Received: 1 November 2017 | Revised: 8 October 2018 | Accepted: 8 October 2018

DOI: 10.1111/lre.12243

RESEARCH NOTE

WILEY Lakes & Reservoirs

Length–weight and length–length relationships of some of the most abundant species in the fish catches of Lake Nokoué and Porto-Novo Lagoon (Benin, West Africa)

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Abstract

The length–weight relationships (LWRs) and length–length relationships (LLRs) are presented for 18 commercial actinopterygian fish species found in Lake Nokoué and the Porto-Novo Lagoon. The fish were collected monthly from fishermen from June 2015 to May 2016. The sample size, length range, weight range, LWRs, LLRs, 95% confidence intervals of *b*, coefficient of correlation r^2 and growth type are given for each species. Values of *b* were between 2.495 (*Elops lacerta*) and 3.235 (*Polydactylus quadrifilis*), and r^2 values between 0.884 (*Elops lacerta*) and 0.999 (*Acanthurus moroviae*). The present study introduces what will serve as the first references regarding LWRs and LLRs for two species (*Eleotris vittata* and *Lutjanus goreensis*) in Lake Nokoué and the Porto-Novo Lagoon. These results will be very useful for future investigations pertaining to population assessment and sustainable conservation practices for the fish stocks in both study areas.

KEYWORDS

Actinopterygii, Benin, ichthyofauna, length–length, length–weight

1 | INTRODUCTION

Lagoons are typically biodiversity-rich ecosystems. They serve as irreplaceable habitats, spawning grounds and nurseries for many species (Ruiz et al., 2006). Lake Nokoué and the Porto-Novo Lagoon taken together occupy the largest area in the Republic of Benin, West Africa. This complex has been part of the RAMSAR 1018 site since 2000. Thus, it is important that its ecological characteristics are preserved, and many studies have been conducted with this goal in mind; namely on the local environmental quality and the species of fish encountered (Chouti, Mama, & Alapini, 2010; Chouti, Mama, Changotade, Alapini, & Boukari, 2010; Chouti et al., 2011; Dimon et al., 2014; Dovonou, Aina, Boukari, & Alassane, 2011; Lalèyè, Niyonkuru, Moreau, & Teugels, 2003; Mama et al., 2011; Niyonkuru & Lalèyè, 2010, 2012; Niyonkuru, Lalèyè, & Moreau, 2010; Youssao et al., 2011). Accordingly, it has conclusively established that both study areas are subjected to overfishing (Lalèyè, Philippart, & Barras, 1993; Lalèyè et al., 2003; Niyonkuru, Lalèyè, Hounkpe, & Moreau, 2003; Niyonkuru et al., 2010). Thus, provision should be made for the rational use of its resources, which requires the availability of specific information relative to the population dynamics of the targeted fish species.

A number of authors have reported this specific information is often obtained from analyses of fish length and weight data (Abowei et al. 2009; Froese, 2006; Le Cren, 1951; Lederoun, Lalèyè, Vreven, & Vandewalle, 2016). One of the most commonly-used parameters in such cases is the relationship between weight and length. The importance of this parameter has been widely discussed (Adeyemi, 2010; Arsalan, Yildirim, & Bektas, 2004; Blackwell, Brown, & Wilis, 2000; Froese, 2006; Garcia, Buarte, Sandoval, Von-Schiller, & Najavas, 1989; Haimovici & Velasco, 2000; Konan, Ouattara, Ouattara, & Gourène, 2007; Lalèyè, 2006; Le Cren, 1951; Lederoun et al., 2016; Tah, Bi, & Da Costa, 2012). It is accepted that the length–weight relationship of fish is an important fishery management tool (Garcia et al., 1989; Haimovici & Velasco, 2000), being used to estimate fish biomass from length frequency distributions and to infer the fish condition (Petrakis & Stergiou, 1995). This relationship can be used in developing fish yield equations, in estimating the number of fish caught and in comparing fish populations from various ecosystems and during different seasons (Beverton & Holt, 1957).

