Turtle survey of Weeki Wachee Springs State Park reveals more than mermaids

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Abstract. During a survey of turtles in Weeki Wachee Springs State Park, Florida, USA, in March 2015, 182 turtles representing ten species were captured, marked, and released, including the Florida Softshell Turtle (Apalone ferox), North American Snapping Turtle (Chelydra serpentina), Florida Chicken Turtle (Deirochelys reticularia chrysea), Striped Mud Turtle (Kinosternon baurii), Suwannee Cooter (Pseudemys concinna suwanniensis), Florida Red-bellied Cooter (P. nelsoni), Peninsula Cooter (P. peninsularis), Loggerhead Musk Turtle (Sternotherus minor minor), Common Musk Turtle (S. odoratus), and Pond Slider (Trachemys scripta). Two subspecies of T. scripta (Red-eared Slider, T. s. elegans, and Yellow-bellied Slider, T. s. scripta) were captured, and both are new county records. The most abundant species was S. odoratus with 101 individuals captured and a relative abundance of 0.555. Among the three Pseudemys species, the presence of P. c. suwanniensis is important because it is currently listed as a species of special concern in Florida. Weeki Wachee Springs had the highest species richness (ten species) and the highest overall diversity (H’ = 1.33) of turtles among Florida spring-fed lotic habitats that have been surveyed over the past thirty years.

Keywords: Florida, freshwater springs, mermaids, Pseudemys, Sternotherus, Trachemys

Introduction

The state of Florida has over 600 freshwater springs, the largest concentration of this particular habitat type in the world (FitzPatrick, 2010; Florida Department of Environmental Protection [FDEP], 2014). These unique and beautiful habitats have been revered, worshiped, explored, and enjoyed by people visiting or inhabiting Florida for over 10,000 years (Scott et al., 2004; Stamm, 2008). In addition, Florida’s freshwater springs offer essential and, at times, critical habitat for many freshwater organisms, such as rare Cave Crayfish (Procambarus sp.) and the endangered West Indian Manatee (Trichechus manatus) (Florida Springs Task Force, 2000). Today, many of these sites are under state protection as part of Florida’s extensive, nationally renowned, and award winning state park system. The Florida State Park and Trail System is the first state park system in the United States to receive a Gold Medal Award three times (FDEP, 2013). As part of the state system, these parks contribute to Florida’s economy and provide recreational opportunities, such as swimming, canoeing, and wildlife watching for millions of people every year (Stamm, 2008).

Weeki Wachee Springs State Park is located in Hernando County, Florida just off of U.S. Highway 19, approximately 115 km north of Tampa Bay, Florida (Fig. 1). The name Weeki Wachee is derived from the
Weeki Wachee Springs State Park is located in Hernando County, Florida, just off of U.S. Highway 19, approximately 115 km north of Tampa Bay, Florida. The spring opens into a 0.5-ha lagoon that drains into a 19-km long spring run. Map created using Esri’s ArcGIS Version 10.3.1; data obtained from Esri Data Products, Southwest Florida Water Management District imagery (www.swfwmd.state.fl.us), U.S. Department of Commerce, U.S. Census Bureau, Geography Division, 2011 Florida Roads Census MAF / TIGER / Line data, and U.S. Geological Survey National Hydrography Dataset (www.datagateway.nrcs.usda.gov).

language of the Seminole Tribe and means “little spring” or “winding river” (FitzPatrick, 2010). The spring is located in a karst environment with an upper quartz sand and residual clay layer formed during the recent Pliocene Epoch, and a lower layer primarily composed of microfossiliferous carbonate and dolomitic-limestone interspersed with intergranular evaporates that was formed during the Eocene Epoch (Hill et al., 2010).

Weeki Wachee Springs is a first magnitude spring that expels more than 430 million litres of crystal clear water per day at a constant temperature of 23°C. The current in this spring run has been documented at over 8 km/h (FitzPatrick, 2010). The basin of the spring boil is over 30 m wide, but the actual depth of the spring cavern leading to the Upper Floridan aquifer system is still unknown (Scott et al., 2004; FitzPatrick, 2010). The spring opens into a 0.5-ha lagoon that winds down into a 19-km long spring run that, within the park, is surrounded by low-lying densely forested swamp, and which outside of the park boundary becomes more urban with housing developments occurring on either bank. The run eventually empties into the Gulf of Mexico (Scott et al., 2004).

