Fishery Inventory and Habitat Assessment of Spring Lake at Aquarena Center

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Introduction and History

In order to assist Aquarena Center with their research and educational program, fishery collections were made in Spring Lake on October 31, 2002. Identifications of fishes were also made during several research diving operations through the present time. Spring Lake is a headwater lake on the San Marcos River (San Marcos, Texas; Hayes County) that was formed by a small dam originally built in 1848 as a hydroelectric facility to power a grist mill operation, and was the oldest dam in Texas. Spring Lake was formerly operated as an amusement park beginning with the first glass bottom boat ride in 1946, where the clear artesian waters gave viewers a look at the many species of fish. The glass bottom boats were followed in 1951 with the first Submarine Underwater Theatre. In 1969, “Ralph” the famous swimming pig took his first swine dive. Southwest Texas State University (now Texas State University) purchased Aquarena Springs in 1994, changing the focus of this 90-acre theme park from entertainment to preservation and education. This acquisition has enabled the University to preserve this pristine and ecologically unique site, while providing an educational experience for the public to learn about spring-flows from the Edwards Aquifer and endangered species. In addition to the ecological aspects of the site, an underwater archeological dig in Spring Lake uncovered Indian artifacts dating back over 12,000 years to the Clovis Indians, which are the oldest known inhabitants of the western hemisphere. It is reportedly the longest continuously inhabited site in North America, according to Dr. Joel Shiner, underwater archeologist. The Balcones Fault fractured the limestone bedrock millions of years ago in the area known as Spring Lake, forming the San Marcos springs. The water flows through 175 miles of honeycomb limestone of the Edwards Aquifer before filling Spring Lake, the body of water on the grounds of Aquarena Center.

However, there is some local recharge from a subcomponent of the aquifer to the west of the springs and surface runoff that affects the lake water quantity and quality. The critical habitat created by San Marcos springs is home to several threatened and endangered species. Thus, this site is important for its ecological, historical, geological, and archeological significance. Scientific diving and research are carefully managed and encouraged. Research divers are an important part of the restoration work, because of their functions in removing invasive plants and replanting native ones, assisting with water quality monitoring, and educating the public.

Endangered and Threatened Species

Aquarena Center is dedicated to the protection and preservation of the San Marcos springs, and the critical habitats of threatened and endangered species. Two endangered species (state and federally listed) occur in the lake, which are the fountain darter and Texas wild rice. The San Marcos salamander is a threatened species. Other rare and endangered fish species live in the San Antonio Pool of the Edwards Aquifer, and are occasionally entrained in groundwater flows in water-filled caverns in the Balcones Fault Zone, and extruded from these deep aquifer habitats (1,300-2,000 feet below the surface in southern Bexar County) to artesian irrigation wells near San Antonio. These include the toothless blindcat and widemouth blindcat. They are unique in having no eyes, no pigment, no air bladder, and a sucker-type mouth. The endangered Texas blind salamander is troglobitic amphibian, which also occupies the subterranean waters of the Edwards Aquifer, although they are found in shallower parts of the aquifer. They live in perpetual darkness, and are stenothermal (i.e., thrive only in a narrow temperature range, and are sensitive to changes in water temperature). It is also neotenic, which means non-transforming and aquatic through its life; and it lives in water-filled cavernous areas in the San Marcos area within the Edwards Aquifer. The endangered San Marcos gambusia have not been observed since 1983, and are presumed extinct. However, that is not an official determination at this time, and efforts continue to find and conserve this species. Reduction in population size to probable extinction was most likely caused by habitat compression from the invasion of exotic elephant ear plants on the headwater river and lake edges, and hybridization with other gambusia species, mainly the western mosquito fish, *Gambusia affinis*, and largespring mosquitofish, *Gambusia geiseri*, which corrupted the genetic integrity of this species. The occurrences of threatened and endangered species in Spring Lake are well documented, and was not the focus of this investigation.

Spring Lake Map Development

We developed a map of Spring Lake using global positioning system (GPS) points and the digital orthoquad (DOQ) maps available for this area. Will Watson and Christy-Ann Archuleta, GPS-GIS experts at the Texas Water Development Board (TWDB), conducted a series of surveys of the lake from a glass bottom boat and by walking along the perimeter of the lake. GPS points were taken at each major spring location (including depths), selected habitat features, and the perimeter of the lake. Two maps were developed using GIS-ArcMap software, and is shown as Figure 1 (overall lake area showing Aquarena Center facilities, contours, and springs) and Figure 2 (western arm of spring lake where most of the major springs are located). Will Watson and Mark Hayes, GIS-DOQ mapping experts with the Texas Water Development Board, made additional edits to the map and added the depth contours from a hydrographic survey conducted in 1996 by the TWDB to assist Aquarena Center. The depth contours and habitat profiles are helpful in understanding the distribution of fish and other aquatic life in the lake. A volumetric assessment of the lake using these contour data was developed by TWDB staff hydrologists, Duane Thomas and Randy Burns, to determine that there is approximately 84 acre-feet (28 million gallons) of water in the lake. The contour map shows that the lake has a highly variable bottom profile, which allows for the formation of many different habitat conditions and plant species. The names of the springs have not been formally established, but Ron Coley, Director, Aquarena Center, glass bottom boat pilots, environmental education staff, and research divers provided most of the names that have historically been associated with the major springs. It was my privilege to name the remaining unnamed major springs in the lake after native species (Maps, Figures 1 and 2).

Geohydrology

The artesian source of the springs is the San Antonio pool component of the Edwards Aquifer. The springs are associated with the San Marcos Springs fault zone (a part of the Balconies fault zone), where the Austin chalk and Taylor marl formations contact may be a confining area for water movement. It has resulted in cracks and fissures in the limestone topography that forces groundwater to flow into the lake bottom. Over 200 springs have been documented in Spring Lake from three large fissures (many more have not been inventoried), producing the water into Spring Lake with flows from the dam that range from 46-316 feet per second. These springs form the San Marcos River. The sand boils in fountain-like appearances in fine substrates (Figure 21). The accompanying maps show the locations of the major springs (Figures 1 and 2). The three larger ones are Weismuller Spring, Installation or Pipe Spring in the scientific diver training area, and Deep Hole Spring, later called Diversion Spring since the spring flow is diverted into a pipe fitted with a collection net. Many of the deep aquifer species have been collected in this manner, and would not have been known to science without this technique. The substrates vary from fine sediments, mainly sand and silt, to gravel, cobble, and some boulder size substrates. Springs are distributed throughout the lake, and their distribution is associated with the San Marcos Spring Fault Zone. Other ecologically important springs include Salt and Pepper, Cobomba, Cream of Wheat, Catfish Hotel, and Rio Grande Springs. Cobomba Springs was named for the aquatic flowering plant Cobomba, as shown in Figure 23, Rio Grande Springs was named after the Rio Grande cichlids that inhabit the area, as seen in Figures 16 and 17, and Catfish Hotel Springs was named for the white channel catfish that inhabit the area.

