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Morphometrics of 39 fishes from the Seychelles artisanal fisheries

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Abstract

A total of 5478 fishes were sampled between 2009 and 2020 to assess length–weight, length–length and weight–weight relationships in 39 marine species from 10 families caught in the Seychelles waters by the artisanal fishery. Two types of length (total length TL, fork length FL) and three types of weight (whole weight WT, gutted weight GW and gilled-gutted weight GGW) were measured. The parameters of the relationships were estimated using the log-transformed allometric model with bias correction. Our results include length–weight, length–length and weight–weight relationships for 39, 20 and 18 species, respectively. Our length–weight data and resulting relationships were compared against FishBase database for 36 species and were in the Bayesian 95% confidence interval of the relationships available for 33 species and above for *Gnathanodon speciosus*, *Lutjanus gibbus* and *Variola louti*. Finally, for five abundant and widely dispersed species we tested for spatial differences in morphometric relationships between the Mahé Plateau and three southern atoll groups. Significant differences were found for two species only, but their magnitude was small. We thus argue for the regression relationships based on pooled data to be used for most types of population and community analyses. The availability of these morphometric relationships will support the application of accurate size-based analyses for Seychelles fisheries survey data, and so enhance understanding of the ecology of the reef-associated fish component of marine ecosystems and food webs, and improve fisheries research management.

Introduction

With an Exclusive Economic Zone (EEZ) of 1.37 million km^2 constituting 99.7% ocean, Seychelles' EEZ is among the top 25 largest in the world and a global biodiversity hotspot with two United Nations Educational Scientific and Cultural Organization (UNESCO) World Heritage Sites of which one is a marine site (Myers *et al.*, 2000). Biodiversity is one of the country's most important assets that supports several major economic sectors, including its two pillars, fisheries and tourism (Bistoquet *et al.*, 2018). Seychelles has committed to protecting 30% of its EEZ (400,000 km^2) of which half equates to 15% no-take zones. A comprehensive marine spatial plan (MSP) aiming at supporting the sustainable and long-term use and health of the Seychelles ocean waters has been developed to support this process (GoS, 2017). Using an ecosystem-based approach, the Seychelles MSP aims to be instrumental for improving ocean fisheries management, ensuring species and habitats have long-term protection, improving coastal ecosystem resilience to climate change, and fostering economic opportunities for fisheries and other ocean-related uses. By 2021, the Seychelles MSP will be the first in the western Indian Ocean, and the second largest in the world (Smith *et al.*, 2018).

A fundamental part of the Seychelles MSP initiative relied on the participation of all stakeholders to gather relevant input on all ocean-related sectors, providing a large range of economic and scientific spatially resolved data as well as local knowledge. Hence, the Seychelles MSP aims to highlight knowledge gaps and provide guidance in collecting the relevant data. The sustainable exploitation of the Seychelles artisanal fishery resources, for instance, requires knowledge of the population dynamics of the various target resources. About 400 artisanal boats operate in Seychelles waters (SFA, 2018), with the majority favouring catch diversification, i.e. balancing fishing effort across a wide range of species. While such a strategy has been shown to ensure local nutritional security and protect fishing livelihoods in data-poor tropical fisheries (Robinson *et al.*, 2020), it challenges the work of the fishery scientists and managers through the need for basic biological data, and specifically length–weight relationships, for all targeted resources.

Length–weight relationships are essential information for fisheries research and management (Froese, 2006). They are essential for stock assessment model inputs and commonly used in ecosystem models, e.g. to calculate the production over biomass ratio of different functional groups (Ricker, 1975; Pauly *et al.*, 2000). In particular, these relationships are used for converting fish numbers to biomass, monitoring changes in average weight, as well as for

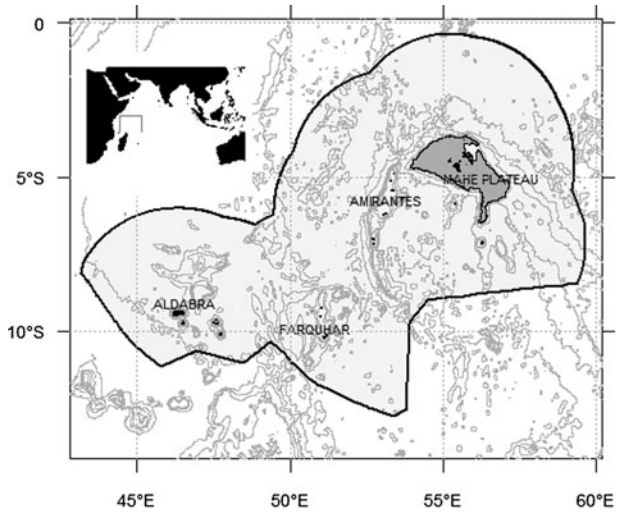

Fig. 1. Map of the Seychelles islands, Western Indian Ocean.

deriving the species composition of the catch in multi-species fisheries (Froese, 2006). To reduce uncertainty when evaluating a fish stock, it is important to first reduce possible causes of variability of the parameters from length–weight analyses. Moreover, length–weight relationships provide valuable insights into fish wellbeing, growth and allometry (variation in form related to variation in size), reproductive characteristics, trophic ecology and general biology, and are used to convert growth-in-length equations to growth-in-weight. Finally, they allow for life history and morphological comparisons between different fish species, or between fish populations from different habitats and/or regions; such studies are relevant principally in regions where fisheries represent one of the most important economic activities and where fish stocks are the main food source for many traditional communities such as Seychelles (Freitas *et al.*, 2014).