Weeki Wachee Springs has a rich and unique history. In 1946 the site was purchased by Newton Perry, a former member of the U.S. Navy, who trained Navy Seals to swim underwater (FitzPatrick, 2010). Perry restored the spring habitat and installed underwater breathing tubes with free-flowing air. He then built the first 18-seat theatre at the spring boil that was situated nearly 2 m below the water’s surface so the public could view the natural beauty of the spring. Shortly thereafter, he began training young women to swim and perform aquatic ballets and other underwater exercises while using the hidden breathing tubes. The first actual “mermaid” show at Weeki Wachee Springs opened on 13 October 1947. The site and show became a huge hit and the spring was purchased by the American Broadcasting Company (ABC) in 1959 (FitzPatrick, 2010). ABC built the current underwater amphitheatre that seats over 400 people, and the company helped develop themes for underwater shows. An estimated one million people per
year visited during the park’s heyday in the 1950s. In 1982, a water park called Buccaneer Bay, with a large sandy beach and swimming area, was added down from the springhead at the opening of the Weeki Wachee River. In November 2008, Weeki Wachee Springs was purchased by the State of Florida and became one of the newest state parks (FitzPatrick, 2010). Although attendance is down considerably from the 1950s, the average number of visitors is still estimated to be over 390,000 people per year since becoming a state park (Park Manager Toby Brewer, pers. comm.).

Anthropogenic inputs have caused an increase in nitrate concentrations by over 1000% during the last 40 years. While \( \text{NO}_3 \) concentrations have increased from 0.07 mg/l in 1974 to approximately 0.90 mg/l in 2013, there was no significant increase in either orthophosphates (inorganic phosphates typically used in fertilisers, including \( \text{PO}_4^{3-} \), \( \text{HPO}_4^{3-} \), and \( \text{H}_2\text{PO}_4^{2-} \)) or total phosphates (TP; orthophosphates; organic phosphates found in human/animal faecal matter, as well as naturally decaying organic matter; and condensed phosphates, such as water additives of \( \text{P}_2\text{O}_{10}^{5-} \) to prevent scaling and corrosion) (Scott et al., 2004; Johnson et al., 2007; FDEP, 2014). Additional changes in the spring system include a 75% reduction in native submerged aquatic vegetation throughout the Weeki Wachee River (Frazer et al., 2006). By 2008, algal mats of invasive \( \text{Lyngbya} \ \text{wollei} \), a filamentous cyanobacterium, had caused a significant decrease in native submerged aquatic vegetation, prompting the Southwest Florida Water Management District to begin a management plan that included the removal of algal mats and excess sediment with plans to replant native vegetation in the main spring area (FDEP, 2014).

Turtles are among the most conspicuous and ecologically important components of spring ecosystems in Florida (Meylan et al., 1992; Lagueux et al., 1995; Jackson and Walker, 1997; Hrychyshyn, 2006; Chapin and Meylan, 2011; Munscher et al., 2015a, b; Johnston et al., 2016). Ease of capture while snorkelling in clear water coupled with the ease of long-term identification through a unique marking system on their shells makes turtles ideal candidates for monitoring in this type of ecosystem. Because of the diverse diets and habitat requirements of different species in turtle assemblages (Meylan, 2006), turtle populations may serve as indicators of ecosystem health and stability. Thus, documenting their numbers may serve as a barometer not only for turtle species, but for a host of other species existing within the ecosystem as well.