Collection Procedure and Support Personnel

All collections were made at the upper end of Spring Lake, due to the diversity of fishes that occur in that area. All coordination and approvals for this fishery collection procedure were obtained from Bridget Lewin, Coordinator of the Scientific Diving Program at Aquarena Center. Kelly Innterarity and Tony Bryant, volunteer research divers, accompanied me in the underwater seining operations. Gordon Linam, Fishery Biologist with the Texas Parks and Wildlife Department (TPWD), identified the fish collected, and preserved a voucher collection in 10% formalin solution for Aquarena Center to use in their educational and research programs. Endangered fountain darters were released unharmed back into the lake after identification, as were spotted gar which were too large to preserve in the polyurethane containers available. Photographs and videography were made of the collection procedure and the fish collections. Karim Aziz, also with TPWD, assisted Gordon Linam in collecting fish from the seine.

SCUBA diving equipment was worn during seining operations. We initially used a 10-foot minnow seine to maneuver through the aquatic vegetation, with the thought that this would have the least impact on the native plants. However, most of the fish were able to easily avoid capture in the net, and thus we decided to use a 25-foot bag seine following that experience.

Fishery observations were also made during diving operations to identify and photograph fish and habitat conditions in Spring Lake. These observations were used to complete the inventory and assessment. Several of the underwater photographs taken by Ray Mathews are included in this document, with some descriptions of identifying characteristics and habitat descriptions Figures 7-27.

Fishery Collection Inventory and Description for Spring Lake at Aquarena Center

Eight fish species were collected from Spring Lake (Table 1). An additional 19 species were visually identified during SCUBA diving (Table 2).

Table 1. Fish species collected in Spring Lake.

Common Name	Scientific Name
Mexican tetra (introduced)	*Astyanx mexicanus*
Roundnose minnow	*Dionda episcopa*
Western mosquitofish	*Gambusia affinis*
Largemouth bass	*Micropterus salmoides*
Redear sunfish	*Lepomis microlophus*
Spotted sunfish	*Lepomis punctatus*
Spotted gar	*Lepisosteus oculatus*
Fountain darter	*Etheostoma fonticola*

Table 2. Fish species visually identified in Spring Lake.

Common Name	Scientific Name
Longnose gar	*Lepisosteus osseus*
Blackstripe topminnow	*Fundulus notatus*
Largespring gambusia	*Gambusia geiseri*
Blacktail shiner	*Cyprinella venusta*
Texas shiner	*Notropis amabilis*
Mimic shiner	*Notropis volucellus*

Channel catfish	*Ictalurus punctatus*
Black bullhead	*Ameiurus melas*
Suckermouth catfish	*Hypostomus plecostomus*
Spotted bass	*Micropterus punctulatus*
Longear sunfish	*Lepomis megalotis*
Bluegill sunfish	*Lepomis macrochirus*
Green sunfish	*Lepomis cyanellus*
Redbreast sunfish (introduced)	*Lepomis auritus*
Rio Grande cichlid (introduced)	*Cichlasoma cyanoguttatum*
Blue tilapia (introduced)	*Tilapia aurea*
American eel	*Anguilla rostrata*
Pacu (introduced)	*Colossoma* spp.
Sailfin molly (introduced)	*Poecilia latipinna*

Species Observations and Habitat Assessment

The fishery inventory indicates a diverse fishery in this unique headwater spring-fed lake, which has clear water, numerous types of habitat, and is highly stenothermic (i.e., non-varying water temperature, 72-74 F). The constant water temperature and continuous water supply over millions of years has provided conditions for the development and evolution of aquatic species that are highly specialized to this environment. The habitat conditions at Spring Lake are pristine, although there are numerous impacts that require management by Aquarena Center staff, with oversight and assistance from professors at Texas State University, and biologists with the Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. These impacts are primarily in the form of introduced species that impact the native fishery. The most important of these impacts are from non-native invasive plant species, especially hydrilla and water hyacinth in the lake and elephant ears along the lake edges, which result in habitat alteration and loss of usable habitat for the native aquatic species of plants, fish, and salamanders.

In addition to non-native plant species, there are several introduced fish species, including blue tilapia, sailfin molly, Rio Grande cichlid, and mexican tetra. There are also several specimens of a genetically bred strain of channel catfish that have a snow white color (often mistaken for albino), and are very interesting to eco-tourist viewing these large unique fish from glass bottom boat rides.

The San Marcos River Recovery Team presently recommends that these channel catfish color morphs be allowed to finish their life cycle in Spring Lake, but not to replace them in the future. Some of the other fish species were reportedly introduced by releases of aquarium fishes into the lake and San Marcos River, which is the probable means by which the sailfin molly got to the lake. This is also the way that an invasive invertebrate species, the giant ramshorn snail, got into the lake and upper San Marcos River. It is not known how the Rio Grande cichlid and blue tilapia got in the lake, although some fishery biologists believe they may have been introduced as game fish many years ago. The Rio Grande cichlid is the only native cichlid in Texas; however, its range was historically restricted to the Rio Grande drainages until introduced into a number of spring systems in the state. There is no program in place to remove these species, although the U.S. Fish and Wildlife Service has authorized Aquarena Center to use underwater spear-guns to remove them. These species do not appear to be doing much damage to the native species, so there is no sense of urgency in removing them. However, the native largemouth bass that live in the lake have become much more prolific than when this was a much shallower headwater river, mainly because the lake habitat conditions are more adaptable for this species. Frequent observations have been made by volunteer scientific divers of bass feeding on endangered fountain darters and San Marcos salamanders when these species make brief swims away from protective habitats. The populations of these endangered species do not appear to be threatened by this situation, and therefore it is not considered a problem.

Resource Management Considerations

Aquarena Center staff has an active and important management program using volunteer scientific divers to remove introduced and invasive plants and re-plant native species. The program appears to be moderately successful, but additional control procedures may be needed for these species. These might include chemical herbicides that are being used successfully in other lakes and rivers, and which have been shown to be non-toxic to the native fishery. However, careful testing of herbicide toxicity would need to be conducted on the endangered species. The aggressive growth characteristics of the invasive species and the difficulty in managing them by mechanical means suggest that a more aggressive technique may enhance the removal of the non-native, nuisance plant species. However, progress is slowly being made in re-establishing the native species, so it may be successful over a longer period of time. The goal is to remove all the introduced plant species, and re-vegetate with native species.

Habitat Zonation of Spring Lake

There are **four major habitat regions** of the lake, based on observations of habitat features, ecological functions, and fishery distributions. There are two major arms of the lake, which consist of the original river channel, which I refer to as the western arm of the lake, and a shallow slough, which is a diverse wetland habitat forming the eastern arm of the lake. The **western arm of the lake** was the headwater portion of the San Marcos River, and is characterized by having all of the major springs, highly variable depth profiles, diverse plant life and fishes, archeological sites, and is the area where the glass bottom boat tours traverse. The spring dependent species, such as the fountain darter and San Marcos salamander are primarily found in this zone. The **eastern arm of the lake** is a shallow, mucky, slough area where a boardwalk was recently constructed over this wetland for viewing waterfowl and other bird species that make frequent use of the emergent vegetation for nesting, roosting, and foraging habitat. Numerous turtle species also use this area. This arm is formed by the inundation of Sink Creek, which has a watershed that extends well above the lake, adjacent to the golf course. A delta in the middle was formed from the dredged spoils in the construction of the submarine canyon. The average depth of the eastern arm of the lake is only about 4-feet, and much of that is a result of soil erosion in the watershed and the distribution of the sediment spoils from the submarine canyon dredging.

