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Short Communication

Length-Weight Relationships of *Oreochromis niloticus* (Linnaeus, 1758) Around the World

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Key words
***Oreochromis niloticus*, Length-weight relationship (LWR), Native and non-native regions, invasive species, Condition and fitness of population, Evaluation**

ABSTRACT

The *Oreochromis niloticus* (Linnaeus, 1758) has been introduced to various countries as a cultured species. Recently, it has been distributed on all continents except Antarctica and Australia, and has a high invasion risk. The invasion of *O. niloticus* has threatened the survival of native species, therefore, it is necessary to evaluate the condition and fitness of *O. niloticus* populations. Length-weight relationship (LWR) was one of the most effective and practical methods to assess fitness and condition and has been widely utilized in fisheries. Thus, the LWRs of this fish have been described in a number of publications. However, there are no systematic reports on LWRs of *O. niloticus* worldwide, especially comparing native and non-native populations. Therefore, the aim of this present research was to provide a systematic report of LWRs of *O. niloticus* on a global scale and to compare the LWRs of *O. niloticus* in native and non-native areas. The results indicated that *O. niloticus* showed negative allometric growth in native regions and the *O. niloticus* populations showed isometric growth in non-native regions. These results showed that *O. niloticus* was better adapted to the environment of the invasion regions and grew better. Given its potential for invasion, the hazards of this species should not be neglected. In addition, some preventive and management methods to eliminate or reduce the adverse effects of further expansion of this species have been provided in the present study.

Oreochromis niloticus (Linnaeus, 1758), a freshwater Cichlid fish, which is native to Central and Western Africa (Senegal, Gambia, Volta, Niger, Benue and Chad river basins) (El-Sayed and Fitzsimmons, 2023). It has been widely cultured in aquaculture because of its fast growth, strong adaptability and wide feeding ability (Tsegay *et al*., 2018). Thus, *O. niloticus* has been introduced outside its native range into many tropical, subtropical and temperate regions (Geletu and Zhao, 2022). And *O. niloticus* is currently distributed on all continents except Australia and Antarctica (Stauffer *et al*., 2022).

Invasive *O. niloticus* has posed a significant threat to native species through a range of mechanisms, including predatory behavior, resource competition, hybridization, and the transmission of disease (Arthur *et al*., 2010; Xiong *et al*., 2015). So, the invasion of *O. niloticus* in non-native sites further affected native fish diversity and fisheries (Xiong *et al*., 2023). It has been shown that in some invaded regions, the number of native species decreased with the establishment of *O. niloticus* populations (Xiong *et al*., 2023). The better fitness of invasive fish populations in an area, the greater threat to the existence of native species. Therefore, it is necessary to assess the condition and fitness of invasive *O. niloticus* populations in different areas.

Several parameters were used to assess the fitness

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and condition of the fish population in a given area, such as the length-weight relationship (LWR), population construction, and lipid accumulation (Schiemer, 2000; Verreycken *et al*., 2011; Xiong *et al*., 2020). Among all parameters, LWR was one of the most effective and practical methods to assess fitness and condition and has been widely utilized in fisheries (Froese, 2006). Thus, the LWRs of this fish have been described in a number of publications. However, most of the studies on the LWRs of *O. niloticus* results came from a single domain (Supplementary Table I). No systematic reports on the LWRs of *O. niloticus* have been recorded worldwide, particularly comparing native and non-native populations.

Thus, the purpose of this study was to provide a comparison of LWRs for the invasive *O. niloticus* between native and non-native regions worldwide and a systematic report of LWRs of *O. niloticus*. In this study, we want to answer the following question: Is there a significant difference in LWRs of *O. niloticus* between native and non-native regional populations or not?

Materials and methods

This study was based on Chinese and English databases such as China National Knowledge Infrastructure (https://www.cnki.net), Web of Science (https://www.webofscience.com/wos), Google Scholar (https://scholar.google.com), etc. A literature search was conducted on the topic "*Oreochromis niloticus*" "length-weight relationship". All LWRs data on *O. niloticus* collected from published literature sources, such as peer-reviewed journals, conference minutes, and dissertations. All data on LWRs of *O. niloticus* were obtained from wild populations. Overall, data on LWRs of *O. niloticus* (233 total:174 combined sexes, 30 males and 29 females) were acquired from literature published in 36 countries from 1987 to 2022 (Supplementary Table I). Of all the data, those with correlation coefficients greater than 0.8 were selected for this study, and these records were not flagged as abnormal due to potential errors or other factors (Froese, 2006). The following exclusion study for 214 populations will not include 19 of 233 data collected (Supplementary Table I) as the correlation coefficient is less than 0.8 (Froese, 2006). Among the 214 populations, 132 were native populations and 82 were invading populations (Supplementary Table I).

Length-weight relationship: The equation for the length-weight relationship was $W = aL^b$, where, W = wet body weight of fish in grams, L = total length of fish in centimeter, a is the intercept; and b is the slope (Froese, 2006). When the LWR was solely represented in logarithmic form (e.g., $\log W = \log a + b\log L$), and dependent on the exponent value and the units selected, parameter a was acquired through the anti-logarithmic transformation (log is logarithm to base 10). As the majority of LWRs rated length in cm and described as TL, conversion factors $a_{cm} = a_{mm}10^b$ and $a_{TL} = a_{LS}$ (TL/ LS)^b (where LS is length type in the original study by standard length (SL) or fork length (FL); TL/ SL = 1.25, TL / FL = 1.02, as calculated from FishBase (Froese and Pauly, 2023) were applied for all studies reporting length in mm and/or LS (Supplementary Table I) (Froese, 2006). The meaning of the exponent, *b*, is straightforwardly physical and independent of the chosen system of units. According to the one-sample t-test, an ideal fish has a "*b*" value of 3 (Supplementary Fig. S1), which indicates isometric development. When the value of "*b*" is not 3, the weight increase is allometric (positive if "*b*" is greater than 3, negative if "*b*" is less than 3), which is a regularly used scale in the study of LWRs (Froese, 2006).