There is no information, however, regarding the length–weight relationships (LWRs) and the length–length relationships (LLRs) of some of the most abundant fish species encountered in Lake Nokoué or in the Porto-Novo Lagoon, apart from previous studies by Lalèyè (1995) and Niyonkuru and Lalèyè (2012), but who only focused on two claroteid and two cichlid species. Thus, the goal of the present study was to remedy this deficiency by more closely examining these RAMSAR ecosystems which are, in fact, in great need of attention. To this end, the present study presents the first reports of LWRs and LLRs for the 18 most common actinopterygian fish species found in Lake Nokoué and the Porto-Novo Lagoon, the results of which will serve as an important reference for future investigators.

2 | MATERIALS AND METHODS

The fish were caught between June 2015 and May 2016 in Lake Nokoué (6°20′ to 6°30′N and 2°20′ to 2°35′E) and Porto-Novo Lagoon (6°25′ to 6° 30′N and 2°30′ to 2°38′E; Figure 1) using scoops, monofilament gillnets, cast nets and acadjas at three sampling sites established on each ecosystem for conducting an inventory of fish fauna and establishing the spatial and temporal distribution of the latter (to be discussed in more detail in a following report). The collected fish specimens were transported to the laboratory where they were identified using the keys of Paugy, Lévêque, and Teugels (2003a,b), and measured for total length (TL) and standard length (SL) to the nearest 0.1 cm using a measuring-tape. Most were weighed (fresh weight, BW) individually to the nearest 0.01 g using an electronic precision balance. Part of the samples were deposited in the Royal Museum for Central Africa (MRAC-Tervuren, Belgium) for future reference.

The relationship between the total length and total weight of the fish was established using the following equation (Le Cren, 1951):

$$BW = a \times TL^b, \quad (1)$$

where BW = wet body weight (g); TL = total length (cm); a = intercept; and b = slope of linear regression. The coefficient b varies between 2 and 4, but is often close to 3 (Tesch, 1971), being an indication of the relative shape of a fish's body. The growth is isometric if b = 3 and allometric if $b \neq 3$ (negative allometric if $b < 3$ and positive allometric if $b > 3$). The 95% confidence limits for b were assessed using Statview software, version 1992–1998 (SAS Institute INC).