The lower end of the lake, which I refer to as the **lake pool area habitat zone**, is characterized by a widening of the river channel into a large pool zone, due to waters backed up by the constricted outflow at the dam. This area formed through geomorphic processes below the confluence of the eastern and western arms of the lake. This zone is characterized by slow flows and heavy vegetated areas in fine sediments. These sediments originate from the slough during storm activity, and settle in the deeper, low velocity pool zone. There are some course sediments in some areas where springs wash away the finer sediments. The **outflow channels zone** is a high velocity scouring flow habitat, with bedrock and boulder substrates in the area upstream of the dam. There are numerous microhabitats in the rocky crevices, and variable flow zones (e.g., eddies, high velocity riffles, fast runs and shoots) within the outflow channel zone. The dam structure and adjacent historic building structure that used to be the old grist mill, later an ice house, and presently a restaurant called Joe's Crab Shack, provides structural habitat that is used by the high velocity tolerant fish species. The spillway is a second component of the outflow channel zone, where velocities are slower, but still provide scouring of the variable size substrates (pebble to cobble size, some boulder) in the flow path.

The **western arm of the lake** has **four habitat sub-zones** that are distinctively different, although they overlap in some areas; which include the old river channel, nursery zone, riparian zone, and diver training area. The **old river channel sub-zone** was changed from a headwater river system to a flowing lake system by the dam. However, the native fishery has adapted well to this ecological transition, probably due to the flows that continue to move down the old river channel from the outflow of spring waters. These springs provide the base flow for the San Marcos River and a major component of the Guadalupe River as well. The original channel cut deep into this narrow watershed, with depths ranging from 10-26 feet deep in close proximity to the bank. The **riparian sub-zone** is a part of the lake adjacent to a heavily vegetated and steeply sloped bank, which provides shade habitat, food items from the trees, and allochthonous material in the form of leaves and branches that provides the biotic energy that drives this spring lake heterotrophic system. Although the original headwater stream was entirely heterotrophic, the present spring lake system has evolved in part into an autochthonous system where aquatic vegetation and phytoplankton provide primary production internally to the spring lake ecosystem. The **nursery area sub-zone** is on a shallow flat limestone plate formation at the upper end of the lake which has dense stands of rooted aquatic plants that provide important nursery habitat for the lake. Since the dam was built about 150 years ago, sediments have been accumulating in this area as a result of converting it from a flowing river to slower flowing lake environment. The **diver training area sub-zone** has more structural habitat than any other area of the lake, resulting from the boat docks, submarine theatre, and pilings. These structures provide undercut ledges, crevices, and walls that many species of fish utilize as their primary habitat. Further observations of fish distribution and behavior will result in the recognition of additional ecological habitat zones. These are the major ones that I have noticed in many years of diving Spring Lake. In review, these major ecological zones and the four sub-zones of the Western Arm of Spring Lake are outlined below, and are indicated on the map in Figure 3:

Major Habitat Zones of Spring Lake (area in feet^2/perimeter in linear feet)

	Area (ft^2)	Perimeter (linear ft)
Western Arm of Spring Lake	174,821	2,776
Sub-Zones		
a. Nursery Area	27,862	795
b. Old River Channel	66,403	1,803
c. Riparian Zone	77,530	4,456
d. Diver Training Area	88,967	1,538
1. Eastern Arm of Spring Lake	523,499	4,915
2. Lake Pool (Confluence Area)	86,978	1,371
3. Outflow Channels	185,053	2,034

The Eastern Arm of Spring Lake is three times as large as the Western Arm of Spring Lake in terms of surface area, and 1.7 times the perimeter. However, due to the shallow depth, the volume of the Western Arm is certainly greater, although we did not conduct analyses to quantify that. The nursery area is the smallest habitat sub-zone, but has the greatest density of fish due to their small size, as well as the shallow habitat, substrate with invertebrate food items, low flow, and warmer temperatures. The Lake Pool is roughly the same size as the Western Arm of Spring Lake, but only has two major springs, Rio Grande and Kettleman. The nutrients and sediment load is probably more concentrated in the Lake Pool, due to the confluence mixing of input from both the San Marcos River and Sink Creek watersheds. The Riparian Zone is generally 2-3 times the perimeter of the other habitat areas due to its configuration as a long narrow corridor along the bank, where tree canopy provides substantial shade and food items. It averages 40-feet wide, based on the reach of the branches over the water and the shade projected by them. The Outflow Channels Zone, consisting of the uncontrolled dam and spillway, are about the same size as the Western Arm of Spring Lake, and contains no major springs. This is a high fluvial energy portion of the lake, and most of the aquatic organisms there are closely associated with rock crevices or behind structure that provides shelter from high velocities.

Major Spring Habitat Descriptions

- Creator Bottoms – A headwater spring in the nursery area. 150 years of siltation since impoundment has resulted in several feet of silt over the spring vent. The silt has covered most of the nursery area, and is good in some ways, because it produces a substrate for food organisms (invertebrates).
- Salt and Pepper / Cream of Wheat – Black humus accumulates on the white gypsum sand (hydrated calcium sulfate), giving it the characteristic salt and pepper look, which may be a mineral reactive component with the gypsum, such as manganese, that is dissolved from the Edwards dolomite.
- Cobomba – Spring flows through rock fault on lake side.
- Old River Channel – Ossified quartz substratum with high calcium content and abundance of submerged tree trunks. This spring is within the old river channel, where it is narrow and deep.
- Catfish Hotel – This is a shallow spring near the bank where the old river bed begins to widen out. It was probably a dry shelf as a river, and there is a large submerged boulder on the side of bank that provides preferred habitat for channel catfish. The spring was named for an 80-pound catfish that frequently resided in the area.
- Deep Hole – The deepest spring system in the lake, at about 28 feet deep. There are several springs that make up this spring component, which are distributed in an observable “W” shape (visible due to sand fountains).
- Kettleman – Water gardening activities are an important recovery project in the area of this spring. Hydrilla must be frequently removed from this area, and native vegetation transplanted from other locations in order to provide cover for the native fish species. Coontail is a native plant species that is abundant in this area.

