourths of the sinkhole had been completely cleaned out. The walls were litter-free and a good start had been make in the bottom of the pit.

Personally, helping with the clean-up gave me an exhausting, grimy, aching-all-over feeling. In other words, I felt great! I was completely satisfied and had an overwhelming feeling of self-fulfillment. Knowing that I, working with others, had made such a visible difference was the best reward possible.

Loading the trash onto the trailer.

WUSS member Michelle Miller sorts recyclables.

Look what I found! Rob Payn holding up an axle.

RESEARCH

A baseline study of the physicochemical characteristics of five inland blue holes on Andros Island, Bahamas

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Andros Island, Bahamas is situated between the Great Bahama Bank and the Tongue of the Ocean approximately 220 km southeast of Miami, Florida USA. The island consists of heavily corroded limestone bedrock and has numerous karst features, such as caves and inland blue holes. These blue holes contain a freshwater lens, a brackish (mixing, halocline) layer, and a saltwater zone. The objective of this study, which was conducted from 10 to 20 May 1998, was to survey the physicochemical characteristics of five inland blue holes on Andros Island: Cousteau's, East Twin, Rainbow, Hubcap, and Stafford Creek blue holes. Temperature, pH, nitrate, phosphate, oxygen, salinity, hydrogen sulfide, sulfate, turbidity, and specific conductance were analyzed. Yellow Springs Instruments (YSI) meter probes were lowered into the blue holes, which ranged in depth from six to 115 meters, to record oxygen, specific conductance, salinity, and pH readings. A Kemmerer Bottle was used to collect water samples at various depths in the water columns and samples were analyzed using several Hach instruments. Temperature remained constant at approximately 25-30 C° throughout all of the blue holes. The pH remained between 7 and 8 in most, with the exception of Stafford Creek, which decreased to 2.75 at the water-substrate interface. Oxygen concentrations and percent oxygen saturation values were much higher near the surface in the freshwater lens. In the mixing layer oxygen decreased and became nearly anoxic in the saline zone. Hydrogen sulfide was inversely correlated with oxygen, being zero at the surface, increasing in the mixing layer, and were 5 mg/l or more in the saline zone. In three of the blue holes, salinity increased from close to zero in the freshwater lens to approximately 35 ppt at the bottom of the column. The other two blue holes, Hubcap and Stafford Creek, were not sufficiently deep to exhibit ocean water salinities and only reached 18.00 ppt and 6.20 ppt, respectively. Specific conductance started at approximately 1000 µS and increased to almost 60000 µS at the water-substrate interface. Nitrate, phosphate, sulfate, and turbidity levels were variable and did not seem to show any distinct patterns among the blue holes that were tested. Cousteau's and East Twin blue holes were deep enough (115 meters and 63 meters, respectively) to show a complete transition from freshwater to saltwater. They exhibited a distinct halocline in the brackish layer that was indicated by the salinity, hydrogen sulfide, and oxygen profiles. High densities of plankton or bacteria could have caused fluctuations in turbidity, oxygen, and temperature. The consistent pH was a result of limestone dissolution and the high buffering capacity of the water.

Introduction

Andros Island, Bahamas is located approximately 220 kilometers southeast of Miami, Florida, USA and is situated between the Great Bahama Bank to the west and the Tongue of the Ocean to the east (Figure 1). The island stretches over 225 kilometers in a north-south direction (Cowles 1993) and is made up of three parts: North Andros, South Andros, and many small islands in between (usually referred to as Mangrove Cay). North Andros is approximately 30 kilometers wide and narrows to about 15 kilometers towards Morgans Bluff at the northern most point of the island. North Andros makes up 3,263 square kilometers, while the entire island is about 6,000 square kilometers (Figure 2) (Gutowski 1995).

The island lies mostly five meters above sea level and consists of limestone. The calcium carbonate bedrock has been

Figure 1. Location of Andros Island, Bahamas. This map was altered from (Bottrell 1991).

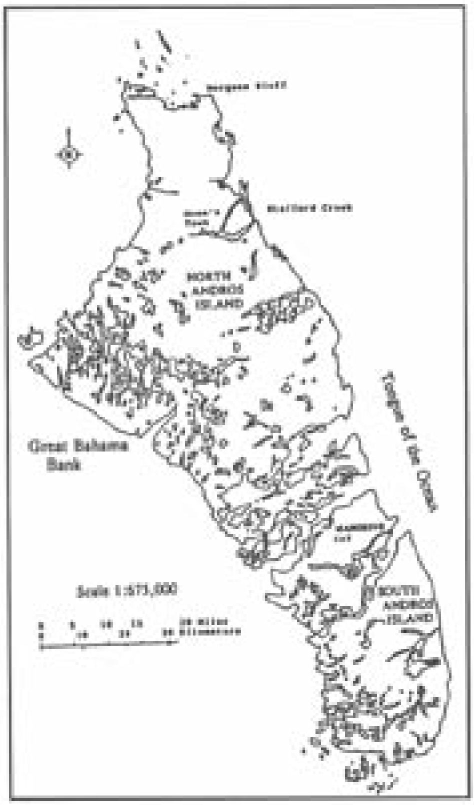


Figure 2. Map of Andros Island, Bahamas (Gutowski 1995).

heavily corroded (dissolution) and has numerous inland blue holes and other karst features that are more heavily concentrated towards the northeastern portion of the island (Smart 1984). Blue holes are cavernous solution pits filled with water that occur inland as well as in the open ocean; inland blue holes are the primary focus of this research. Surprisingly, very few studies have been conducted on the physicochemical characteristics of inland blue holes. What is known about these flooded vertical shafts are from geological studies in which water chemistry and aquatic flora and fauna were not the main focus (Bottrell et al. 1991, Raeisi and Mylroie 1995).

Blue holes can have many different shapes depending on how the limestone is corroded, but generally the walls of the blue hole are vertical or may bell out from the surface. Inland blue holes contain three distinct layers of water: a fresh water lens, a brackish interface layer, and a deep saline zone. At the surface, rain water collects to form the fresh water lens which can extend 30 meters in depth. Below the fresh water is a thinner, brackish layer (also known as the mixing or interface layer). In the mixing zone (the halocline), brackish water is chemically intricate and is able to restore calcium carbonate dissolution. Hydrogen sulfide reactions increase the limestone dissolution by increasing the carbon dioxide and by the increase of carbonate undersaturation due to acidity from sulfide oxidation (Bottrell *et al.* 1991). The depth of this brackish lens is determined by the amount of fresh water above sea level that compresses the fresh water/saline interface (Raeisi and Mylroie 1995). Beneath the brackish zone is saline water, which may or may not be affected by the ocean current, depending on the ground water system in the area.

The objective of this study was to survey the physicochemical characteristics of five inland blue holes on Andros Island. The five blue holes tested were: Cousteau's, East Twin, Rainbow, Hubcap, and Stafford Creek (Figure 3). All of these

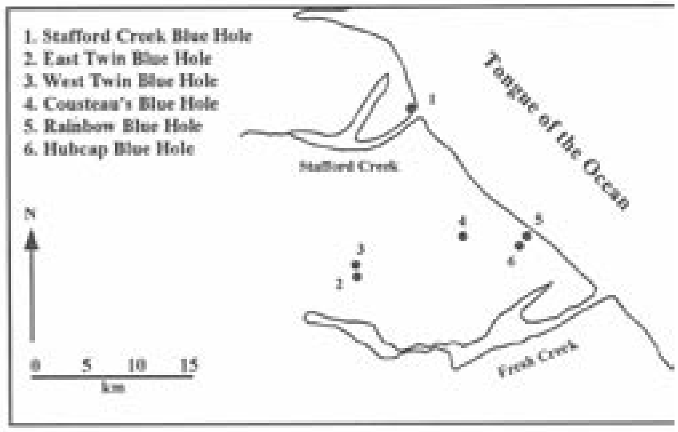


Figure 3. Approximate location of blue holes on North Andros Island that were in this study. This map was altered from (Smart 1984).

karst features are located near the east coast of North Andros Island and are less than 63 meters in depth, with the exception of Cousteau's Blue Hole, which is approximately 115 meters deep. Various chemical parameters were analyzed throughout the water column of each blue hole and at least one data set was collected from each blue hole to create a baseline of information for future studies.

Site Descriptions

Cousteau's Blue Hole was located 24° 46' 35" N, 77° 54' 56" W. This blue hole, 115m deep and 56m in diameter, was the largest water column that was sampled. East Twin Blue Hole was located 24° 45' 06" N, 78° 00' 21" W, approximately 18km west of the ocean and was the farthest inland of any blue hole studied. The maximum depth was 63m and it was 47m in diameter. Rainbow Blue Hole was located 24° 47' 06" N, 77° 51' 36" W, about 1.25km inland of the east coast of the island. This blue hole was 24m deep and 40m in diameter. Hubcap Blue Hole was located 24° 46' 32" N, 77° 51' 26" W, and was approximately 1.75km inland. It was 19m at the deepest point and 67m in diameter. There was a large limestone wall that wrapped around approximately 1/3 of the perimeter. Stafford Creek Blue Hole was located 24° 53' 58" N, 77° 56' 13" W, which was on the north side of Stafford Creek near its mouth. It was the smallest blue hole that was tested, six meters in depth and approximately 10m in diameter.

Methods and Materials

While on Andros Island, food, lodging, and transportation were provided by Forfar Field Station. Forfar Field Station is owned by International Field Studies of Columbus, Ohio and is located on the eastern coast of North Andros, south of Stafford Creek.

The precise location of the five blue holes was determined by a Magellan Trailblazer handheld global positioning system. Observations of vegetation and geology were made around the perimeter of each site. Using a two and a half person inflatable raft, each blue hole was surveyed for depths and diameters using the Hummingbird LCR 4-ID depth finder and a KVH Datascope digital compass/rangefinder. Data were entered into the Compass ® computer program for perimeter and profile plots. Water sampling began once the deepest portion of each blue hole was located. A line was secured across the blue hole to which the boat was attached. Probes from a YSI Model 30 salinity/conductivity/temperature (SCT) meter and a YSI Model 55 dissolved oxygen meter were lowered into the water column. Data were recorded every meter for approximately 25 meters. Once the interface was located using the salinity and oxygen data, water samples were taken from the surface to the bottom with a Kemmerer Bottle at chosen depths. These samples were placed in acid-washed one liter polyethylene Boston Bottles and transported to the shore, where they were stored in a light-tight cooler for subsequent analyses. All chemical testing was done at Forfar Field Station within 12 hours.

A 20cm secchi disc reading was taken from all of the blue holes except for Cousteau's Blue Hole. StowAway XTI Electronic temperature data loggers were placed in submersible cases and were attached to a buoy in Cousteau's Blue Hole. They were positioned at 0.0, 4.2, 6.2, 15.2, 24.8, 34.6, 44.6, 54.3, 64.0, 84.0, and 93.5 meters in the water column in order to record temperature continuously for a 36 hour duration.

The pH was measured using an Accumet 1001 pH meter and turbidity readings were determined by a Model #2100P Hach Turbidimeter. Nitrogen, phosphorus, hydrogen sulfide, and sulfate concentrations were obtained using a Hach DREL 2010 Water Quality Laboratory Kit.

