A SURVEY OF THE FRESHWATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDA) OF THE UPPER BARREN RIVER SYSTEM, TENNESSEE

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ABSTRACT

The freshwater mussel fauna of the Barren River system in Kentucky is well documented, but information on mussel occurrence in the Tennessee portion of the system was lacking. We conducted mussel surveys at 56 sites in 22 streams in the Barren River system in Tennessee. We found six species at 14 sites: Alasmidonta viridis (Slippershell), Fusconaia flava (Wabash Pigtoe), Lampsilis cardium (Plain Pocketbook), Lampsilis siliquoidea (Fatmucket), Pyganodon grandis (Giant Floater), and Villosa ortmanni (Kentucky Creekshell). Our records of V. ortmanni are the first reports of this species from Tennessee, and our records of L. siliquoidea considerably expand the known range of that species in the state. We found live or freshly dead V. ortmanni at five sites, and at least two sites supported relatively large populations with evidence of recent recruitment. These observations represent important information for the conservation of this imperiled species. Overall, mussel populations in the Barren River system of Tennessee were small and scattered, which may be due, in part, to the lower mussel abundance typical of headwater streams. However, the occurrence of widespread mussel declines in this region suggests that human factors may have further reduced mussel abundance.

KEY WORDS: Barren River, mussel records, Tennessee, headwaters, Villosa ortmanni, Alasmidonta viridis, Lampsilis siliquoidea

INTRODUCTION

The Barren River drains approximately 4,302 km² and is the largest tributary of the Green River (Fig. 1). The Green River joins the Ohio River south of Evansville, Indiana, and drains a greater percentage of Kentucky’s land area than any other river system in the state (Burr and Warren 1986). The upper Barren River system is the only portion of the Green River drainage in Tennessee and drains 1,119 km² in that state. The Green River drainage supports high fish and mussel species richness, including eight endemic fishes and, potentially, one endemic mussel species (Villosa ortmanni; Haag and Cicerello 2016). The fish fauna of the Barren River system, including the Tennessee portion, is well known (Burr and Warren 1986; Etnier and Starnes 1993; Ceas and Page 1997). The mussel fauna of the Kentucky portion of the Barren River system is similarly well documented (Haag and Cicerello 2016), but the fauna of the Tennessee portion is largely unknown. No mussel records exist in the databases of the Tennessee Department of Environment and Conservation (TDEC) (D. Withers, TDEC, personal communication), Tennessee Wildlife Resources Agency (D. Hubbs, Tennessee Wildlife Resources Agency, personal communication), and Tennessee Valley Authority (T. Amacker, Tennessee Valley Authority, personal communication). Parmalee and Bogan (1998) provided no Tennessee mussel records from the Barren River system and did not mention it in their discussion of river systems of the state even though it appeared on two state
Finally, there are no specimens from the Tennessee portion of the Barren River system in any of the mollusk collections we contacted (North Carolina Museum of Natural Sciences, Carnegie Museum of Natural History, University of Michigan Museum of Zoology, Florida Museum of Natural History, University of Tennessee McClung Museum of Natural History and Culture [MMNHC], The Ohio State University Museum of Biological Diversity, and Harvard University Museum of Comparative Zoology). Several Barren River tributaries in Tennessee are of substantial size, suggesting that the lack of mussel records is due to lack of sampling.

We conducted a comprehensive mussel survey of the Tennessee portion of the Barren River system from December 2016 to May 2019. We discuss how our results expand our knowledge of mussel distribution in this region and contribute to conservation efforts for the Green River drainage mussel fauna.

**METHODS**

**Study Area**

The Barren River system in Tennessee lies in Sumner, Macon, and Clay counties, and includes 906 km of streams and 18 ha of impoundments (TDEC 2007; Fig. 1). On the western side of the system in Tennessee, the largest tributaries are West Fork Drakes Creek, Middle Fork Drakes Creek, and Trammel Creek, which converge in Kentucky to form Drakes Creek, the largest tributary of the Barren River. On the eastern side of the system in Tennessee the largest tributaries are Long Creek, Salt Lick Creek, Long Fork, and Line Creek, all of which ultimately flow into the upper Barren River. Streams in the Barren River system in Tennessee are on the Eastern Highland Rim or Western Pennyroyal Karst subunits of the Interior Low Plateaus physiographic province. Streams in this area are upland in character and flow over sand, gravel, and bedrock substrates.