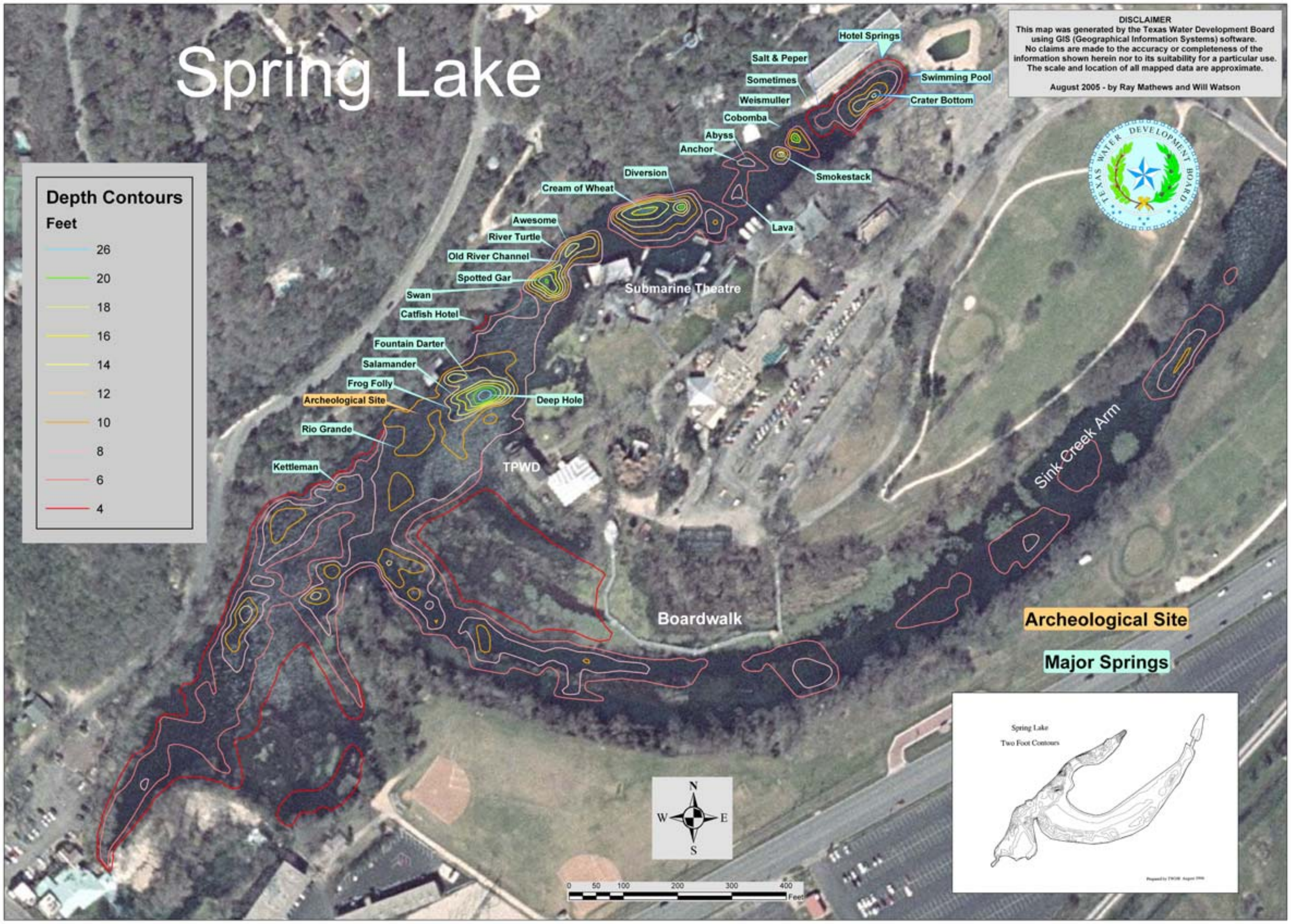

Figure 1. GPS-DOQ map of Spring Lake. Major springs and habitat features are shown with depth contours; based on hydrographic survey, depth and GPS measurements.

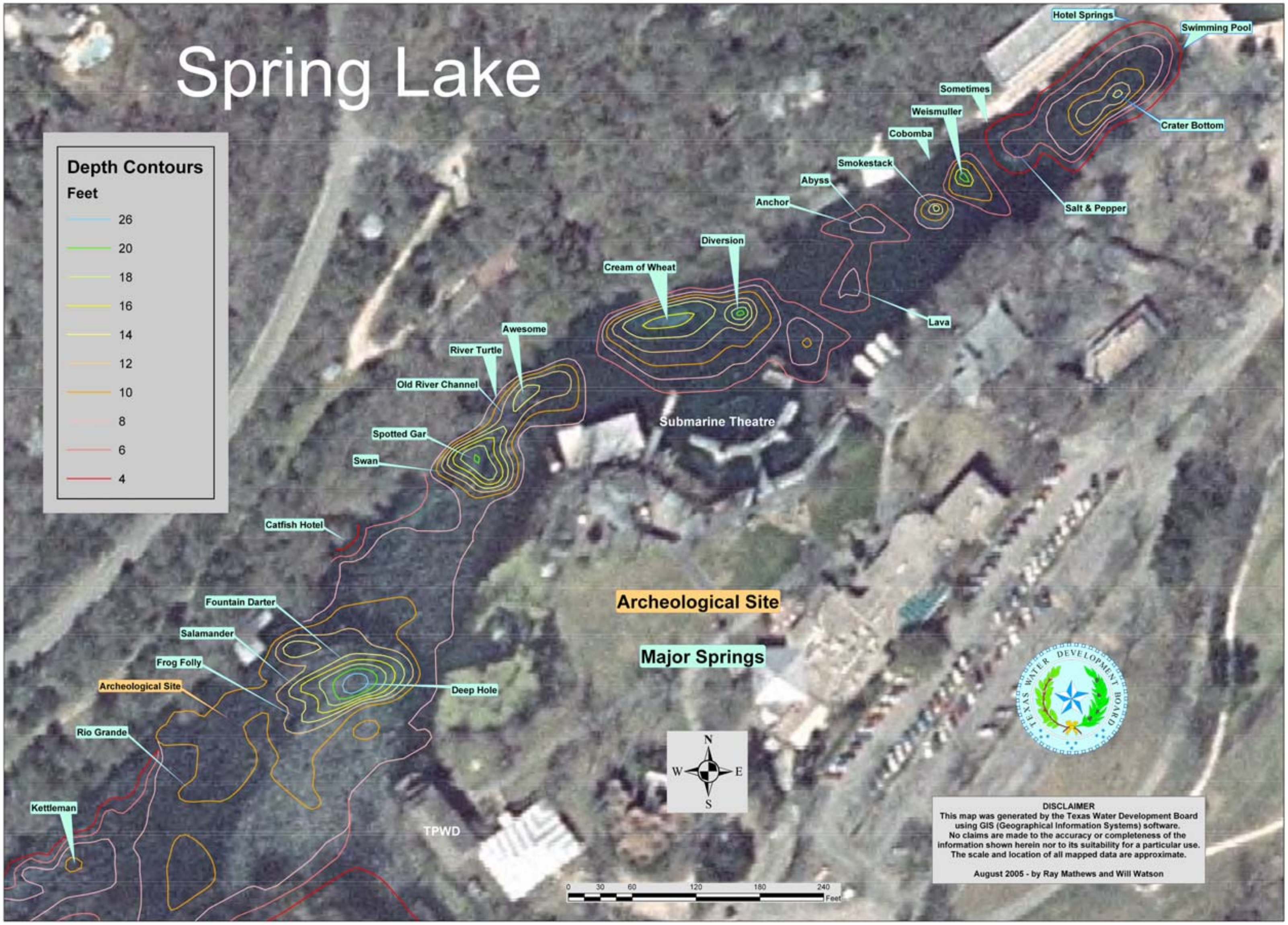

Figure 2. GPS-DOQ detail map of the Western Arm of Spring Lake, which contains all of the major springs.