Despite their ecological importance, the basic biology of Seychelles artisanal fish species is still poorly known. The present study provides information on the morphometrics of 39 fish species targeted by artisanal fishers in the Seychelles EEZ. The estimated length–weight relationship parameters were compared with values for the same species from different regions and oceans available in FishBase (http://www.FishBase.org). Finally, spatial differences in morphometric relationships between the Mahé Plateau, where most of the fishing activities are taking place, and three southern atoll groups (Aldabra, Farquhar and Amirantes; Figure 1) were examined for five fish species.

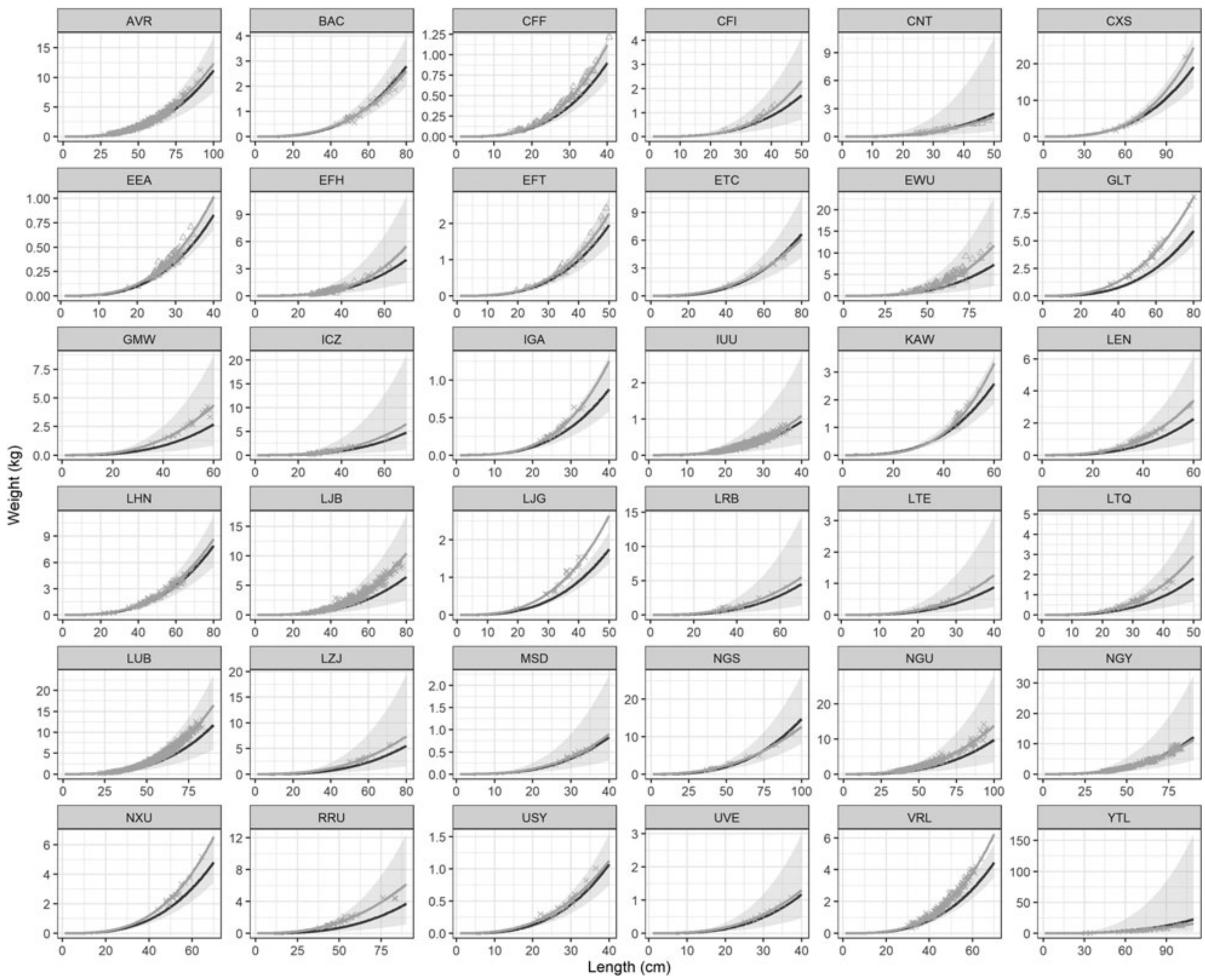

Fig. 2. Length–weight relationships (grey lines) estimated for 36 fish species from the Seychelles waters and compared with length–weight Bayesian relationships obtained from FishBase (black lines). The species code and related names are provided in Table 1; parameters of the equations for each species are provided in Table 2. Measured weight data correspond to total weight (WT, kg); Measured length data correspond to total length (TL, cm) for Balistidae and grouper species (i.e. CNT and CFF, CFI, EEA, EFH, EFT, EWU, respectively), and to fork length (FL, cm) for the other 29 species.

