Ichthyol. Explor. Freshwaters, Vol. 21, No. 1, pp. 63-72, 3 figs., 1 tab., March 2010

An overview of North America's diminutive freshwater fish fauna

Micah G. Bennett* and Kevin W. Conway*

Based on a review of the literature, we compile a table of North American freshwater fishes with maximum standard length (SL) less than or equal to 50 mm and information on size at sexual maturity. Using previously published criteria for miniature fishes (<26 mm maximum SL, or those that mature at SL <20 mm), we found evidence for seven miniature fishes on the North American continent: *Elassoma alabamae*, *E. zonatum*, *Leptolucania ommata*, *Heterandria formosa*, *Megupsilon aporus*, *Cyprinodon macularius* and *Notropis saladonis*, the smallest being *E. alabamae* (Spring Pygmy Sunfish, maximum size 25.5 mm SL). We compare the number of miniature species in North America to those from Africa, South Asia and South America and discuss patterns of distribution, habitat preference and imperilment amongst North America's smallest freshwater fishes.

Introduction

The North American continent contains one of the most diverse temperate freshwater fish faunas in the World (Abell et al., 2000; Lundberg et al., 2000), with over 1050 described and numerous undescribed species (Page & Burr, 1991; Lundberg et al., 2000). At the turn of the 20th century the North American ichthyofauna was credited with the distinction of having some of the "smallest known fishes and at the same time the smallest known vertebrates" (Smith, 1902). In more recent years the North American continent has lost its "smallest vertebrate" status, which has passed back and forth between Indo-Pacific, Australasian and South East Asian countries (Herre, 1929; Winterbottom & Emery, 1981; Watson & Walker, 2004). Among these is the recent description of the cypriniform genus *Paedocypris* (Kottelat et al., 2006), which contains the smallest living vertebrate species *(P. progenetica)*, maturing at sizes under 8 mm in standard length (SL).

Though small-bodied fishes have always been of interest, ichthyologists have only fairly recently began to undertake continent-wide assessments of small-bodied species. Weitzman & Vari (1988) undertook the first such survey documenting the numerous miniature freshwater fish species of South America. They defined miniature fishes as those no greater than 26 mm SL or maturing at sizes smaller than 20 mm SL and identified 85 such species. Costa & Le Bail (1999) added 26 more to the count for South America. Using Weitzman & Vari's criterion, Kottelat & Vidthayanon (1993) provided a list of miniature fishes for south and southeast Asia and, more recently, Conway & Moritz (2006) compiled a similar list for Africa. Besides providing a more thorough knowledge of continental biodiversity, identifying and tabulating the number of small-

* Department of Biology, Saint Louis University, 3507 Laclede Avenue, St. Louis, MO 63103, USA.
E-mail: micahgbennett@yahoo.com, conwaykw@gmail.com

bodied fishes is important to largescale ecological and evolutionary investigations such as those focused on geographic gradients in body size (e.g., Belk & Houston, 2002; Knouft, 2004), phylogenetic trends in body size (e. g., Knouft & Page, 2003; Ruber et al., 2007), life history evolution (e. g., Weitzman & Vari, 1988), and issues of conservation concern, such as size-biased extinction risks (e. g., Olden et al., 2007).

In this paper we provide a list of all North American freshwater fishes with a maximum SL less than or equal to 50 mm in order to assess whether the North American ichthyofauna contains any miniature species of fish (sensu Weitzman & Vari, 1988) and to determine the smallest North American fish species.

Methods

We conducted surveys of peer-reviewed literature and books on fishes and fish biology using four standard publication databases (Web of Science, Biological Abstracts, Google Scholar, JSTOR) and compiled a table of all freshwater fishes with a maximum standard length (SL) of less than or equal to 50 mm that inhabit North America (including Mexico). This was necessarily an arbitrary cut-off point, but it was chosen in order to include the lower tail of the size distribution of North American freshwater fishes (sensu Knouft & Page, 2003) and to include any miniature species (< 26 mm maximum SL, sensu Weitzman & Vari, 1988). We used the University of Michigan Museum of Zoology online catalogue of the Division of Fishes (UMMZ, 2009) which includes SL information to determine if specimens larger than those documented in the literature survey had been collected for species for which maximum standard lengths had been published. That catalogue also served as a source of information for species for which no literature could be found. Literature information was also used to compile data on the minimum SL at maturity of all species with standard lengths of less than 50 mm in order to assess whether any species included in our survey matured at sizes below 20 mm SL. Lastly, we utilized the most recent status rankings of the American Fisheries Society (Jelks et al., 2008) to examine patterns of imperilment among diminutive fishes.