Little is known about the turtle populations inhabiting the Weeki Wachee River. Enge and Wood (2000) captured Florida Chicken Turtles (\( \text{Deirochelys reticularia} \ \text{chrysea} \)), Striped Mud Turtles (\( \text{Kinosternon baurii} \)), Florida Mud Turtles (\( \text{K. steindachneri} \)), and Eastern Musk Turtles (\( \text{Sternotherus odoratus} \)) in drift fence arrays in wetlands approximately 4 km north of the Weeki Wachee River. Ballou et al. (2015, 2016) conducted a basking turtle survey in the Weeki Wachee River and documented the occurrence of Suwannee Cooters (\( \text{Pseudemys concinna} \ \text{suwanniensis} \)), Peninsula Cooters (\( \text{P. peninsularis} \)), and Florida Red-bellied Cooters (\( \text{P. nelsoni} \)). In March 2015, the Turtle Survival Alliance North American Freshwater Turtle Research Group (TSA-NAFTRG) added Weeki Wachee Springs to its list of study sites. The TSA-NAFTRG has been conducting turtle population assessments for the past
19 years in other Florida spring locations including Wekiwa Springs State Park (Munscher et al., 2015a, b; Walde et al., 2016), Volusia Blue Spring (Riedle et al., 2016; Walde et al., 2016), Peacock Springs (Walde et al., 2016), and Manatee Springs (Walde et al., 2016). To our knowledge, no previous turtle population research involving the capture and marking of freshwater turtles has ever been conducted in the park, or the Weeki Wachee River. TSA-NAFTRG’s goal was to conduct an initial survey of the Weeki Wachee Springs boil, lagoon, and as much of the spring run as possible, with a focus on turtle species richness and relative abundance, and to put this in context of other spring systems throughout the state. This survey is intended to provide a baseline to which future surveys may be compared.

**Materials and Methods**

We surveyed Weeki Wachee Springs from 25–27 March 2015. Twelve divers were in the spring from 0700–0900 h before the park opened to the public. The Mermaid Lagoon, Buccaneer Bay, and the Water Park Lagoon were surveyed first (Figs. 1, 2), followed by approximately 4.8 km of the spring run. Two capture sessions, from 0800–1000 h and 1800–2000 h, were conducted each day. Researchers have time limitations to be in the water due to daily mermaid shows and boat tours that begin at 1100 h and run on the hour, every hour. All turtles were captured by hand, placed in kayaks or canoes, and brought to a central location in the spring run, where they were processed and released as close to their point of capture as possible (Fig. 3). *Trachemys scripta* is not native to this region of Florida and the

**Figure 3.** All turtles were captured by hand, placed in kayaks and canoes and brought to a central location in the spring run, where they were processed and released as close to their point of capture as possible. Shown here, a volunteer with a haul of turtles, including several species of *Pseudemys* and some *Sternotherus odoratus* captured in the Mermaid Lagoon. Photo by Jessy Wayles.
Florida Fish and Wildlife Conservation Commission requires us to remove invasive Red-eared Sliders (*T. s. elegans*), but release Yellow-bellied Sliders (*T. s. scripta*).

Turtles were measured with tree callipers to obtain straight-line measurements of maximum carapace length (CL), maximum plastron length (PL), carapace width (CW), and shell height (SH), recorded to the nearest mm. Turtles were then sexed based on secondary sexual characteristics, such as tail and claw length (Ernst and Lovich, 2009). Unique identifying features, such as damage, scars, or colouration, were noted and photographed for each turtle and will aid in confirming identity during future surveys. All turtles were weighed to the nearest g using Ohaus top-loading scales (Ohaus, Parsippany, New Jersey, USA) or to the nearest 50 g for turtles over 5 kg using Pesola spring scales (Pesola AG, Schindellegi, Switzerland). The carapace of each turtle was marked by filing a unique notching pattern, a variation of the technique described by Cagle (1939).

All captured turtles with CL > 70 mm were injected with a passive integrated transponder (PIT) tag (Biomark, Boise, Idaho, USA). PIT tags were inserted under the right bridge of the shell, anterior to the right rear leg. This area is considered an acceptable site for PIT tag retention (Runyan and Meylan, 2005). PIT tag insertion methods were described in greater detail by Munscher et al. (2015a). Capture and handling protocols were approved by FDEP (District III, Orlando, Florida) and conform to those promulgated by the American Society of Ichthyologists and Herpetologists (ASIH), the Herpetologists League, and the Society for the Study of Amphibians and Reptiles animal use guidelines (ASIH, 2004).

We counted the number of species captured to determine species richness and calculated relative abundance (RA) of each species by determining the proportion of each species relative to the total number of individual turtles captured. We calculated a natural log Shannon Index (H’) to describe diversity and Equitability (J’) to estimate heterogeneity. Taxonomy follows the Turtle Taxonomy Working Group (2017).