Table 1. Classification of the studied fish species collected from the Seychelles waters with English (UK), French (FR) and Seychelles creole (SEY) names and FAO-ASFIS standard 3-letter codes

Family	Scientific name	Name UK	Name FR	Name SEY	FAO code
Balistidae	Rough triggerfish	*Canthidermis maculata*	Baliste rude	Mosobo	CNT
Carangidae	Yellowspotted trevally	*Carangoides fulvoguttatus*	Carangue pailletée	Karang plat	NGU
Carangidae	Bludger	*Carangoides gymnostethus*	Carangue balo	Karang balo	NGY
Carangidae	Malabar trevally	*Carangoides malabaricus*	Carangue monique	Manik	NGS
Carangidae	Black jack	*Caranx lugubris*	Carangue noire	Karang nwar	NXU
Carangidae	Bigeye trevally	*Caranx sexfasciatus*	Carangue vorace	Karang grolizye	CXS
Carangidae	Mackerel scad	*Decapterus macarellus*	Comète maquereau	Mawan	MSD
Carangidae	Rainbow runner	*Elagatis bipinnulata*	Comète saumon	Galate	RRU
Carangidae	Golden trevally	*Gnathanodon speciosus*	Carangue royale	Karang saser	GLT
Carangidae	Longfin yellowtail	*Seriola rivoliana*	Sériole limon	Somon	YTL
Carangidae	Cottonmouth jack	*Uraspis secunda*	Carangue coton	NA	USE
Kyphosidae	Brassy chub	*Kyphosus vaigiensis*	Saupe grise à lignes jaunes	Pwason dai	KYV
Lethrinidae	Blue-lined large-eye bream	*Gymnocranius grandoculis*	Empereur tatoué	Kaptenn blan	GMW
Lethrinidae	Yellowtail emperor	*Lethrinus crocineus*	Empereur à queue jaune	Laskar	ICZ
Lethrinidae	Blackeye emperor	*Lethrinus enigmaticus*	Lascar	Laskar	LTE
Lethrinidae	Sky emperor	*Lethrinus mahsena*	Empereur mahsena	Madanm beri	LTQ
Lethrinidae	Smalltooth emperor	*Lethrinus microdon*	Empereur tidents	Bek bek	LEN
Lethrinidae	Spangled emperor	*Lethrinus nebulosus*	Empereur moris	Kaptenn rouz	LHN
Lethrinidae	Slender emperor	*Lethrinus variegatus*	Empereur bas cou	Baksou	LHV
Lutjanidae	Green jobfish	*Aprion virescens*	Vivaneau job	Zob gri	AVR
Lutjanidae	Deepwater longtail red snapper	*Etelis coruscans*	Vivaneau flamme	Zob laflanm	ETC
Lutjanidae	Two-spot red snapper	*Lutjanus bohar*	Vivaneau chien rouge	Varavara	LJB
Lutjanidae	Humpback red snapper	*Lutjanus gibbus*	Vivaneau pagaie	Terez	LJG
Lutjanidae	Humphead snapper	*Lutjanus sanguineus*	Vivaneau têtu	Bordomar	LZJ
Lutjanidae	Emperor red snapper	*Lutjanus sebae*	Vivaneau bourgeois	Bourzwa	LUB
Lutjanidae	Lavender jobfish	*Pristipomoides sieboldii*	Colas lavande	Kalkal	LRB
Scaridae	Blue-barred parrotfish	*Scarus ghobban*	Perroquet barbe bleue	Kakatwa blan	USY
Scaridae	Ember parrotfish	*Scarus rubroviolaceus*	Perroquet braisé	Kakatwa rouz	UVE
Scombridae	Kawakawa	*Euthynnus affinis*	Thonine orientale	Bonit	KAW
Serranidae	Peacock hind	*Cephalopholis argus*	Vieille la prude	Vyey kwizinyen	CFF
Serranidae	Coral hind	*Cephalopholis miniata*	Vieille de corail/Vieille etoiles bleues	Vyey zannannan	CFI
Serranidae	Tomato hind	*Cephalopholis sonnerati*	Vieille ananas	Msye angar	EFT
Serranidae	Brownspotted grouper	*Epinephelus chlorostigma*	Mérou pintade	Makonde/Makonde bordaz	EFH
Serranidae	Blacktip grouper	*Epinephelus fasciatus*	Merou de Goree	Madanm dilo	EEA
Serranidae	White-blotched grouper	*Epinephelus multinotatus*	Mérou plate grise	Vyey plat	EWU
Serranidae	Yellow-edged lyretail	*Variola louti*	Croissant queue jaune	Krwasan/Gran ke	VRL
Siganidae	Streamlined spinefoot	*Siganus argenteus*	Sigan vermiculé	Kordonnyen soulfanm/ Kannalo	IGA
Siganidae	Shoemaker spinefoot	*Siganus sutor*	Sigan pintade	Kordonnyen blan	IUU
Sphyraenidae	Pickhandle barracuda	*Sphyraena jello*	Bécune jello	Bekin karo	BAC

Table 2. Length–weight relationships for 39 fish species from the Seychelles waters. The relationships between total length (TL, cm) and total weight (WT, kg), and between fork length (FL, cm) and total weight (WT, kg) were estimated for 26 and 33 species, respectively