Results

Our survey documented 146 species of North American freshwater fishes with a maximum SL less than, or equal to, 50 mm, 6 of which mature at sizes of less than 20 mm SL (Table 1). The pool of diminutive fishes (equal to or below 50 mm SL) covers a broad range of North American fish families but is made up largely of Poeciliidae (32.0 %), Cyprinidae (18.4 %), Cyprinodontidae (17.0 %), and Percidae (14.3 %). Three of these, the Cyprinidae, Percidae and Poeciliidae are the most diverse families of fishes in North America, making up about 26 %, 16 % and 8 %, respectively, of that fauna (Page & Burr, 1991; Lundberg et al., 2000; Jelks et al., 2008), whereas the Cyprinodontidae accounts for a much smaller portion of that fauna (less than 4 %; Jelks et al., 2008). Thus the composition of Table 1 is not merely reflective of the overall pattern of North American freshwater fish diversity. Using the definition of Weitzman & Vari (1988) seven of these 146 species are considered miniature: *Elassoma alabamae* (Fig. 1), *Leptolucania ommata* (Fig. 2), *Heterandria formosa*, *Megupsilon aporus* (Fig. 3), *Cyprinodon macularius*, *Notropis saladonis* and *Elassoma zonatum*. *Elassoma alabamae* is the only species considered a miniature based on maximum known size (25.5 mm SL). The remaining miniatures are defined as such based on minimum size at maturity as all achieve maximum standard lengths greater than 26 mm.

Discussion

In comparison to other continents for which lists of miniature freshwater fishes have been compiled (South America – Weitzman & Vari, 1988; Southeast Asia – Kottelat & Vidthayanon, 1993; Africa – Conway & Moritz, 2006) North America has few truly miniature freshwater fish species. Africa contains 24 miniature freshwater fish species (Conway & Moritz, 2006), South America harbors well over 100 such species (Weitzman & Vari, 1988; Costa & Le Bail, 1999), and Southeast Asia contains over 50 species (Kottelat & Vidthayanon, 1993; Kottelat et al., 2006), compared to only seven species in North America (Table 1). There is currently no published list of European miniature species but based on Kottelat & Freyhof (2007) there appears to be just two: *Economidichthys trichonis* (maximum size 25 mm SL) and

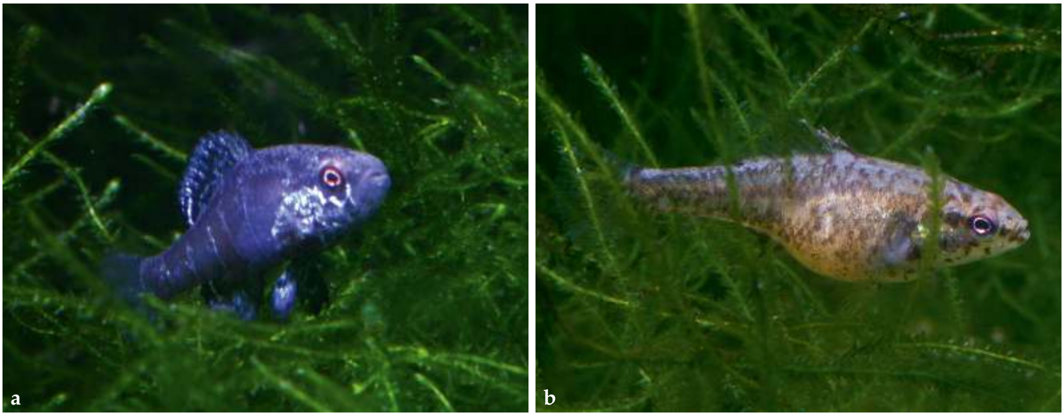

Fig. 1. *Elassoma alabamae*; U.S.A.: Alabama: Limestone County: Beaverdam Creek. **a,** male; **b,** female. Photographs courtesy of P. Rakes and J. R. Shute.

Fig. 2. *Leptolucania ommata*; locality unknown. **a,** male. **b,** female. Photographs courtesy of P. Loiselle.

Table 1. North American freshwater fishes with a maximum known standard length (SL) less than or equal to 50.0 mm. All measurements are in SL unless otherwise stated. Taxa highlighted in bold are miniature species (sensu Weitzman and Vari 1988). Conservation status abbreviations (following Jelks et al. 2008): E, endangered; T, threatened; V, vulnerable; X, extinct; Xn, extirpated in nature; Xp, possibly extinct; –, not assessed.