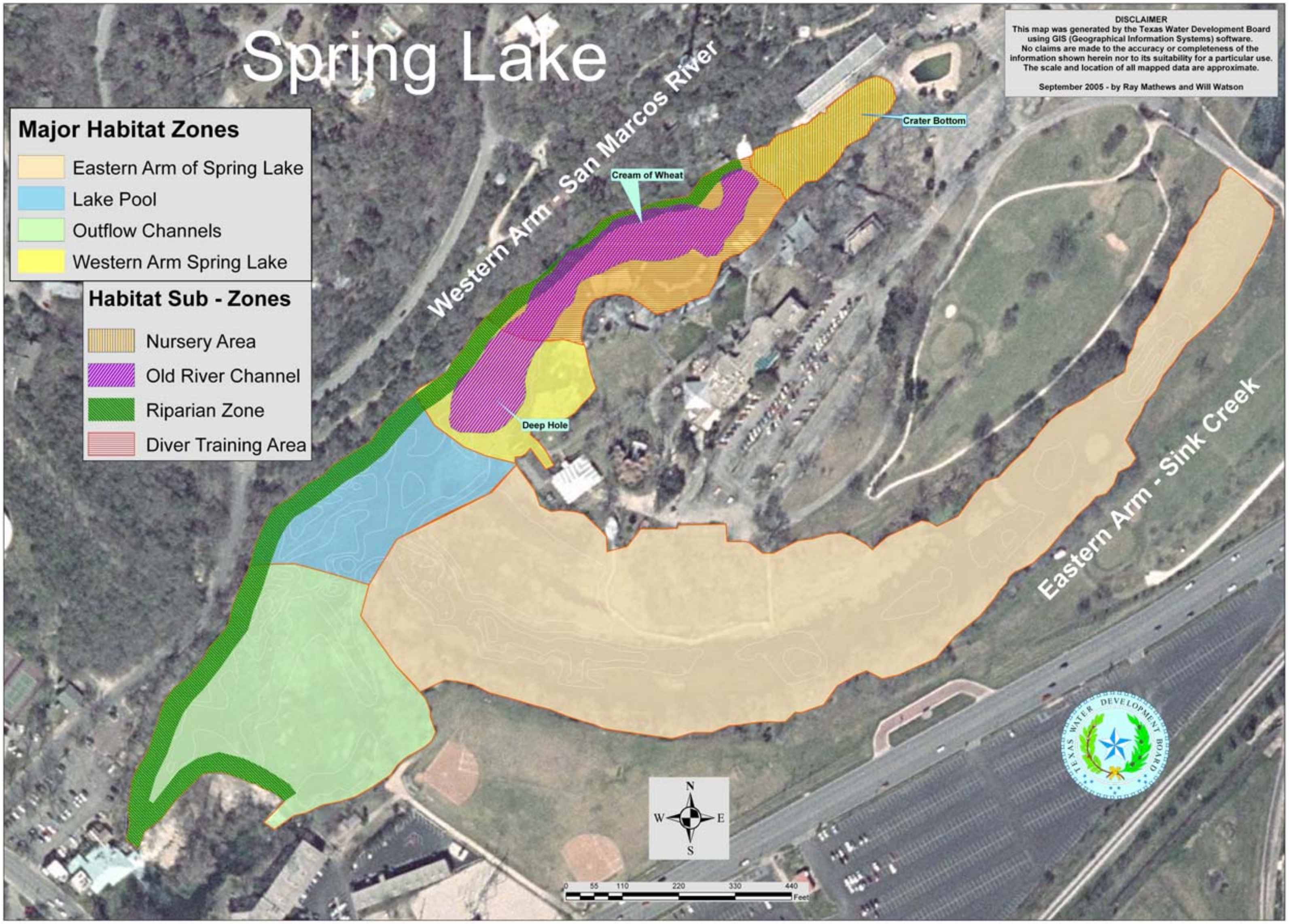

Figure 3. Major habitat zones of Spring Lake, and habitat sub-zones of the Western Arm of the lake.

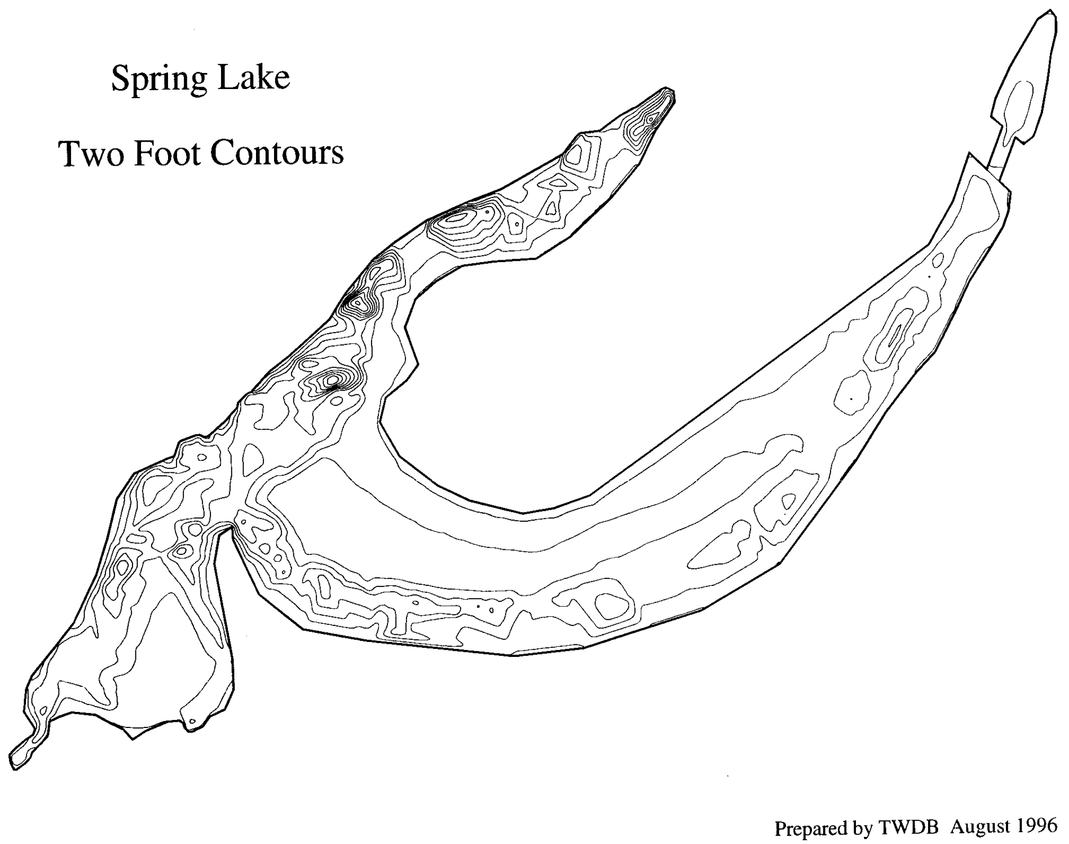

Figure 4. Bathymetric contour map of Spring Lake prepared from hydrographic survey by the Texas Water Development Board (TWDB) in 1996. The variations in depth are greatest at the upper end of the lake, where the major springs are located, and where the greatest diversity of fish and habitats were found in the lake. The outer contour is 574' msl, and the deepest contour is 561' msl, for a 13' depth differential. However, some deeper areas, such as Deep Hole that are 28.5' deep (546' msl) were not covered in this overall lake survey. The slough off to the east side of map is primarily a shallow mucky wetland that supports turtles and waterfowl.