The Barren River system in Tennessee is largely rural and undeveloped. The largest municipality (Portland) has fewer than 12,000 people (US Census Bureau 2020). Land use in the Tennessee portion of the system is 50.2% forest (deciduous, evergreen, and mixed), 23.8% developed and barren land, 21.1% hay pasture and herbaceous, 1.9% cultivated crops,
Table 1. Mussel survey sites in the Barren River system, Tennessee.

| Site | Stream | Location | County | Coordinates           | Date            | Stream Order |
|------|--------|----------|--------|-----------------------|-----------------|--------------|
| 1    | West Fork Drakes Creek | Coker Ford Road | Sumner | 36.64760, 86.50632 | December 13, 2016 | 3            |
| 2    | West Fork Drakes Creek | Rapids Road | Sumner | 36.63122, 86.49150 | December 13, 2016 | 3            |
| 3    | West Fork Drakes Creek | State Route 259 | Sumner | 36.62369, 86.48972 | December 13, 2016 | 3            |
| 4    | West Fork Drakes Creek | Below Denning Ford Road | Sumner | 36.60750, 86.47914 | December 13, 2016 | 3            |
| 5    | West Fork Drakes Creek | Above Denning Ford Road | Sumner | 36.60673, 86.46865 | December 1, 2017 | 3            |
| 6    | West Fork Drakes Creek | Railroad Lane | Sumner | 36.50152, 86.46963 | December 13, 2016 | 3            |
| 7    | West Fork Drakes Creek | Butler Bridge Road | Sumner | 36.55553, 86.46758 | December 13, 2016 | 1            |
| 8    | Grace Creek | 500 m upstream of mouth | Sumner | 36.64297, 86.50388 | December 13, 2016 | 3            |
| 9    | Caney Fork Creek | State Route 52 | Sumner | 36.58240, 86.41974 | December 16, 2016 | 3            |
| 10   | Sulfur Fork | North Jones Road | Sumner | 36.64780, 86.40761 | May 17, 2019 | 2            |
| 11   | Sulfur Fork | Gregory Road | Sumner | 36.62643, 86.39260 | December 14, 2016 | 2            |
| 12   | Sulfur Fork | Absher Branch Road | Sumner | 36.63798, 86.39447 | December 14, 2016 | 2            |
| 13   | Middle Fork Drakes Creek | State line | Sumner | 36.64781, 86.33271 | May 16, 2019 | 3            |
| 14   | Middle Fork Drakes Creek | Hershel Lyles Road | Sumner | 36.63608, 86.32859 | December 14, 2016 | 3            |
| 15   | Middle Fork Drakes Creek | Confluence w/Dutch Creek | Sumner | 36.61704, 86.33000 | December 14, 2016 | 3            |
| 16   | Middle Fork Drakes Creek | Keen Hollow Road | Sumner | 36.60292, 86.32947 | December 14, 2016 | 3            |
| 17   | Middle Fork Drakes Creek | Haskell Akin Road | Sumner | 36.58310, 86.32889 | December 14, 2016 | 3            |
| 18   | Middle Fork Drakes Creek | State Route 52 | Sumner | 36.56636, 86.32060 | December 14, 2016 | 3            |
| 19   | Little Trammel Creek | Old U.S. 31E (State Route 174) | Sumner | 36.63788, 86.26626 | December 16, 2016 | 3            |
| 20   | Garrett Creek | John Beasley Road | Sumner | 36.63666, 86.24210 | May 16, 2019 | 2            |
| 21   | Trammel Creek | State line | Macon | 36.63861, 86.19751 | May 16, 2019 | 3            |
| 22   | Trammel Creek | Buck Haynes Road | Macon | 36.62149, 86.19234 | December 15, 2016 | 3            |
| 23   | Trammel Creek | Hawkins Road | Macon | 36.60054, 86.19722 | December 15, 2016 | 3            |
| 24   | Trammel Creek | Sister Hollow Road | Macon | 36.58633, 86.20043 | December 16, 2016 | 3            |
| 25   | Long Creek | State Line | Macon | 36.63479, 86.11480 | May 16, 2019 | 3            |
| 26   | Long Creek | Hanestown Road | Macon | 36.62362, 86.11152 | December 15, 2016 | 3            |
| 27   | Unnamed tributary to Long Creek | Negro Hollow | Macon | 36.62118, 86.10926 | May 16, 2019 | 1            |
| 28   | Long Creek | Adjacent to Clifty Road | Macon | 36.61881, 86.11500 | December 15, 2016 | 3            |
| 29   | Long Creek | Adjacent to Clifty Road | Macon | 36.61131, 86.11568 | December 15, 2016 | 3            |
| 30   | Long Creek | Shiloh Road | Macon | 36.60717, 86.11895 | December 15, 2016 | 3            |
| 31   | West Fork Long Creek | Shiloh Road | Macon | 36.60681, 86.12221 | December 15, 2016 | 2            |
| 32   | Puncheon Creek | Green Valley Road | Macon | 36.62828, 86.00595 | May 16, 2017 | 3            |
| 33   | Puncheon Creek | Puncheon Creek Road | Macon | 36.61174, 86.01224 | November 30, 2017 | 3            |
| 34   | White Oak Creek | Cook Road | Macon | 36.62254, 85.93653 | November 30, 2017 | 3            |
| 35   | White Oak Creek | Coley Road | Macon | 36.56656, 85.98312 | November 30, 2017 | 3            |
| 36   | Long Fork | Hagan Circle | Macon | 36.62309, 85.92411 | May 17, 2019 | 3            |
| 37   | Long Fork | Wilson Road | Macon | 36.61519, 85.92942 | November 30, 2017 | 3            |
Table 1, continued.