order – family/species	max SL (mm)	min SL at maturity (mm)	reference (maximum known SL; minimum known SL at maturity)	Conservation Status
Cypriniformes – Cyprinidae				
Cyprinella alvarezdelvillari	43.8	25.0 (♂)	Miller et al., 2005: 110	E
Dionda diaboli	48	?	Miller et al., 2005: 116	E
Dionda erimyzonops	39	21.0 (♂)	Miller et al., 2005: 117; Hubbs & Miller, 1974	–
Evarra tlahuacensis	48	?	Miller et al., 2005: 120	X
Extrarius n. sp. cf. *aestivalis*	50	?	Gilbert, 1992	rare?
Hybopsis amecae	41	?	Miller et al., 2005:127	–
Hybopsis aulidion	39	?	Miller et al., 2005: 130	–
Iotichthys phlegethontis	41	?	Miller & Behnke, 1985	E
Lythrurus alegnotus	50	?	Boschung & Mayden, 2004	–
Lythrurus snelsoni	43.2	?	Robison, 1985	V
Notropis alborus	50	?	Hubbs & Raney, 1947: 11	–
Notropis ammophilus	'ca.' 48.0	29.0 (♂); 31.0 (♀)	Boschung & Mayden, 2004	–
Notropis anogenus	48	?	Bailey, 1959	T
Notropis buchanani	41	?	Miller et al., 2005: 132	–
Notropis calbazas	26.8	?	Lyons & Mercado-Silva, 2004	E
Notropis chalybaeus	50	?	Boschung & Mayden, 2004	V
Notropis harperi	49	25.0 (♀)	Boschung & Mayden, 2004	–
Notropis melanostomus	38	21	Boschung & Mayden, 2005; Suttkus & Bailey, 1990	T
Notropis ortenburgeri	50	?	UMMZ, 2009	V
Notropis rafinesquei	'ca.' 43.0	22.5	Haag et al., 2007	–
Notropis sabinae	49	38.0 (♀; TL)	Heins, 1981; Williams & Bonner, 2006	–
Notropis saladonis	**38**	**19.0 (♂); 21.0 (♀)**	Miller et al., 2005: 135; Hubbs & Hubbs, 1958	Xp
Notropis tropicus	41	27.0 (♂)	Miller et al., 2005:137	–
Oregonichthys kalawatseti	49.2	?	Markle et al., 1991: 280	V
Stypodon signifer	40	?	Miller et al., 2005: 140	X
Lythrurus roseipinnis	'ca.' 50.0	28	Boschung & Mayden, 2004	–
Characiformes – Characidae				
Hyphessobrycon compresus	46	?	Miller et al., 2005: 158	–
Siluriformes – Ictaluridae				
Noturus stanauli	36.2	?	Etnier & Jenkins, 1980	E
Percopsiformes – Amblyopsidae				
Amblyopsis rosae	43	?	UMMZ, 2009	T
Chologaster cornuta	48	20.0 (♀)	Ross & Rhode, 2003: 110	–
Atheriniformes – Atherinopsidae				
Atherinella lisa	45	?	Miller et al., 2005: 189	E
Cyprinodontiformes – Cyprinodontidae				
Cualac tessellatus	45.5	?	Miller et al., 1956: 9	E
Cyprinodon arcuatus	42	?	Minckley et al., 2003	Xp
Cyprinodon atrorus	35	?	Miller et al., 2005: 298	E
Cyprinodon beltrani	41	?	Miller et al., 2005: 299	V
Cyprinodon diabolis	28	?	UMMZ, 2009	E
Cyprinodon elegans	49	?	Suttkus & Williams, 2008	E
Cyprinodon eremus	41.5	?	Minckley et al., 2005	E
Cyprinodon eximius	46	?	Miller et al., 2005: 303	T
Cyprinodon fontinalis	50	?	Miller et al., 2005: 303	E
Cyprinodon labiosus	40	?	Miller et al., 2005: 304	E

Table 1. (continued).