Results

Cousteau's Blue Hole

Cousteau's Blue Hole was sampled 10 May 1998. Temperature remained consistent at approximately 28.3 °C from the surface to 50 meters in depth. The pH also was very consistent at about 7.40 for those same depths. Oxygen concentration measured 6.20 mg/l at the

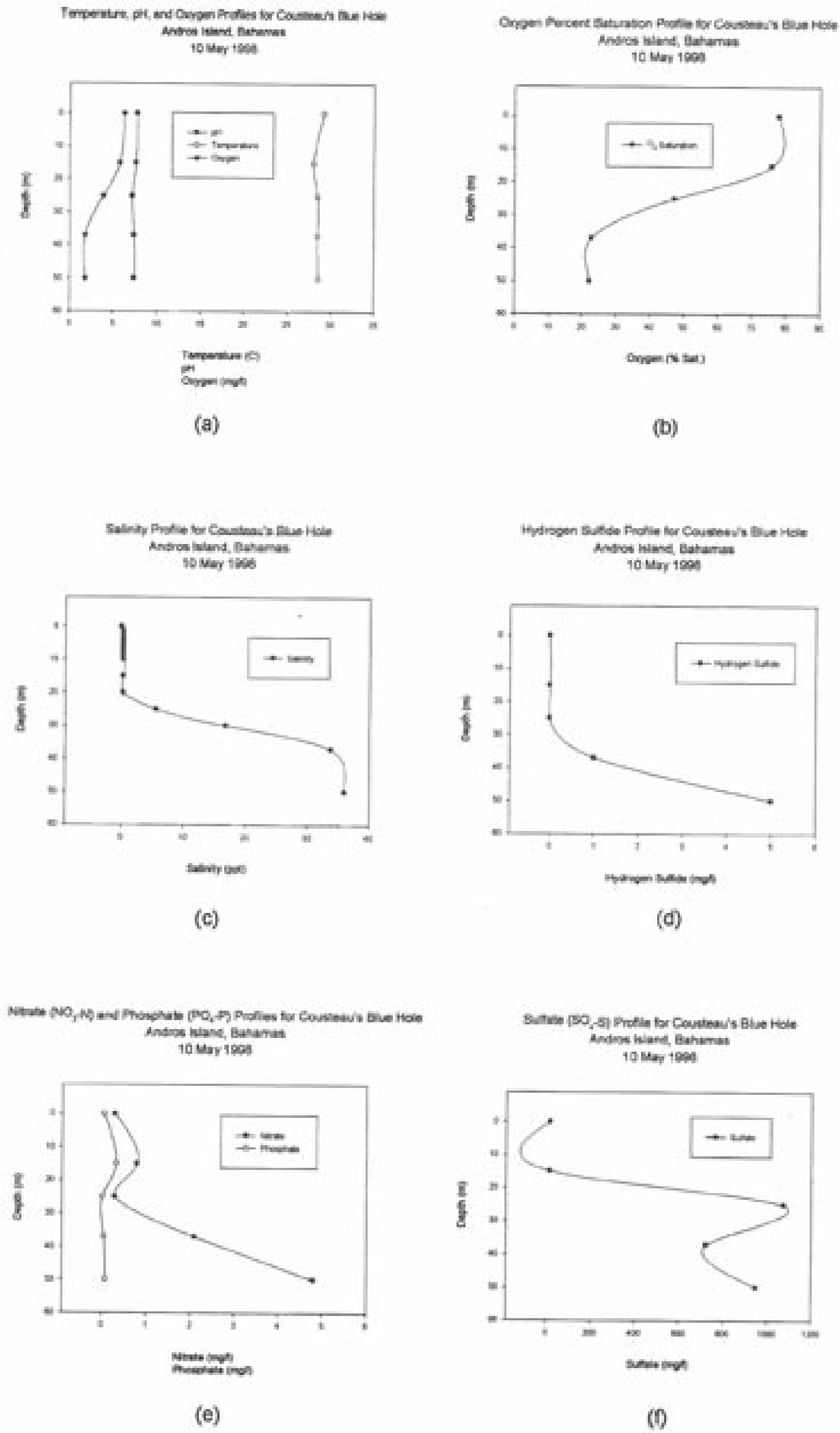


Figure 4. Physicochemical profiles for Cousteau's Blue Hole.

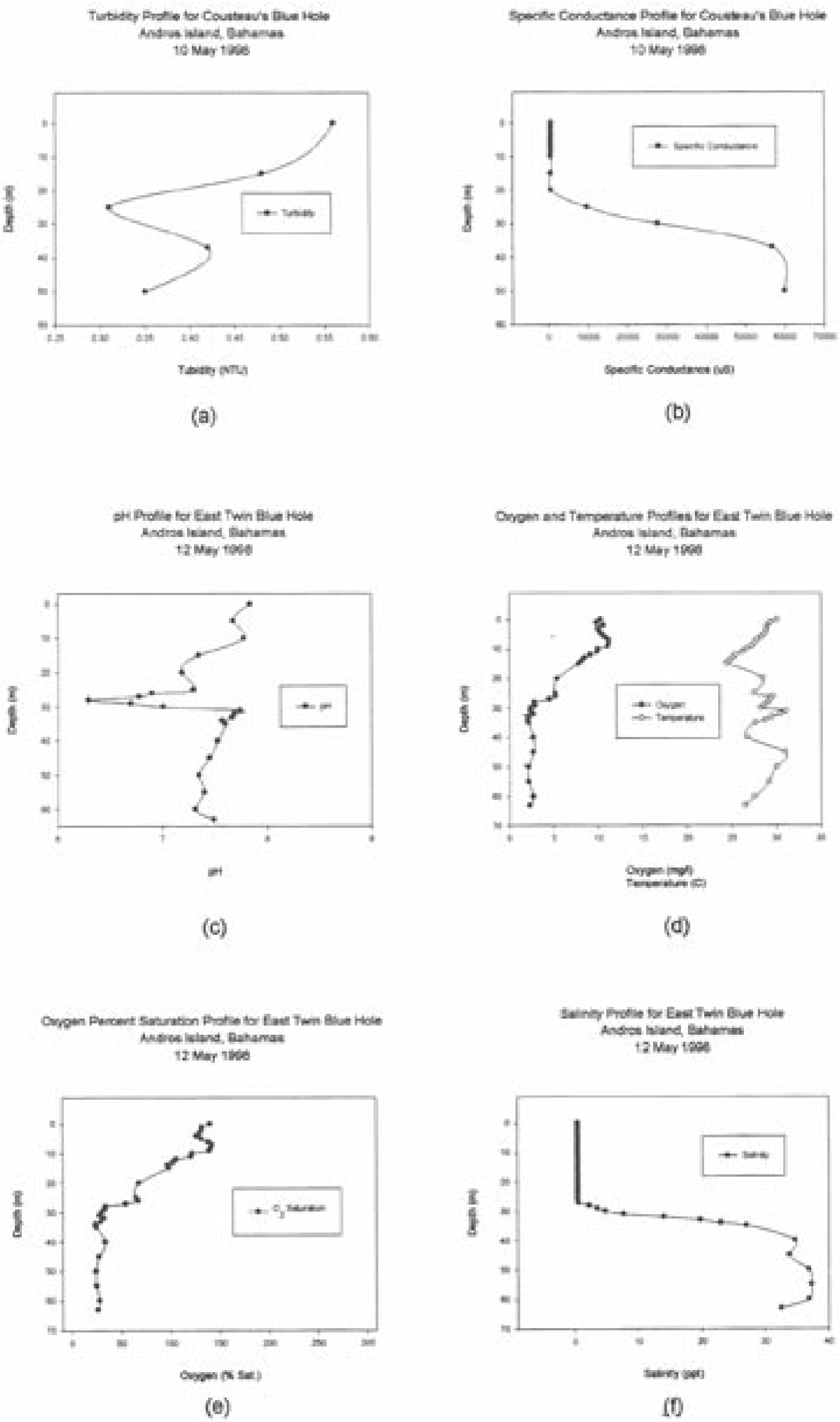


Figure 5. Physicochemical profiles for Cousteau's and East Twin blue holes.

surface and gradually decreased to 1.77 mg/l at 50 meters (Figure 4a). The percent oxygen saturation was 77.9% at the surface and slowly decreased to 22.3% at 50 meters (Figure 4b). Salinity remained at 0.30 ppt until 25 meters where it rose significantly to 5.60 ppt and continued to increase to 36.00 ppt at 50 meters (Figure 4c). Hydrogen sulfide concentrations were 0.00 mg/l from the surface to 37 meters where they increased to 1.00 mg/l and then increased to 5.00 mg/l at 50 meters (Figure 4d). Nitrate concentrations varied little from 0.5 mg/l at the surface to 25 meters then increased to 4.8 mg/l at 50 meters. Phosphate concentrations remained at approximately 0.05 mg/l throughout the water column (Figure 4e). Sulfate concentrations were 20 mg/l at the surface through 25 meters, where they increased dramatically to 1075 mg/l then decreased to about 900 mg/l (Figure 4f). The turbidity began at 0.56 NTU at the surface, decreased to 0.31 NTU at 25 meters, and then increased slightly to 0.42 NTU at 37 meters (Figure 5a). Specific conductance was 600 μS•cm^{-1} at the surface to 25 meters where

Cousteau's Blue Hole. The deepest blue hole that was studied (115 meters), named after the famous French diver Jacques Cousteau.

it increased to 9770 μS•cm^{-1}, then dramatically increased up to 60000 μS•cm^{-1} at 50 meters (Figure 5b).

Data loggers placed in Cousteau's Blue Hole recorded temperature in °C by depth over a 36-hour duration (see Appendix A). At the surface the temperature fluctuated dramatically, the highest reading occurring around noon each day at approximately 36 °C and the lowest near 20 °C around 05:00am. At 4.2 meters the temperature remained at

27.95 °C, while at 6.2 meters the temperature was stable at approximately 26.9 °C. At 15.2 meters the temperature was consistent at slightly below 23.5 °C. At 24.8 meters the temperature fluctuated slightly from 24.3 °C to 24.65 °C through out the 36 hours. At 34.6 meters the temperature remained constant at 24.46 °C. At 44.6 meters the temperature stayed at 24.33 °C with no fluctuations. At 54.3 meters the temperature remained at 24.07 °C as well. At 64.0 meters the temperature stayed consistent at 24.24 °C. At 84.0 meters the temperature remained at 24.16 °C with no fluctuations. At 93.5 meters the temperature remained consistent at 24.09 °C for the 36-hour duration.

East Twin Blue Hole

East Twin Blue Hole was sampled 12 May 1998 and tested for the same parameters. The secchi disc reading for East Twin Blue Hole was 8.25 meters. The pH fluctuated slightly around 7.20 throughout the first 31 meters and was consistent at 7.50 throughout the rest of the column (Figure 5c). Temperature oscillated around 28 °C. Oxygen concentration started at over 10.00 mg/l and slowly decreased to 2.80 mg/l at 28 meters where it remained (Figure 5d). Percent oxygen saturation decreased from 140.2% at the surface to 26.5% at the substrate (Figure 5e). Salinity stayed at 0.5 ppt until 26 meters and then gradually increased to approximately 37.0 ppt at the bottom of the water column (Figure 5f). Hydrogen sulfide concentrations did not rise above 0.00 mg/l until 40 meters, then increased to >5.00 mg/l (Figure 6a). Nitrate concentrations fluctuated around 0.2 mg/l until 30 meters, then increased to about 9.0 mg/l near the substrate. Phosphate concentrations remained uniform at approximately 0.04 mg/l, except for an isolated increase to 1.12 mg/l at 26 meters (Figure 6b). Sulfate concentrations stayed at approximately 20 mg/l until 28 meters, then fluctuated around 400 mg/l throughout the rest of the water column (Figure 6c). Turbidity fluctuated greatly around 2.00 NTU, the highest reading was 6.27 NTU at 34 meters while the

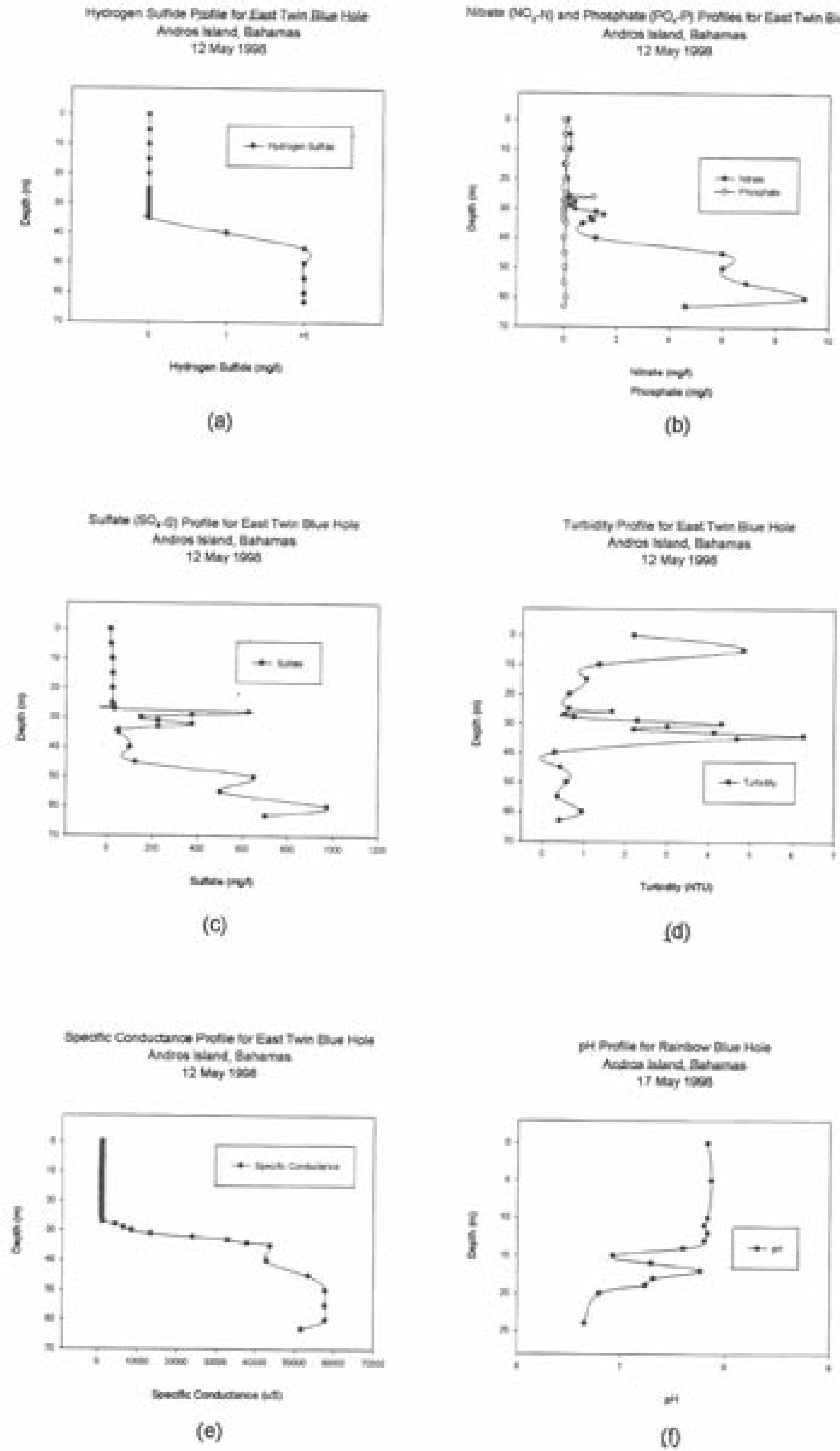


Figure 6. Physicochemical profiles for East Twin and Rainbow blue holes.