| Site  | Stream                      | Location                       | County | Coordinates                  | Date             | Stream Order |
|-------|-----------------------------|--------------------------------|--------|------------------------------|------------------|--------------|
| 38    | Long Fork                   | Spring Hollow Road             | Macon  | 36.56791, 85.93932           | November 30, 2017| 2            |
| 39    | Saltlick Creek              | Pitcock Road                   | Macon  | 36.61074, 85.89944           | November 29, 2017| 3            |
| 40    | Saltlick Creek              | Parkhurst Road                 | Macon  | 36.59100, 85.88032           | November 29, 2017| 3            |
| 41    | Saltlick Creek              | 1.1 km W of Bethany Cemetery   | Macon  | 36.56933, 85.86982           | May 17, 2019     | 3            |
| 42    | Unnamed tributary to Saltlick Creek | 1.1 km WSW of Bethany Cemetery | Macon  | 36.56657, 85.86644           | May 17, 2019     | 1            |
| 43    | Saltlick Creek              | Above confluence with Long Hungry Creek | Macon | 36.56492, 85.86948          | May 17, 2019     | 2            |
| 44    | Long Hungry Creek           | Above confluence with Saltlick Creek | Macon | 36.56477, 85.87075          | May 17, 2019     | 2            |
| 45    | Saltlick Creek              | 3.1 km SE of Sunrise           | Macon  | 36.55566, 85.86714           | May 17, 2019     | 2            |
| 46    | Saltlick Creek              | Maxie Bluff Road               | Macon  | 36.55170, 85.85699           | November 29, 2017| 2            |
| 47    | Saltlick Creek              | Red Boiling Springs            | Macon  | 36.54040, 85.85042           | November 29, 2017| 2            |
| 48    | Saltlick Creek              | Below old dam site             | Macon  | 36.54431, 85.85877           | November 29, 2017| 2            |
| 49    | Saltlick Creek              | Old Lake Road to old dam site  | Macon  | 36.54205, 85.85469           | November 30, 2017| 2            |
| 50    | Unnamed spring              | Red Boiling Springs            | Macon  | 36.53888, 85.84972           | November 29, 2017| 1            |
| 51    | Little Saltlick Creek       | Sutton Road                    | Macon  | 36.58147, 85.85700           | November 29, 2017| 1            |
| 52    | Unnamed tributary to Little Saltlick Creek | Sutton Road | Macon | 36.58219, 85.85346          | November 29, 2017| 1            |
| 53    | Trace Creek                 | State Route 52                 | Clay   | 36.57592, 85.78019           | November 30, 2017| 2            |
| 54    | Line Creek                  | Copars-York Road               | Clay   | 36.60908, 85.75448           | November 28, 2017| 2            |
| 55    | Line Creek                  | Homer-Bray Road                | Clay   | 36.60930, 85.76675           | November 28, 2017| 2            |
| 56    | Line Creek                  | Adj. to Line Creek Road        | Clay   | 36.60880, 85.73158           | November 28, 2017| 2            |
1.9% shrub/scrub, and 0.8% wetlands (open water, woody, and herbaceous) (Yang et al. 2018). Despite the undeveloped nature of the system, a number of major tributaries of the Barren River system in Tennessee are considered impaired due to siltation, habitat degradation, or poor water quality associated with point and nonpoint discharges (TDEC 2007). These include Big Trammel Creek, Little Trammel Creek, Long Creek, Long Fork, West Fork Drakes Creek, Middle Fork Drakes Creek, Salt Lick Creek, Trace Creek, Town Creek, and West Fork Long Creek. A widespread problem in the Barren River system of Tennessee is illegal gravel dredging, which is widespread because of the area’s relative remoteness and the abundance of gravel substrate in the larger streams (TDEC 2007).