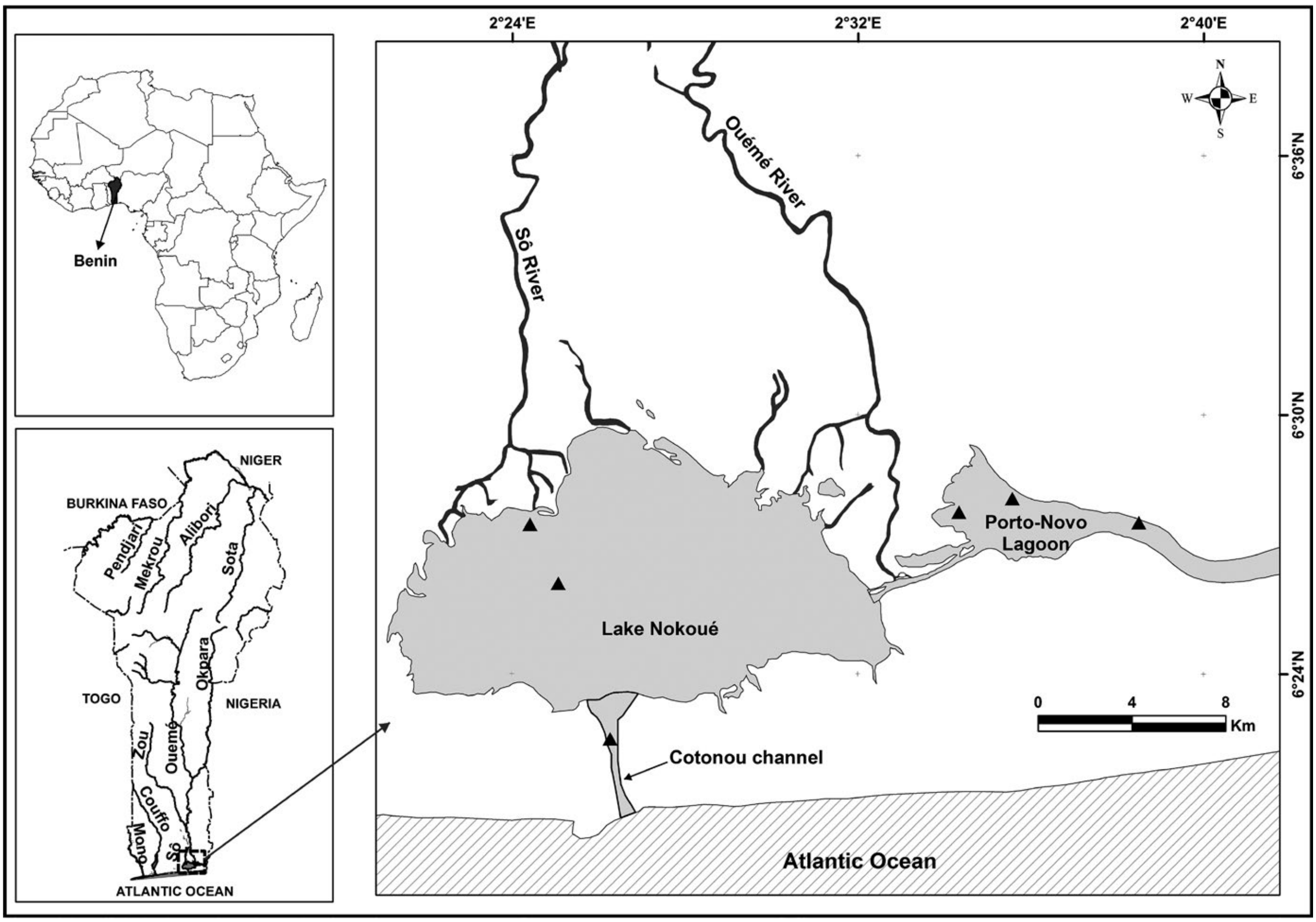

FIGURE 1 Study area, showing sampling sites

TABLE 1 Descriptive statistics and estimated parameters of length–weight relationships (BW = $a \times TL^{b}$) for 18 selected fish species collected from Lake Nokoué and Porto-Novo Lagoon

		TL (cm)	BW (g)	Regression parameters						
	N	Min–Max	Min–Max	*a*	*b*	*SE of b*	95% CL of b	r^2	Growth	Study area
Gymnarchidae										
Gymnarchus niloticus Cuvier, 1829	10 (J)	10.0-14.0	11.13–32.23	0.012	2.947	0.231	2.400–3.493	0.959	I	PL
Elopidae										
Elops lacerta Valenciennes, 1846	21	8.4–20.9	3.13-50.40	0.022	2.495	0.208	2.060–2.930	0.884	A−	PL
Clupeidae										
Ethmalosa fimbriata (Bowdich, 1825)	2,442	2.8–17.7	0.17-54.90	0.015	2.838	0.018	2.803–2.874	0.911	A−	LN + PL
Mochokidae										
Synodontis nigrita Valenciennes, 1840	33	12–23.7	14.57-89.10	0.030	2.553	0.135	2.278–2.827	0.921	A−	PL
Claroteidae										
Chrysichthys (Chrysichthys) auratus (Geoffroy Saint-Hilaire, 1808)	67	10.3–24.9	9.01-168.00	0.007	3.117	0.109	2.899–3.335	0.926	A+	PL
Chrysichthys (Melanodactylus) nigrodigitatus (Lacépède, 1803)	425	4.3–37.3	1.00-455.24	0.012	2.854	0.027	2.802–2.906	0.965	A−	LN + PL
Mugilidae										
Mugil cephalus Linnaeus, 175	87	9.3–39.2	8.72–603.71	0.010	2.958	0.056	2.848–3.069	0.978	I	LN + PL