Figure 5. Hydrographic survey boat piloted by Duane Thomas of the TWDB staff, shown maneuvering through dense Hydrilla masses to complete depth profiles for Spring Lake. Hydrilla is an introduced invasive rooted aquatic plant that can competitively exclude native vegetation. The Aquarena Center management program has made considerable progress in removing much of this plant cover and recovering native plant species.

Figure 6. Hydrographic survey of Spring Lake showing dense overstory tree canopy in riparian zone, which is important to the fishery by providing shade, allochthonous inputs of nutrients in the form of leaves, branches, stems, bark, flowers that are washed into the lake, as well as direct food items (primarily insects) that drop off of trees into the water. Streams are basically heterotrophic, with almost all of the biotic energy that drives the stream community, being dead organic matter that is derived from outside the channel. However, since the stream was dammed in 1848, it has an autochthonous energy input from primary production by phytoplankton in the lake. This has changed much of the food chain dynamics of the system.

Figure 7. Large schools of shiners and minnows in the upper portion of Spring Lake thrive in the nursery ground habitats created by this headwater spring-lake ecosystem.

Figure 8. Diverse assemblage of shiners and minnows using shallow areas with prolific vegetation that provides numerous types of microhabitats biotic niches. The fish assemblage includes the Texas, mimic, and blacktail shiners, roundnose minnow, and Mexican tetra.

Figure 9. Topwater minnows include the western mosquitofish, blackstripe topminnow, and largespring gambusia.

These species feed on the organic material that collects on the surface and phytoplankton in the upper water column.

Figure 10. Top left: Small minnow seine being checked for fish collections. Top right: Pulling net onto dock with fish. Bottom: Large bag seine being pulled up to remove fish collected and identified by Gordon Linam (striped sweater).

Figure 11. Series of underwater seining operations with bag seine to collect fish at the upper end of Spring Lake. Ray Mathews and Tony Bryant pulled seine through several areas to collect smaller fishes, which require identification by topside evaluation of diagnostic characteristics.

Figure 12. Largemouth bass use the dense stands of aquatic vegetation for cover and ambush shelter seek out their prey and forage on the schooling shiners and small sunfish.

Figure 13. Redbreast sunfish and largemouth bass actively forage around rocks and native vegetation. These species are the top predators in Spring Lake.

Figure 14. Redear sunfish were observed near edges of coontail vegetation, and are also predators on the shiners and minnows. The red edge on the black ear-flap and pointed pectoral fin are clearly visible diagnostic characteristics for identification of this species.

Figure 15. Redear sunfish frequent areas of dense vegetation at moderate depths of Spring Lake.

Figure 16. Rio Grande cichlids are the only native cichlid in the United States. Originally restricted to extreme south Texas in the Rio Grande basin, they have now become resident in many spring systems throughout the Edwards Plateau. We noted numerous fungal outbreaks on this species, reportedly because of the cool temperatures in Spring Lake are stressful to Rio Grande cichlids and make them vulnerable to fungal infections.

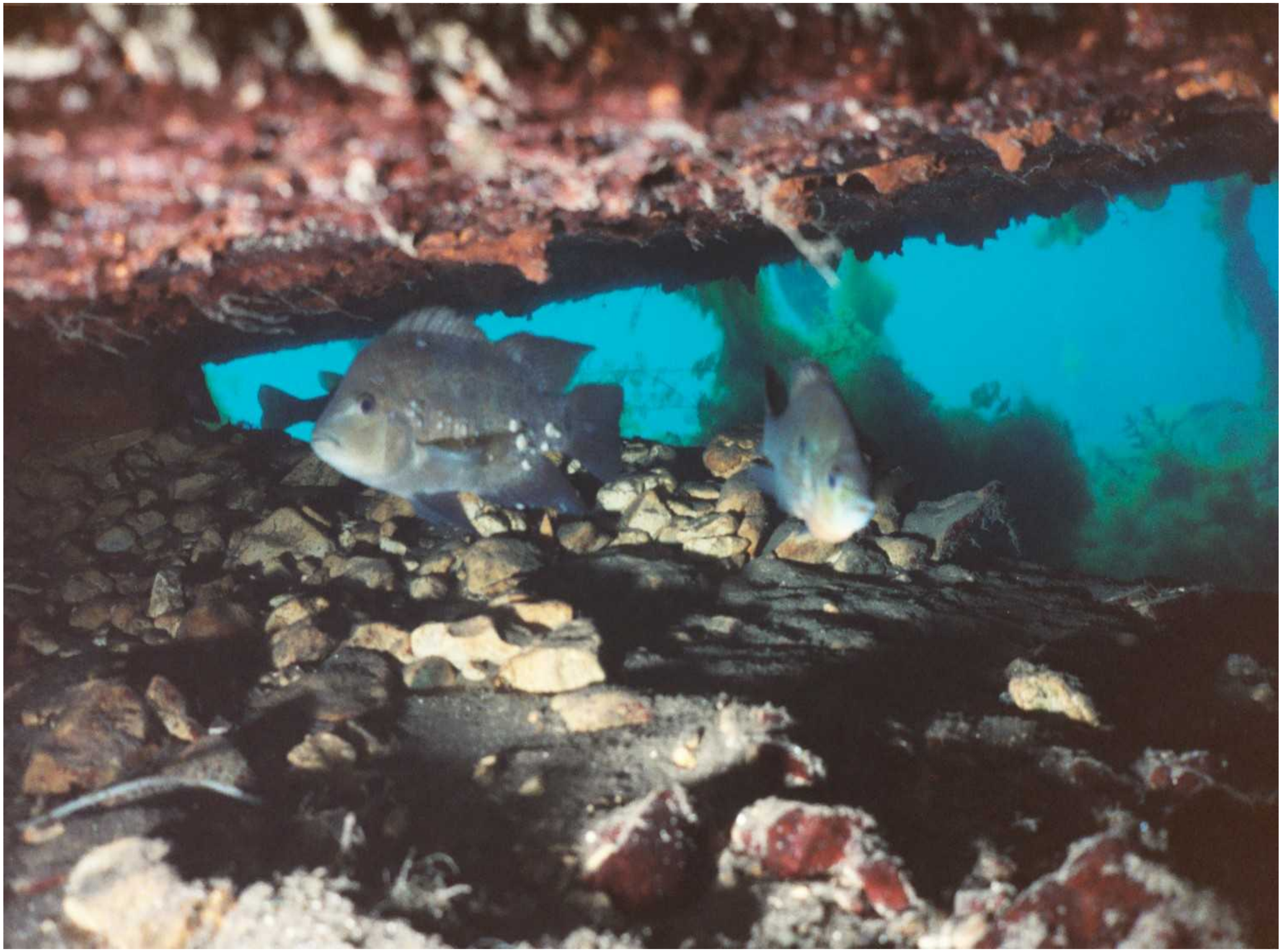

Figure 17. Rio Grande cichlids spend much of their time in dark habitats, such as over this rocky substrate located below the diving pier at Spring Lake.