Family	Species	N_{TL}	TL range	a_{TL}	b_{TL}	SEb_{TL}	r^2_{TL}	N_{FL}	FL range	a_{FL}	b_{FL}	SEb_{FL}	r^2_{FL}	G
Balistidae	*Canthidermis maculata*	35	24–48	8.8×10^{-5}	2.576530	0.084237	0.966	15	24–47	0.000110	2.531419	0.133772	0.965	A-
Carangidae	*Carangoides fulvoguttatus*	357	36–107	2.1×10^{-5}	2.838736	0.020070	0.983	357	31–95	0.000052	2.711755	0.018223	0.984	A-
Carangidae	*Carangoides gymnostethus*	370	42–92	2.1×10^{-5}	2.868941	0.015860	0.989	381	36–83	0.000047	2.754721	0.014540	0.990	A-
Carangidae	*Carangoides malabaricus*	16	44–101	5.0×10^{-5}	2.643649	0.074908	0.989	16	37–93	0.000181	2.423198	0.061950	0.991	A-
Carangidae	*Caranx lugubris*	16	49–72	8.0×10^{-6}	3.117112	0.215220	0.937	16	44–64	0.000017	3.027248	0.167613	0.959	I
Carangidae	*Caranx sexfasciatus*	15	52–114	2.0×10^{-6}	3.405066	0.145752	0.977	15	45–104	0.000006	3.237915	0.166961	0.967	A+
Carangidae	*Decapterus macarellus*							20	26–36	0.000019	2.919750	0.182279	0.934	I
Carangidae	*Elagatis bipinnulata*							36	38–84	0.000080	2.500503	0.077328	0.969	A-
Carangidae	*Gnathanodon speciosus*	30	42–90	2.7×10^{-5}	2.799809	0.089316	0.972	30	36–80	0.000047	2.775908	0.055399	0.989	A-
Carangidae	*Seriola rivoliana*	34	35–115	3.7×10^{-5}	2.696440	0.050399	0.989	34	31–102	0.000061	2.653399	0.050812	0.988	A-
Carangidae	*Uraspis secunda*							40	18–34	0.000023	3.038852	0.125695	0.939	I
Kyphosidae	*Kyphosus vaigiensis*							19	23–30	0.000033	2.900208	0.165874	0.947	I
Lethrinidae	*Gymnocranius grandoculis*							18	36–58	0.000046	2.799781	0.126973	0.968	I
Lethrinidae	*Lethrinus crocineus*	41	27–66	1.8×10^{-5}	2.978029	0.152955	0.907	41	25–61	0.000026	2.924974	0.142061	0.916	I
Lethrinidae	*Lethrinus enigmaticus*	15	21–36	1.2×10^{-5}	3.077594	0.140677	0.974	15	20–34	0.000022	2.973190	0.099982	0.986	I
Lethrinidae	*Lethrinus mahsena*	47	22–46	2.0×10^{-5}	2.973814	0.075290	0.972	47	20–43	0.000023	3.005108	0.069483	0.977	I
Lethrinidae	*Lethrinus microdon*	54	26–64	2.1×10^{-5}	2.872818	0.079166	0.962	54	23–58	0.000028	2.861257	0.056845	0.980	A-
Lethrinidae	*Lethrinus nebulosus*	117	24–80	2.0×10^{-5}	2.891917	0.052671	0.963	117	22–71	0.000022	2.941321	0.036246	0.983	A-
Lethrinidae	*Lethrinus variegatus*	15	20–38	2.1×10^{-5}	2.851206	0.081868	0.989	36	18–35	0.000024	2.917786	0.050711	0.990	I
Lutjanidae	*Aprion virescens*	482	29–100	9.0×10^{-6}	2.999864	0.019034	0.981	482	28–91	0.000026	2.839197	0.016720	0.984	A-
Lutjanidae	*Etelis coruscans*							15	39–73	0.000073	2.589186	0.089804	0.985	A-
Lutjanidae	*Lutjanus bohar*	393	28–80	1.2×10^{-5}	3.068049	0.030948	0.962	418	26–78	0.000011	3.140867	0.026850	0.970	A+
Lutjanidae	*Lutjanus gibbus*							17	20–42	0.000025	2.957675	0.115097	0.978	I
Lutjanidae	*Lutjanus sanguineus*							15	50–71	0.000057	2.685978	0.224269	0.917	I
Lutjanidae	*Lutjanus sebae*	1008	23–88	1.1×10^{-5}	3.115995	0.008703	0.992	1008	22–83	0.000014	3.107609	0.008626	0.992	A+
Lutjanidae	*Pristipomoides sieboldii*	24	34–72	4.2×10^{-5}	2.707272	0.265269	0.826	24	30–63	0.000052	2.724364	0.215930	0.879	I
Scaridae	*Scarus ghobban*							28	21–36	0.000050	2.716277	0.155274	0.922	I
Scaridae	*Scarus rubroviolaceus*							17	25–37	0.000036	2.845995	0.075732	0.989	A-
Scombridae	*Euthynnus affinis*							15	42–54	0.000002	3.498932	0.459764	0.817	I
Serranidae	*Cephalopholis argus*	73	14–40	1.3×10^{-5}	3.081933	0.032196	0.992							A+
Serranidae	*Cephalopholis miniata*	15	24–41	4.0×10^{-6}	3.393147	0.142533	0.978							A+
Serranidae	*Cephalopholis sonnerati*	30	20–49	1.5×10^{-5}	3.049810	0.083400	0.979							I

Serranidae	*Epinephelus chlorostigma*	124	26–62	3.0×10^{-6}	3.393075	0.085051	0.929							A+
Serranidae	*Epinephelus fasciatus*	88	18–34	1.4×10^{-5}	3.035237	0.098247	0.917							I
Serranidae	*Epinephelus multinotatus*	100	35–88	5.0×10^{-6}	3.260246	0.088094	0.933							A+
Serranidae	*Variola louti*	178	36–74	4.0×10^{-6}	3.233404	0.052486	0.956	178	30–64	0.000008	3.193739	0.047698	0.962	A+
Siganidae	*Siganus argenteus*							31	22–33	0.000008	3.242513	0.103406	0.971	A+
Siganidae	*Siganus sutor*							1436	16–37	0.000023	2.918381	0.014854	0.964	A–
Sphyraenidae	*Sphyraena jello*	15	48–80	9.9×10^{-5}	2.235639	0.136048	0.954	37	43–77	0.000016	2.739082	0.105731	0.950	A–

N is sample size; range corresponds to the minimum and maximum length (TL or FL, cm) recorded; a and b are the parameters of the equations $WT = a.TL^b$ and $WT = a.FL^b$; *SEb* is the standard error of *b*; r^2 is the coefficient of determination; *G* is the type of growth (I: isometry, A–:positive allometry, A+: negative allometry).