Neochelon falcipinnis (Valenciennes 1836)	45	7.3–27.6	3.09–135.26	0.008	2.972	0.074	2.822–3.122	0.973	I	LN + PL
Carangidae										
Caranx hippos (Linné, 1766)	82 (J)	3.2–20.3	0.80-119.62	0.012	3.037	0.051	2.936–3.139	0.978	I	LN + PL
Lutjanidae										
Lutjanus goreensis (Valenciennes, 1830)	218	3.3–20.9	0.40–169.04	0.016	3.017	0.059	2.901–3.134	0.924	I	LN
Gerreidae										
Eucinostomus melanopterus (Bleeker, 1863)	415	3.3–16.7	0.55-109.20	0.011	3.08	0.048	2.985–3.174	0.909	I	LN + PL
Haemulidae										
Pomadasys jubelini (Cuvier, 1830)	26 (J)	6.7–22.6	4.26–169.58	0.013	3.016	0.04	2.934–3.099	0.995	I	LN + PL
Polynemidae										
Polydactylus quadrifilis (Cuvier, 1829)	24 (J)	10.5–20.2	6.00–55.6	0.004	3.235	0.099	3.030–3.441	0.979	A+	LN + PL
Monodactylidae										
Monodactylus sebae (Cuvier, 1829)	18	3.8–12.7	1.20-61.50	0.022	3.156	0.124	2.893–3.419	0.9758	A+	PL
Cichlidae										
Coptodon guineensis (Bleeker in Günther, 1862)	362	3.5–21.6	1.56-238.10	0.030	2.856	0.033	2.790–2.921	0.953	A−	LN + PL
Sarotherodon melanotheron melanotheron Rüppell, 1852	872	4.6–21.9	2.76–187.44	0.038	2.726	0.018	2.690–2.761	0.962	A−	LN + PL
Eleotridae										
Eleotris vittata Duméril, 1858	89	8.9–22.5	6.50-62.76	0.046	3.098	0.067	2.964–3.232	0.960	I	PL
Acanthuridae										
Acanthurus monroviae Steindachner, 1876	10 (J)	5.8–22.3	4.34–181.66	0.032	2.744	0.038	2.657–2.831	0.999	A−	LN