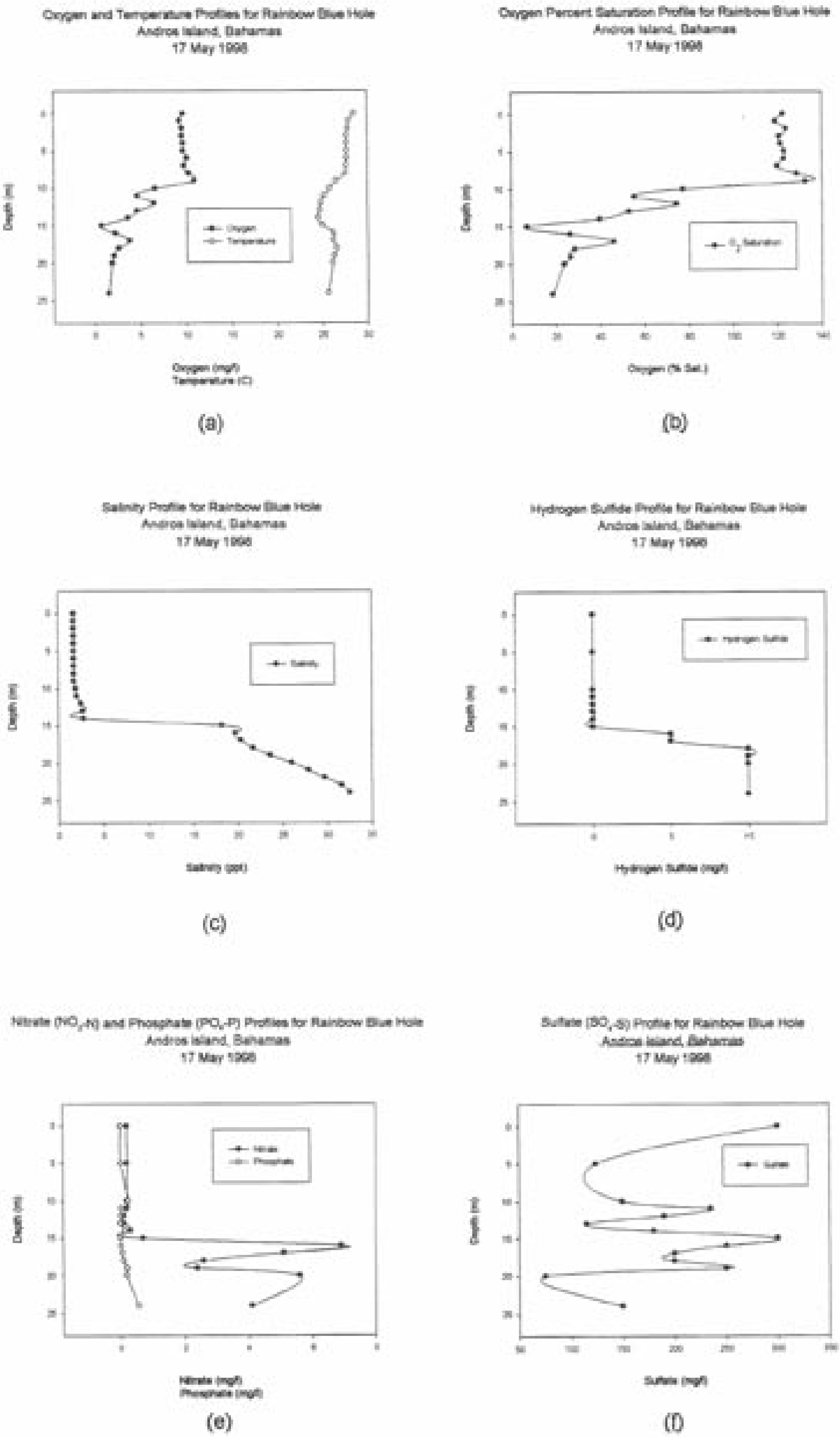


Figure 7. Physicochemical profiles for Rainbow Blue Hole.

lowest reading was 0.30 NTU at 40 meters (Figure 6d). Specific conductance remained at approximately 1000 µS•cm^{-1} until 27 meters, then increased to about 58000 µS•cm^{-1} near the substrate (Figure 6e).

Rainbow Blue Hole

Rainbow Blue Hole was sampled 17 May 1998. The secchi disc reading was 7.4 meters and the pH remained neutral at approximately 7.6 from surface to substrate (Figure 6f). Temperature was consistent at approximately 26 °C throughout the blue hole. Oxygen concentrations stayed around 10.00 mg/l for the first nine meters, then lowered to 0.70 mg/l at 15 meters (Figure 7a). Percent oxygen saturation started at 122.6% at the top and slowly decreased to 18.6% at the bottom of the blue hole (Figure 7b). Salinity remained below 3.00 ppt until 14 meters, increased to approximately 20.00 ppt, and then rose to

Rainbow Blue Hole. The transect line was used to hold the boat in place and to gain a cross section of depth readings.

32.50 ppt at the substrate (Figure 7c). Hydrogen sulfide levels measured zero until 15 meters, increased to 5.00 mg/l and rose to >5.00 mg/l at 18 meters (Figure 7d). Nitrate concentrations were consistent at 0.2 mg/l for the first 14 meters, increased to 6.9 mg/l, then gradually decreased to 4.10 mg/l at the bottom of the water column. Phosphate concentrations remained near 0.05 mg/l until 17 meters, then steadily increased to 0.56 at 24 meters (Figure 7e). Sulfate concentrations fluctuated around 200 mg/l throughout the column. The lowest sulfate readings were 75 mg/l at 20 meters and the highest reading was 300 mg/l, which occurs at the surface and at

15 meters (Figure 7f). Turbidity stayed below 1.00 NTU until 14 meters where it increased to 27.00 NTU, then decreased back to around 3.00 NTU (Figure 8a). Specific conductance began at 3503 µS•cm^{-1} and increased to 50000 µS•cm^{-1} at the substrate (Figure 8b).

Hubcap Blue Hole

Hubcap Blue Hole was sampled 20 May 1998. It was not possible to get a secchi disc reading for this blue hole because most of the blue hole was too shallow. The area into which the Kemmerer bottle was lowered was in the shade and was too small to permit entry of the secchi disc. Temperature was about 28 °C for the first five meters and then decreased to around 25 °C for the remainder of the column. Oxygen concentrations began at 9.30 mg/l and decreased to 3.70 mg/l at 7 meters. They remained near zero between 8 meters and 15 meters, then increased to about 3.00 mg/l towards the bottom (Figure 8c). Percent oxygen decreased from 118.1% at the surface to approximately 3% at 10 meters where it remained until 16 meters. It then increased to 48.5% at the substrate level (figure 8d). The pH of Hubcap Blue Hole remained around 7.40 with the exception of a strong decrease to 5.48 at 15 meters (Figure 8e). Salinity stayed at 1.70 ppt until 13 meters, then gradually increased to 18.00 ppt at the water-substrate interface (Figure 8f). Hydrogen sulfide concentrations remained at zero until 13 meters in depth and then gradually increased to >5.00 mg/l at the bottom of the water column (Figure 9a). Nitrate concentrations stayed below 1.0 mg/l until 13 meters, then increased to 6.30 mg/l at 19 meters (substrate).

Hubcap Blue Hole.

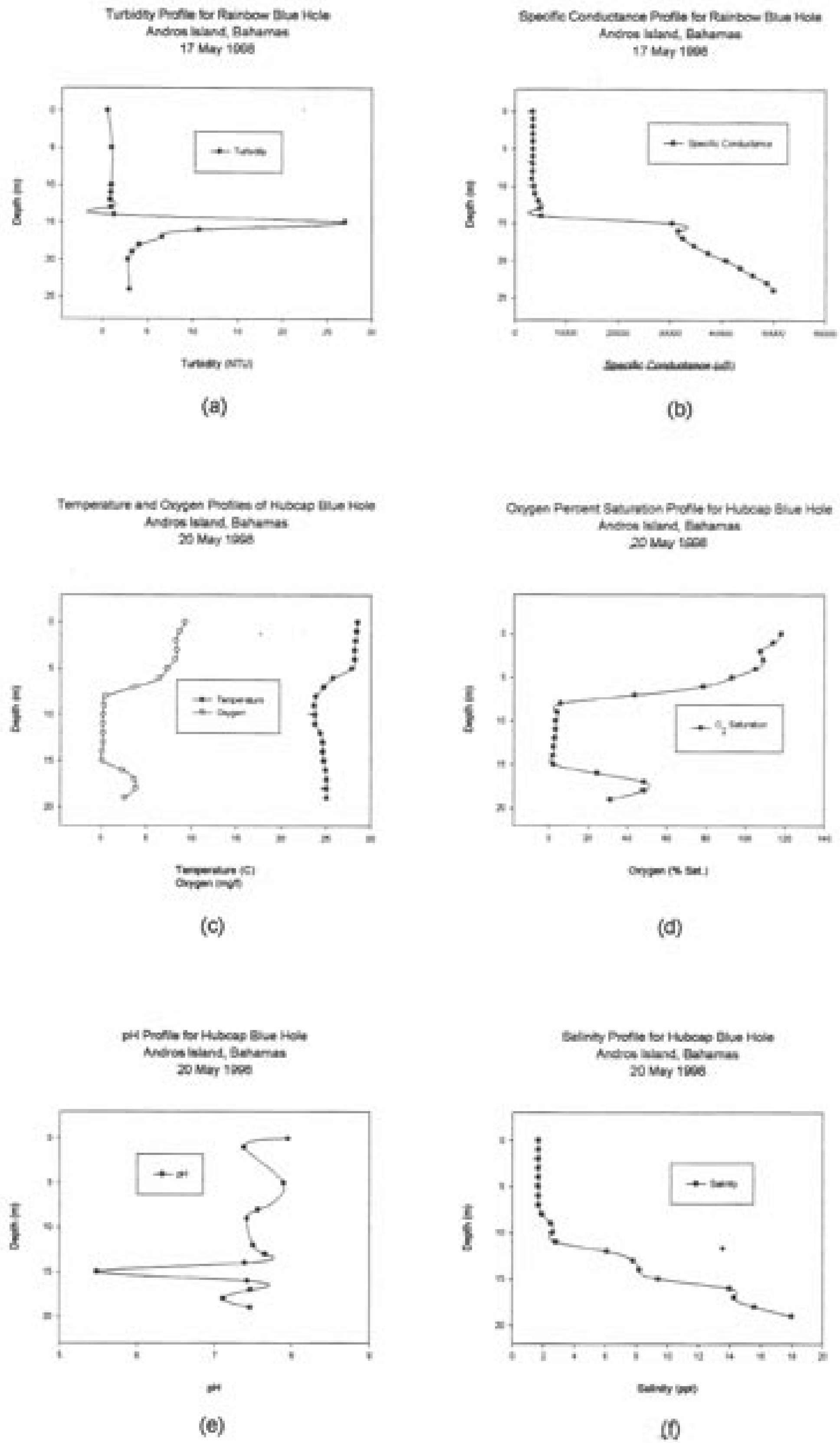


Figure 8. Physicochemical profiles for Rainbow and Hubcap blue holes.