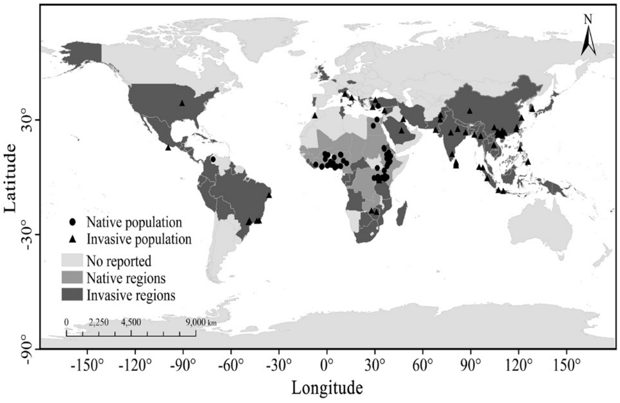

Fig. 1. The distribution was available on the FishBase website (Froese and Pauly, 2023), and *Oreochromis niloticus* (Linnaeus, 1758) was found in 92 countries. In the figure, the light gray sections were the native areas and the black sections were the invasive areas. In the 36 countries with the Length-weight relationships (LWRs) of *O. niloticus* data, the solid circles represented the native populations and the triangles indicated the invasive populations.

The figure of log (a') vs b was used in the LWRs data of *O. niloticus*. Using this technique, outliers that diverged from the regression line by more than two standard deviations were identified. And then the figure of log (a') vs b contained 14 outliers that were identified as problematic in Supplementary Table I and eliminated in subsequent research. After excluding outliers, a total of 200 data were available, of which 126 data were from the native region and 74 from the invaded region (Supplementary Table I).

In this study, IBM SPSS Statistics 23 was used to test if the data satisfied the normal distribution by Kolmogorov-

Smirnov test. And it also be used to test whether there were differences between invasive and native populations by Mann-Whitney test, and one-sample Wilcoxon test was used to compare the differences between invasive and native populations with 3, and all statistics were considered to be different at $p < 0.05$.

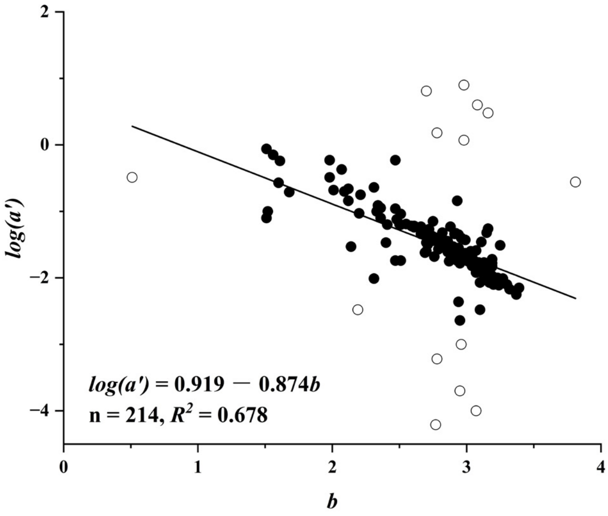

Fig. 2. The 214 length-weight relationships of *O. niloticus* were plotted in log (a') vs b. Fourteen outliers were marked in the graph with blank circles and were eliminated in subsequent analyses. Regression line: log(a') = 1.16-0.95b, n = 200, $R^2 = 0.702$, $p < 0.05$.

Results and discussion

The range of values for b in the present study was from 1.51 in Wase Dam and Naivasha Lake (Kenya, Nigeria) to 3.39 in the Malewa Lake (Kenya). Generally, the b-values range from 2.5 to 3.5 (Tubb and Carlander, 1969). However, of 233 data collected, 44 were below 2.5. After correlation coefficient were less than 0.8 and log (a') vs b filtering, 28 were still below 2.5. We then reviewed the original literature and found that studies have shown that poor environmental conditions, lack of food, harsh climate and high population density can lead to low b-values (Vianny *et al*., 2015; Batool *et al*., 2017; Obayemi *et al*., 2019; Yem *et al*., 2020).

The Kolmogorov-Smirnov test rejected this distribution as normal (Fig. 3). In Figure 3, when compared with the normal distribution curve, all b-value distributions were lower than the normal curve except for 1.4-2.0 and 3.0-3.2. Among all LWRs data for *O. niloticus*, the median value of b was 2.94 (SE = 0.02). 90% of the values ranged from 2.07 to 3.21. As shown in Figure 3, the majority of b (n = 121, 60.5% of the total) was located to the left of the isometric line ($b > 3$). In addition, there was a significant difference ($p < 0.05$) in median b between the native region ($b = 2.91$, $SE = 0.03$) and the invasive region ($b = 3.01$, $SE = 0.03$) (Supplementary Table II). Median value of b ($b = 2.91$, $SE = 0.03$) for native populations was less than 3 ($p < 0.05$) and median value of b ($b = 3.01$, $SE = 0.03$) and 3 for invasive populations was not different ($p > 0.05$) (Supplementary Table II). This suggested that the body shape of this species differed between the two regions.

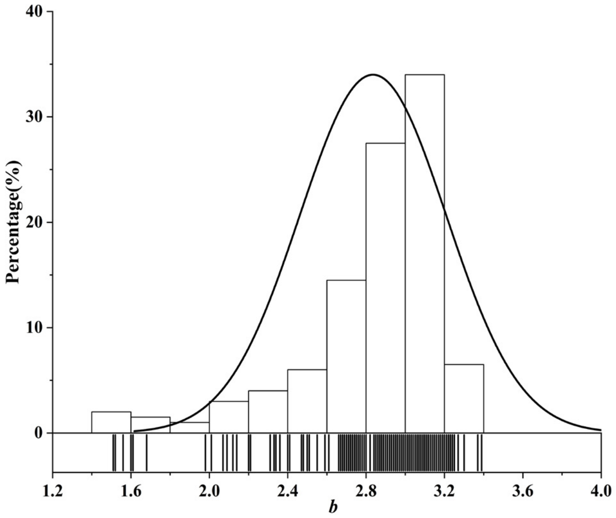

Fig. 3. Frequency distribution of index b based on 200 records for *O. niloticus*, 5th percentile= 2.07 and 95th percentile = 3.21. Gaussian distribution line was superimposed.