Note. A+: positive allometric growth; A−: negative allometric growth; *a*: intercept; *b*: allometric growth coefficient = slope; BW: body weight; CL: confidence limit; I: isometric growth; J: juvenile; LN: Lake Nokoué; Min: minimum; Max: maximum; *N*: sample size; PL: Porto-Novo Lagoon; r^2: coefficient of correlation; TL: total length.

TABLE 2 Descriptive statistics and estimated parameters of length–length relationships (TL = *p* + *q* SL) for 18 selected fish species collected from Lake Nokoué and Porto-Novo Lagoon

	N	TL (cm) Min–Max	SL (cm) Min–Max	Regression parameters TL = *p* + *q* SL	*SE* of *q*	r^2	Study area
Gymnarchidae							
Gymnarchus niloticus Cuvier, 1829	10 (J)	10.0–14.0	8.3–12.0	TL = 0.503 + 1.126 SL	0.090	0.957	PL
Elopidae							
Elops lacerta Valenciennes, 1846	21	8.4–20.9	6.4–15.9	TL = 0.444 + 1.267 SL	0.043	0.979	PL
Clupeidae							
Ethmalosa fimbriata (Bowdich, 1825)	2,470	2.8–19.5	2.1–15.0	TL = −0.033 + 1.309 SL	0.005	0.968	LN + PL
Mochokidae							
Synodontis nigrita Valenciennes, 1840	33	12.0–22.0	8.0–14.8	TL = 0.011 + 1.505 SL	0.070	0.937	PL
Claroteidae							
Chrysichthys (Chrysichthys) auratus (Geoffroy Saint-Hilaire, 1808)	67	10.3–24.9	7.3–18.7	TL = 1.060 + 1.280 SL	0.029	0.968	PL
Chrysichthys (Melanodactylus) nigrodigitatus (Lacépède, 1803)	425	4.3–37.3	3.5–27.0	TL = −0.074 + 1.399 SL	0.009	0.982	LN + PL
Mugilidae							
Mugil cephalus Linnaeus, 175	91	9.3–39.2	6.9–28.5	TL = 0.266 + 1.317 SL	0.011	0.994	LN + PL
Neochelon falcipinnis (Valenciennes 1836)	44	7.3–23.8	5.8–17.7	TL = −0.689 + 1.397 SL	0.02	0.991	LN + PL
Carangidae							
Caranx hippos (Linné, 1766)	82 (J)	3.2–20.3	2.5–14.3	TL = −0.387 + 1.392 SL	0.014	0.992	LN + PL
Lutjanidae							
Lutjanus goreensis (Valenciennes, 1830)	228	3.3–20.9	2.5–16.2	TL = 0.086 + 1.278 SL	0.008	0.99	LN
Gerreidae							
Eucinostomus melanopterus (Bleeker, 1863)	416	3.3–24.6	2.5–19.0	TL = 0.311 + 1.281 SL	0.011	0.969	LN + PL
Haemulidae							
Pomadasys jubelini (Cuvier, 1830)	36 (J)	6.7–25.1	5.1–19.3	TL = −0.052 + 1.287 SL	0.012	0.997	LN + PL
Polynemidae							
Polydactylus quadrifilis (Cuvier, 1829)	30 (J)	10.3–20.2	7.2–14.1	TL = 0.332 + 1.392 SL	0.024	0.991	LN + PL
Monodactylidae							
Monodactylus sebae (Cuvier, 1829)	18	3.8–12.7	2.6–9.1	TL = −0.163 + 1.403 SL	0.051	0.979	PL
Cichlidae							
Coptodon guineensis (Bleeker in Günther, 1862)	362	4.6–21.8	3.4–16.7	TL = 0.328 + 1.304 SL	0.008	0.987	LN + PL
Sarotherodon melanotheron melanotheron Rüppell, 1852	891	4.6–27.5	3.3–22.1	TL = 0.339 + 1.301 SL	0.005	0.987	LN + PL
Eleotridae							
Eleotris vittata Duméril, 1858	92	6.4–19.1	5.0–15.1	TL = −0.106 + 1.287 SL	0.021	0.976	PL
Acanthuridae							
Acanthurus monroviae Steindachner, 1876	13 (J)	5.8–22.3	4.4–17.3	TL = −0.14 + 1.325 SL	0.036	0.992	LN

Note. J: juvenile; LN: Lake Nokoué; *N*: sample size; *p*: intercept; PL: Porto-Novo Lagoon; *q*: slope; r^2: coefficient of correlation; SL: standard length; TL: total length.

The Student t-test was conducted to determine whether or not *b* is significantly different from 3, following the procedure of Sokal and Rohlf (1987) as follows:

$$ts = (b - 3)/SE, \qquad (2)$$

where ts = *t*-test value; *b* = slope; and *SE* = standard error of *b*.

Consistent with other researchers (Konan et al., 2007; Lalèyè, 2006; Lederoun et al., 2016; Tah et al., 2012), only species represented by a sample size of more than ten individuals were considered. The LLRs were established using a linear regression analysis, as follows:

$$\mathrm{TL} = p + q, \quad (3)$$

where p = intercept; and q = slope. The order of families in the tables follows that adopted by Nelson, Grande, and Wilson (2016), and the genera and species are listed in alphabetical order.

3 | RESULTS

A total of 5,329 specimens comprising 18 fish species (15 families; 17 genera) were collected, 5,246 of which were weighed and measured individually to establish the relationships between total length and body weight.

The sample size ranged from 10 specimens for both *Gymnarchus niloticus* (Cuvier, 1829) and *Acanthurus monroviae* (Steindachner, 1876) to 2,470 specimens for *Ethmalosa fimbriata* (Bowdich, 1825; Tables 1 and 2). The smallest recorded length was 2.8 cm TL for *E. fimbriata*, while the longest was 39.2 cm TL for *Mugil cephalus* (Linnaeus, 1758). The weight ranged from 0.17 g for *E. fimbriata* to 603.71 g for *M. cephalus*. The coefficients of correlation (r^2) were both positive for the length–weight relationships, and significant for all species investigated, ranging from 0.884 for *Elops lacerta* (Valenciennes, 1846) to 0.999 for *A. moroviae*. The intercept (a) ranged from 0.004 for *Polydactylus quadrifilis* (Cuvier, 1829) to 0.046 for *Eleotris vittata* (Duméril, 1858) with an average of 0.019 ± 0.012.