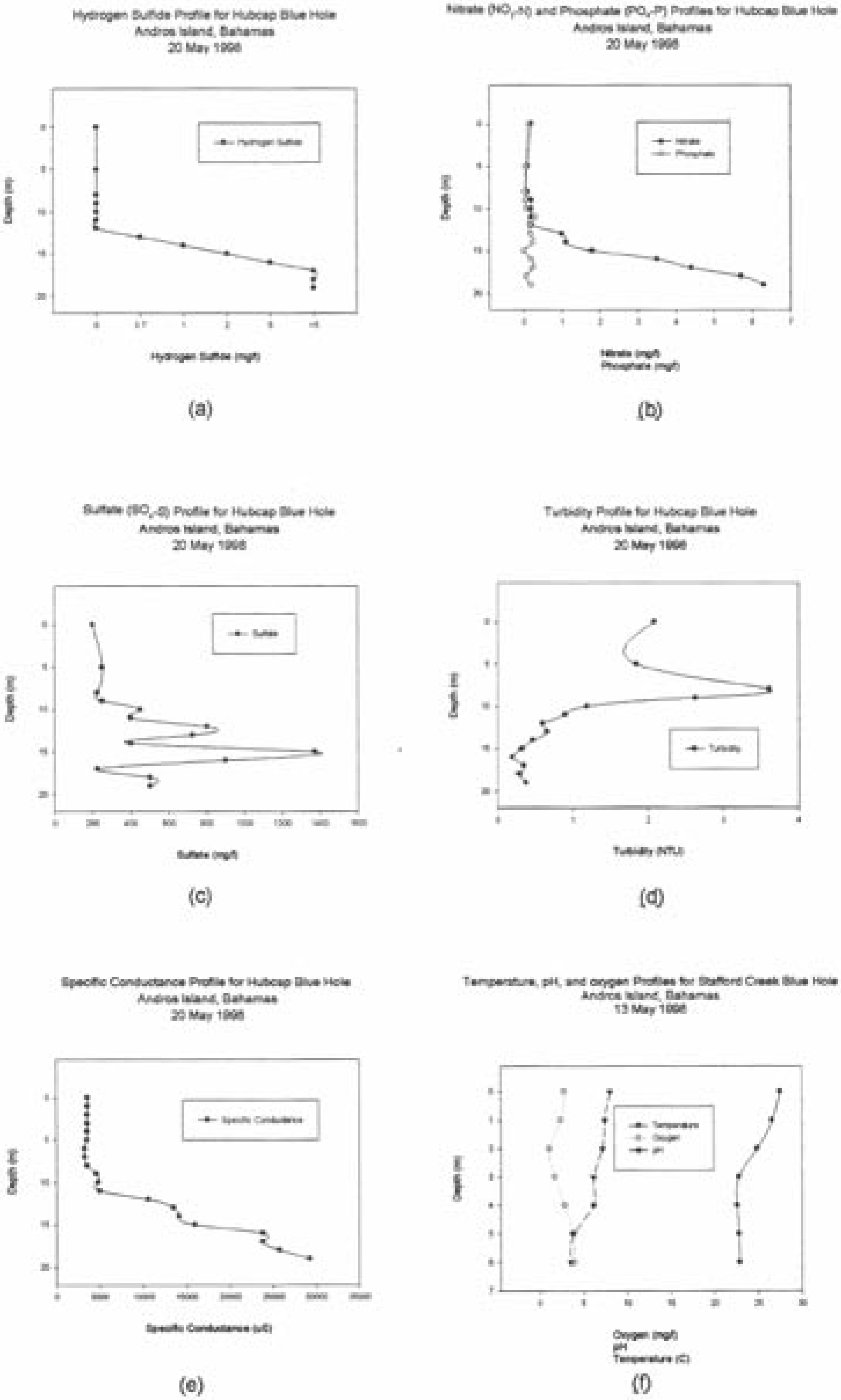


Figure 9. Physicochemical profiles for Hubcap and Stafford Creek blue holes.

Phosphate concentrations were uniform at approximately 0.2 mg/l throughout the blue hole (Figure 9b). Sulfate concentrations fluctuated around 400 mg/l, with a strong increase to 1375 mg/l at 15 meters (Figure 9c). Turbidity fluctuated around 2.00 NTU for the first 10 meters and then decreased to around 0.40 NTU for the rest of the blue hole (Figure 9d). Specific conductance stayed below 5000 $\mu S \cdot cm^{-1}$ until 11 meters, then gradually increased to about 30000 $\mu S \cdot cm^{-1}$ at the substrate (Figure 9e).

Stafford Creek Blue Hole

Stafford Creek Blue Hole was sampled 13 May and 19 May 1998. The secchi disc reading for Stafford Creek Blue Hole on 13 May 1998 was 2.25 meters. The temperature began at 27 °C at the surface, then decreased slightly to around 23 °C. The pH started at 8.02 at the surface and dropped to 3.49 at six meters. Oxygen concentration started at 2.77 mg/l at the surface, decreased to 1.70 mg/l at three meters, then increased to 3.95 mg/l at six meters (Figure 9f). Percent oxygen saturation was 34.5% at zero meters, decreased to 12.2% at two meters, then gradually increased to 22.9% at six meters (Figure 10a). Salinity slowly increased from 0.50 ppt at zero meters to 7.30 ppt at six meters (Figure 10b). Hydrogen sulfide remained at 0.00 mg/l from zero to three meters, then increased to 5.00 mg/l at four meters, and increased again to >5.00 mg/l at five meters (Figure 10c). Nitrate concentrations stayed at approximately 0.5 mg/l until three meters, then increased to about 5.0 mg/l for the rest of the column. Phosphate concentrations remained below 0.15 mg/l for the entire blue hole with the exception of the surface, which was 0.30 mg/l (Figure 10d). Sulfate concentrations increased from 30 mg/l at zero meters to 300 mg/l near the substrate (Figure 10e). Turbidity started at 1.50 NTU at the surface, increased to 32.50 NTU at three meters, and decreased to 3.22 NTU at six meters (Figure 10f). Specific conductance started at 1089 $\mu S \cdot cm^{-1}$ at zero meters and increased to 12170 $\mu S \cdot cm^{-1}$ at six meters (Figure 11a).

The secchi disc reading for Stafford Creek Blue Hole on 19 May 1998 was 2.7 meters. Temperature was consistent at approximately 24 °C throughout the blue hole. The pH started around 7.00 at zero meters and decreased to 2.75 at six meters. Oxygen concentrations began at 4.05 mg/l at the surface and lowered to 0.17 mg/l at the substrate (Figure 11b). Percent oxygen saturation was approximately 30.0% at zero meters and decreased to 1.8% at six meters (Figure 11c). Salinity increased from 0.60 ppt at zero meters to 6.20 ppt at six meters (Figure 11d). Hydrogen sulfide was 0.00 mg/l from zero to three meters, then increased to >5.00 mg/l at five meters (Figure 11e). Nitrate concentrations remained below 0.4 mg/l until five meters where it jumped to 5.4 mg/l and then decreased slightly to 3.2 mg/l at six meters. Phosphate concentrations stayed below 0.15 mg/l throughout the whole water column (Figure 11f). Sulfate concentrations increased from 40 mg/l at the surface to 450 mg/l at the substrate (Figure 12a). Turbidity remained below 10.00 NTU throughout the blue hole, except for a strong jump to 67.50 NTU at four meters (Figure 12b). Specific conductance increased from 1170 µS•cm^{-1} at zero meters to 10440 µS•cm^{-1} at six meters (Figure 12c).

Some of the vegetation found on Andros Island around the blue holes include *Cladium jamaicensis*, a common grass that was located in close proximity to the blue holes. There were two very common palms that were identified as *Coccothrinax argentata* and *Thrinax morrissi*. A shrub present around the perimeter of the blue holes was *Crysobalonus icaco*. A thorned shrub, called *Acacia choriophylla*, also is common on Andros. Other vegetation found in the coppice and shrub-lands were *Smilax havanensis*, *Cordia bahamensis*, *Tabebuia bahamensis*, *Suriana maritima*, *Pinus caribaea*, *Metopium toxiferum*, which is a poisonous plant that is very abundant on the island, and *Cassytha filiformis*, which is a vine that chokes out other plants.

Various observations also were made on the organisms that were present in these blue holes. Several species of

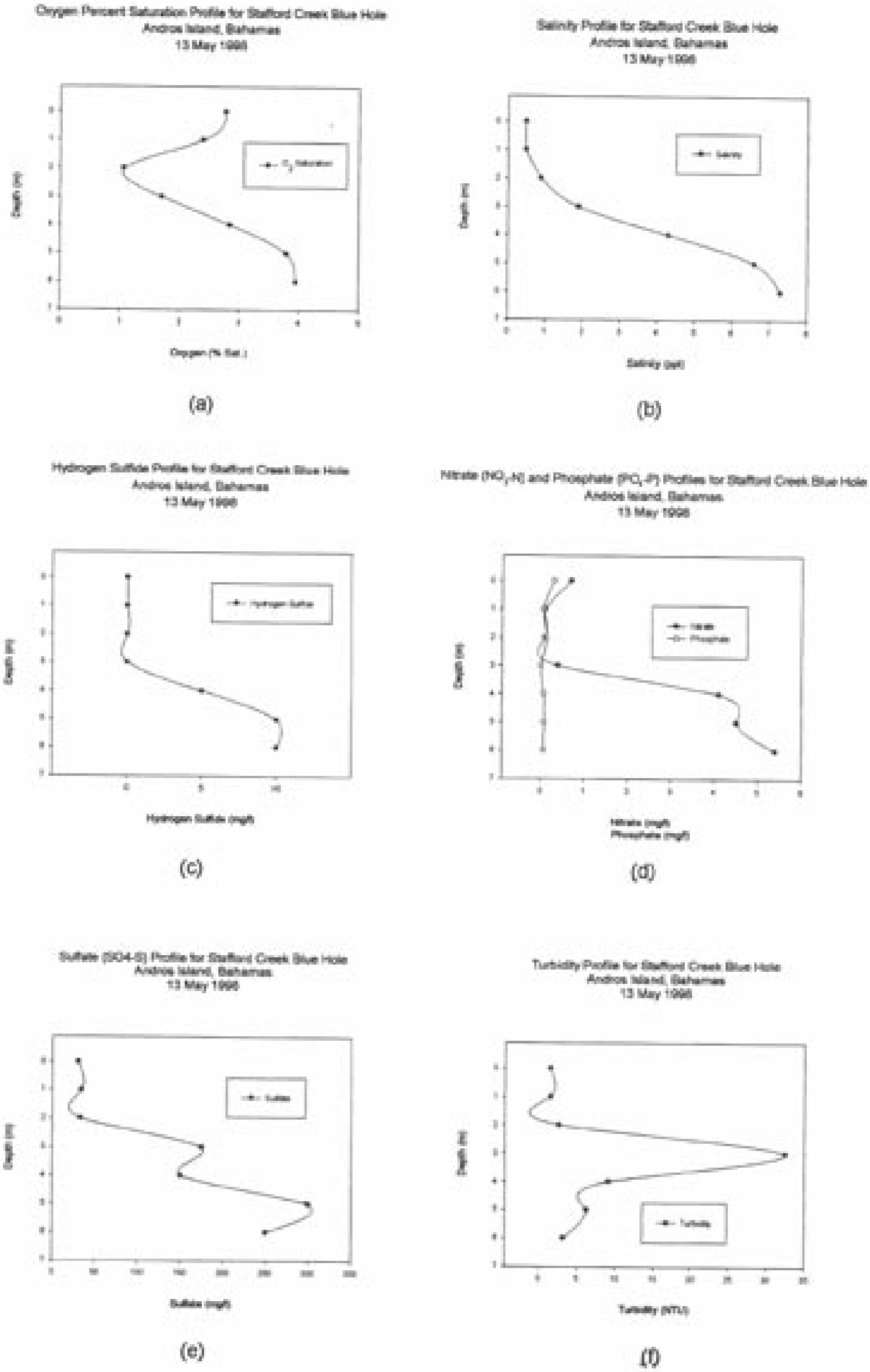


Figure 10. Physicochemical profiles for Stafford Creek Blue Hole.