Materials and methods

A total of 39 fish species from 10 families (Table 1) were collected between 2009 and 2020 from the Seychelles waters. Fishes were caught by the artisanal fishery using diverse small boats and gears (handlines, traps), and during scientific cruises using handlines and droplines onboard the research vessel 'L'Amitié' of the Seychelles Fishing Authority (SFA). Fishes were processed as soon as possible after being caught either onboard or at landing sites on Mahé Island, Farquhar or Aldabra by staff of the SFA, the Island Conservation Society and the Seychelles Island Foundation, respectively. All fishes were measured for whole weight (WT, nearest 0.1 kg) and length (total length TL and/or fork length FL, nearest 0.1 cm). When possible, the fish gutted weight (WG, nearest 0.1 kg) and gilled-gutted weight (WGG, nearest 0.1 kg) were also recorded.

The parameters of the length–weight, length–length and weight–weight relationships for the studied species (sex combined) were estimated using a maximum likelihood approach with bias correction after logarithmic transformation of the following equations (Hayes *et al*., 1995):

$$\mathrm{WT} = a \times L^b$$

$$\mathrm{TL} = c \times \mathrm{FL}^d$$

$$\mathrm{WT} = e \times W^f$$

with WT, the whole fish weight in kg; L, the fish length in cm (Total length TL or Fork length FL); and W, the gutted (GW) or gilled-gutted weight (GGW) in kg.

The model residuals were assumed to be independent and identically distributed normal random variables with mean zero and constant variance. Assumptions of homoscedasticity and Gaussian distribution were checked through the residuals. Model fitting was performed using the lm function implemented in R version 3.6.3 (R Core Team 2020). Species for which morphometrics were collected were ones that recorded 15 or more individuals, and covered a relatively wide size range. These were selected for the estimation of the length–weight, length–length and weight–weight relationships (Jenkins & Quintana-Ascencio, 2020). Moreover, extreme outliers attributed to data collection error were omitted from the analyses (i.e. 8 individuals representing <0.15% of total fish number).

Second, the effect of area on length–weight relationships was tested for species occurring in spatially distant areas of the Seychelles EEZ with a sufficient number of samples. A stepwise linear regression procedure was used to test for the influence of area variable in the linear model with the function stepAIC implemented in R version 3.6.3 (R Core Team 2020). The Akaike Information Criterion (AIC) was used to evaluate the improvement of the model when adding or dropping a term. The predictor variables for log(whole fish weight) included log(fish length), area, species as main effects. In addition, an interaction between area and species was included in the model. The term log(fish length) was fitted as a continuous variable, and the terms area and species were fitted as factors.

Results and discussion

A total of 5478 fishes were collected between 2009 and 2020 from the Seychelles waters. From the 39 fish species investigated, the most represented family was Carangidae with 10 species, followed by Lutjanidae, Serranidae and Lethrinidae (seven species each).

Table 3. Total length *vs* fork length relationships for 20 fish species from the Seychelles waters

Family	Species	N	TL range	FL range	*c*	*d*	SE*d*	r^2	TL/FL
Balistidae	*Canthidermis maculata*	15	24–48	24–47	0.892042	1.023610	0.004760	1.000	1.0311
Carangidae	*Carangoides fulvoguttatus*	357	36–107	31–95	0.725913	1.043788	0.004806	0.993	1.1524
Carangidae	*Carangoides gymnostethus*	370	42–92	36–83	0.759312	1.036985	0.004900	0.992	1.1301
Carangidae	*Carangoides malabaricus*	16	44–101	37–93	0.588074	1.090481	0.015908	0.997	1.1756
Carangidae	*Caranx lugubris*	16	49–72	44–64	0.823582	1.019393	0.056888	0.958	1.1225
Carangidae	*Caranx sexfasciatus*	15	52–114	45–104	0.744543	1.039545	0.032546	0.987	1.1346
Carangidae	*Gnathanodon speciosus*	30	42–90	36–80	0.826174	1.007078	0.027082	0.980	1.1765
Carangidae	*Seriola rivoliana*	34	35–115	31–102	0.837269	1.013788	0.011688	0.996	1.1240
Lethrinidae	*Lethrinus crocineus*	41	27–66	25–61	0.898750	1.013716	0.022256	0.982	1.0603
Lethrinidae	*Lethrinus enigmaticus*	15	21–36	20–34	0.824292	1.035872	0.029860	0.989	1.0763
Lethrinidae	*Lethrinus mahsena*	47	22–46	20–43	0.979251	0.983403	0.019309	0.983	1.0828
Lethrinidae	*Lethrinus microdon*	54	26–64	23–58	0.895606	1.006322	0.016494	0.986	1.0910
Lethrinidae	*Lethrinus nebulosus*	117	24–80	22–71	0.966461	0.986769	0.010479	0.987	1.0914
Lethrinidae	*Lethrinus variegatus*	15	20–38	18–35	0.960052	0.978591	0.023616	0.992	1.1195
Lutjanidae	*Aprion virescens*	482	29–100	28–91	0.692926	1.051343	0.005400	0.987	1.1701
Lutjanidae	*Lutjanus bohar*	393	28–80	26–78	1.072841	0.969851	0.005386	0.988	1.0501
Lutjanidae	*Lutjanus sebae*	1008	23–88	22–83	0.935362	1.001621	0.001498	0.998	1.0621
Lutjanidae	*Pristipomoides sieboldii*	24	34–72	30–63	0.843576	1.016438	0.028358	0.983	1.1152
Serranidae	*Variola louti*	178	36–74	30–64	0.816643	1.005834	0.010743	0.980	1.1969
Sphyraenidae	*Sphyraena jello*	15	48–80	43–77	1.049229	0.964107	0.041011	0.977	1.1049