Eight of the 18 species exhibited isometric growth (b = 3). The b coefficient was significantly <3 for seven species, meaning the growth was of the negative allometric type. For the remaining three species, the b coefficient was significantly larger than 3, indicating the growth for those fish was positively allometric.

In the total length-standard length relationship, the coefficient of correlation (r^2) obtained was significant for all species, varying from 0.937 for *Synodontis nigrita* (Valenciennes, 1840) to 0.997 for *Pomadasys* jubelini (Cuvier, 1830), with an average value of 0.980 ± 0.015 (Table 2).

4 | DISCUSSION

Length–weight relationships are used particularly for studies focusing on growth, and in which growth–weight results are to be inferred from lengthwise growth (Lalèyè, 2006; Lederoun et al., 2016; Tah et al., 2012). This relationship has been widely used in fish stock assessments to estimate biomass by size, and for managing fish populations (Le Cren, 1951; Lederoun et al., 2016; Petrakis & Stergiou, 1995). Kulbicki, Moutham, Thollot, and Wanteiz (1993) and King (1996) also have reported that fish growth and mean weight at a given body length can be determined with this relationship.

The coefficient of correlation values (r^2) for all the species are generally both positive and very high (0.953 ± 0.033), indicating an increased length induces an increased weight of the fish. The values obtained for the allometric growth coefficient b fall within the values (2–4) usually found in fish (Bagenal & Tesch, 1978; Hile, 1936), and 2.5–3.5, according to Carlander, 1969). Froese, Thorson, and Reyes (2014) have shown that the value of b is between 2.9 and 3.1 for most species. In the present study, 61.1% of the values obtained are within that range. The differences obtained in the b values are generally attributable to several factors, including gonad maturity, sex, diet, stomach fullness, health, age and fishing time, as well as the intrinsic characteristics of the ecosystem and fishing vessels (Bagenal & Tesch, 1978). It is worthy to note that the variations obtained in the present study (2.495–3.235) are similar to those reported by Konan et al. (2007) for 57 species from the coastal rivers of Southeastern Ivory Coast (2.213–3.729), and similar to those reported by Tah et al. (2012) for 36 species from Lakes Ayame I and Buyo in Ivory Coast (2.173 to 3.472). Lalèyè (2006) obtained values ranging from 2.330 to 3.518 in the Ouémé basin of Benin, also similar to those calculated for the two ecosystems in the present study.

According to the FishBase database online version of May 2018 (Froese & Pauly, 2018), this is the first time information about LWRs is presented for *Eleotris vittata* and *Lutjanus goreensis*.

In conclusion, the present study contributes to our understanding of the biology of some of the most abundant fish species encountered in the study waterbodies. This key for deciphering LWRs and LLRs will make it easier for current and future fisheries biologists to derive weight estimates for single and unweighted, but otherwise measured, fish and assist in estimating the biomass of the captured fish. Based on the data available in FishBase (Froese & Pauly, 2018), the information relative to length–weight relationship parameters is new for two of the studied fish species.

ACKNOWLEDGEMENTS

The authors are grateful to Nanbyl Mohammed Famgbémi and Pamphile Agbohessou (Laboratory of Hydrobiology and Aquaculture, University of Abomey-Calavi) for field assistance. We are also grateful to the fishermen who work in the study area, especially Zinsou Mehinto (Lake Nokoué), Philippe Zannou and Jacob Kounasso (Porto-Novo Lagoon), for their participation in data collection. We wish to thank the two anonymous referees and the editor for their constructive comments on previous versions of the manuscript. We also thank the NWO-WOTRO Netherlands Organisation for Scientific Research Wotro Science for Global Development, which funded this project within the framework of Improving the Resilience of Continental Fishermen Communities and Aquatic Systems with regard to Overfishing and Water Quality Degradation in Benin.

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How to cite this article: Lederoun D, Lalèyè KR, Boni AR, et al. Length–weight and length–length relationships of some of the most abundant species in the fish catches of Lake Nokoué and Porto-Novo Lagoon (Benin, West Africa) . *Lakes & Reserv*. 2018;00:1–7. https://doi.org/10.1111/lre.12243