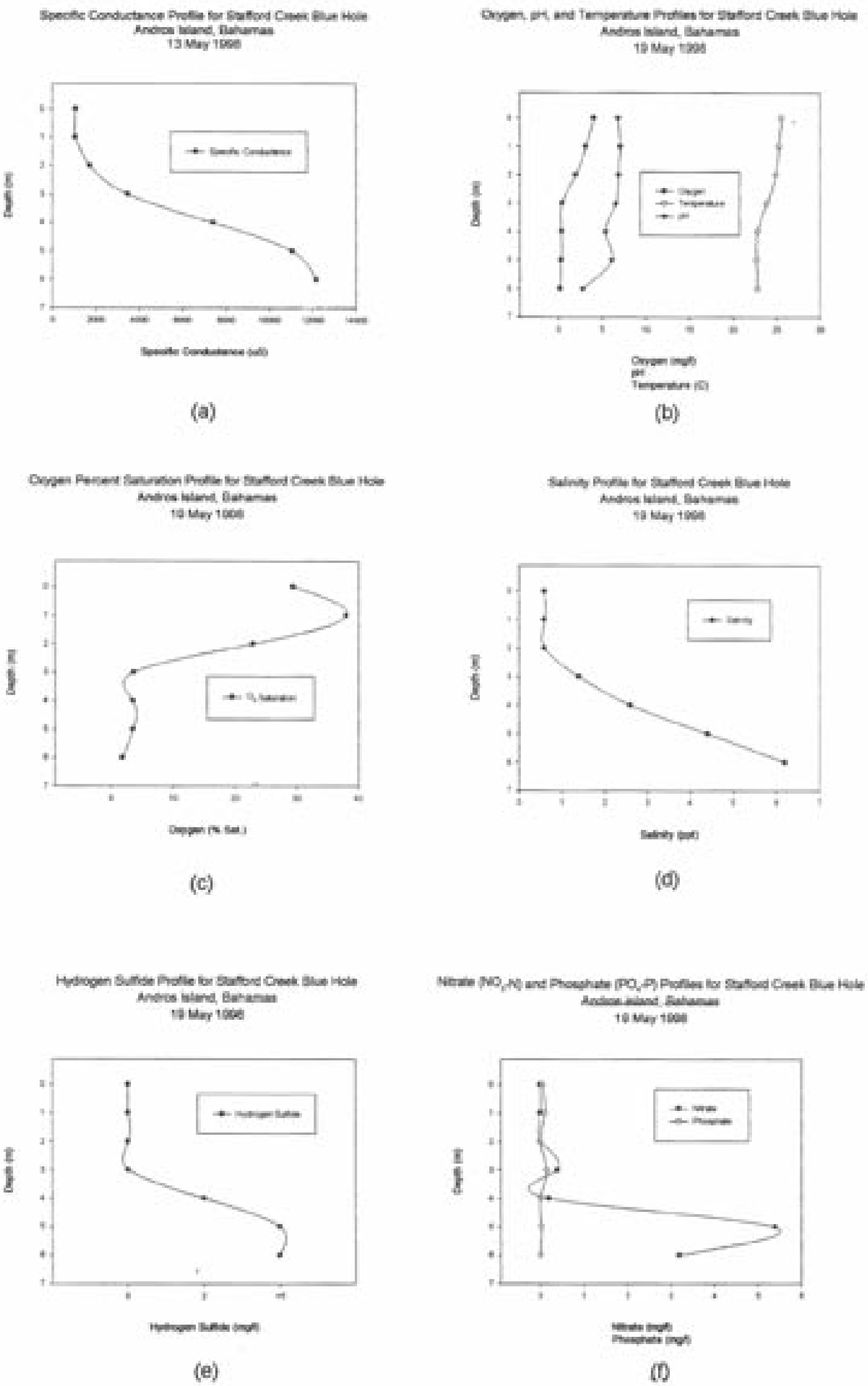


Figure 11. Physicochemical profiles for Stafford Creek Blue Hole.

fishes were seen, two of which were identified as *Gambusia manni* and *Gobiomorus dormitor*. *G. manni* was very common at the surface of almost all of the blue holes and a single individual of *G. dormitor*, approximately 27cm in length, was collected from Cousteau's Blue Hole. This was one of the largest fishes that was observed in the blue holes. Other macroinvertebrates include one species of Nepidae and two species of Gyrinidae that were observed on the surface waters of several blue holes.

Discussion

The temperature in all five blue holes was nearly isothermal around 25-30 °C with the surface water being slightly warmer than the rest of the water column, due to solar warming (Smart 1984, Whitaker and Smart 1990). East Twin Blue Hole exhibited a fluctuating temperature profile that might have been in response to bacterial densities throughout the column. High densities of bacteria can cause periodic increases in water temperature at various depths (Smart 1984, Whitaker and Smart 1990). Bacterial plates have been identified in East Twin and Cousteau's blue holes by Smart (1984).

The pH of these inland blue holes was fairly consistent, at approximately 7.5 throughout the column, because of the high buffering capacity supplied by the calcium carbonate walls. However, in the halocline the oxidation of organic matter increases the concentration of carbon dioxide, which also produces carbonic acid. Carbonic acid aids in the calcium carbonate dissolution as well as decreasing the pH (Bottrell *et al.* 1991, Raeisi and Mylroie 1995). These types of reactions could have contributed to the decrease of pH in the halocline of East Twin, Rainbow, Hubcap, and Stafford Creek blues holes.

Oxygen concentrations and percent oxygen saturation were the highest at the surface because of photosynthetic reactions produced by phytoplankton. In the halocline, bacteria utilize oxygen and use it for a sulfur redox reaction, turning it into carbon dioxide (Bottrell *et al.* 1991, Raeisi and Mylroie 1995). Therefore, oxygen decreases through the mixing layer until it is nearly anoxic in the saline zone. All of the blue holes in this study exhibited a significant decrease in oxygen in the saline lens, but none of them demonstrated a completely anoxic state. This may have been due to a miscalibration in the oxygen probes or residual oxygen present within the membrane of the probes.

The salinity at the surface of all five blue holes was close to zero, and increased through the brackish layer. In three of the blue holes, the salinity increased to approximately 35 ppt at the water-substrate interface (Smart 1984, Whitaker and Smart 1990, Smart *et al.* 1998). The other two blue holes, Hubcap and Stafford Creek, were not sufficiently deep to exhibit ocean water salinities. Even through East Twin Blue Hole was located the farthest inland there is still strong evidence that there is exchange of ocean water within the greatest depths of the blue hole (Whitaker and Smart 1990). In many of the blue holes a tidal fluctuation was observed, but actual measurements were not recorded. Stafford Creek Blue Hole's close proximity to Stafford Creek might be the reason for the low salinity reading, because of possible exchange with river or estuarine water.

Hydrogen sulfide readings typically are inversely correlated to the oxygen profiles. Throughout the freshwater lens the hydrogen sulfide was zero because the sulfur that was present was displayed as sulfate. In the halocline mixing layer the hydrogen sulfide was present in small concentrations, while it increased greatly in the saline zone, where oxygen concentrations were very low. According to Bottrell *et al.* (1991) anaerobic bacteria aid in the conversion of sulfate into hydrogen sulfide in the saline layer. Near the water-substrate interface readings were 5 mg/l or greater in all five blue holes. Even though Stafford Creek Blue Hole did not exhibit ocean salinities in the deepest layers, oxygen decreased practically to zero and hydrogen sulfide increased to >5 mg/l, demonstrating typical blue hole profiles.

Sulfate concentration increased throughout the water column, paralleling the specific conductance profile. The saline layer has the highest specific

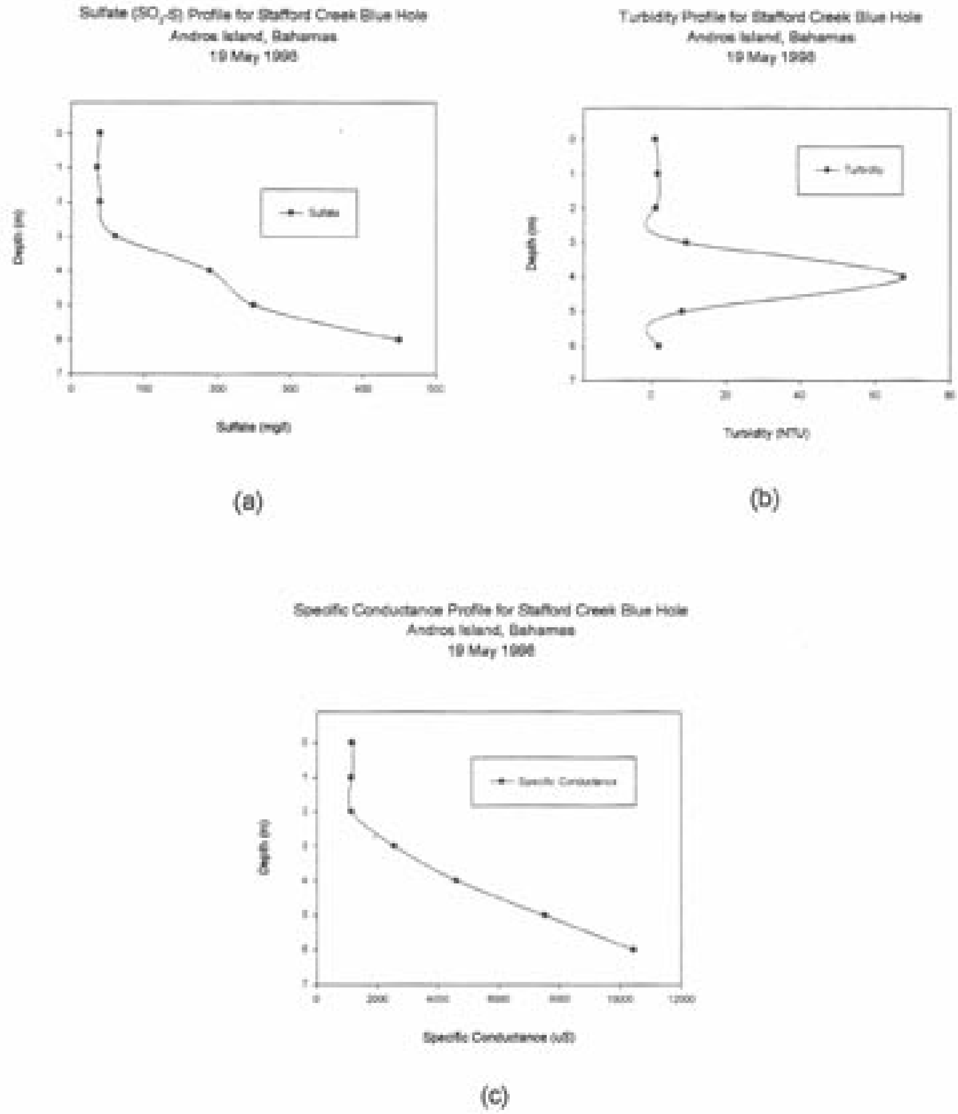
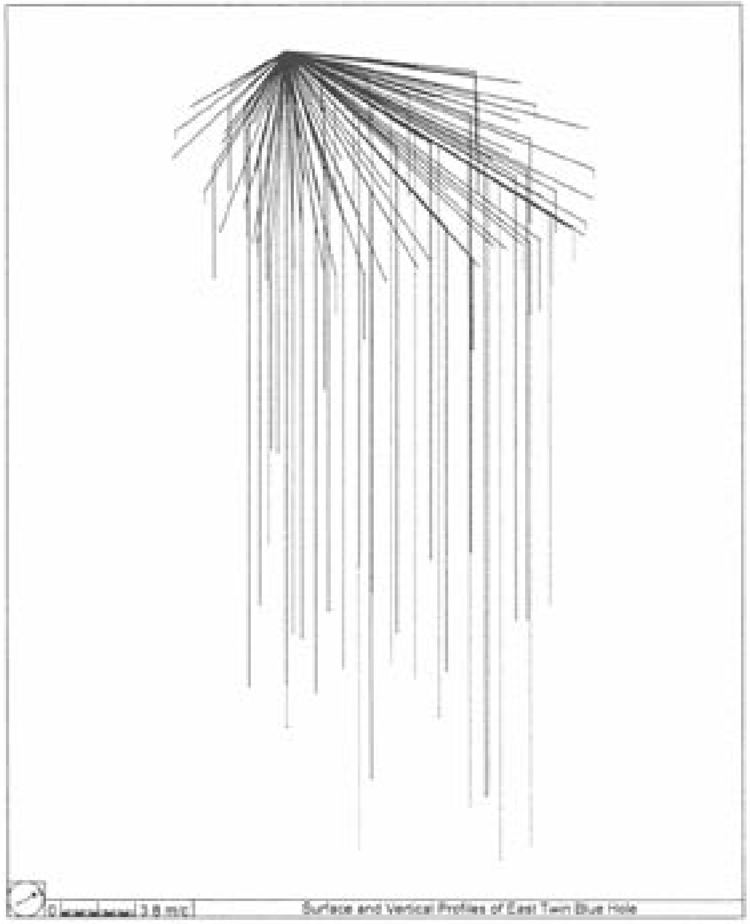
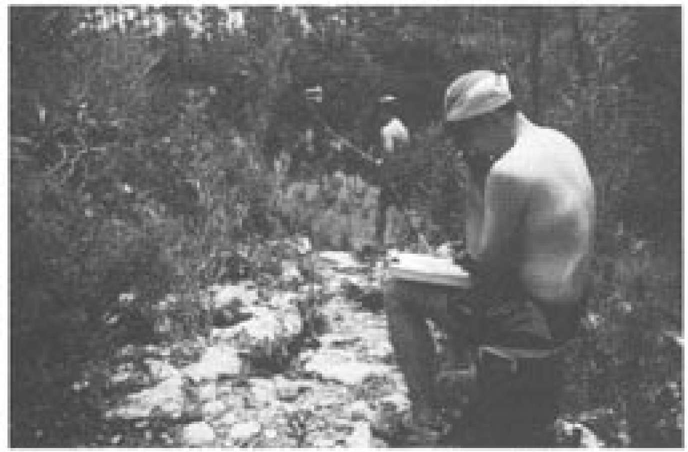


Figure 12. Physicochemical profiles for Stafford Creek Blue Hole.