Mussel Surveys

We conducted mussel surveys at 56 sites on 22 streams from December 2016 to May 2019 (Fig. 2 and Table 1). Sample sites were selected based on access, stream position, distance to other sample sites, and presence of suitable mussel habitat, such as shallow riffles and runs with gravel and cobble substrates. At each site, we conducted qualitative visual and tactile searches for live mussels, and we searched shorelines, gravel bars, and submerged vegetation for stranded live mussels and shells. We spent at least 1 person-h at each site except at sites where the habitat was extremely degraded or the water quality was obviously compromised. Longer search times were used at sites where live mussels or freshly dead shells were found. At some sites, we used a rake to disturb the top few centimeters of substrate. We sampled upstream of bridges, fords, and culverts to examine reaches unaffected by those structures. Live mussels were identified to species, measured (anterior to posterior length, nearest 1 mm), counted, and reinserted into the substrate. Freshly dead shells (tissue remaining, shiny nacre) and relic shells (chalky nacre, weathered periostracum) were identified, counted, and cataloged at MMNHC. At each site, we also recorded presence or absence of the invasive species Corbicula fluminea (Asian Clam). Our nomenclature follows Williams et al. (2017).

RESULTS

We found live mussels, freshly dead shells, or relic shells at 14 sites; only relic shells were found at four sites (Table 2). Mussels were found in nine third-order streams and in five second-order streams; no first-order streams yielded evidence of mussel occurrence. We found a total of six mussel species, but only five were represented by live individuals or freshly dead shells, and only one to three species were observed at each site. Live mussels were generally uncommon and represented by only one to three individuals at most sites. Exceptions were site 13 (Middle Fork Drakes Creek), where 24 individuals of Lampsilis siliquoidea were found, and sites 45 and 46 (Saltlick Creek), where V. ortmanni was represented by nine individuals at each site. Corbicula fluminea was present at 25 sites, including all but two of the sites with mussels (Table 2). Live Corbicula were uncommon at all sites.

Alasmidonta viridis, L. siliquoidea, and V. ortmanni were the most widespread species in the system, each present at five to six sites (Table 2). Alasmidonta viridis was represented by adults only; no juvenile individuals were found (Fig. 3). Lampsilis siliquoidea was represented by a range of sizes, but no juveniles were found. Villosa ortmanni was represented by a range of sizes and included small individuals indicative of recent recruitment (Fig. 3). Three species were found at a single site and represented by single individuals: Fusconaia flava, Lampsis cardium, and Pyganodon grandis; F. flava was represented only by a single relic shell at site 2 (West Fork Drakes Creek). In addition, we found two freshly dead L. fasciola at one site in Middle Fork Drakes Creek a few hundred meters downstream of the Kentucky state line, but we

| Species                  | Site | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|-------------------------|------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Alasmidonta viridis     | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Fusconaia flava         | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Lampsis cardium         | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Lampsis siliquoidea     | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Pyganodon grandis      | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Villosa ortmanni        | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Unidentifiable unionid  | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| shell fragments         | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Corbicula fluminea      | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Total no. of species    | P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|
| Total no. of individuals| P    | P | P | P | P | NP| P | NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP| NP|

Table 2. Mussels found in the Barren River system, Tennessee, 2016–19. Cell entries are the combined number of live and freshly dead mussels or the number of relic shells (in parentheses). Totals do not include unidentifiable shell fragments or Corbicula fluminea, which is reported only as present (P) or not present (NP). See Table 1 for site specifications.
could not confirm its occurrence in the Tennessee portion of the Barren River system.

DISCUSSION

The Barren River system in Tennessee supports a limited mussel fauna typical of headwater streams in the Green River system and elsewhere in the Ohio River basin. Alasmidonta viridis and L. siliquoidea are characteristic headwater species throughout much of this region, and P. grandis is a stream-size generalist that is often common in small streams (Parmalee and Bogan 1998; Watters et al. 2009; Haag and Cicerello 2016). Lampsilis cardium and F. flava also occur in a wide variety of habitats, but neither species typically occurs far into the headwaters (Haag and Cicerello 2016). We found both of these species only in a larger stream (West Fork Drakes Creek), about 3 stream km upstream of the Kentucky state line. Lampsilis fasciola is widely distributed in the Barren River system in Kentucky and also may occur in the lower reaches of Barren River tributaries in Tennessee, but we could not confirm its presence.

