DISTRIBUTION OF THE BLUEFIN KILLIFISH *LUCANIA GOODEI* IN GEORGIA AND THE CAROLINAS

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The Bluefin Killifish *Lucania goodei* (Figure 1) is a species that is well known to most killifish and native fish hobbyists. It is primarily occurs in Florida where it is distributed throughout the peninsula and the panhandle as far west as the Choctawhatchee River drainage and barely into southeast Alabama in the Chipola River drainage and southwest Georgia in the Flint River and Suwanee drainages (Freeman and Albanese 2009; Page and Burr 2011; Robins et al. 2018). It has also been introduced into California and Texas as well as coastal Georgia and the Carolinas (USGS Nonindigenous Aquatic Species; https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=696).

THE WAY IT WAS: GEORGIA
(Brett Albanese)

The historical presence of the Bluefin Killifish in Atlantic coastal Georgia is perplexing. It has been reported from three barrier islands (Sapelo, Blackbeard, and St. Simons) and within a spring-run tributary of the Ogeechee drainage (Magnolia Springs) (Freeman and Albanese 2009) (Figure 2). The Sapelo Island population was first documented from unnamed ponds near the south end of the island in 1954 and is represented by specimens in the Georgia Museum of Natural History (GMHN 3421; Dr. Byron J. Freeman, Georgia Museum of Natural History, personal communication). Dr. Steve Vives (Georgia Southern University, personal communication) saw them in a heavily vegetated freshwater pond adjacent to the University of Georgia's Marine Institute (UGAMI) in 1990–91 while sampling with Dr. Gene Helfman's (UGA) Ichthyology Class. The UGAMI pond is also located on the south end of the island, but it is uncertain if this pond is one of the historical ponds surveyed in 1954. I collected them with UGA colleagues and students in the UGAMI pond in May of each year between 2006–2010 using minnow traps set overnight and dip-netting. Bluefin Killifish were reported as rare (< 10) to common (10–100) during these surveys, while Sailfin Molly *Poecilia latipinna* and Least Killifish *Heterandria formosa* were common and mosquitofish (*Gambusia* sp.) were abundant (>100). We resurveyed the pond in 2017 and collected *Gambusia* sp. and *Poecilia latipinna* but did not record their relative abundance. Noah Kelly (UGA) surveyed the UGAMI pond in 2021 for a class research project but only captured five *Gambusia* sp. using dip nets. Significant decreases in water levels in the pond have occurred during drought periods, but the pond does not appear to have dried out completely (Gracie Townsend, UGAMI, personal communication). Other impacts to the pond include eutrophication associated with lower water levels and bird guano and seawater flooding during Hurricane Irma in 2017 (Dr. Damon Gannon, UGAMI, personal communication). Other potential habitats on Sapelo Island (freshwater and low-salinity ditches) have been sampled extensively during field courses led by Albanese, Vives, and other student groups visiting the island, but these surveys have not documented *L. goodei*. The Bluefin Killifish was collected from a pond on the north end of Blackbeard Island in 1953 and 1957 and is also represented by specimens in the Georgia Museum of Natural History (GMNH 2682). Blackbeard Island is immediately north of Sapelo Island but is completely undeveloped and only accessible by boat. Three specimens were collected on 26 February 1945 in headwaters of Dunbar Creek, St. Simons, Island (GMNH 131217). The occurrence of *Lucania goodei* on three separate barrier islands (St. Simons, Sapelo, and Blackbeard) between

Figure 1. Bluefin Killifish *Lucania goodei* from Pawleys Island, South Carolina. (Photo by Zach Alley)