N is sample size; range corresponds to the minimum and maximum total length (TL, cm) and fork length (FL, cm) recorded; *c* and *d* are the parameters of the equation $TL = c.FL^d$; SE*d* is the standard error of *d*; r^2 is the coefficient of determination; TL/FL is the conversion factor (ratio between TL and FL).

The parameters obtained from the length–weight relationships for each species are shown in Table 2 and Figure 2. Linear regressions on log-transformed data were highly significant ($P < 0.001$) for all species (Tables 2–4). No significant heteroscedasticity was apparent from residual plots. The coefficients of determination (r^2) ranged between 0.817 for *Euthynnus affinis* and 0.992 for *Lutjanus sebae* and *Cephalopholis argus*. The exponent b of the length–weight relationships ranged between 2.2356 for *Sphyraena jello* and 3.4989 for *Euthynnus affinis* and the intercept value ranged between 2.0×10^{-6} for *Caranx sexfasciatus* and *Euthynnus affinis*, and 1.8×10^{-4} for *Carangoides malabaricus*.

A total of 16 species (41% of the total number of studied species) showed isometric growth (Table 2), implying that there is no change of body shape as the fish grows and that weight increases as the third power of length (i.e. $b = 3$). Moreover, 14 and 9 species (total 23 species, 59%) showed a negative allometric growth (A−; the fish becomes slenderer as it becomes longer with $b < 3$) or a positive allometric growth (A+; the fish becomes relatively stouter or deeper-bodied as it increases in length with $b > 3$), respectively.

Moreover, the relationships between fork length *vs* total length, total weight *vs* gutted weight, and total weight *vs* gilled-gutted weight, and the related conversion factors are provided for 20, 11 and 14 species, respectively (Tables 3 and 4, Figures 3 and 4).

Of the 39 species, we reported updated maximum lengths and weights and subsequently more robust and comprehensive length–weight relationships for two species, namely the Carangidae *Uraspis secunda* and the Lethrinidae *Lethrinus variegatus*, that were not considered accurate in the FishBase database (Froese & Pauly, 2020). Moreover, we reported species-specific length–weight relationships for two species (the Balistidae *Canthidermis maculata* and the Lethrinidae *Lethrinus crocineus*), that were estimated at the sub-family and genus levels in Fishbase, respectively. Of the remaining species, 33 species showed comparable length–weight relationships between this study and FishBase (Figure 2), and three species, namely the Carangidae *Gnathanodon speciosus*, the Lutjanidae *Lutjanus gibbus* and the Serranidae *Variola louti*, were higher than the upper 95% confidence interval bounds of the FishBase length–weight Bayesian relationships.

Five species met the criteria for wide spatial distribution and high numbers of individuals collected from the different areas. For all species, the best model included the factors species and area only, while the interaction area:species had no effect on the AIC and was thus removed. Significant differences in the length–weight relationship among areas were observed for two species only (*Epinephelus multinotatus* and *Lethrinus nebulosus*), with individuals from the Mahé Plateau being bigger than those from the southern atoll groups for a given size ($P < 0.001$; Figure 5). Spatial differences in intraspecific morphometrics are possible due to the effects of spatial differences in food availability, and/or life history characteristics. However, the absolute differences were small and adding the factor area to the model resulted in a low reduction of the AIC and associated residual sum of squares. We thus conclude that the regression models, based on the pooled data, would be adequate for estimating body weight of the species concerned across the Seychelles EEZ.

Conclusion

This study presents information on morphometric relationships for 39 ecologically and economically important fish species from the Seychelles waters. Such information is essential for determining accurate fisheries data such as biomass estimates,

Table 4. Weight–weight relationships for 18 fish species from the Seychelles waters