Cyprinodon latifasciatus	43	?	Miller et al., 2005: 304	X
Cyprinodon macrolepis	44	?	Miller et al., 2005: 305	E
Cyprinodon macularius	**37.8**	**15**	Minckley et al., 2004; Schoenherr, 1988	E
Cyprinodon meeki	49	?	Miller et al., 2005: 307	E
Cyprinodon nazas	46	?	Miller et al., 2005: 308	T
Cyprinodon pecosensis	'ca.' 50.0	?	Garrett, 1982	E
Cyprinodon pisteri	49.3	23.0-25.0 (♂)	Minckley et al., 2002: 688, 689	E
Cyprinodon rubrofluviatilis	48	?	UMMZ, 2009	–
Cyprinodon simus	33	?	Miller et al., 2005: 309	E
Cyprinodon suavium	45.5	?	Strecker, 2003	–
Cyprinodon variegatus hubbsi	35	?	Gilbert, 1992	V
Cyprinodon verecundus	35	?	Humphries, 1984: 63	E
Garmanella pulchra	38	?	Miller et al., 2005: 315	–
Jordanella floridae	39	?	McEachran & Fechhelm, 1998:899	–
Megupsilon aporus	**36**	**15.0 (♂); 18.0 (♀)**	Miller et al., 2005: 317	Xn
Cyprinodontiformes – Fundulidae				
Adenia xenica	42	?	Boschung & Mayden, 2004	–
Leptolucania ommata	**27**	**12.0 (♂); 15.0 (♀)**	Boschung & Mayden, 2004	–
Lucania goodei	42	?	Boschung & Mayden, 2004	–
Lucania interioris	~35.0	?	Miller et al., 2005: 316	E
Cyprinodontiformes – Goodeidae				
Allodontichthys polylepis	50	?	Miller et al., 2005: 269	E
Allotoca maculata	48	?	Miller et al., 2005: 274	E
Allotoca meeki	50	?	Miller et al., 2005: 274	E
Allotoca zacapuensis	50	?	Miller et al., 2005: 275	E
Characodon garmani	27	?	Miller et al., 2005: 279	X
Crenichthys nevadae	44	?	Hubbs, 1932	T
Cyprinodon pachycephalus	50	?	Miller et al., 2005: 308	E
Skiffia bilineata	42	?	Miller et al., 2005: 284	E
Skiffia francesae	43	?	Miller et al., 2005: 284	Xn
Cyprinodontiformes – Poeciliidae				
Brachyrhaphis hartwegi	43	?	Miller et al., 2005: 219	–
Gambusia alvarezi	38	?	Miller et al., 2005: 221	E
Gambusia atrora	40	?	Miller et al., 2005: 221	–
Gambusia aurata	34	?	Miller et al., 2005: 222	–
Gambusia clarkhubbsi	43	?	Garrett & Edwards, 2003	E
Gambusia eurystoma	36	?	Miller et al., 2005: 223	V
Gambusia hurtadoi	36	?	Miller et al., 2005: 223	E
Gambusia krumholzi	38	?	Miller et al., 2005: 223	V
Gambusia longispinis	29	?	Miller et al., 2005: 224	E
Gambusia regani	42	32.0 (♀)	Miller et al., 2005: 225	–
Gambusia senilis	46	?	Miller et al., 2005: 226	T
Gambusia sexradiata	43	?	Miller et al., 2005: 227	–
Gambusia speciosa	48	?	Miller et al., 2005: 227	T
Gambusia vittata	37	25.0 (♀)	Miller et al., 2005: 228	–
Heterandria formosa	**30**	**15.0 (♀)**	Boschung & Mayden, 2004	–
Heterophallus echeagarayi	35	?	Miller et al., 2005: 230	–
Heterophallus milleri	31	?	Miller et al., 2005: 231	–
Heterophallus rachovii	32	?	Miller et al., 2005: 231	–
Phallichthys fairweatheri	46	?	Miller et al., 2005: 232	–
Poecilia chica	46	?	Miller et al., 2005: 234	V
Poecilia sulphuraria	50	?	Miller et al., 2005: 239	T
Poeciliopsis baenschi	44	?	Miller et al., 2005: 241	–
Poeciliopsis balsas	43	?	Miller et al., 2005: 242	–
Poeciliopsis fasciata	45	?	Miller et al., 2005: 242	–
Poeciliopsis latidens	48	?	Miller et al., 2005: 245	T

Table 1. (continued).

Poeciliopsis lucida	~42.0	?	Miller et al., 2005: 246	–
Poeciliopsis monacha	44	?	Miller et al., 2005: 246	–
Poeciliopsis occidentalis	48	?	Miller et al., 2005: 246	E
Poeciliopsis presidionis	~45.0	?	Miller et al., 2005: 248	–
Poeciliopsis prolifica	42	?	Miller et al., 2005: 248	–
Poeciliopsis viriosa	46	?	Miller et al., 2005: 251	–
Priapella bonita	45	?	Miller et al., 2005: 251	X
Priapella intermedia	45	?	Miller et al., 2005: 253	–
Xiphophorus andersi	40	?	Miller et al., 2005: 255	–
Xiphophorus clemenciae	46	?	Miller et al., 2005: 255	T
Xiphophorus continens	~30.0	?	Miller et al., 2005: 256	–
Xiphophorus cortezi	50	?	Miller et al., 2005: 257	–
Xiphophorus couchianus	37	?	Miller et al., 2005: 257	E
Xiphophorus evelynae	48	?	Miller et al., 2005: 257	–
Xiphophorus gordoni	30	?	Miller et al., 2005: 258	E
Xiphophorus maculatus	45	?	Miller et al., 2005: 259	–
Xiphophorus meyeri	46.2	?	Miller et al., 2005: 260	E
Xiphophorus milleri	35	?	Miller et al., 2005: 261	E
Xiphophorus multilineatus	~45.0	?	Miller et al., 2005: 262	–
Xiphophorus nigrensis	42	?	Miller et al., 2005: 263	–
Xiphophorus pygmaeus	37.2	?	Morris & Ryan, 1995	–
Xiphophorus xiphidium	49	?	Miller et al., 2005: 264	–
Cyprinodontiformes – Rivulidae				
Millerichthys robustus	33	?	Miller et al., 2005: 207	E
Rivulus tenuis	40	?	Miller et al., 2005: 208	–
Perciformes – Elassomatidae				
Elassoma alabamae	**25.5**	**?**	Mayden, 1993	E
Elassoma boehlkei	27	?	Rohde & Arndt, 1987	T
Elassoma evergladei	28	?	Boschung & Mayden, 2004	–
Elassoma okatie	28.7	?	Rohde & Arndt, 1987	V
Elassoma okefenokee	28	?	Boschung & Mayden, 2004	–
Elassoma zonatum	**38.5**	**19.2 (♀)**	Walsh & Burr, 1984: 36, 41	
Perciformes – Percidae				
Etheostoma australe	50	?	Miller et al., 2005: 335	E
Etheostoma chlorosoma	50	?	Page, 1983	–
Etheostoma denoncourti	28.6	?	Stauffer & Van Sink, 1997	V
Etheostoma ditrema	45	?	Page, 1983	T
Etheostoma edwini	49	27.0 (♀)	Boschung & Mayden, 2004	–
Etheostoma fonticola	35.5	24.4 (♀ TL)	Burr, 1978; Schenk & Whiteside, 1977	E
Etheostoma fusiforme	46	32.0 (TL)	Boschung & Mayden, 2004	–
Etheostoma gracile	49	35.0 (TL)	Boschung & Mayden, 2004	–
Etheostoma grahami	44	?	Miller et al., 2005: 336	T
Etheostoma lugoi	37.6	?	Norris & Minckley, 1997: 162	E
Etheostoma microperca	37	~28.0	Etnier & Starnes, 1993	–
Etheostoma nuchale	45	?	Boschung & Mayden, 2004	E
Etheostoma okaloosae	48	?	Burkhead et al., 1992	E
Etheostoma pottsi	50	?	Miller et al., 2005: 337	T
Etheostoma proeliare	40	29.2 (♂); 30.7 (♀)	Boschung & Mayden, 2004	–
Etheostoma rubrum	46	27.0 (♀)	Raney & Suttkus, 1966; Knight & Ross, 1992:102	E
Etheostoma segrex	43.8	?	Norris & Minckley, 1997: 171	E
Etheostoma stigmaeum	48.9	35.6 (♂); 35.7 (♀)	Boschung & Mayden, 2004	–
Etheostoma tippecanoe	36	22.5 (♂); 21.2 (♀)	Stauffer & Van Sink, 1997; Warren et al., 1986	V
Etheostoma trisella	49	37	Boschung & Mayden, 2004; Ryon, 1986: 81	E
Etheostoma zonifer	38	?	Boschung & Mayden, 2004	–
Scorpaeniformes – Cottidae				
Cottus paulus	38	25	Williams, 2002; Boschung & Mayden, 2004	E