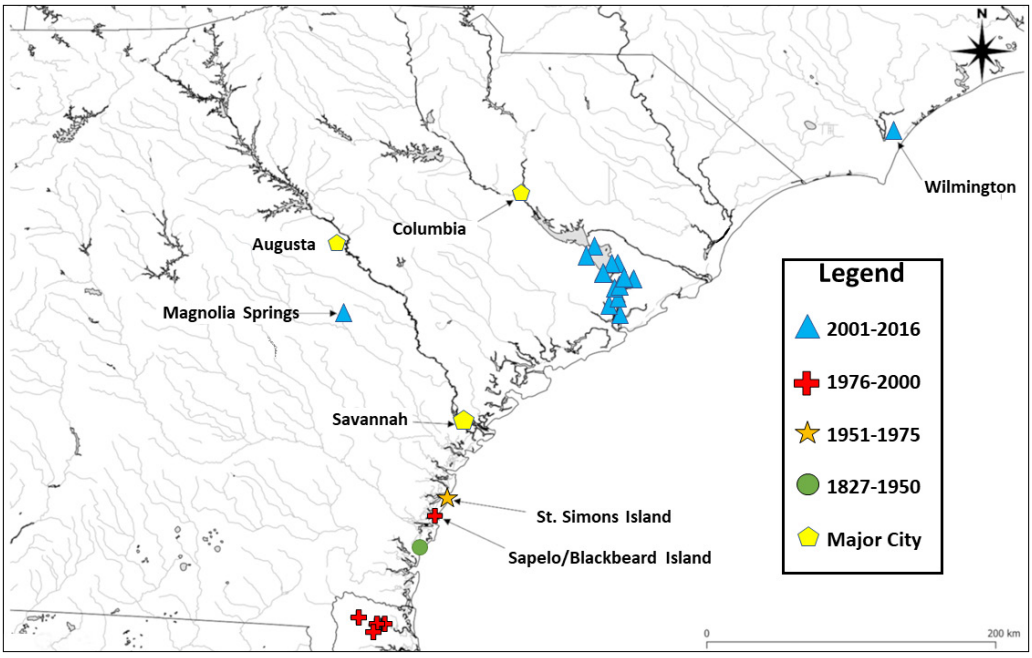

Figure 2. Distribution of *Lucania goodei* 1945 through 2016.

the 1940s and early 2000s, including an island that is remote and difficult to access (Blackbeard), suggests that this species may be native to coastal Georgia. Freshwater habitats on Georgia's barrier islands have declined due to aquifer depletion and ditching (Jason Lee, Georgia Department of Natural Resources, personal communication), which may explain why the species is so sparsely represented. Additional surveys targeting high-quality freshwater ponds are warranted.

Magnolia Springs occurs in the Southeastern Plains ecoregion in Jenkins County, Georgia. Bluefin Killifish were first documented in this spring by Dr. Bill Ensign (Kennesaw State University, retired) in the early 2000s (Figure 3). I surveyed this spring by seining with Georgia DNR staff in 2009 and 2022. The spring run is impacted by a dam, which slows flow, blocks fish passage, and likely contributes to excessive growth of nuisance algae. Despite these impacts, Bluefin Killifish occur both upstream and downstream of the dam and are very abundant (> 100 observed during both surveys) in the heavily vegetated reach between the dam and the park boundary downstream. Voucher specimens and photographs were retained by Georgia DNR during both surveys. The spring also supports many other coastal plain fishes (e.g., Largemouth Bass *Micropterus salmoides,* Golden Shiner *Notemigonus crysoleucas,* American Eel *Anguilla rostrata,* mosquitofish, Swamp Darter *Etheostoma fusiforme*), native freshwater mussels, and alligators. Steve Vives surveyed nearby Ft. Stewart in the 1990s and did not record the species from any of the Canoochee or Ogeechee tributaries or wetlands he sampled. The nativity of this population is uncertain given its distance from other known populations on the Georgia coast.

Figure 3. Magnolia Springs, Georgia, January 27, 2022. (Photo by Brett Albanese)

THE WAY IT WAS: SOUTH CAROLINA
(Fritz Rohde)