According to current research, *O. niloticus* was growing at negative allometric growth in native regions and at isometric growth in invasive regions. This showed that *O. niloticus* grew better in the invasion area than its origin. Further expansion of *O. niloticus* populations in invasive sites would compete with native species and destroy biodiversity (Stauffer *et al*., 2022). Therefore, considering this potential threat, the harmfulness of this invasive species should not be ignored.

Some measures should be taken to suppress or mitigate further invasion of *O. niloticus* while maintaining economic benefits: (1) Improve the evaluation, early warning, identification and monitoring, management and eradication of invasive alien species, and establish appropriate rules and regulations; (2) For exotic farmed fish, the farming unit should strengthen the monitoring and management of the farming environment, take adequate anti-avoidance and isolation measures, and strictly control farmed species in a specific range of farmed waters; (3) If prevention methods fail, management of invasive organisms should use a combination of biological, physical and chemical means to address this problem (Fletcher *et al*., 2016; Dong *et al*., 2020).

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Ethical statement andIRB approval

This study did not sacrifice fish, so institutional review board (IRB) approval was not required.

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20230530080554

Statement of conflict of interest

The authors have declared no conflict of interest.

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Supplementary Material

Length-Weight Relationships of *Oreochromis niloticus* (Linnaeus, 1758) Around the World

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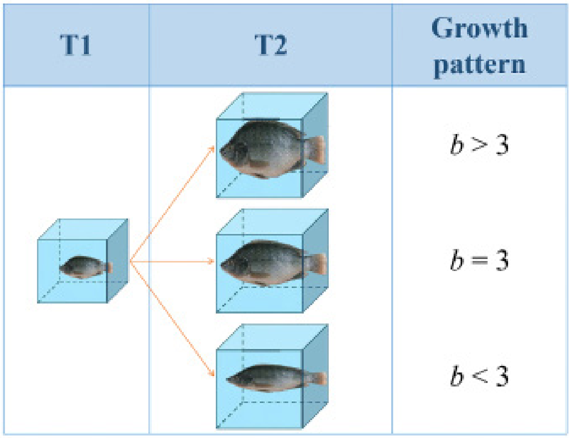

Supplementary Fig. S1. A simple diagram of three different growth patterns from T1 to T2. If $b = 3$, then this species is isometric growth, T1 has the same form and condition as T2. If $b > 3$, then this species is positive-allometric growth, T2 increases in relative body thickness or plumpness more than T1. If $b < 3$, then this species is negative-allometric growth, body shapes of T2 are changed to become more elongated.

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Supplementary Table I. Parameters of length-weight relationships of *Oreochromis niloticus* (Linnaeus, 1758).

Country/ Location	Sampled year	Gender	n	L_{min}- L_{max}	LS	a'	b	R^2	References
Be´nin sampled from native population (N)									
1. Oue´me´ River	1999-2001	C	18	7.5-26.5	TL	0.0330	2.80	0.98	Lale`ye (2006)
2. Sô river	2015-2016	C	31	6.7-32.9	TL	0.0190	2.99	1.00	Hazoume et al. (2017)
3. Couffo river	NA	C	26	NA	TL	0.0300	2.80	0.97	Amoussou et al. (2017)
4. Couffo river	NA	M	15	NA	TL	0.0400	2.74	0.96	Amoussou et al. (2017)
5. Couffo river	NA	F	11	NA	TL	0.0200	2.90	0.98	Amoussou et al. (2017)
6. Toho Lake	NA	C	30	NA	TL	0.0300	2.82	0.98	Amoussou et al. (2017)
7. Toho Lake	NA	M	15	NA	TL	0.0400	2.77	0.99	Amoussou et al. (2017)
8. Toho Lake	NA	F	15	NA	TL	0.0300	2.84	0.97	Amoussou et al. (2017)
9. Ouémé river	NA	C	29	NA	TL	0.0300	2.80	0.96	Amoussou et al. (2017)
10. Ouémé river	NA	M	14	NA	TL	0.0600	2.61	0.91	Amoussou et al. (2017)
11. Ouémé river	NA	F	15	NA	TL	0.0100	3.22	0.97	Amoussou et al. (2017)
Benin and Togo (N)									
12. Mono basin	2011-2014	C	219	8.4-23.1	TL	0.022	2.93	0.90	Ledeound et al. (2016)
Burkina Faso (N)									
13. Volta River	NA	C	14	17-29	SL	0.0541	2.72	0.93	Coulibaly (2003)[1]
14. Hippopotamus Pond	NA	C	96	NA	TL	0.0377	2.80	0.97	Béarez (2003)
15. Peelé reservoir	2015-2016	C	193	NA	SL	0.0281	2.85	NA	Parfait et al. (2018)[1]
16. Peelé reservoir	2015-2016	M	94	NA	SL	0.0442	2.68	NA	Parfait et al. (2018)[1]
17. Peelé reservoir	2015-2016	F	99	NA	SL	0.0245	2.86	NA	Parfait et al. (2018)[1]
18. Peelé reservoir	2016-2017	C	274	NA	SL	0.1217	2.34	NA	Parfait et al. (2018)[1]
19. Peelé reservoir	2016-2017	M	137	NA	SL	0.1759	2.21	NA	Parfait et al. (2018)[1]
20. Peelé reservoir	2016-2017	F	137	NA	SL	0.0596	2.59	NA	Parfait et al. (2018)[1]
21. Peelé reservoir	2015-2016	C	98	NA	SL	0.0443	2.94	NA	Parfait et al. (2018)[1]
22. Peelé reservoir	2015-2016	M	46	NA	SL	0.0442	2.68	NA	Parfait et al. (2018)[1]
23. Peelé reservoir	2015-2016	F	52	NA	SL	0.0245	2.86	NA	Parfait et al. (2018)[1]
24. Peelé reservoir	2016-2017	C	126	NA	SL	0.0373	2.78	NA	Parfait et al. (2018)[1]
25. Peelé reservoir	2016-2017	M	62	NA	SL	0.0317	2.71	NA	Parfait et al. (2018)[1]
26. Peelé reservoir	2016-2017	F	64	NA	SL	0.0437	2.71	NA	Parfait et al. (2018)[1]
27. Peelé reservoir	2015-2016	C	95	NA	SL	0.0634	2.51	NA	Parfait et al. (2018)[1]
28. Peelé reservoir	2015-2016	M	48	NA	SL	0.0632	2.41	NA	Parfait et al. (2018)[1]
29. Peelé reservoir	2015-2016	F	47	NA	SL	0.0793	2.36	NA	Parfait et al. (2018)[1]
30. Peelé reservoir	2016-2017	C	148	NA	SL	0.2199	2.12	NA	Parfait et al. (2018)[1]
31. Peelé reservoir	2016-2017	M	75	NA	SL	0.3259	1.98	NA	Parfait et al. (2018)[1]
32. Peelé reservoir	2016-2017	F	73	NA	SL	0.0651	2.55	NA	Parfait et al. (2018)[1]
33. Peelé reservoir	2015-2017	C	467	7.1-15.1	SL	0.0762	2.48	NA	Parfait et al. (2018)[1]
34. Peelé reservoir	2015-2017	M	231	7.3-17	SL	0.1118	2.36	NA	Parfait et al. (2018)[1]
35. Peelé reservoir	2015-2017	F	236	7.5-15.1	SL	0.0435	2.69	NA	Parfait et al. (2018)[1]
Côte d'Ivoire (N)									
36. Ayamé I Reservoir	1997-1998	C	1006	8-27.5	TL	0.024	2.69	0.94	Tah et al. (2012)