### Results

We captured and processed a total of 182 turtles representing ten species and 11 taxa at Weeki Wachee Springs State Park (Table 1). Two taxa constitute new records for Hernando County according to records of the Florida Museum of Natural History (FLMNH). Photographic vouchers were submitted to the FLMNH to be catalogued. New records include one *T. s. scripta* (FLMNH 175364) and one *T. s. elegans* (FLMNH 175366). The most frequently captured species was

### Table 1

<table>
<thead>
<tr>
<th>Species</th>
<th>Weeki Wachee Springs</th>
<th>Rainbow Run</th>
<th>Ichetucknee River</th>
<th>Volusia Blue Spring</th>
<th>Santa Fe River</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Apalone ferox</em></td>
<td>4 (0.022)</td>
<td>1 (0.002)</td>
<td>1 (0.003)</td>
<td>3 (0.006)</td>
<td>3 (0.003)</td>
</tr>
<tr>
<td><em>Chelydra serpentina</em></td>
<td>2 (0.011)</td>
<td>0 (0.0)</td>
<td>4 (0.01)</td>
<td>6 (0.011)</td>
<td>30 (0.027)</td>
</tr>
<tr>
<td><em>Chrysemys picta</em>¹</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (0.002)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td><em>Deirochelys reticularia</em></td>
<td>1 (0.006)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td><em>Graptemys pseudogeographica</em></td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (0.002)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td><em>Kinosternon baurii</em></td>
<td>1 (0.006)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>1 (0.002)</td>
<td>4 (0.004)</td>
</tr>
<tr>
<td><em>Macrochelys suwanniensis</em></td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>9 (0.008)</td>
</tr>
<tr>
<td><em>Pseudemys nelsoni</em></td>
<td>20 (0.11)</td>
<td>1 (0.002)</td>
<td>3 (0.008)</td>
<td>63 (0.116)</td>
<td>17 (0.016)</td>
</tr>
<tr>
<td><em>Pseudemys peninsularis</em></td>
<td>41 (0.225)</td>
<td>15 (0.034)</td>
<td>0 (0.0)</td>
<td>214 (0.395)</td>
<td>18 (0.016)</td>
</tr>
<tr>
<td><em>Pseudemys concinna suwanniensis</em></td>
<td>8 (0.044)</td>
<td>22 (0.05)</td>
<td>79 (0.2)</td>
<td>0 (0.0)</td>
<td>625 (0.570)</td>
</tr>
<tr>
<td><em>Sternotherus minor</em></td>
<td>2 (0.011)</td>
<td>294 (0.662)</td>
<td>222 (0.566)</td>
<td>230 (0.424)</td>
<td>228 (0.208)</td>
</tr>
<tr>
<td><em>Sternotherus odoratus</em></td>
<td>101 (0.555)</td>
<td>111 (0.25)</td>
<td>19 (0.048)</td>
<td>5 (0.009)</td>
<td>2 (0.002)</td>
</tr>
<tr>
<td><em>Trachemys scripta</em></td>
<td>2 (0.011)²</td>
<td>0 (0.0)</td>
<td>60 (0.153)</td>
<td>18 (0.033)²</td>
<td>160 (0.146)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>182</strong></td>
<td><strong>444</strong></td>
<td><strong>388</strong></td>
<td><strong>542</strong></td>
<td><strong>1096</strong></td>
</tr>
</tbody>
</table>

1 Species not native to Florida

2 Individuals collected outside of their native ranges
S. odoratus \((n = 101, \text{RA} = 0.555)\) followed by \(P. peninsularis\) \((n = 41, \text{RA} = 0.225)\) and \(P. nelsoni\) \((n = 20, \text{RA} = 0.11)\) (Table 1). Species richness was 10, the Shannon Index \((H')\) was 1.33, and Equitability \((J')\) was 0.5786 (Table 2).

### Discussion

At Weeki Wachee Springs State Park, the most abundant large river turtle was \(P. peninsularis\), next was \(P. nelsoni\), and third was \(P. c. suwanniensis\). Both \(P. peninsularis\) and \(P. nelsoni\) are considered common within their ranges (Jackson, 2006; Thomas and Jansen, 2006), whereas \(P. c. suwanniensis\) has been a species of special concern in Florida for many years and has suffered population declines (Carr, 1940; Heinrich et al., 2010, 2015). Interestingly, Carr (1940) observed that \(P. nelsoni\) “are rarely found in numbers where \(S. floridana\) (= \(P. peninsularis\) and \(P. c. suwanniensis\)) is abundant,” which is contrary to our findings in this diverse spring habitat. All three \(Pseudemys\) species \(\left(P. c. suwanniensis, P. nelsoni, P. peninsularis\right)\) occur together in the Santa Fe River (north of Gainesville), Ichetucknee River (northwest of Gainesville), and Rainbow Run (~120 km north of Tampa Bay) (Meylan et al., 1992; Chapin and Meylan, 2011; Johnston et al., 2016). Published data on relative abundances of these species in these locations differ from those observed at Weeki Wachee. Of note is that each spring system seems to have a dominant \(Pseudemys\) and \(Sternotherus\) species.