The Bluefin Killifish has been documented in at least eight locations around Charleston, South Carolina, particularly in rice fields in and near the Cooper River around the Berkeley-Charleston County line (Rohde et al. 2009) (Figure 2). Dr. Harold Loyacano from Clemson University was the first to document its occurrences in South Carolina and in the lower Cooper River (Loyacano 1975), followed shortly afterwards by Christie and Curtis (1983) who discussed its establishment in the Cooper River. Christie (1984) went on to describe it as the most abundant species in the main channel of the West Cooper River (50% of the total catch) and adjacent rice fields (44% of the catch). Interestingly, Christie also reported collecting Banded Killifish *Fundulus diaphanus* in the river and rice fields, but there are no known existing specimens to verify their presence (Richard Christie, personal communication). The only other records of Banded Killifish in South Carolina are from the lower Waccamaw River at the southern extent of its range (Rohde et al. 2009). Also, Dr. Edward Menhinick (Menhinick and Braswell 1997) stated "Isolated populations occur near the coast in Georgia and in Charleston (Gilbert and Burgess 1980) and Brookgreen Gardens in South Carolina (pers. obs.)." He went on to say that "The North Carolina population of Bluefin Killifish is considerably isolated from populations in South Carolina: it is either a remnant from a previously wider range or an introduction, or perhaps undiscovered intermittent populations exist (such as the Brookgreen Gardens population discovered in 1993)." All of his UNCC collection has been transferred to the North Carolina State Museum of Natural Sciences, and there is no evidence that he ever vouchered specimens from the Brookgreen Gardens site. But what a prescient statement that he wrote in 1997 about undiscovered intermittent populations. More recently, in the early to mid-2000s, *Lucania goodei* has been documented from lower Lake Moultrie (North Carolina State Museum Collection; Dustin Smith, personal communication), which is connected to the Cooper River but separated from it by the large Pinopolis Dam.

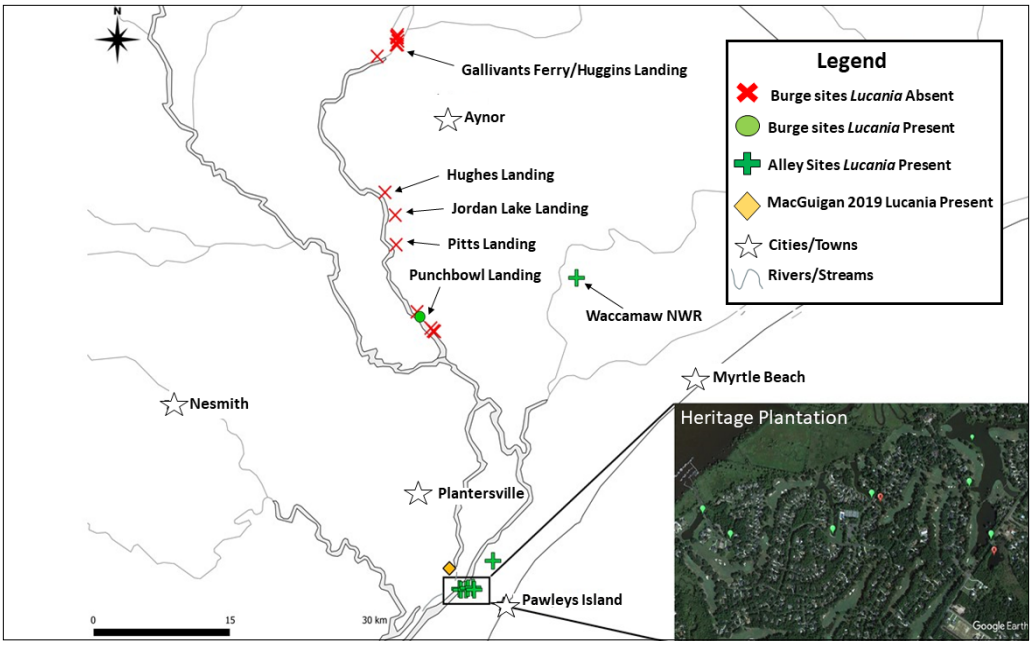

Figure 4. Map of South Carolina's *Lucania goodei* invasion.

THE WAY IT WAS: NORTH CAROLINA
(Fritz Rohde)

Around the same time that this species was found in South Carolina, Bluefin Killifish was also collected in Burnt Mill Creek, an urban stream in Wilmington, North Carolina (Lindquist et al. 1977) (Figure 2). Burnt Mill Creek runs through the city of Wilmington, and it still persists there today despite many physical and chemical perturbations to the creek (Fritz Rohde, personal observation). [NANFA member Pete Price informed Fritz on 7/14/2022 that he collected many Bluefin Killifish in an unnamed tributary of the Northeast Cape Fear River, about 14 miles north of Wilmington.]