Family	Species	WT range	N_{GW}	e_{GW}	f_{GW}	SEf_{GW}	r^2_{GW}	WT/GW	n_{GGW}	e_{GGW}	f_{GGW}	SEf_{GGW}	r^2_{GGW}	WT/GGW
Balistidae	*Canthidermis maculata*	0.29–1.76	30	0.856652	0.970239	0.012191	0.996	1.1550						
Carangidae	*Carangoides fulvoguttatus*	0.68–14.21	26	0.886023	1.034953	0.012895	0.996	1.0928	318	0.900623	0.998565	0.003108	0.997	1.1134
Carangidae	*Carangoides gymnostethus*	0.93–9.7							355	0.886103	0.987398	0.002821	0.997	1.1464
Carangidae	*Carangoides malabaricus*	1.07–11.02							16	0.902625	1.001316	0.008265	0.999	1.1071
Carangidae	*Decapterus macarellus*	0.21–0.64	20	0.942295	1.004036	0.011585	0.998	1.0649						
Carangidae	*Gnathanodon speciosus*	0.94–9.02							28	0.904076	1.000638	0.010013	0.997	1.1062
Carangidae	*Uraspis secunda*	0.17–0.98	21	0.930311	0.996926	0.016324	0.995	1.0729						
Kyphosidae	*Kyphosus vaigiensis*	0.28–0.66	16	0.913536	0.975776	0.026312	0.990	1.0755						
Lethrinidae	*Lethrinus mahsena*	0.19–1.73	17	0.931872	0.985886	0.020337	0.994	1.0599	27	0.914539	1.018963	0.008919	0.998	1.1067
Lethrinidae	*Lethrinus nebulosus*	0.19–5.85	72	0.918468	1.019820	0.007339	0.996	1.0737	64	0.872767	1.020495	0.012351	0.991	1.1335
Lutjanidae	*Aprion virescens*	0.35–11.25	125	0.950694	0.998549	0.005611	0.996	1.0550	444	0.915463	0.993331	0.003188	0.995	1.0991
Lutjanidae	*Lutjanus bohar*	0.29–8.75	266	0.925036	0.999247	0.008997	0.979	1.0923	351	0.860845	1.012109	0.008949	0.973	1.1679
Lutjanidae	*Lutjanus sebae*	0.21–13.09						1.0839	930	0.913536	0.998531	0.001331	0.998	1.0976
Serranidae	*Cephalopholis argus*	0.05–1.21						1.0000	71	0.888949	0.986983	0.004602	0.999	1.1075
Serranidae	*Epinephelus chlorostigma*	0.15–3.35							64	0.934203	1.047526	0.019565	0.979	1.1109
Serranidae	*Epinephelus multinotatus*	0.6–11.58	72	0.925105	1.014971	0.008518	0.995	1.0661	72	0.912477	0.999001	0.010823	0.992	1.0998
Serranidae	*Variola louti*	0.34–4.7	123	0.893823	1.063098	0.010779	0.988	1.0944	137	0.836329	1.088210	0.012444	0.983	1.1561
Siganidae	*Siganus sutor*	0.07–0.85						1.2662	1403	0.835082	1.000878	0.003200	0.986	1.2030

The relationships between total weight (WT, kg) and gutted weight (GW, kg), and between total weight (WT, kg) and gilled-gutted weight (GGW, kg) were estimated for 11 and 14 species, respectively. N is sample size; range corresponds to the minimum and maximum total weight (WT, kg) recorded; *e* and *f* are the parameters of the equations $WT = e.GW^f$ and $WT = e.GGW^f$; SE*f* is the standard error of *f*; r^2 is the coefficient of determination; WT/GW and WT/GGW are the conversion factors (ratios between WT and GW, and between WT and GGW, respectively).