One interesting result of this survey was that the most frequently captured turtle was \(S. odoratus\), a species that is often captured in low numbers at other freshwater spring sites in Florida (Marchand, 1942; Chapin and Meylan, 2011; Munscher et al., 2015a, c). The relative abundance for this species at Weeki Wachee Springs was 0.555. In comparison, relative abundance for \(S. odoratus\) in other habitats ranges from 0.002 in Santa Fe River to 0.25 in Rainbow Run (Table 2) (Meylan et al. 1992; Johnston et al. 2016). The highest reported density of \(S. odoratus\) in a Florida spring run is 106 turtles/ha in Rainbow Run (Meylan et al., 1992), but this species is consistently less abundant than the congeneric Loggerhead Musk Turtle \((S. minor minor)\) at study sites where the two species co-occur (Carr, 1940; Meylan et al., 1992; Chapin and Meylan, 2011; Munscher et al., 2015c; Johnston et al., 2016). Relative abundance for \(S. m. minor\) at Weeki Wachee Springs was 0.011, while at our comparison sites relative abundance ranged from 0.280–0.662 (Table 1). Munscher et al. (2015c) suggested that \(S. odoratus\) was unable to compete with the larger, more aggressive \(S. m. minor\), and as such is typically found in reduced numbers or pushed to marginal habitat. Weeki Wachee Springs is near the southern boundary of the known range of \(S. m. minor\). We captured only two \(S. m. minor\) during this initial sampling session, suggesting that the habitat here is not favourable for this species.

Weeki Wachee Springs has a rich freshwater turtle fauna. We were able to document the presence of nine of the ten freshwater turtle species whose native geographic ranges include Weeki Wachee Springs (Krysko et al., 2011). We failed to find the Florida Mud Turtle \((K. steindachneri)\) during this initial survey, but this was expected. Springs are not considered a preferred habitat type for this turtle (Carr, 1952; Ashton and Ashton, 1985; Meshaka and Gibbons, 2006), and we have never found \(K. steindachneri\) in any Florida spring system during our 17 years of surveys. In addition, \(T. s. scripta\) is native to Florida.
Florida, but not native as far south as Hernando County (Krysko et al., 2011). It should therefore be considered introduced at Weeki Wachee Springs. However, given that this taxon is native to Florida, we did not remove it from the spring system. All non-native species, including the new county record for *T. s. elegans*, were removed from the site in accordance with Rule 68-5.001 (Florida Administrative Code).

The species composition and relative abundances (RA) of each species (Table 1) as well as the diversity (H') and equitability (J') indices (Table 2) provided us with data to compare the Weeki Wachee Springs turtle assemblage against published data from similar assemblages. We used data presented by Meylan et al. (1992), Chapin and Meylan (2011), Johnston et al. (2016) and Riedle et al. (2016) to calculate H' and J' for Rainbow Run, Ichetucknee Springs, Santa Fe River and Volusia Blue Spring, respectively. Species richness, H' and J' were similar among sites (Table 2). Weeki Wachee Springs and Volusia Blue Spring had the highest species richness; however, species richness for both of these systems was inflated by the presence of one non-native species at Weeki Wachee Springs and three non-native species at Volusia Blue Spring. Weeki Wachee had the highest diversity of native species (n = 9) (Table 2).

Clearly, more than mermaids inhabit this iconic habitat of Florida. The existence of a diverse turtle fauna in Weeki Wachee Springs shows that this spring system provides quality habitat for turtles despite its many historic uses. We plan to continue conducting surveys twice annually with the goal of marking enough turtles to allow for accurate population estimates and to monitor turtle populations here over time. Using our baseline parameters (species richness, RA, H', and J') and subsequent monitoring, we will be able to evaluate whether continued urbanisation, eutrophication, or water loss have long-term effects on this diverse spring system.

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**References**


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Accepted by Hinrich Kaiser