Stafford Creek Blue Hole was the shallowest blue hole that was studied (6m). It was also the closest in proximity to the ocean.





Matt Beversdorf (foreground) and Brian Bowen help record data from East Twin Blue Hole.

conductance levels and is able to hold more dissolved ions in solution. Bacteria may have caused the increase in sulfate because of the redox reactions that occur in the mixing zone and at greater depths (Bottrell *et al.* 1991).

The amount of phosphate is limited because a large percentage of phosphorus is locked up in rock and is not readily dissolvable. Since Andros does not have much agricultural land there is not much phosphorus or nitrogen runoff resulting from fertilizers.

Turbidity remained below 5 NTU in most of the blue holes, with a small increase within the halocline. However, Stafford Creek and Rainbow blue holes exhibited a larger increase in hydrogen sulfide in the mixing zone and could potentially have had more sulfur bacteria present, increasing the turbidity readings. There were other smaller fluctuations in turbidity throughout the water columns that could have been caused by high densities of plankton and bacteria as well.

Specific conductance remained below 5000 $\mu S \cdot cm^{-1}$ through the freshwater lens of all blue holes with the exception of Cousteau's Blue Hole, which started at 10000 $\mu S \cdot cm^{-1}$. The specific conductance increased through the mixing zone until it reached open ocean readings, 50000-60000 $\mu S \cdot cm^{-1}$, in the saline waters (Smart 1984, Bottrell et al. 1991). This also suggests that the blue holes reaching open ocean specific conductance readings have exchange with ocean water.

Even though all five of the blue holes studied have some common properties, each blue hole also has unique characteristics. Special attention should be given to every blue hole and generalizations should be carefully made in future studies. Little is known about how blue holes function and even less is understood concerning their biology. Much additional research is required on these and numerous other inland blue holes and this study provides baseline data that will be useful for much needed future investigations.

NOTE: Several additional blue holes were scouted in the process of locating testing sites. The U.S.G.S. topography map, Andros Sheet 8, indicated a body of water labeled blue hole that was in fact, just a shallow pond. The coordinates for this pond are 24° 48' 44" N and 78° 01' 48" W. This may have been a blue hole at one time but has filled with sediment.

Acknowledgments

I would like to thank the Faculty Research Fund Board and Department of Biology at Wittenberg University for funding this study. A special thanks is extended to Dr. Timothy Lewis, Chairmen of the Department of Biology at Wittenberg University, for the exception that was made for allowing me to receive both grants.

Thanks to International Field Studies and Director Ben Bohls for helping ship all of our equipment and making sure it returned home safely. To the staff at Forfar Field Station, appreciation is extended for all of their help and for acting so quickly when we realized there was no inflatable boat to use. I am particularly indebted to the Commonwealth of the Bahamas for granting me permission to conduct this study.

I would also like to thank Dr. Horton H. Hobbs III for advising this project and believing in my wacky, crazy idea. A special thanks to team members Matthew "Arnie" Beversdorf, Beth Hagen, Brian "Eugene" Bowen, and Dr. Horton H. Hobbs III for all of their hard work and for their wonderful humor; I could not have done it without them.

Adviser Dr. Horton Hobbs III at East Twin Blue Hole.

Team members Beth Hagen, Matt Beversdorf and Brian Bowen.

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Adventures on Andros

Article by Matthew Beversdorf

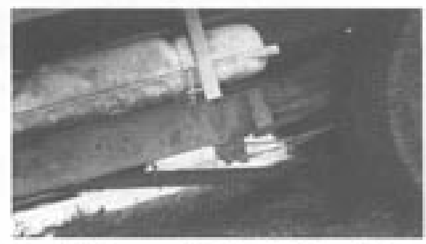
Andros Island is the largest but probably one of the least vacationed islands in the Bahamas. A few famous attractions do lend it credibility as a great place to visit. The Great Barrier Reef, claimed to be the third largest in the world,

Paradise! The beach near Nicholl's Town.

stretches along the eastern side of the island with a beautiful variety of sea creatures. Bonefishing in the offshore flats and blueholes also attracts fishermen from around the world. Andros is also the source of the vividly colored hand-made Androsia fabrics. However, we did not come as tourists, but to do some research on the little known inland blue holes on the island.

Researching blue holes in the Bahamas in May was not always fun in the sun.The first three days of studying them quickly taught us that. Starting out the temperature reached over 100° F. As a result the sweat streaming down our bodies immediately attracted the evil doctor flies (Tabanidae). These little flies were comparable to a rose thorn piercing the skin. No insect repellant would rid them. Our only defense were the dragonflies that hovered around the blue holes.
In addition, we learned to shy away from the notorious poison wood (*Metopium toxiferum*). Touching any part of this plant subjected one to a blistering rash at the point of contact.
To make things worse, we ran into some complications on our second day out in the field. In the morning we packed a truck and headed out in search of another blue hole. Soon after driving off, we took a turn and headed into the woods on old logging roads. We bounced along for awhile looking for the right road to take to the blue hole. All of a sudden, a loud noise was heard from below. We stopped, looked under the truck, and to our dismay the driveshaft had fallen off. Whoops! Fortunately we were able to hike back to the road and hitch a ride back to the field station. We had no luck in the afternoon either when we went hunting for a different blue hole to sample on another part of the island. We saw first hand the interesting karst solution limestone pavement of the ground; with hardly any soil on top. After a long 3.5-hour hike through burned brush and with no water in sight, we gave up. Later when walking back to the van we decided to drive to the nearby Church's blue hole and take a refreshing swim. Following these rough starts, we finally put things together and worked hard at collecting as much information on the blue holes as we could in the two weeks that we were in the Bahamas.

Things went well for us, until the second week, when we noted a leak in our inflatable raft. Apparently it had been cut on the sharp limestone edge of Rainbow Blue Hole as we boarded or exited the boat. If not fixed soon, we would not have enough air to continue with our work that day. I hiked back the half mile over the uneven terrain to the van looking for the repair kit. Finding none, I went back to the blue hole. With the discovery of no repair kit, we took inventory to see if there was anything we could use to fix the leak or whether we should abort and head back to the field station. Luckily Beth had some gum and waterproof Band-Aids. Between that and some duck tape we effectively sealed the hole for the rest of the day!



Oops! There went the drive shaft. Looks like we'll be walking.

Taking a dip into Church's Blue Hole after a long day.

Fortunately, blue hole research did not consume the whole time we were in the Bahamas. On our first free day, the cavers among us could not resist the invitation to visit a couple of the caves on the island. After a quick breakfast, we headed to the northernmost tip of Andros to see Morgan's Bluff. Like

Dr. Hobbs at the northern most tip of the island (Morgan's Bluff).

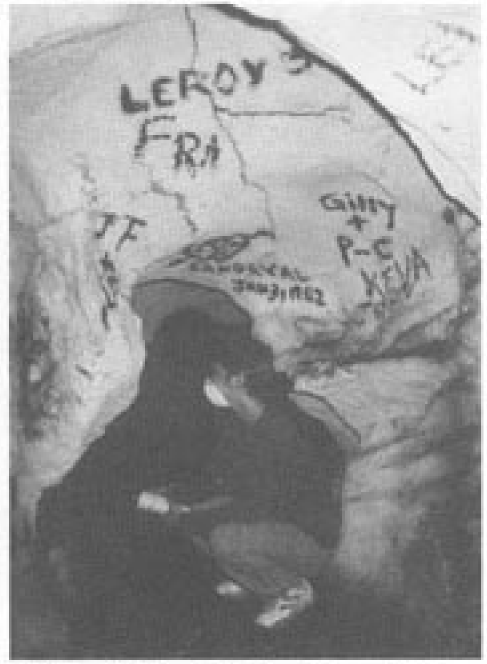
most of the landscape of the Bahamas, the surface rock was limestone, and very uneven due to dissolution by rain and waves splashing up onto the bluff. Our stop there was refreshing, as we were able to see the highest view on the island, watch the waves pound into the rock, and feel the cool spray fall on our skin. It was already a good day and we had not even been caving yet.

From Morgan's Bluff we traveled to Morgan's Cave where our guide from the Forfar Field station pointed out the "tourist tree" which has a pink and peeling bark. (Not much different from the color of our skin after being out on the blue holes for the last few days!) Morgan's Cave is not very large

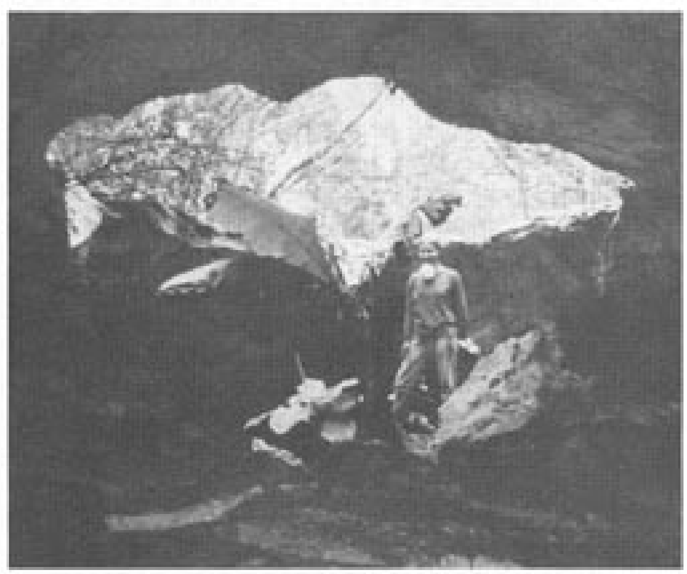
Morgan's Cave entrance.

and quite open to the surface; we did not need lights to look around. It consisted primarily of a large elongated room, which tapered at the ends. One end had a short crawl to another entrance. It was interesting to note the 'pillars' in the caves that were roots from the trees above, reaching through the expanse of the cave to the dirt below.

After the quick tour of Morgan's Cave we drove to Bat Cave. This cave was a bit more extensive than the previous one, taking us almost 45 minutes to go through it. Bat Cave begins with a short drop of about 7-8 ft. Then after a short crawl we ended up in a larger room. In this room the floor was covered with guano and crawling with cockroaches. This cave, as are many in the Bahamas, is a flank margin cave. Believed to form by dissolution along the freshwater lens of an island, it does not have any flowing water (as our phreatic caves do) to wash away the guano (Mylroie et al. 1995). Thus we were forced to protect ourselves from Histoplasmosis by wearing filter masks over our mouths and nose. In this cave, much graffiti covered the walls, left by visitors who felt it appropriate to write something by spreading the guano on the walls. After the guano room, we had to duck under a rock, slime our backs with guano, and continue on our way. We came out near another entrance with a surprise waiting for us. There in the middle of the hole



Graffiti in Bat Cave. Notice the solution pocketing the walls, typical of flank margin caves.



Ever get hungry in a cave? Just look for the nearest banana tree. [Bat Cave].

was a banana tree. About this time we began to wonder where were all the bats? Fortunately for us, there was another passage that continued on, which opened up into a larger vaulted room. There we saw numerous bats flying around and resting on the ceiling. From that room, we exited though another short crawl, ending our day of caving. After a short walk to the van, we documented our experience in the traditional muddy-WUSS fashion.

Muddy WUSSes? No, it's guano from Bat Cave!

The rest of the two weeks on Andros was spent mostly researching the physicochemical properties of the inland blue holes. You can read more about that in Katie's paper (this issue). In our additional free time, we did get a few chances to see some of the famous places on the island. A trip to the Bahamas could not be complete without a little bit of the fun in the sun, right? We had an opportunity to go snorkeling along the reef and around an offshore blue hole. The colors and the soothing motion of the waves took us to a world that you could never imagine in Ohio. We also enjoyed trying some of the local foods such as conch fritters and conch salad. By the end of the two weeks, the day would not seem complete if we did not cool down at Mr. White's bar, enjoying a cool glass of Kalik beer and playing Dominos with the islanders.