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Country/ Location	**Sampled year**	**Gender**	**n**	**L_{min}- L_{max}**	**LS**	**a’**	**b**	**R^2**	**References**
37. Buyo Reservoir	2004-2005	C	650	4-33	TL	0.021	2.76	0.95	Tah et al. (2012)
38. Coastal Rivers	1995-1997, 2003-2005	C	135	6.8-26.6	SL	6.5304	2.70	0.94	Konan et al. (2007)[1,2]
Cameroon (N)									
39. Mbˆo Floodplain Rivers	2014-2015	C	66	12-26	TL	0.0124	3.08	0.90	Tiogué et al. (2018)
Congo Dem Rp (N)									
40. Edward Lake	NA	C	28	22.1-35.8	TL	0.0023	2.95	0.97	Vakily (1989)
Egypt (N)									
41. Manzalah Lake	2000	C	39	8-16	TL	0.0702	2.75	0.99	Bakhoum and Abdallah (2002)
42. Manzalah Lake	2000	C	32	5-15	TL	0.0167	2.95	1.00	Bakhoum and Abdallah (2002)
43. Nile river	2008-2009	C	801	8.3-35.4	TL	0.0180	3.02	0.91	Shalloof and El- Far (2017)
44. Abu-Zabal Lake	2005-2006	C	NA	NA	TL	0.0282	2.86	1.00	Ibrahim et al. (2008)
Ethiopia (N)									
45. Zeway Lake	NA	C	651	NA	TL	0.2	2.09	0.90	Fiseha (1989)
46. Zeway Lake	NA	C	761	NA	TL	0.025	2.90	NA	Fiseha (1989)
47. Tana Lake	1992-1993	C	680	12-34.8	TL	0.0424	2.74	0.94	Tadesse (1997)[3]
48. Tana Lake	1992-1993	M	383	NA	TL	0.0414	2.75	0.95	Tadesse (1997)[3]
49. Tana Lake	1992-1993	F	297	NA	TL	0.042	2.75	0.93	Tadesse (1997)[3]
50. Hayq Lake	2018	F	339	NA	TL	0.065	2.50	0.89	Tessema et al. (2019)
51. Hayq Lake	2018	M	553	NA	TL	0.099	2.33	0.85	Tessema et al. (2019)
52. Chamo Lake	2018	M	2201	NA	TL	0.0112	3.14	0.97	Shija (2020)
53. Chamo Lake	2018	F	3577	NA	TL	0.0102	3.19	0.98	Shija (2020)
54. Chamo Lake	2018	C	5778	NA	TL	0.0102	3.18	0.97	Shija (2020)
55. Tekeze Reservoir	2015-2016	C	1826	NA	TL	0.0470	2.92	0.95	Teame et al. (2018)
56. Tekeze Reservoir	2015-2016	M	845	NA	TL	0.0253	3.03	0.97	Teame et al. (2018)
57. Tekeze Reservoir	2015-2016	F	981	NA	TL	0.0203	2.91	0.95	Teame et al (2018)
58. Hawassa Lake	2003-2005	C	1000	14-36	TL	0.0184	3.02	0.96	Tekle-Giorgis et al. (2017)
59. Koka Lakes	2005-2006	C	205	NA-27.2	TL	0.0261	2.89	0.99	Tesfaye (2008)
60. Ziway Lakes	2005-2006	C	279	NA-29	TL	0.0104	3.19	0.97	Tesfaye (2008)
61. Langano Lakes	2005-2006	C	525	NA-27.2	TL	0.0164	3.04	0.88	Tesfaye (2008)
62. Chamo Lake	1996-1997	F	689	NA	TL	0.0225	2.97	0.98	Admassu (2002)[3]
63. Chamo Lake	1996-1997	M	740	NA	TL	0.0211	2.99	0.98	Admassu (2002)[3]
64. Chamo Lake	1996-1997	C	1429	12-61	TL	0.0217	2.98	0.99	Admassu (2002)[3]
65. Koka Lakes	2011	C	573	4.7-35.2	TL	0.0153	3.05	0.99	Engdaw et al. (2013)
66. Tropic Reservoir	2006-2007	C	87	10-42	TL	0.008	3.20	0.96	Degefu et al. (2012)
67. Koka Lake	2019-2020	C	132	NA	SL	0.0085	3.17	0.96	Asmamaw and Tessema (2021)[1]
68. Ziway Lake	2019-2020	C	130	NA	SL	0.0085	3.10	0.87	Asmamaw and Tessema (2021)[1]
69. Langano Lake	2019-2020	C	129	NA	SL	0.0256	3.07	0.96	Asmamaw and Tessema (2021)[1]
70. Koka Reservoir	NA	M	82	16.03-29.94	TL	0.0085	3.21	0.97	Asmamaw et al. (2019)
71. Koka Reservoir	NA	F	50	20.04-29.01	TL	0.0256	2.87	0.90	Asmamaw et al. (2019)
72. Koka Reservoir	NA	C	132	16.03-29.94	TL	0.0097	3.17	0.96	Asmamaw et al. (2019)

Table continued on next page.................