Knipowitschia goerneri (maximum size 22 mm SL).

Any explanation for this disparity is at this time highly speculative; however, Africa, Asia and South America differ greatly from North America in several key aspects that may promote miniaturization and diversification of diminutive fishes. The equatorial position of much of Africa, South and Southeast Asia and South America is likely a major factor in diversification on those continents in general (Lundberg et al., 2000). The large number of species in the tropics has also been suggested to make miniature species simply more likely to evolve (Weitzman & Vari, 1988). Collette (1962) suggested a link between the acidic environments inhabited by *Etheostoma fusiforme* (Swamp Darter) and its reduced lateral line system and overall small body size. Similarly Weitzman & Vari (1988) noted that many South American miniatures occur in this environment, which is common across many portions of the continent. They also recognized that most of the miniature freshwater fishes included in their table, if not found explicitly in acidic waters, inhabited still or slow-flowing habitats or microhabitats. Kottelat & Vidthayanon (1993) and Kottelat et al. (2006) also commented that most miniature Southeast Asian freshwater fishes occupy lentic or slow-flowing habitats. Our review further supports the notion that miniature fishes are more likely to occur in habitat with little flow. *Cyprinodon macularius*, *Elassoma alabamae* and *Megupsilon aporus* occur in springs or spring-fed pools with little or no flow (Hendrickson & Romero, 1989; Mayden, 1993; Miller & Walters, 1972). *Leptolucania ommata* and *Elassoma zonatum* are found in vegetated swamps and backwaters or streams with little flow (Boschung & Mayden, 2004). *Heterandria formosa* prefers pools of sluggish, heavily-vegetated streams (Boschung & Mayden, 2004) and *Notropis saladonis* inhabits slow-flowing, silty streams (Hubbs & Hubbs, 1958). In addition, many of the smallest species in Table 1, while not miniature by the definition of Weitzman & Vari (1993), are found mostly in swamp and spring habitats (e. g. *Elassoma*, *Xiphophorus*). These habitats, as well as smaller streams (even swift-flowing), likely limit dispersal, and thus gene flow, among populations of small-bodied fishes, promoting diversification (Knouft & Page, 2003).

While this general model encompasses most of the diminutive species we examined (and indeed those studied on other continents), there is

Fig. 3. *Megupsilon aporus*, Mexico: Matinal de El Potosi Nuevo Leon. Male. Photograph courtesy of P. Loiselle.

also a small component of diminutive North American freshwater fish diversity that inhabits fast flowing, large and medium-sized upland rivers and streams with gravel, cobble, boulder and bedrock as predominant sediments (e. g. *Noturus stanauli, Etheostoma tippecanoe, E. denoncourti*). Similar habitat preferences have been reported for a small number of miniature taxa from other continents, including the catfishes *Hoplomyzon papillatus* (Stewart, 1985), *Horiomyzon retropinnatus* (Stewart, 1986), and the cichlid *Nannochromis minor* (Roberts & Stewart, 1976). The microhabitats associated with the cryptobenthic behavior of these latter species may be characterized by reduced flow and analogous to the slow velocities of oxbows, springs and swamp.