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NEWS

1999 OVR Annual Conservation Project: Sloan's Valley Cave System. ***Tentative Date: early to mid October, 1999.*** The project promises to be a very interesting combination of cave clean-up and speleothem restoration in this world-class cave. Primitive camping will be available on-site on Tom Crockett's farm within view of the project site cave entrance. Water and limited electric hook-ups will be available for the project weekend. Please make plans now to attend and participate in this long overdue and greatly deserving restoration project. And please look at your caving event calendar and get in touch with us to help choose the best date for all. Bill McCuddy (937) 767-9427, John Cole (606) 245-3383.

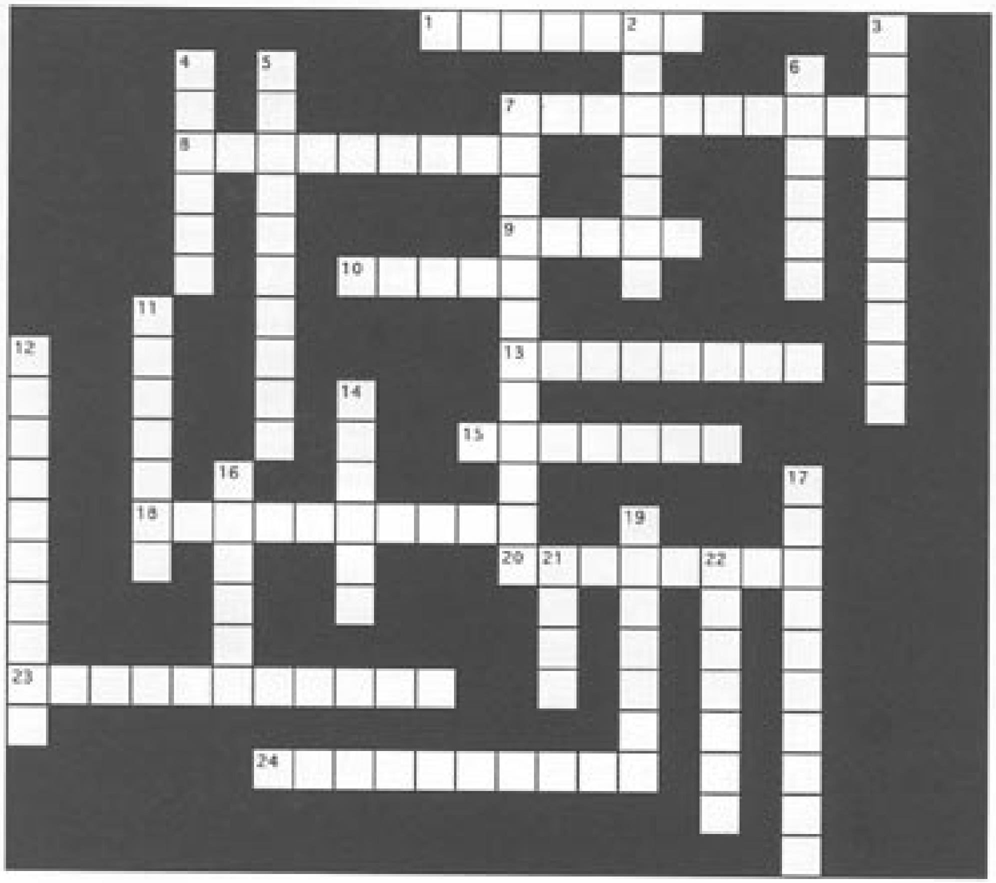
WUSS mailing list. If you cannot make meetings, a good way to keep track of the happenings of WUSS is to join our mailing list. You can subscribe by sending a message to *majordomo@wittenberg.edu* with *subscribe cavers-dis* in the message box.

Outgoing officers. Due to the decision to print the current officers in the front of *Pholeos*, the outgoing officers this year have not had a chance to be published in *Pholeos*. To hopefully make up for this, we would like to thank the outgoing officers Matt Beversdorf (President), Beth Hagen (Vice President), Sara Anderson (Secretary), Jay Cross (Treasurer), Jason Moon (Editor), Amy Larson (Asst. Editor), and Michelle Miller (Social chair) for their hard work and devotion to the caving club this past year. A special farewell is also said to our late WUSS ambassador to Japan, Yuriy Fedkiw.

NSS Convention. A belated congratulations to two recent WUSS alumni appearing in the November 1998 issue of the *NSS News* for having won awards at Convention. Megan Porter was awarded the James G. Mitchell Award and Toby Dogwiler received the Best Paper on a Show Cave Award. Keep up the good work!

20th anniversary. Yes, it's almost time for our 20th anniversary. Hard to believe that the last celebration was just 4 years ago. Look forward to a banquet here at Wittenberg next spring and a special 20th anniversary issue of *Pholeos*. If you have anything to submit, from old photographs to recollections and stories, go ahead and send it to the grotto address. And look forward to more information in the upcoming issue of *Pholeos*.

CROSSWORD PUZZLE



ACROSS

1. A thin, curtain-shaped speleothem caused by a sheet of dripping water.
7. A cave organism unable to live outside the cave environment.
8. An oval-shaped, aluminum-alloy or steel link with a spring-loaded gate in one side; used in climbing and rappelling.
9. Bat dung.
10. A passage lower than three feet requiring hands-and-knees or belly crawling.
13. Zone where voids in the rock are completely filled with water.
15. A narrow crack, break, or fracture.
18. A human cave dweller.
20. A half-sliding, half-climbing movement used to negotiate steep or muddy slopes.
23. A cave animal.
24. Thin hollow forms of stalactites from which water drips and deposits calcite at the tip.

Created by Marsha Butto and Jason Moon

DOWN

2. The process of attaching ropes and cavers to safe and secure anchors.
3. The study of caves.
4. A secure point to which a caving rope, caver, belayer, or ladder can be safely attached.
5. Bridging across a narrow canyon or pit with arms and leg on opposite walls.
6. A hole in the ceiling of a cave.
7. A cave organism that frequently completes its life cycle in caves but is not confined to this habitat.
11. The most common cave mineral; a crystalline form of calcium carbonate.
12. The point where a cave stream reappears on the surface.
14. The zone where voids in the rocks in the rock are partly filled with air and through which water descends under gravity.
16. A speleothem formed where a hanging stalactite and a rising stalactite have grown together.
17. Generic name for cave deposits of calcite, aragonite, and gypsum; includes stalactites, stalagmites, columns, & drapery.
19. Made of 2-inch webbing with a waistband and sewn loop for legs and rear end.
21. A natural void beneath the earth, usually made of several rooms and passages.
22. A honey-comb like speleothem of calcite projecting from a cave wall or ceiling.

Survey of Two Small Carter County Caves

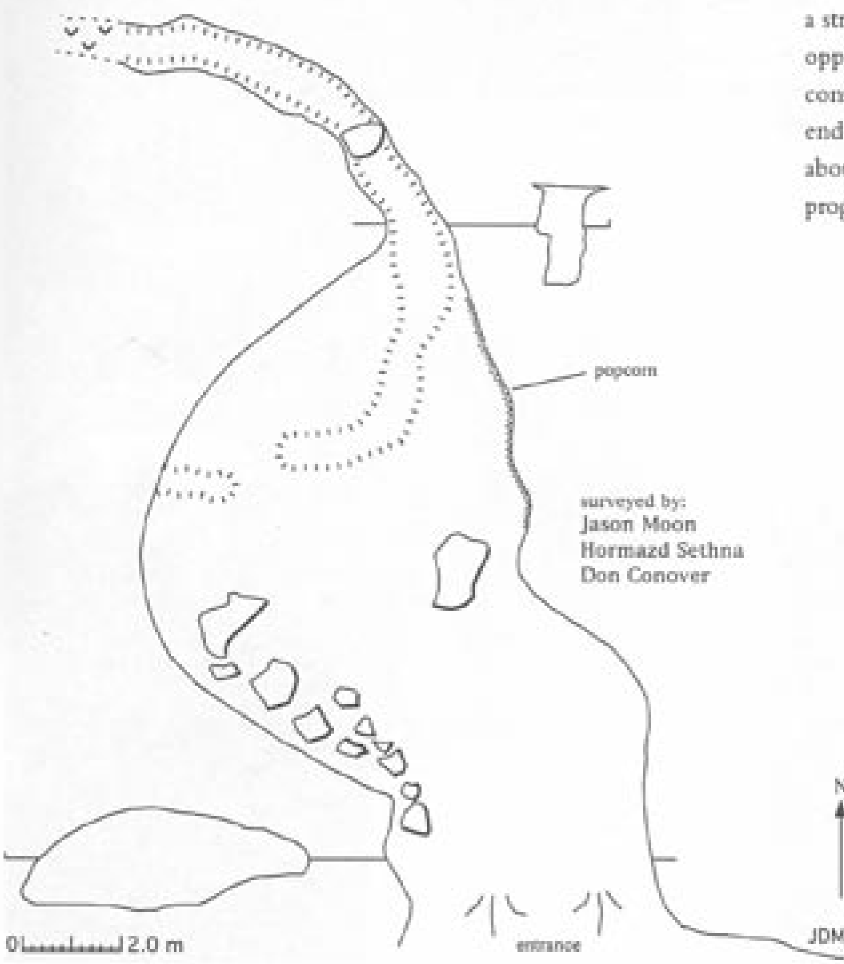
by Jason Moon

WUSS members Kay Mauldin and Ray Steen chillin outside of Constipation Cave.

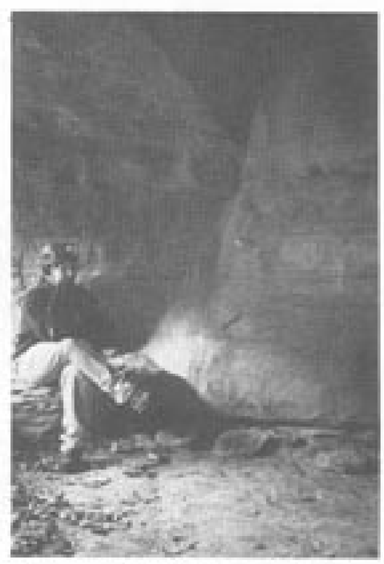
Inside shot of Constipation Cave. Notice the dry stream bed.

Constipation Cave

Carter County, KY
THC: 22.63m
12 Sept. 1998



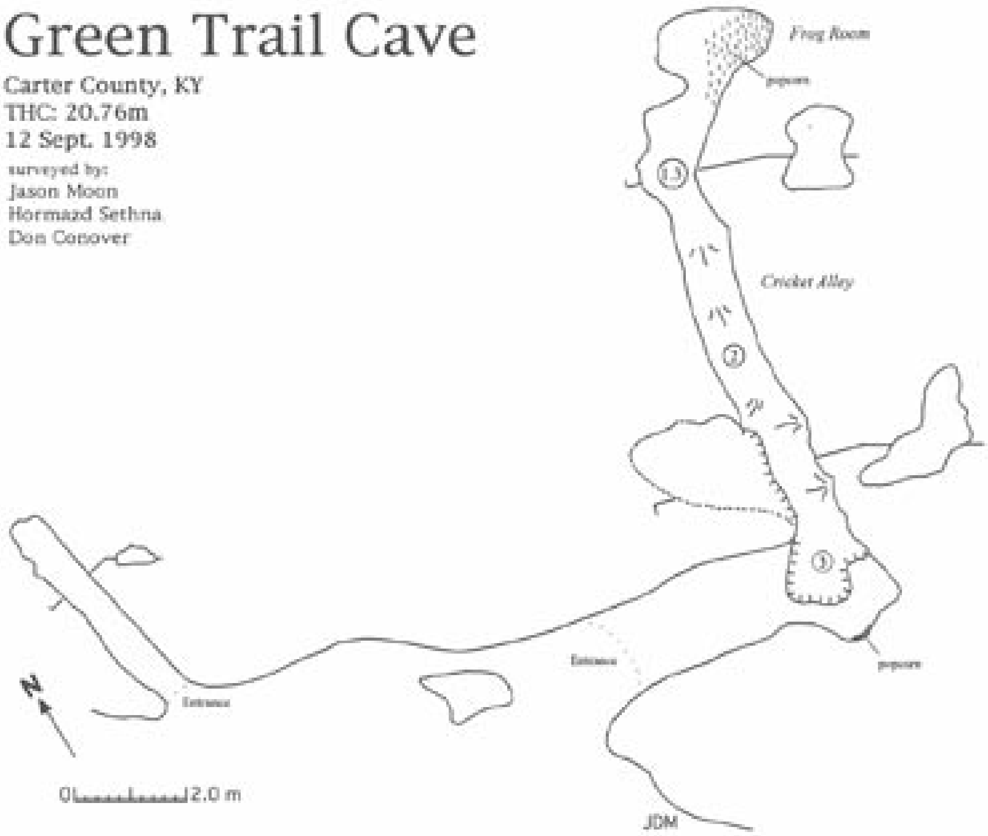
Constipation Cave (THC: 22.63m) is entered through a 2 meter high leaf-filled entrance. After sloping downward, the passage opens into a large room. Near the left wall is some breakdown and beyond that a streambed exits into the wall. On the right wall opposite the stream channel are some speleothems, consisting primarily of popcorn and flowstone. At the end of the room is a canyon passage that continues for about 8 m until secondary deposits block further progress.