NOVEL RECORDS IN THE WACCAMAW BASIN
(Zach Alley)

In 2018, I spent the summer months in the Pawleys Island, South Carolina area, nestled between the lower Waccamaw and the Atlantic Ocean. Much of my time was spent surveying the many roadside ditches, neighborhood ponds, and tidal creeks that characterize the region. One evening, while dip netting a roadside ditch running adjacent to Tradition Golf Club, a glimmer of blue and gold caught the sunlight, and I immediately recognized *Lucania goodei* in my net. At the time I didn't think much of it, for I knew this species was in the Carolinas. After consulting the *Freshwater Fishes of South Carolina* (Rohde et al. 2009), I realized that this was a significant find, so I set out to define the extent of their occurrence in the area. I was afforded access to the ponds within the Heritage Plantation community and golf course via family friends, so the community served as a starting point for this investigation. Surveys in this community found that all but one pond, which was separated from the others by an 8-foot-high dam, had abundant numbers of *Lucania goodei*. Another pond, located just outside the community in the headwaters of this pond system, also proved to have all species but *Lucania goodei* in common with the neighborhood ponds within the community (Figure 4). Since these findings, Fritz Rohde and I managed to collect Bluefin Killifish near Conway, SC, near the Waccamaw National Wildlife Refuge. Here, they seem to be restricted to an uncharacteristically clear water pond, with no *Lucania* recorded to date in any of the surrounding ponds on the refuge. With one collection recorded by Dr. Dan McGuigan and Daemin Kim (YPM ICH 033057, Yale Peabody Museum) in the lower Pee Dee (Figure 4), it's reasonable to infer that this species has spread throughout the lower Waccamaw. Menhinick and Braswell's (1997) report of *Lucania goodei* in Brookgreen Gardens in 1993 suggests that this species may have found its way into the lower Waccamaw via plant imports from Florida. Surveys in neighboring basins have shown that the extent of this invasion needs more thorough investigation, with upstream collections in the Pee Dee River basin by the Burge family (see following section of this report) raising the possibility of a much broader occurrence of this species in South Carolina.

AND "BEYOND"
(The Burge Family)

Erin Burge and his sons, William (11) and Wyatt (13), opportunistically, and with some regularity, dip net several sites along the Little Dee Pee River (LPDR) in Horry and Marion counties of northeastern South Carolina. The boys are especially fond of netting in a swamp outlet and small pool that seasonally flows into the main river just upstream of Punch Bowl Landing (PBL) (Figure 4). From this site and at low water levels, the boys regularly catch Tadpole Madtom *Noturus gyrinus,* Pirate Perch *Aphredoderus sayanus,* Golden Topminnow *Fundulus chrysotus,* Tessellated Darter *Etheostoma olmstedi,* Banded Pygmy Sunfish *Elassoma zonatum,* Swampfish *Chologaster cornuta,* Eastern Mosquitofish (including melanistic individuals) *Gambusia holbrooki,* several species of sunfishes (primarily Redbreast, Dollar, Spotted, and Bluegill) *Lepomis* spp., and juveniles of Redfin Pickerel *Esox americanus,* Longnose Gar *Lepisosteus osseus,* and Bowfin *Amia calva.*

On 30 July 2021, Will and Erin were joined by friend and Coastal Carolina University ornithologist and dragonfly expert Dr. Chris Hill at PBL. Chris was searching for exuviae of a rarely seen dragonfly, and "sampling" was also an excuse for cooling off in the river on a typically hot South Carolina afternoon in late July. Will was netting his favorite pool and the inches-deep outflow (Figure 5) when he needed help with an identification. Even though he is only 11 years old, Will and brother Wyatt, are rarely stumped by a freshwater fish from the LPDR because they have been netting there since each could walk, and they share a copy of *Freshwater Fishes of South Carolina* (Rohde et al. 2009). In Will's net and mixed in with a dozen or so Eastern Mosquitofish collected from sparse emergent vegetation (likely Shade Mudflower *Micranthemum umbrosum;* J. Luken, personal communication) where the slough joined the river, were three Least Killifish. This was a species Will had only seen once before from a water control ditch on

Figure 5. Will Burge checking a spot for Bluefin Killifish above Punch Bowl Landing, LPDR, 24 September 2021. (Photo by Erin Burge)

Figure 6. Poor picture of a male Bluefin Killifish collected from Punch Bowl Landing, Little Pee Dee River, 30 July 2021. (Photo by Erin Burge)

Coastal Carolina University's campus (Waccamaw River watershed). In fact, years of prior sampling by the Burges, Dr. Derek Crane's ichthyology class at Coastal Carolina University (Derek Crane, personal communication), and systematic work in Horry County to find Least Killifish (Nelson and Burge 2014) at PBL had never found them at all from this site or any other on the LPDR.