Imperilment was high among diminutive fishes, with 58 % of those listed in Table 1 labeled as vulnerable (9 % of total), threatened (10.2 %), endangered (32.0 %) or extinct (6.8 %) according to Jelks et al. (2008). Only barely over 42 % of these fishes did not warrant listing by Jelks et al. (2008) (i. e. not threatened). *Elassoma alabamae* is particularly threatened and in need of further protection (Conway & Mayden, 2006). Our review also highlights the lack of critical life history information (minimum size at maturity) for many of the fish species we examined. We anticipate that with more study of reproductive biology, additional species on our list will be identified as miniature based on size at maturity (less than 20 mm SL) in the future.

Small bodied freshwater fishes are particularly faced with a great threat of extinction, but may get less attention than their larger commercially-harvested relatives (Olden et al., 2007). Without a better knowledge of the processes and conditions that gave rise to and help maintain the diversity of small bodied freshwater fishes, and the habitats that they rely on, there will be little hope for preserving these interesting and unique components of global biodiversity.

Acknowledgements

We are grateful to C. Dillman, J. Knouft, N. Lang, R. Mayden and L. Page for discussions on small-bodied North American freshwater fishes, P. Rakes and J. R. Shute (Conservation Fisheries Inc.) for the photographs of *Elassoma alabamae*, P. Loiselle for the photographs of *Leptolucania* and *Megupsilon* and M. Kottelat and R. Vari for helpful comments on an earlier draft of the manuscript. Finally, we thank R. Mayden and R. Wood for their continuing support and advice. This research was supported by Saint Louis University and the National Science Foundation (DEB 0808446 to KWC).

Literature cited

Abell, R. A., D. M. Olsen, E. Dinerstein, P. T. Hurley, J. T. Diggs, W. Eichbaum, S. Walters, W. Wettengel, T. Allnutt, C. J. Loucks & P. Hedao. 2000. Freshwater ecoregions of North America: a conservation assessment. Island Press, Washington, 319 pp.

Bailey, R. M. 1959. Distribution of the American cyprinid fish *Notropis anogenus*. Copeia, 1959: 119-123.

Belk, M. C. & D. D. Houston. 2002. Bergmann's rule in ectotherms: a test using freshwater fishes. American Naturalist, 160: 803-808.

Boschung, H. T. & R. L. Mayden. 2004. Fishes of Alabama. Smithsonian Press, Washington, 736 pp.

Burkhead, N. M., J. D. Williams & R. W. Yerger. 1992. Okaloosa darter, *Etheostoma okaloosae*. Pp. 23-30 in C. R. Gilbert (ed.), Rare and endangered biota of Florida. Volume III. Fishes. University Presses of Florida, Gainesville, 283 pp.

Burr, B. M. 1978. Systematics of the percid fishes of the subgenus *Microperca*, genus *Etheostoma*. Bulletin of the Alabama Museum of Natural History, 4: 1-53.

Conway, K. W. & R. L. Mayden. 2006. Threatened fishes of the world: *Elassoma alabamae* Mayden, 1993 (Elassomatidae). Environmental Biology of Fishes, 75: 195-196.

Conway, K. W. & T. Moritz. 2006. *Barboides britzi*, a new species of miniature cyprinid from Benin (Ostariophysi: Cyprinidae), with neotype designation for *B. gracilis*. Ichthyological Exploration of Freshwaters, 17: 73-84.

Costa, W. J. E. M & P.-Y. Le Bail. 1999. *Fluviphylax palikur*: a new poecilid from the Rio Oiapoque Basin, Northern Brazil (Cyprinodontiformes: Cyprinodontoidei), with comments on miniaturization in *Fluviphylax* and other Neotropical freshwater fishes. Copeia, 1999: 1027-1034.

Etnier, D. A. & R. E. Jenkins. 1980. *Noturus stanauli*, a new madtom catfish (Ictaluridae) from the Clinch and Duck Rivers, Tennessee. Bulletin of the Alabama Museum of Natural History, 5: 17-22.

Etnier, D. A. & W. C. Starnes. 1993. Fishes of Tennessee. University of Tennessee Press, Knoxville, 689 pp.

Garrett, G. P. 1982. Variation in reproductive traits of the Pecos Pupfish, *Cyprinodon pecosensis*. American Midland Naturalist, 108: 355-363.

Garrett, G. P. & R. J. Edwards. 2003. New species of *Gambusia* (Cyprinodontiformes: Poeciliidae) from Del Rio, Texas. Copeia, 2003: 783-788.

Gilbert, C. R. 1992. Rare and endangered biota of Florida. Volume II. Fishes. University Press of Florida, Gainesville, 247 pp.

Haag, W. R., A. M. Commens-Carson & M. L. Warren. 2007. Life history variation in the Yazoo Shiner *(Notropis rafinesquei)* in three Mississippi streams. American Midland Naturalist, 158: 306-320.

Heins, D. C. 1981. Life history pattern of *Notropis sabinae* (Pisces: Cyprinidae) in the lower Sabine River drainage of Louisiana and Texas. Tulane Studies in Zoology and Botany, 22: 67-84.