Country/ Location	Sampled year	Gender	n	L_{min}- L_{max}	LS	a'	b	R^2	References
73. Shala Lake	2018	C	343	7.7-33	TL	0.0189	3.19	0.98	Wagaw et al. (2022)
74. Shala Lake	2018	M	165	NA	TL	0.0148	3.19	0.97	Wagaw et al. (2022)
75. Shala Lake	2018	F	178	NA	TL	0.0165	3.19	0.98	Wagaw et al (2022)
Ghana (N)									
76. Golinga Reservoir	NA	C	20	15.1-19.1	TL	0.0062	3.37	0.83	Naangmenyele et al. (2021)
77. Golinga Reservoir	2013/2014	C	321	NA	SL	0.0176	3.07	0.79	Alhassan et al. (2015)[1]
Kenya (N)									
78. Winam gulf	2018	C	240	NA	TL	0.0548	3.16	0.95	Ngodhe and Owuor-JB (2019)
79. Crescent Lake	2017	C	224	NA	TL	0.02	2.98	0.93	Waithaka et al. (2020)
80. Hippo Point Lake	2017	C	66	NA	TL	0.024	2.90	0.96	Waithaka et al. (2020)
81. Korongo Lake	2017	C	128	NA	TL	0.024	2.94	0.96	Waithaka et al. (2020)
82. Malewa Lake	2017	C	20	NA	TL	0.007	3.39	0.87	Waithaka et al. (2020)
83. Mid Lake	2017	C	33	NA	TL	0.011	3.13	0.96	Waithaka et al. (2020)
84. Off Crescent	2017	C	30	NA	TL	0.012	3.14	0.99	Waithaka et al. (2020)
85. Oserian Lake	2017	C	498	NA	TL	0.053	2.67	0.88	Waithaka et al. (2020)
86. Sher Lake	2017	C	22	NA	TL	0.015	3.07	0.98	Waithaka et al. (2020)
87. Whole lake	2017	C	1,021	NA	TL	0.031	2.86	0.92	Waithaka et al. (2020)
88. Victoria Lake	2014-2015	M	809	14-47.5	TL	0.0210	2.98	NA	Yongo et al. (2018)
89. Victoria Lake	2014-2015	F	672	14-45	TL	0.0180	3.01	NA	Yongo et al. (2018)
90. Victoria Lake	2014-2015	C	1512	14-47.5	TL	0.0190	3.01	0.98	Yongo et al. (2018)
91. Ferguson's Gulf	1985-1986	F	49	NA	TL	0.0098	3.17	0.98	Stewar (1988)
92. Ferguson's Gulf	1985-1986	M	62	NA	TL	0.011	3.13	0.97	Stewar (1988)
93. Ferguson's Gulf	1985-1986	C	111	20-50	TL	0.0107	3.14	0.98	Stewar (1988)
94. Ferguson's Gulf	1985	C	6	NA	TL	0.0331	2.82	0.97	Stewar (1988)
95. Ferguson's Gulf	1986	C	25	NA	TL	0.0078	3.24	0.96	Stewar (1988)
96. Ferguson's Gulf	1986	C	27	NA	TL	0.0151	3.04	0.97	Stewar (1988)
97. Ferguson's Gulf	1986	C	20	NA	TL	0.0091	3.19	0.99	Stewar (1988)
98. Ferguson's Gulf	1986	C	16	NA	TL	0.0098	3.14	0.94	Stewar (1988)
99. Ferguson's Gulf	1974	C	89	NA	TL	0.0282	2.94	0.99	Stewar (1988)
100. Ferguson's Gulf	1974	C	75	NA	TL	0.0282	2.91	0.99	Stewar (1988)
101. Ferguson's Gulf	1974	M	32	NA	TL	0.0214	3.00	0.99	Stewar (1988)
102. Ferguson's Gulf	1974	F	37	NA	TL	0.0178	3.06	0.99	Stewar (1988)
103. Ferguson's Gulf	1974	C	6	NA	TL	0.0115	3.17	1.00	Stewar (1988)
104. Ferguson's Gulf	1974-1976	C	NA	NA	TL	0.0234	2.99	NA	Stewar (1988)
105. Ferguson's Gulf	1953	C	NA	NA	TL	0.0123	3.16	NA	Stewar (1988)
106. Crater Lake	NA	C	NA	NA	TL	0.0182	2.93	NA	Stewar (1988)
107. Naivasha Lake	2013-2014	M	46	NA	TL	0.0001	3.07	0.97	Otieno et al. (2014)[2]
108. Naivasha Lake	2013-2014	M	46	NA	TL	0.0002	2.95	0.96	Otieno et al. (2014)[2]
109. Naivasha Lake	2013-2014	C	67	NA	TL	0.863	1.51	NA	Otieno et al. (2014)
110. Naivasha Lake	2013-2014	C	69	NA	TL	0.7129	1.56	NA	Otieno et al. (2014)[2]
111. Naivasha Lake	2013-2014	C	104	NA	TL	0.1972	1.68	NA	Otieno et al. (2014)

Table continued on next page.................