A few more dips, and several specimens of another unfamiliar fish turned up in Will's net. At a glance they resembled Coastal Shiner *Notropis petersoni,* but these fish were smaller and deeper-bodied and just not quite right to be a shiner. As Erin cogitated on an identification, Will quickly caught several more for a total of 10 specimens. Sexual dimorphism was apparent, and Erin really thought they looked like Bluefin Killifish, but he had never collected them and he knew they weren't reported from the LPDR and rarely from South Carolina at all (Rohde et al. 2009). Erin remembered that he and Zach Alley had corresponded in early 2019 about Zach's catches of Bluefin Killifish in the Pawleys Island area (see above).

Will and Erin brought home a few specimens for photos (Figure 6) and subsequently posted one to the NANFA Facebook group where it was quickly positively identified as Bluefin Killifish. The next day, Will and big brother Wyatt insisted that we had to return to PBL to see this new fish, and go for a swim as it was still really hot! That collection (31 July 2021) yielded 10 more individuals from the same site, a few of which were kept for the boys' native fish tank; the Bluefins were still thriving there in December 2021. Another week passed, and a return visit to PBL on 8 August yielded three more Bluefins and four more Least Killifish, but this time from the sandy beach area adjacent to the swamp outflow. The slough had flowed out and dried up in the heat of the summer in the last week.

Urged on by Fritz Rohde, Erin and Will planned a more thorough collecting effort to look for Bluefin Killifish along other stretches of the LPDR. On 12 August, the two visited other shore-accessible sites upstream of PBL. These included Pitts Landing, Jordan Lake Landing, and Hughes Landing. No Bluefin Killifish or Least Killifish were collected. On 21 August, Erin's family and friends used a flotilla of watercraft including canoes, kayaks, inner tubes, and pool floats, to drift while the boys sampled another river section from Galivants Ferry to Huggins Landing. Will and Wyatt dip netted in likely spots along sand bar edges, submerged and emergent aquatic vegetation, and levee backwaters, but no Bluefin or Least killifishes were collected (Figure 4). The boys were excited to catch an adult American Eel *Anguilla rostrata* in their turtle trap, and Will netted a juvenile Flathead Catfish *Pylodictis olivaris*. Both were Fish List firsts for the boys.

In the search for Bluefins, a borrowed skiff with a finicky motor facilitated reaching some locations not accessible from shore. The boys used the excuse of searching for Bluefins to organize a river camping trip above Galivants Ferry for 17–19 September with Erin, the boys' mother Courtney Burge, Chris Hill, and friend Haiven Biggerstaff (13). All three boys dip netted likely spots, but due to very low water levels the slow, backwater habitat with minimal current and abundant vegetation apparently favored by Bluefin Killifish was scarce. A few drying puddles on the sandbars contained many Tadpole Madtom, Swampfish, and Redbreast Sunfish *Lepomis auritus,* in addition to the ubiquitous *Gambusia* but no Bluefin or Least killifishes. Using the boat again on 24 September, Will and Erin were joined by Coastal Carolina Dive Safety Officer and friend Steve Luff to search downstream from PBL to near the confluence of the river with the Great Pee Dee River. Despite areas that looked appropriate for fishes that like slow-to-no current and abundant vegetation, no Bluefin or Least killifishes were found (Figure 7).

Returns to PBL through the end of summer and fall 2021 (6 and 26 September) have not resulted in additional catches of Bluefin or Least killifish. Surprisingly, Least Killifish were netted by Will from an isolated private pond near Punch Bowl on 13 November. The river continued to be very low through most of the fall, and the slough where they were caught in July and August has remained dry. Sampling along the sandy beach adjacent to the slough was also unsuccessful.