Hendrickson, D. E. & A. V. Romero. 1989. Conservation status of the desert pupfish *Cyprinodon macularius* in Mexico and Arizona. Copeia, 1989: 478-483.

Herre, A. W. 1929. The smallest known vertebrate. Science, 69: 329-330.

Hubbs, C. L. 1932. Studies of the fishes of the order Cyprinodontes. XII. A new genus related to *Empetrichthys*. Occasional Papers of the Museum of Zoology, University of Michigan, 252: 1-7.

Hubbs, C. L. & C. Hubbs. 1958. *Notropis saladonis*, a new cyprinid fish endemic in the Rio Salado of northeastern Mexico. Copeia, 1958: 297-307.

Hubbs, C. L. & R. R. Miller. 1974. *Dionda erimyzonops,* a new, dwarf cyprinid fish inhabiting the gulf coastal plain of Mexico. Occasional Papers of the Museum of Zoology University of Michigan, 671: 1-17.

Hubbs, C. L. & E. C. Raney. 1947. *Notropis alborus*, a new cyprinid fish from North Carolina and Virginia. Occasional Papers Museum of Zoology University of Michigan, 498: 1-19.

Humphries, J. M. 1984. *Cyprinodon verecundus*, n. sp., a fifth species of pupfish from Laguna Chichancanab. Copeia, 1984: 58-68.

Jelks, H. L., S. J. Walsh, N. M. Burkhead, S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. J. Schmitter-Soto, E. B. Taylor & M. L. Warren. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. Fisheries, 33: 372-407.

Knight, J. G. & Ross, S. T. 1992. Reproduction, age and growth of the Bayou Darter *Etheostoma rubrum* (Pisces, Percidae): an endemic of Bayou Pierre. American Midland Naturalist, 127: 91-105.

Knouft, J. H. 2004. Latitudinal variation in the shape of the species body size distribution: an analysis using freshwater fishes. Oecologia, 139: 408-417.

Knouft, J. H. & L. M. Page. 2003. The evolution of body size in extant groups of North American freshwater fishes: speciation, size distributions, and Cope's rule. American Naturalist, 161: 413-421.

Kottelat, M. & C. Vidthayanon. 1993. *Boraras micros*, a new genus and species of minute freshwater fish from Thailand (Teleostei: Cyprinidae). Icthyological Exploration of Freshwaters, 4: 161-176.

Kottelat, M. & J. Freyhof 2007. Handbook of European Freshwater Fishes. Kottelat, Cornol & Freyhof, Berlin, 646 pp.

Lundberg, J. G., M. Kottelat, G. R. Smith, M. L. J. Stiassny & A. C. Gill. 2000. So many fishes so little time: an overview of recent ichthyological discovery in continental waters. Annals of the Missouri Botanical Garden, 87: 26-62.

Lyons, J. & N. Mercado-Silva. 2004. *Notropis calabazas* (Teleostei; Cyprinidae): new species from the Rio Panuco basin of central Mexico. Copeia, 2004: 868-875.

Markle, D. F., T. N. Pearsons & D. T. Bills. 1991. Natural history of *Oregonichthys* (Pisces: Cyprinidae), with a description of a new species from the Umpqua River of Oregon. Copeia, 1991: 277-293.

Mayden, R. L. 1993. *Elassoma alabamae*, a new species of pygmy sunfish endemic to the Tennessee River drainage of Alabama (Teleostei: Elassomatidae). Bulletin of the Alabama Museum of Natural History, 16: 1-14.

McEachran, J. D. & J. D. Fechhelm. 1998. Fishes of the Gulf of Mexico: Myxiniformes to Gasterosteiformes. University of Texas Press, Austin, 1120 pp.

Miller, D. L. & R. J. Behnke. 1985. Two new intergeneric cyprinid hybrids from the Bonneville Basin, Utah. Copeia, 1985: 509-515.

Miller, R. R. 1956. A new genus and species of cyprinodontid fish from San Luis Potosi, Mexico, with remarks on the subfamily Cyprinodontinae. Occasional Papers Museum of Zoology, University of Michigan, 581: 1-17.

Miller, R. R. & V. Walters. 1972. A new genus of cyprinotoid fish from Nuevo Leon, Mexico. Contributions in Science, (Los Angeles), 233: 1-13.

Miller, R. R., W. L. Minckley & S. M. Norris. 2005. Freshwater fishes of Mexico. University of Chicago Press, 490 pp.

Minckley, W. L., R. R. Miller & S. M. Norris. 2002. Three new pupfish species, *Cyprinodon* (Teleostei, Cyprinodontidae), from Chihuahua, Mexico, and Arizona, USA. Copeia, 2002: 687-705.

Morris, M. R. & M. J. Ryan. 1995. Large body size in the pygmy swordtail *Xiphophorus pygmaeus*. Biological Journal of the Linnean Society,54: 383-395.

Olden, J. D., Z. S. Hogan & M. J. Vander Zanden. 2007. Small fish, big fish, red fish, blue fish: size-biased extinction risk of the world's freshwater and marine fishes. Global Ecology and Biogeography, 16: 694-701.