Country/ Location	Sampled year	Gender	n	L_{min}- L_{max}	LS	a’	b	R^2	References
112. Naivasha Lake	2013-2014	C	65	NA	TL	0.5821	1.61	NA	Otieno et al. (2014)
113. Naivasha Lake	2013-2014	C	68	NA	TL	0.208	2.01	NA	Otieno et al. (2014)
114. Naivasha Lake	2013-2014	C	373	NA	TL	0.2291	2.31	NA	Otieno et al. (2014)
Nigeria (N)									
115. Wudil River	2010	C	20	11-16.3	TL	0.88	0.14	0.43	Getso et al. (2017)
116. Wudil River	2010	C	20	9-13.3	TL	0.8913	0.80	0.51	Getso et al. (2017)
117. Wudil River	2010	C	20	5-15	TL	0.32	0.51	0.82	Getso et al. (2017)
118. Wudil River	2010	C	20	7.6-15.5	TL	0.72	0.19	0.29	Getso et al. (2017)
119. Wase Dam	NA	C	137	6-24	TL	0.1000	1.52	0.81	Yem et al. (2020)[3]
120. Wase Dam	NA	M	81	6-22	TL	0.0800	1.51	0.88	Yem et al. (2020)[3]
121. Wase Dam	NA	F	56	6-24	TL	0.1100	1.50	0.71	Yem et al. (2020)[3]
122. Cross River	2004-2006	C	2007	NA	TL	0.0251	2.70	0.90	Offem et al. (2009)
123. Nwaniba River	2014	C	NA	8-19.7	TL	1.5030	2.78	0.98	Esenowo et al. (2016) [2]
124. Benue River	2016-2017	C	NA	NA	TL	0.6655	1.02	0.01	Edward (2018)
125. Benue River	2016-2017	C	NA	NA	TL	4.7072	1.43	0.00	Edward (2018)
126. Benue River	2016-2017	C	NA	NA	TL	1.4302	0.36	0.11	Edward (2018)
127. Benue River	2016-2017	C	NA	NA	TL	1.6688	0.12	0.01	Edward (2018)
128. Cross River	2004-2006	C	NA	NA	TL	0.0033	2.19	0.91	Offem et al. (2007)[2,3]
129. Cross River	2004-2006	C	NA	NA	TL	0.0044	2.94	0.87	Offem et al. (2007)[3]
130. Cross River	2004-2006	C	NA	NA	TL	0.0190	3.04	0.93	Offem et al. (2007)[3]
131. Nokoue Lake	2007	C	137	NA	TL	0.0104	2.77	0.77	Johnson and Ndimele et al. (2011)[3]
132. Strabag lake	2013-2014	C	127	11.8-22.1	TL	0.0340	2.70	0.83	Amoo and Komolame (2016)
133. Gold Mine Reservoir	2015-2016	C	57	8.1-24.2	TL	0.5929	1.98	0.86	Obayemi et al. (2019)
South Sudan (N)									
134. Juba	NA	C	600	28-41	TL	0.2692	1.60	0.91	Deng et al. (2020)
Sudan (N)									
135. Khashm El-Girba Lake	2016	C	525	7.9-27.7	SL	0.0280	2.88	0.96	Abdalla et al. (2020)[1]
136. Khashm El. Girba Reservoir	2016-2017	C	734	7-32	TL	0.0399	2.96	0.91	Adow (2019)
137. Khashm El. Girba Reservoir	2016-2017	F	NA	NA	TL	0.0456	2.91	0.89	Adow (2019)
138. Khashm El. Girba Reservoir	2016-2017	M	NA	NA	TL	0.0372	2.99	0.92	Adow (2019)
Uganda (N)									
139. Victoria Lake	2000-2002	C	573	37-525	TL	0.0136	3.12	0.99	Bwanika et al. (2007)[1]
140. Wamala Lake	1988-1996	C	NA	NA	TL	0.0340	2.40	0.93	Vianny et al. (2015)[1]
141. Wamala Lake	1998-2000	C	NA	NA	TL	0.0124	3.15	0.96	Vianny et al. (2015)[1]
142. Wamala Lake	2011-2014	C	NA	NA	TL	0.5929	2.47	0.94	Vianny et al. (2015)[1]
Bangladesh (I)									
143. Kaptai Reservoir	1995-1996	C	1741	15-53	TL	0.0366	2.84	0.98	Ahmed et al. (2003)
144. Karatoya River	2014-2015	C	22	NA-39	TL	0.0099	3.15	NA	Hossain et al. (2016)

Table continued on next page.................