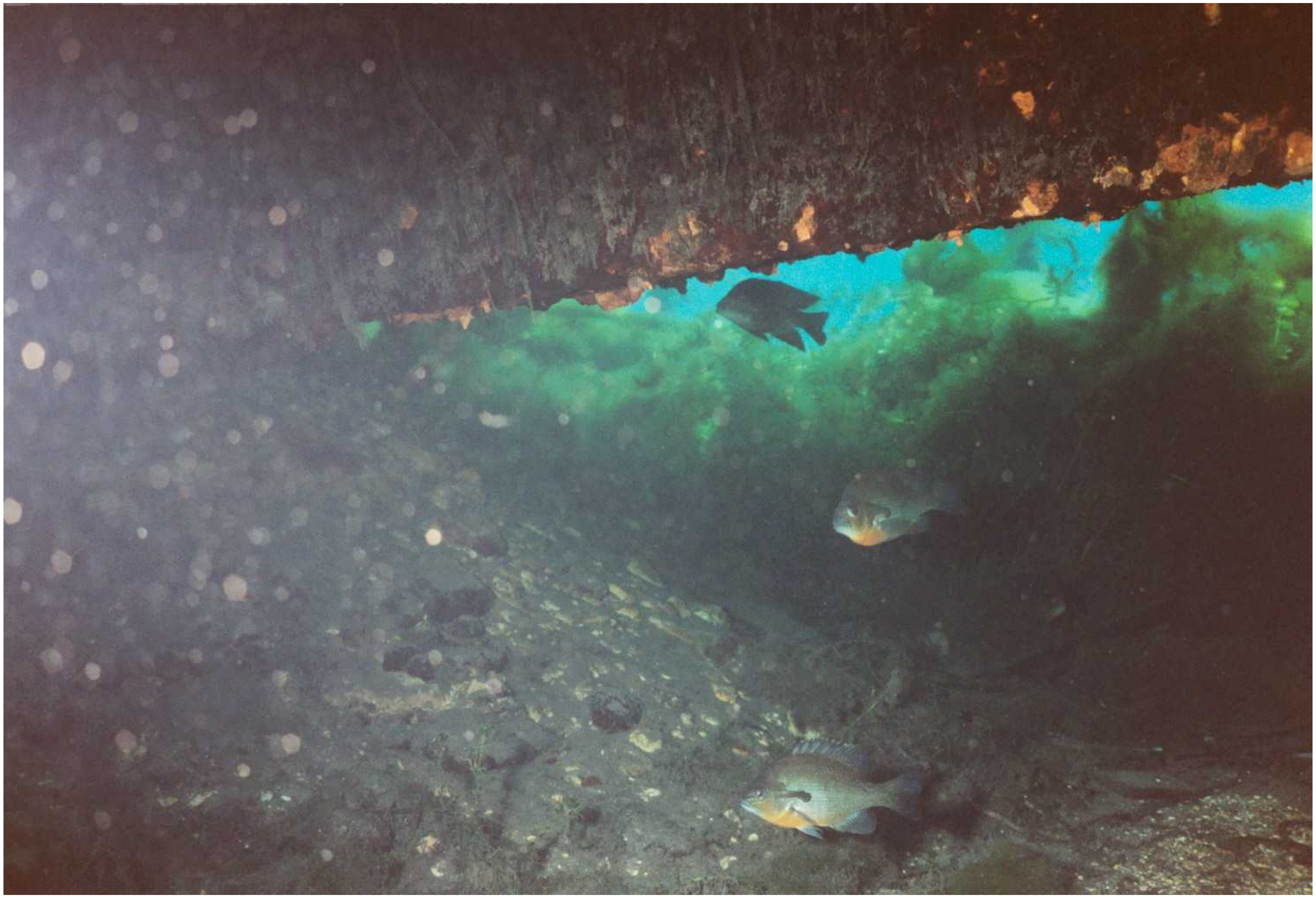

Figure 18. Redbreast sunfish and blue tilapia. Blue tilapia are native to Senegal, middle Niger, Benue River, Chad, lower Nile, and Jordan River system. It is an introduced species to Spring Lake, and is in the same family, Perciformes, as the Rio Grande cichlid. Their behavior and preferred habitats are similar because of their close relationship.

Figure 19. This white color morph of the native channel catfish was genetically bred for this color. Due to the genetic breeding, it is sterile, and present recommendations from the San Marcos Recovery Team call for allowing these color morphs to live out their life cycle, but not to replace them. Channel catfish are native throughout Texas, and the natural color varieties also exist in Spring Lake.

Figure 20. Largemouth bass patrol deep valleys of the lake provided by dense stands of aquatic vegetation. Green algae blooms frequently occur in the summer due to the clear water and ample sunlight penetration.

Figure 21. Fountains of sand occur where artesian spring flow pushes sand up into the water column, and this habitat is sometimes used by the endangered fountain darter, for which it was named.