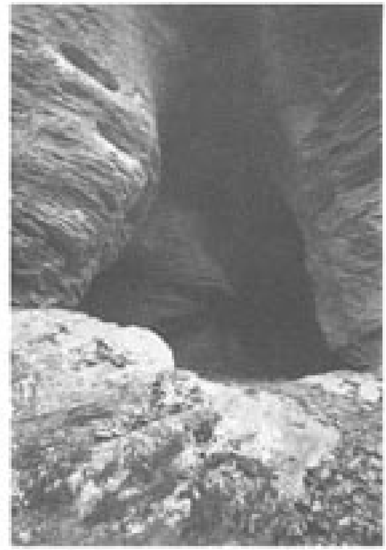


Hmmm…what should we name this cave? How about CONSTIPATION Cave!?!

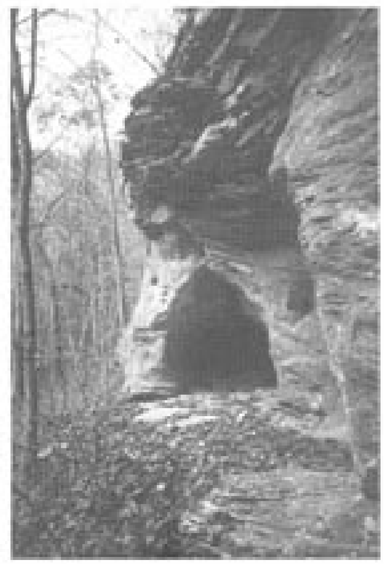
Green Trail Cave

Carter County, KY
THC: 20.76m
12 Sept. 1998
surveyed by:
Jason Moon
Hormazd Sethna
Don Conover





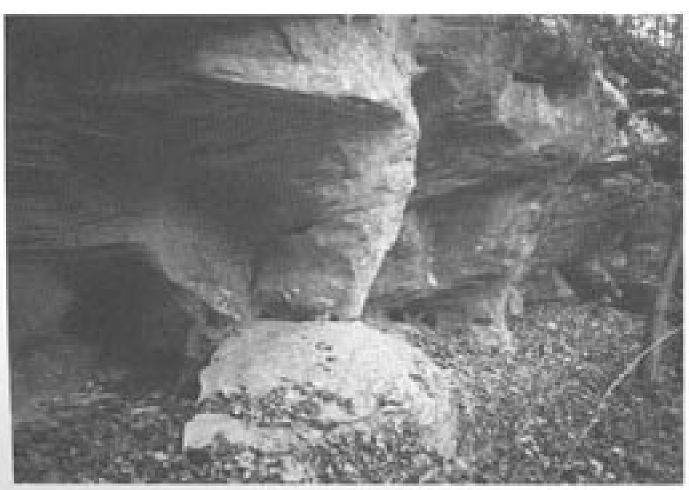
The entrance of Green Trail Cave.



Second entrance to Green Trail Cave.

Green Trail Cave (THC: 20.76m), located in Carter Caves State Resort Park, is actually two caves located 5.5m apart. The smaller of the two has a low crawlway passage that quickly ends after 4.2 meters. A few leaves can be seen in the entrance and further in breakdown can be found. At the end of the passage light can be seen coming through a crack.

The 2.5m high entrance of the second cave is in a cliff face that is 6 meters high. Beyond the graffiti-filled entrance, the passage drops down into a small room approximately three meters high. Here some popcorn can be seen on the right wall. Off of the room branches two passages, one leading to the west and the other leading north. The west passage slopes down and soon ends while the north passage, aptly named Cricket Alley, continues for about 5 meters until it finally tightens and then leads into a popcorn-adorned room. Surveyors observed a good number of crickets, a few spiders, and surprisingly, a frog in this cave.



Left: Outside view of Green Trail. Notice the column blocking the view of the entrance.

Right: Cricket Alley. Green Trail Cave

OTR '98

Photos by Yuriy Fedkiw.

Hungry anyone? Breakfast at the WUSS camp site.

Another traditional WUSS photograph.

WUSS officers just hanging out.

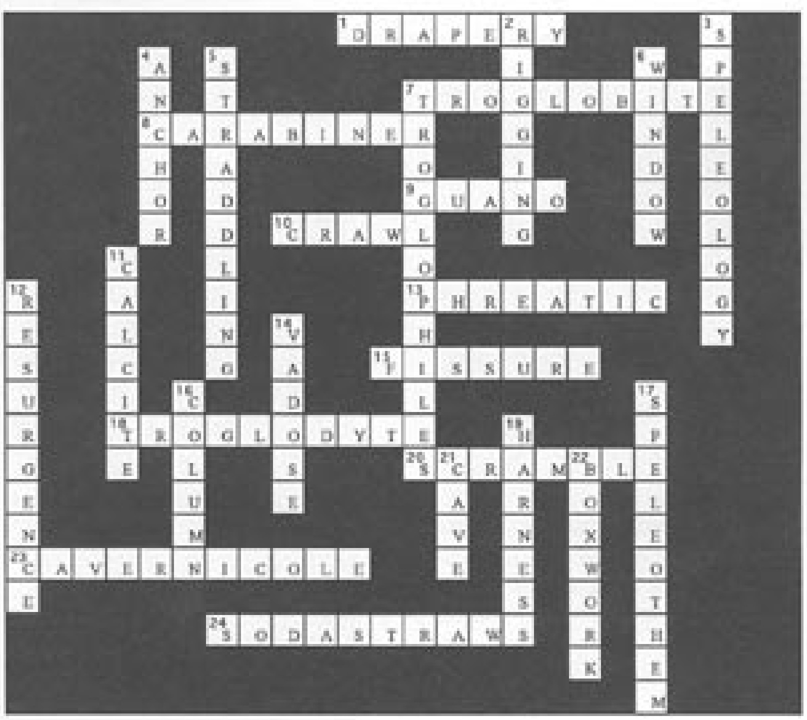
Mother Hobbs. WUSS officers pose around Susan Hobbs at OTR.

PHOTOS

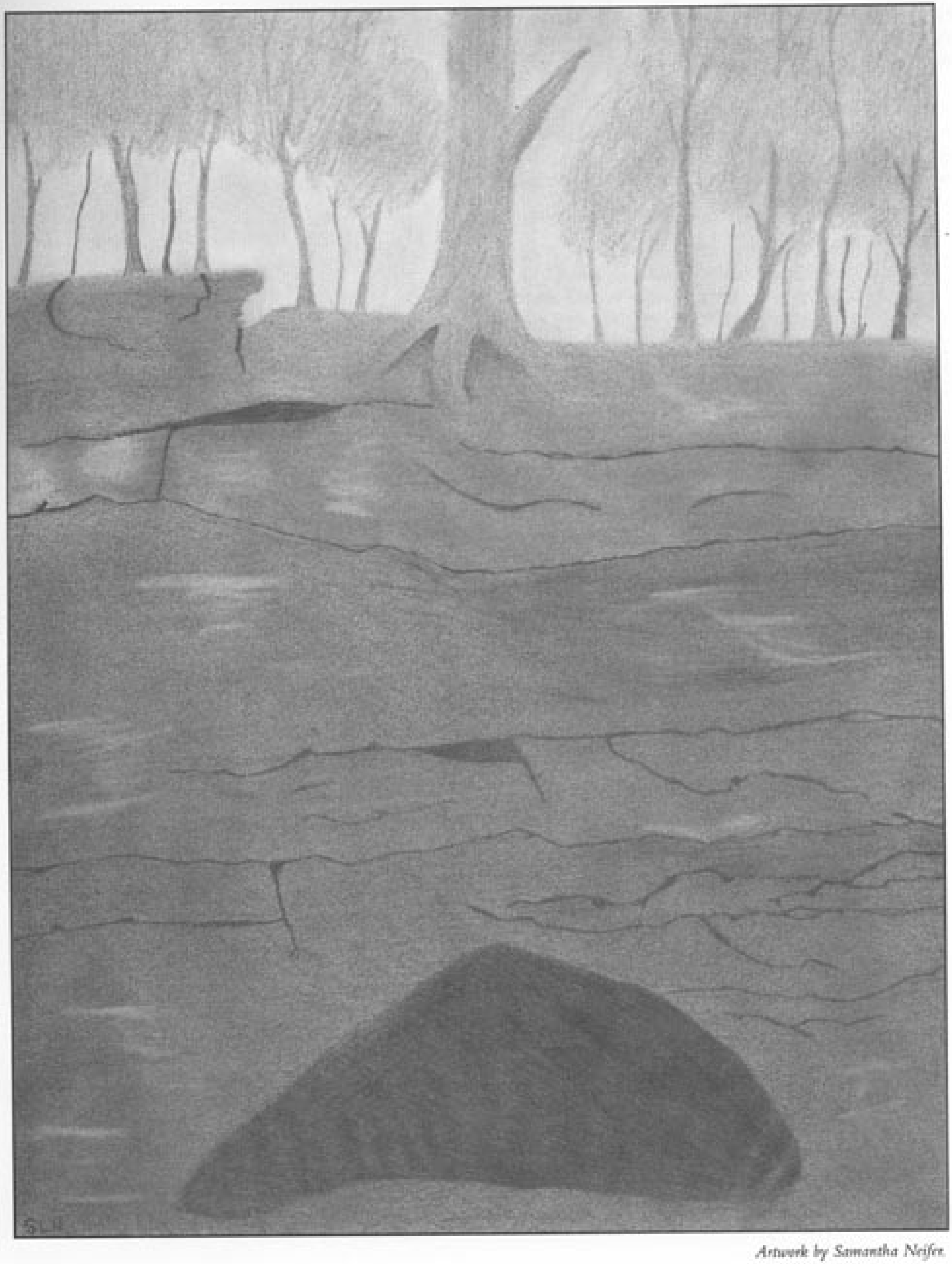
President Beth Hagen climbing at the wall. Photo by Matt Beversdorf.

Congratulations to Andrew and Melanie Burrow! These two were married August 15, 1998 in Toledo, Ohio. Andrew was an active WUSS member during his years at Wittenberg, finishing his senior year as president for the fall semester of 1997. Melanie, although not an active caver, was a great friend to all. Good luck in the future you two!

Crossword Solution



ARTWORK



Artwork by Samantha Neifer.

INFORMATION FOR CONTRIBUTORS

EDITORIAL POLICY: Manuscripts treating basic research in any aspect of speleology will be considered for publication. They must not have been previously published, accepted for publication, or be under consideration elsewhere.

All manuscripts are to be in English. Metric and Celsius units must be used, and SI units are preferred. The CBE Style Manual, the Handbook for Authors of Papers of the American Chemical Society, and Webster's Ninth Collegiate Dictionary are useful guides for matters of form and spelling.

The original of the manuscript must be typed doubled-spaced on one side of white bond paper approximately 8.5 X 11 inches, leaving margins of one inch. Use triple space above headings. Submit four copies for prompt review. Number pages consecutively at the top right-hand corner. Underline scientific names of genera and lower categories. Acknowledgments should be on a separate, double-spaced page. Each figure and table must be referred to in the text. Text references are by author, followed by year of publication. The sequence of material in the manuscript should be as follows.

1. The *title* page should include the title, author's name, affiliation, and mailing address.
2. The *abstract* should not exceed one double-spaced page. It should contain a summary of significant findings and note the implications of these findings.
3. The *introduction.*
4. *Methods and materials.*
5. *Results.*
6. *Discussion.*
7. *Literature Cited.* List all publications referred to in the manuscript alphabetically by first author on a separate sheet of paper (double-spaced). Each citation must be complete, according to the following examples:

   Article: Peck, S.B. 1974. The food of the salamanders *Eurycea lucifuga* and *Plethodon glutinosus* in caves. NSS Bulletin, 36(4): 7-10.

   Book: Moore, G.W., and N. Sullivan. 1997. Speleology: Caves and the cave environment. St. Louis, Missouri: Cave Books.

   Chapter: Hobbs, H.H. 1992. Caves and springs. *In*, C.T Hackney, S.M. Adams, and W.A. Martin (eds.), Biodiversity of Southeastern United States/Aquatic Communities. John Wiley & Sons, pp. 59-131.
8. *Figures and Tables.* Should be self-explanatory, with caption. Each table should start on a separate sheet. Headings and format should be consistent.

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