Country/ Location	Sampled year	Gender	n	L_{min}- L_{max}	LS	a’	b	R^2	References
Brazil (I)									
145. Mundaú River Running	2015	C	277	0.9-6.4	TL	0.012	3.07	0.97	Terra et al. (2017)
146. Mundaú River Pool	2015	C	60	1.5-25.2	TL	0.01	3.23	0.99	Terra et al. (2017)
147. Guandu River	2010-2011	C	10	9-26.4	TL	0.0099	3.22	0.99	Costa et al. (2014)
148. Taquari River	2011-2013	C	142	1.3-8.2	SL	0.0154	3.05	0.98	Nobile et al. (2015)[1]
149. Coastal Lagoons	2011	C	25	1-7.9	TL	0.0178	2.87	0.98	Franco et al. (2014)
150. Barra Bonita Reservoir	2004-2005	C	1715	11-31.2	SL	0.0585	2.88	0.89	Novaes and Carvalho (2012)[1]
151. Guaraguaçu River,	2004-2007	C	16	17-43.3	TL	0.0189	3.01	0.97	Carvalho et al. (2022)
China (I)									
152. Beipan River	2017	C	310	51-364	SL	0.0308	2.86	0.99	Li et al. (2021)[1]
153. Liujiang River	2020-2021	C	98	0.888-3.396	TL	0.274	3.81	0.95	Huang (2021)[2]
154. Liujiang River	2020-2021	C	98	0.72-2.46	SL	1.1685	2.98	0.90	Huang (2021)[1,2]
155. Shanmei reservior	2015	C	200	12-28	SL	0.1088	2.47	0.87	Tu (2016)[1,3]
156. Zuojiang River	2017-2018	C	57	NA	SL	0.0177	3.05	0.98	Zhao (2019)[1]
157. Zuojiang River	2017-2018	C	21	NA	SL	0.0103	3.20	0.96	Zhao (2019)[1]
158. Zuojiang River	2017-2018	C	28	NA	SL	0.0260	2.92	0.95	Zhao (2019)[1]
159. Youngjiang River	2017-2018	C	31	NA	SL	0.0903	2.51	0.82	Zhao (2019)[1]
160. Zuojiang River	2017-2018	C	53	NA	SL	0.0451	2.73	0.95	Zhao (2019)[1]
161. Youjiang River	2017-2018	C	37	NA	SL	0.0575	2.61	0.94	Zhao (2019)[1]
162. Zuojiang River	2017-2018	C	29	NA	SL	4.5303	1.33	0.53	Zhao (2019)[1]
163. Youjiang River	2017-2018	C	23	NA	SL	0.0107	3.23	0.99	Zhao (2019)[1]
164. Youjiang River	2017-2018	C	60	NA	SL	0.0205	3.00	0.97	Zhao (2019)[1]
165. Qianjiang River	2017-2018	C	41	NA	SL	0.1941	2.16	0.61	Zhao (2019)[1]
166. Qianjiang River	2017-2018	C	14	NA	SL	0.0393	2.77	0.98	Zhao (2019)[1]
167. Yujiang River	2017-2018	C	98	NA	SL	0.0488	2.70	0.89	Zhao (2019)[1]
168. Yujiang River	2017-2018	C	75	NA	SL	0.7819	1.96	0.74	Zhao (2019)[1]
169. Xunjiang River	2017-2018	C	28	NA	SL	0.0113	3.18	0.99	Zhao (2019)[1]
170. Xunjiang River	2017-2018	C	82	NA	SL	0.0151	3.07	1.00	Zhao (2019)[1]
171. Shuikou Reservior	2011	C	606	NA	SL	0.0285	2.89	0.98	He et al. (2013)[1]
172. Hongkan	2005-2009	C	1178	NA	SL	0.1459	2.12	NA	Ye et al. (2010)[1]
173. Dawangtan Reservior	2016-2017	C	746	5.1-29.6	SL	0.0167	3.04	0.89	Li (2018)[1]
174. Shanghai	1991-1994	F	NA	NA	SL	0.0199	2.96	0.98	Li (2018)[1]
175. Shanghai	1991-1994	C	63	10.3-19.3	SL	0.0177	3.02	0.98	Li (2018)[1]
176. Shanghai	1991-1994	M	NA	NA	SL	0.0151	3.06	0.94	Li (2018)[1]
177. Hongshui River	20,092,013	C	91	4.5-29.1	TL	0.0134	3.13	0.99	Que et al. (2015)
India (I)									
178. Damodar River	2014-2016	C	57	10-44	TL	0.0146	3.13	1.00	Sandhya et al. (2020)
179. Barur Reservoir	2012-2013	C	189	97-160	TL	0.0098	2.31	NA	Marx et al. (2014)[1]
180. Halali Reservoir	2018-2019	C	1250	7.5-44.5	TL	0.0010	2.96	0.93	Johnson et al. (2020)[2]
181. Yamuna River	2011-2012	M	167	NA	TL	0.0295	2.88	0.94	Alam et al. (2020)
182. Yamuna River	2011-2012	F	174	NA	TL	0.0585	2.66	0.91	Alam et al. (2020)

Table continued on next page.................

Country/ Location	**Sampled year**	**Gender**	**n**	**L_{min}- L_{max}**	**LS**	**a'**	**b**	**R^2**	**References**
183. Yamuna River	2011-2012	F	341	NA	TL	0.0006	2.78	0.92	Alam et al. (2020)[2]
Indonesia (I)									
184. Jatiluhur Reservoir	1985	C	63	13.5-44	TL	0.0292	2.90	0.99	Hardjamulia et al. (1988)[1,3]
185. Jatibarang Reservoir	2020	C	56	95-349	TL	0.0097	3.27	0.95	Rahman et al. (2021)[1]
186. Lampulo Fishery Port	2017	C	NA	NA	TL	0.0105	2.30	0.61	Perdana et al. (2018)
187. Maninjau Lake	2017	C	31	6.7-22	TL	0.0156	3.11	0.99	Samir et al. (2021)
188. Matang Guru River	2015	C	NA	NA	TL	0.0124	1.30	0.41	Muttaqin et al. (2016)[1]
Iraq (I)									
189. Garmat Ali River	2018-2019	C	1342	7.7-23.2	TL	0.0140	3.08	0.96	Mohamed and Al-Wan (2020)
190. Garmat Ali River	2008	C	2050	7-25.5	TL	0.0350	3.11	0.97	Mohamed and Salman (2021)[1]
Italy (I)									
191. Lesina Lagoon	1999-2000	C	176	5-230	TL	0.0180	2.51	0.98	Scordella et al. (2003)[1]
192. Fossa Calda Stream	2007	C	153	NA	TL	0.0159	3.13	0.82	Piazzini et al. (2010)[1]
193. Fossa Calda Stream	2007	C	153	NA	TL	0.0159	2.98	0.75	Piazzini et al. (2010)[1]
Japan (I)									
194. Minami River	2007	C	20	NA	TL	0.0148	3.10	0.99	Yamamoto et al. (2009)
195. Minami River	2007	C	13	NA	TL	0.0165	3.06	1.00	Yamamoto et al. (2009)
196. Minami River	2007	C	9	NA	TL	0.0222	2.98	0.98	Yamamoto et al. (2009)
197. Minami River	2007	C	5	NA	TL	0.0080	3.30	0.99	Yamamoto et al. (2009)
198. Minami River	2007	C	7	NA	TL	0.0188	3.03	0.99	Yamamoto et al. (2009)
199. Minami River	2007	C	9	NA	TL	0.0157	3.08	1.00	Yamamoto et al. (2009)
200. Minami River	2007	C	12	NA	TL	0.0165	3.05	0.99	Yamamoto et al. (2009)
201. Minami River	2007	C	21	NA	TL	0.0209	2.98	0.99	Yamamoto et al. (2009)
202. Minami River	2007	C	13	NA	TL	0.0177	3.01	1.00	Yamamoto et al. (2009)
203. Minami River	2007	C	11	NA	TL	0.0186	3.01	1.00	Yamamoto et al. (2009)
Korea (I)									
204. Dalseo Stream	2019	C	533	NA	TL	0.0479	3.15	0.99	Wang et al. (2020)[1]
Lao (I)									
205. Nam Theun 2 Reservoir	2015-2017	C	34	31-222	SL	0.0220	3.04	0.99	Guillard et al. (2019)[1]
206. Nam Theun 2 Reservoir	2015-2017	F	118	112-320	SL	0.0479	2.82	0.93	Guillard et al. (2019)[1]
207. Nam Theun 2 Reservoir	2015-2017	M	105	79-360	SL	0.0033	3.10	0.99	Guillard et al. (2019)[1]
Mexico (I)									
208. Coatetelco Lake	1993	C	1039	8.9-16.5	SL	0.0180	2.47	0.81	Gómez-Márquez et al. (2008)[1]
Morocco (I)									
209. Al-Massira Reservoir	2020-2021	C	40	10.5-43	TL	0.0304	2.84	0.98	Ouahb et al. (2021)
Myanmar (I)									
210. Sunye lake	2016-2017	C	190	108-241	TL	0.0001	2.77	0.93	Winn et al. (2021)[2]
Pakistan (I)									
211. Indus River	20,062,009	M	60	14-18.5	TL	0.0457	2.66	0.90	Naeem et al. (2010)
212. Indus River	20,062,009	F	65	9.1-17.9	TL	0.0364	2.75	0.91	Naeem et al. (2010)
213. Indus River	20,062,009	C	125	9.1-18.5	TL	0.0393	2.72	0.91	Naeem et al. (2010)