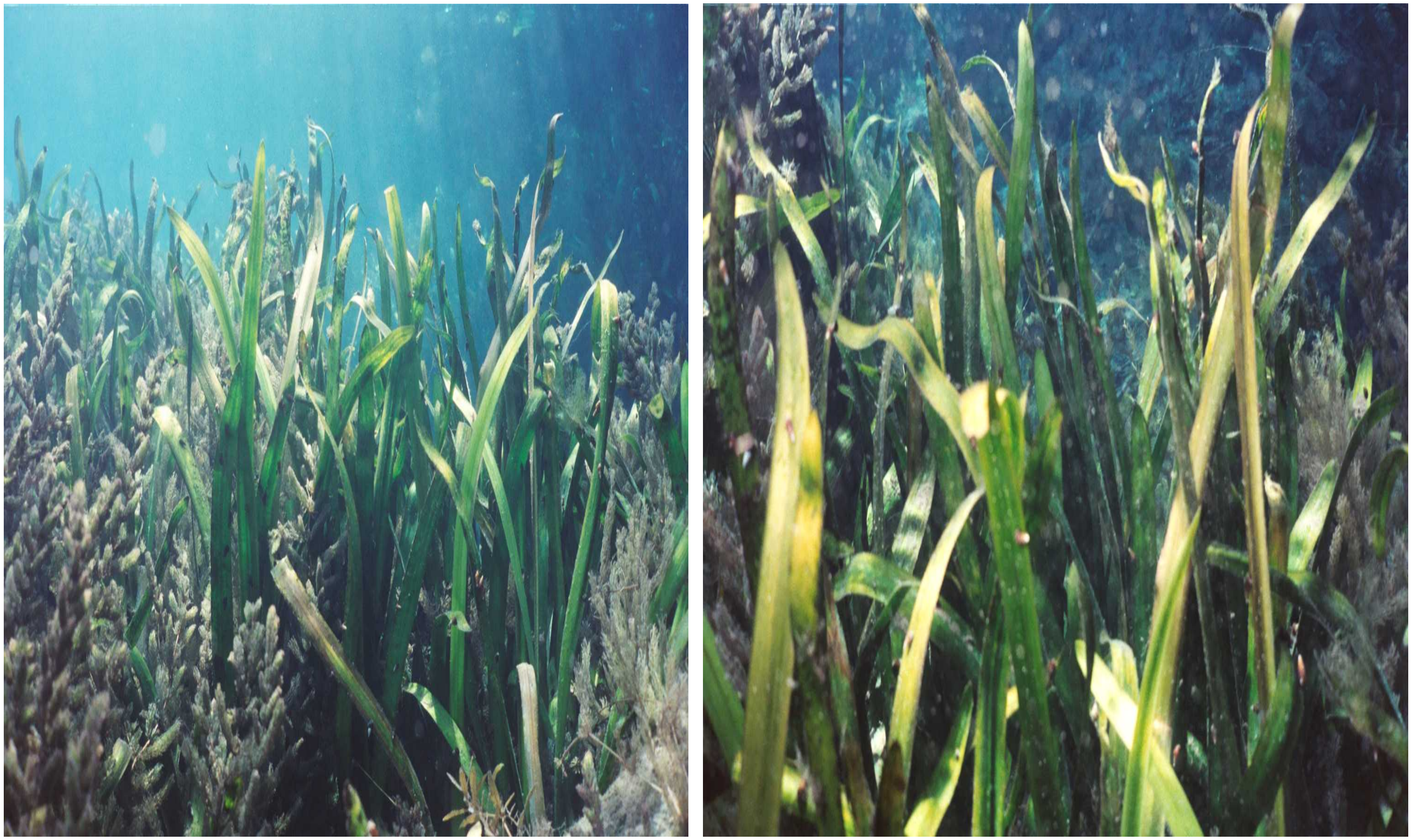

Figure 22. Broad-leaf aquatic vegetation provides egg-laying habitat for species such as the endangered Fountain darter. The introduced giant ramshorn snail, as seen on these leaves, forages on the surface of these leaves and often ingests attached fish eggs. The Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service have a management program designed to remove these snails and educate people on the perils of emptying their aquariums in the lake. Most people are unaware of the impacts they cause by releasing non-native aquarium life into waters where they have no predators. The result is often that species such as these proliferate out of control, and cause extensive damage to habitats and native species.

Figure 23. Flowering Cobomba are seen during the summer, but Hydrilla often covers native vegetation. This results in habitat loss for fishes that avoid Hydrilla stands. Eventually, the introduced Hydrilla excludes the native vegetation because of its rapid growth, lack of predators, and expansive coverage that reduces light penetration and reproduction.

Figure 24. Coontail is a native vegetation, which is an important aquatic habitat in Spring Lake for both protective cover by small prey species and use by ambush predators.

Figure 25. Extensive stands of aquatic vegetation provide microhabitats in Spring Lake, which accounts for the diverse fishery. Fish tend to use every available habitat in this stable ecosystem, and develop a nice that provides for their long-term survival.

Figure 26. Endangered fountain darter. This species was named after the spring fountains that this is sometimes associated with. Though rare overall, they are abundant in Spring Lake, which is an indication that this is a healthy ecosystem for this species.

Figure 27. Threatened San Marcos salamanders frequent gravel, pebble, cobble size substrates. This species is also thriving very well in Spring Lake, further indicating a healthy ecosystem.

Figure 28. Endangered Texas wild rice is found only in Spring Lake and the San Marcos River below the dam, and in Comal Springs in New Braunfils. Picture from Aquarena Center web site at the following address: http://www.continuing-ed.swt.edu/aquarena/

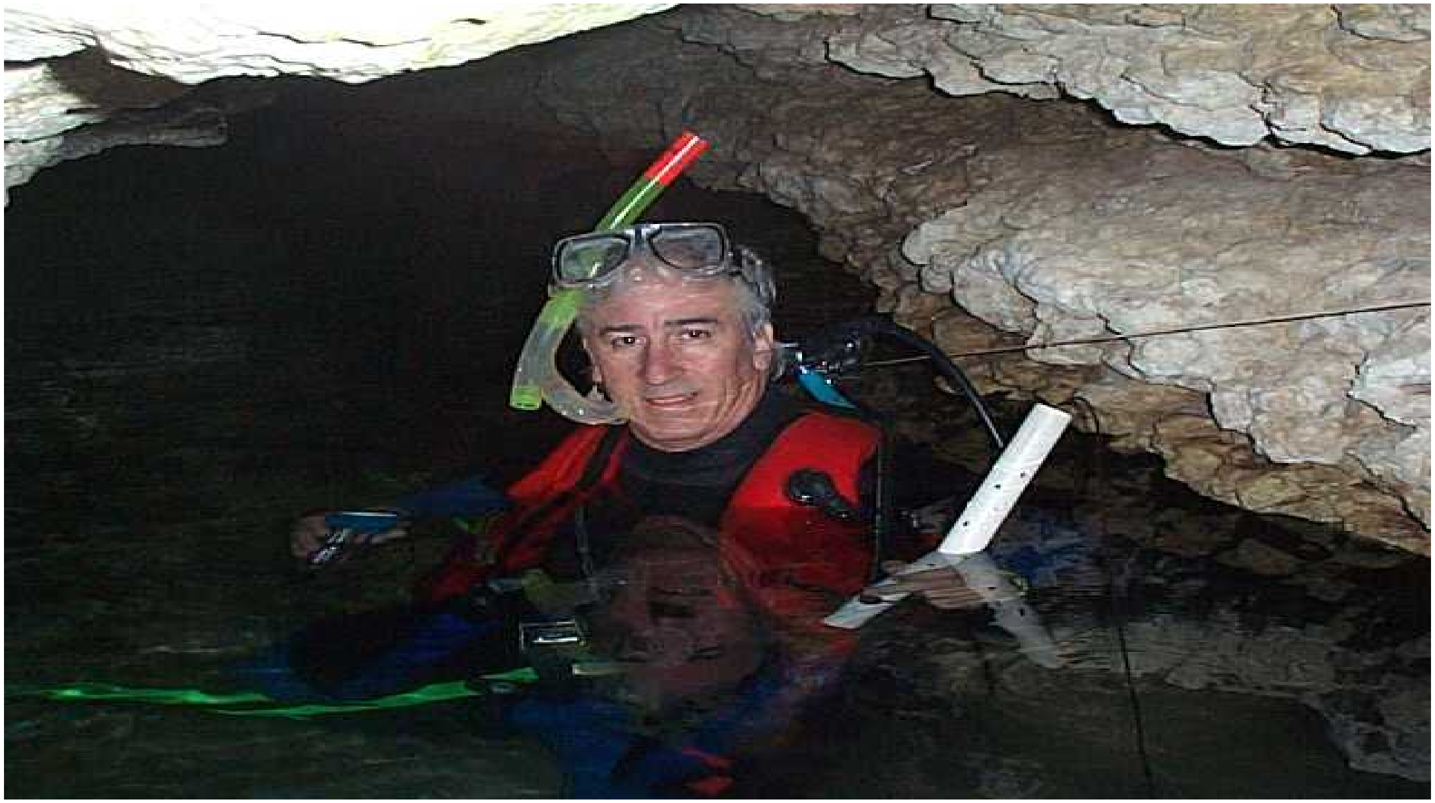

Figure 29. Ray Mathews in Texas cave dive study. Aquifer waters that provide for spring-flows are an important consideration in managing Spring Lake. There have been numerous drought periods when spring flow has been greatly reduced by low groundwater levels in the Edwards Aquifer, indicating the vulnerability of this pristine, yet potentially fragile ecosystem.

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