Villosa ortmanni traditionally is considered endemic to the upper Green River drainage, but there is uncertainty about its relationship to Villosa vanuxemensis in the adjacent Red River system (Cumberland River drainage; Kuehn 2009; Haag and Cicerello 2016); until that issue is resolved, we follow the traditional view of this species as endemic to the Green River drainage. Villosa ortmanni occurs in a wide variety of stream habitats from the mainstem Green River to small streams, but it is a characteristic species of headwaters, particularly spring runs, where it may be the only species present (Haag and Cicerello 2016). Along with A. viridis, V. ortmanni was the only species we found in second-order streams. Prior to our study, V. ortmanni was considered endemic to Kentucky (Haag and Cicerello 2016).

Tennessee has the second-highest number of mussel species in the USA, behind Alabama (Parmalee and Bogan 1998, Williams et al. 2008). Our discovery of V. ortmanni in the Barren River system of Tennessee brings the total number of recognized species in the state to 140 (G. Dinkins, personal observation). This is the first new record of a previously recognized species from Tennessee since reports of L. siliquoidea in 1985 and 1994 (MMNHC; Kesler and Manning 1996). Prior to our study, L. siliquoidea was reported in Tennessee only from direct tributaries of the Mississippi River (Reelfoot Lake and Wolf River), and our records of that species are the first from the Ohio River basin in Tennessee. In addition, our study provides the first mussel records of any species from the Barren River system in Tennessee.

In part, the scarcity of mussels in the upper Barren River system may be a natural feature of these headwater streams, where mussel abundance typically is lower than it is in larger streams (Haag 2012). However, the extremely low abundance we observed may be a result of human factors that have further reduced mussel populations. Entire mussel assemblages have nearly disappeared from much of the Barren River system and from many other upland streams in the southeastern USA, but the reasons for these disappearances are unknown (Irwin 2018; Reed et al. 2019; Haag 2019). The upper Barren River system is now isolated by Barren River Reservoir in Kentucky, which hinders mussel dispersal and gene flow. We observed several sources of stream degradation including illegal gravel mining (West Fork Drakes Creek, Middle Fork Drakes Creek, Long Creek, Trace Creek), channelization (Salt Lick Creek, Line Creek), and brine discharge from abandoned gas wells (Little Salt Lick Creek, Middle Fork Drakes Creek), but we have no information about the extent of these impacts or their effects on water quality or mussels in the Barren River system.

Our discovery of additional populations of V. ortmanni is important from a conservation perspective, regardless of this species’ taxonomic status. The species was once widespread and common in the Green River drainage, but it has declined
A

*Alasmidonta viridis*

N=7

$\bar{x}=41.3$ mm

B

*Lampsilis siliquoidea*

N=23

$\bar{x}=95.8$ mm

C

*Villosa ortmanni*

N=22

$\bar{x}=53.9$ mm
dramatically in the last 30 yr and now survives in only a few small populations; populations of *V. vanuxemensis* in the adjacent Red River system have declined similarly (Haag and Cicerello 2016; M. Compton, Office of Kentucky Nature Preserves, personal communication). In 2010, the Center for Biological Diversity petitioned the U.S. Fish and Wildlife Service to include *V. ortmanni* on the federal list of endangered species. Our findings considerably expand the known range of this species, and at least two of the sites we surveyed supported relatively large populations with evidence of recent recruitment.

With the exception of *V. ortmanni*, all of the mussel species we observed remain widespread and common in at least some parts of their ranges, but enigmatic mussel declines in the Barren River system and elsewhere threaten the survival of even widespread species. Headwater streams provide unique aquatic habitats but are vulnerable to a wide range of human impacts (Downing et al. 2012; Wohl 2017). Approximately 12,000 m of a tributary to Line Creek is being restored as part of the Tennessee Stream Mitigation Program (T. Dinkins, Stantec Consulting Services, Inc., personal communication). Efforts such as this are necessary to improve and ensure the health of headwater streams and the mussel assemblages they support.

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Figure 3. Length frequency distributions of live and freshly dead (a) *Akaclidonta viridis* in Salt Lick and Line creeks, (b) *Lampsilis siliquoidea* in West Fork Drakes and Middle Fork Drakes creeks, and (c) *Villosa ortmanni* in Salt Lick and West Fork Drakes creeks, Barren River system, Tennessee. Sample size (N) and mean length (x) is provided for each species.