Table continued on next page.................

Country/ Location	**Sampled year**	**Gender**	**n**	**L_{min}- L_{max}**	**LS**	**a'**	**b**	**R^2**	**References**
214. Chashma Barrage	2014	C	480	52-217	FL	0.0295	2.14	0.94	Mehak et al. (2017)[1]
215. Keenjhar Lake	2014	C	246	16-28	TL	0.4226	2.07	0.84	Batool (2017)
216. Keenjhar Lake	2014	C	239	15-28	TL	0.0076	3.39	0.75	Batool (2017)
Philippines (I)									
217. Agusan Marsh	2014-2015	C	261	11.5-47	TL	0.031	3.25	0.97	Jumawan and Seronay (2017)
218. Candaba wetland	2007-2008	C	386	4-21.3	SL	0.0183	3.04	0.97	Garcia (2010)[1]
Saudi Arabia (I)									
219. Wadi Hanifah River	2011-2012	M	310	76-273	TL	3.0354	3.16	0.92	Mortuza and Al-Misned (2013)[1,2,3]
220. Wadi Hanifah River	2011-2012	F	265	69-261	TL	7.9264	2.98	0.83	Mortuza and Al-Misned (2013)[1,2,3]
221. Wadi Hanifah River	2011-2012	C	575	69-273	TL	3.9675	3.08	0.96	Mortuza and Al-Misned (2013)[1,2,3]
Sri Lanka (I)									
222. Chandikawewa reservoir	1995-1997	C	30	14-39	TL	0.0370	2.76	NA	Athukorala and Amarasinghe (2010)
223. Minneriya reservoir	1998-2000	C	306	NA	TL	0.0270	2.79	NA	Prabath et al. (2017)
224. Udawalawe reservoir	1998-2000	C	491	NA	TL	0.1430	2.93	NA	Prabath et al. (2017)
225. Victoria reservoir	1998-2000	C	113	NA	TL	0.0940	2.20	NA	Prabath et al. (2017)
Tanzania (I)									
226. Victoria Lake	1995	C	146	12.6-46.1	TL	0.0351	2.86	NA	Witte and Winter (1995)
227. Victoria Lake	1995	C	415	4.8-52	TL	0.0161	3.07	NA	Witte and Winter (1995)
Turkey (I)									
228. Sakarya River	NA	C	260	30-289	TL	0.0103	3.16	0.99	Emịrdğlu et al. (2018)[1]
229. Köyceğiz Lagoon	2017	C	93	6-28.6	TL	0.0168	3.09	0.97	Reis (2020)
USA (I)									
230. Mississippi River	2002-2006	C	259	41.3-400	TL	0.0211	2.99	0.99	Grammer et al. (2012)[1]
Zambia (I)									
231. Kariba Lake	2014	C	NA	NA	TL	0.0212	3.02	0.87	Nyirenda (2017)[1]
Zimbabwe (I)									
232. Chivero Lake	2011	M	659	30-226	SL	0.0212	3.35	0.68	Utete and Chikova (2013)[1]
233. Chivero Lake	2011	F	473	30-225	SL	0.4226	3.10	0.78	Utete and Chikova (2013)[1]

Status means an indication of species status, N: sampled from native populations, I: sampled from invasive populations. Gender = sex (F, female; M, male; C, combined sexes). n, sampled size. L_{min} is the minimum length and L_{max} is the maximum length; LS, type of length in the original source study (TL, total length; FL, fork length; SL, standard length). *a',* the original standardized intercept *(a)* corresponding to a_{TL} and a_{cm}; b = the slope of the relationship $W = aL^b$; R^2 = coefficient of determination; "NA" means no data in the literature. [1], length-weight relationship corresponding to cm, g. [2], questionable records, the respective point deviated more than two standard deviations from the regression line between log (a') and b. [3], R^2 is converted from R.

Supplementary Table II. Estimated *b* value for *Oreochromis niloticus* (Linnaeus, 1758).

		n	**Min**	**Max**	**Median**	**SE**	**95%CI**
Native	b	126	1.51	3.39	2.91	0.03	2.85-2.95
Invasive	b	74	2.07	3.30	3.01	0.03	2.90-3.05

N, sampled size; *CI,* means confidence interval of the median; *SE* is the standard error.

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