Page, L. M. 1983. Handbook of Darters. TFH Publications, Jersey City, 271 pp.

Raney, E. C. & R. D. Suttkus. 1966. *Etheostoma rubrum,* a new percid fish of the subgenus *Nothonotus* from Bayou Pierre, Mississippi. Tulane Studies in Zoology, 13: 95-102.

Roberts, T. R. & D. J. Stewart. 1976. An ecological and systematic survey of fishes in the rapids of the lower Zaire or Congo River. Bulletin of the Museum of Comparative Zoology, 147: 239-317

Robison, H. W. 1985. *Notropis snelsoni,* a new cyprinid from the Ouachita Mountains of Arkansas and Oklahoma. Copeia, 1985: 126-134.

Rohde, F. C. & R. G. Arndt. 1987. Two new species of pygmy sunfishes (Elassomatidae, *Elassoma*) from the Carolinas. Proceedings of the National Academy of Sciences, 139: 65-85.

Ross, S. W. & F. C. Rhode. 2003. Life history of the swampfish from a North Carolina stream. Southeastern Naturalist, 2: 105-120.

Rüber, L., M. Kottelat, H. H. Tan, P. K. L. Ng & R. Britz. 2007. Evolution of miniaturization and the phylogenetic position of *Paedocypris,* comprising the world's smallest vertebrate. BMC Evolutionary Biology, 7: 38.

Ryon, M. G. 1986. The life history and ecology of *Etheostoma trisella* (Pisces: Percidae). American Midland Naturalist, 115: 73-86.

Schenk, J. R. & B. G. Whiteside. 1977. Reproduction, fecundity, sexual dimorphism and sex ratio of *Etheostoma fonticola*. American Midland Naturalist, 98: 365-375.

Schoenherr, A. A. 1988. A review of the life history and status of the Desert Pupfish, *Cyprinodon macularius*. Bulletin of the Southern California Academy of Sciences, 87: 104-134.

Smith, H. M. 1902. The smallest known vertebrate. Science, 15: 30-31.

Stauffer J. R. & E. Van Snik. 1997. New species of *Etheostoma* (Teleostei: Percidae) from the upper Tennessee River. Copeia, 1997: 116-122.

Stewart, D. J. 1985. A review of the South American catfish tribe Hoplomyzontini (Pisces, Aspredinidae), with descriptions of a new species from Ecuador. Fieldiana: Zoology, 25: 1-19.

— 1986. A new pimelodid catfish from the deep-river channel of the Río Napo, eastern Ecuador (Pisces: Pimelodidae). Proceedings of the Academy of Natural Sciences of Philadelphia, 138: 46-52.

Strecker, U. 2003. Description of a new species from Laguna Chichancanab, Yucatan, Mexico: *Cyprinodon suavium* (Pisces: Cyprinodontidae). Hydrobiologia, 541: 107-115.

Suttkus, R. D. & R. M. Bailey. 1990. Characters, relationships, distribution, and biology of *Notropis melanostomus*, a recently named cyprinid fish from southeastern United States. Occasional Papers Museum of Zoology University of Michigan, 722: 1-15

Suttkus, R. D. & E. C. Raney. 1955. *Notropis hypsilepis*, a new cyprinid fish from the Apalachicola River system of Georgia and Alabama. Tulane Studies in Zoology, 2: 161-170.

Suttkus, R. D. & J. D. Williams. 2008. A note on three collections of Cyprinodontid fishes housed in the British Museum of Natural History, including syntypes and historically important specimens. Southeastern Fishes Council Proceedings, 50: 19-24.

UMMZ (University of Michigan Museum of Zoology). 2009. Online catalogue of the Division of Fishes. Accessed 24 February 2009. http://www.ummz.lsa.umich.edu/fishes/collection.html

Warren, M. L., B. M. Burr & B. R. Kuhajda. 1986. Aspects of the reproductive biology of *Etheostoma tippecanoe* with comments on egg-burying behavior. American Midland Naturalist, 116: 215-218.

Watson, W. & H. J. Walker. 2004. The world's smallest vertebrate, *Schindleria brevipinguis*, a new paedomorphic species in the family Schindleriidae (Perciformes: Gobioidei). Records of the Australian Museum, 56: 139-142.

Weitzman, S. H. & R. P. Vari. 1988. Miniaturization in South American freshwater fishes: an overview and discussion. Proceedings of the Biological Society of Washington, 101: 444-465.

Williams, C. S. & T. H. Bonner. 2006. Habitat associations, life history and diet of the Sabine Shiner *Notropis sabinae* in an east Texas drainage. American Midland Naturalist, 155: 84-102.

Williams, J. D. 2000. *Cottus paulus*, a replacement name for the Pygmy Sculpin, *Cottus pygmaeus* Williams 1968. Copeia, 2000: 302.

Winterbottom, R. & A. R. Emery. 1981. A new genus and two new species of gobiid fishes (Perciformes) from the Chagos Archipelago, Central Indian Ocean. Environmental Biology of Fishes, 6: 139-149.

Received 30 May 2009
Revised 29 October 2009
Accepted 3 November 2009