Although Bluefin Killifish and Least Killifish are small, we are confident that if either species were present at PBL prior to the collections in 2021 described here, we would have recognized them. Given the apparently wide but new and patchy distribution of Bluefins in the lower Waccamaw/Pawleys Island area (see the section above), we speculate that these two species became much more widely dispersed due to catastrophic regional flooding that occurred after Hurricane Florence in September/October 2018 (Figures 8, 9). In fact, the LPDR remained

Figure 7. Will Burge (left) and Steve Luff sampling on the lower Little Pee Dee River near the confluence with the Great Pee Dee River, 24 September 2021. (Photo by Erin Burge)

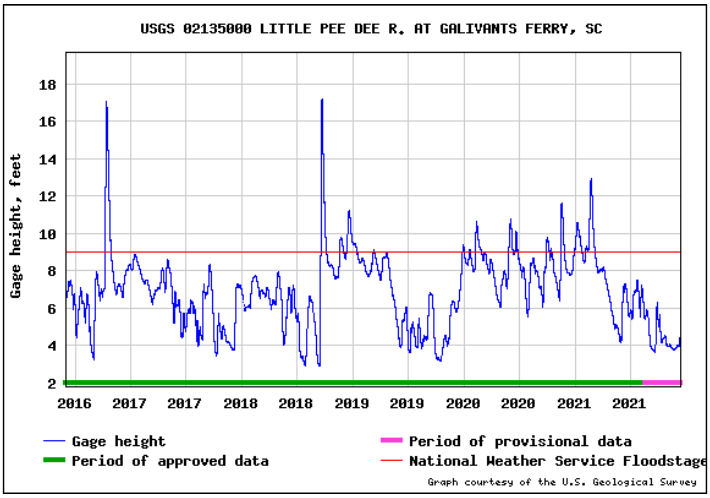

Figure 8. Water above approximately 9-foot gauge height restricts river access near Punch Bowl Landing, LPDR.

close to flood stage at Galivants Ferry (>9 feet gauge height) upriver of PBL through early spring of 2019 (Figure 8). Dip net sampling in 2019 on 13 dates from 28 April–11 November resulted in no catches of either species. In 2020, we sampled sites on the LPDR stretching between PBL and Red Bluff Landing near Marion, SC, on 10 days from 3–26 September. Spring and summer low water levels resulted in no Bluefin or Least killifishes collected. In 2021, the boys sampled at PBL on 25 April and 15 May. On 31 May, Steve Luff requested fish handling assistance from the Burge boys to attempt to relocate some large, adult Bowfin stranded in a nearly dry lake near Cartwell Bay Landing. Several hours of intense netting and multiple runs to the river with full coolers resulted in the relocation of 111 (we counted) Bowfin, many from mud puddles only inches deep (Figures 10–11). The boys also caught Blackbanded Sunfish *Enneacanthus chaetodon,* Bluespotted Sunfish *Enneacanthus gloriosus,* Warmouth *Lepomis gulosus,* Flier *Centrarchus macropterus,* Largemouth Bass, and small bullheads *Ameiurus* spp. No Bluefin or Least killifish were caught in the puddles or main river near Cartwell Bay. Other LPDR samplings on four days in June 2021 were also fruitless for both.

WHERE TO FROM HERE?

While it's easy to infer with a high degree of confidence that populations of *Lucania goodei* recorded in the Carolinas, as well as most of Georgia, are introduced, there's still much to be done. Continued surveys are needed to determine the extent of the *Lucania* invasion, and potential sources of introduction need to be identified. The authors (ZA, FR) of this article are working to compile a *Lucania goodei* tissue collection at the University of West Alabama, where they will be utilized in future population genetics projects. We hope to be able to determine once and for all the status of *Lucania goodei* in the Carolinas and Georgia.

Do you live in the coastal plain of North Carolina, South Carolina, or Georgia? Keep your eyes peeled for these flashy little fish in your future fish adventures.

Figure 9. The Little Pee Dee River floods with some regularity. Here in February 2021, Little Pee Dee River flood waters have reached over 2.5 miles from Punch Bowl Landing, which is through the road cut in the background. Flooding after Hurricane Florence (September/October 2018) was approximately 4 feet higher than this. (Left to right: Will Burge, Austen Deal, Wyatt Burge, and Marlowe Deal) (Photo by Erin Burge)

Figure 10. Operation Bowfin Rescue. Cartwheel Bay, Little Pee Dee River, 31 May 2021. Wyatt (right) and Will (left). (Photo by Erin Burge)

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Figure 11. Operation Bowfin Rescue. Left to right: Will Burge, Steve Luff, Wyatt Burge. (Photo by Erin Burge)

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