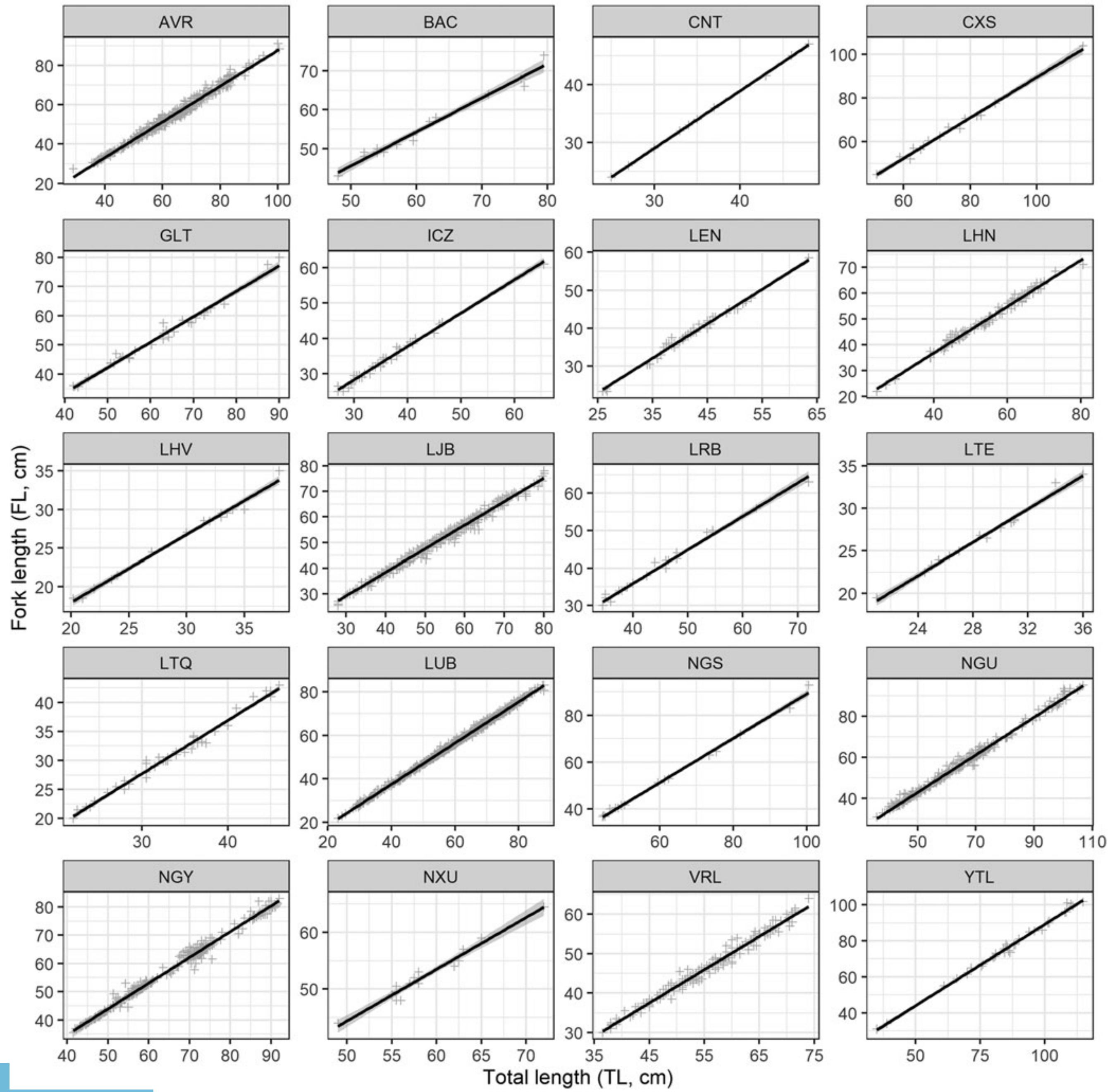

Fig. 3. Length–length relationships estimated for 20 fish species from the Seychelles waters. The species code and related names are provided in Table 1; parameters of the equations for each species are provided in Table 3.

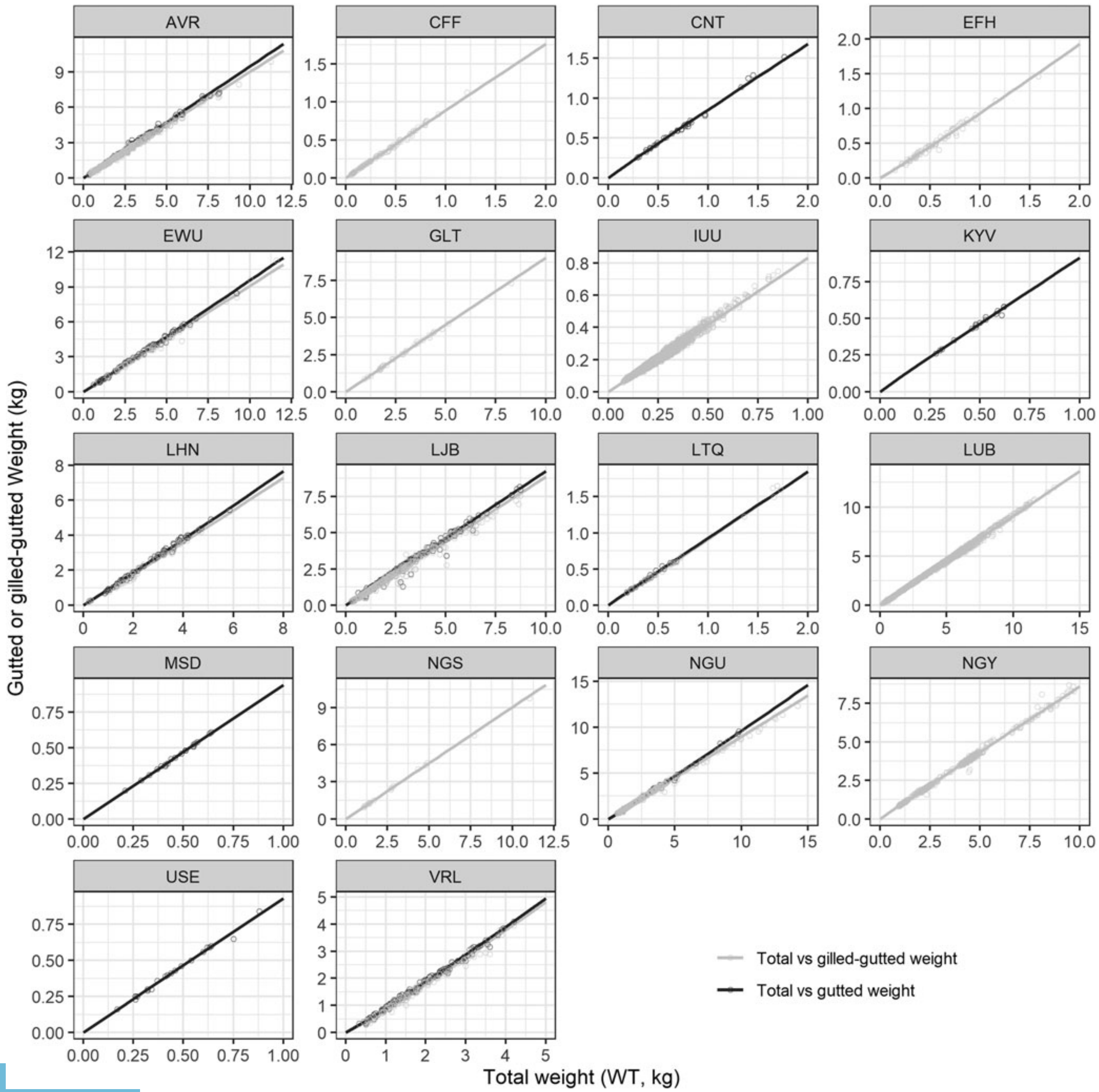

Fig. 4. Weight–weight relationships estimated for 18 fish species from the Seychelles waters. The species code and related names are provided in Table 1; parameters of the equations for each species are provided in Table 4. Dark grey lines represent total weight (WT, kg) *vs* the gutted weight (GW, kg); Light grey lines represent total weight (WT, kg) *vs* gilled-gutted weight (GGW, kg).

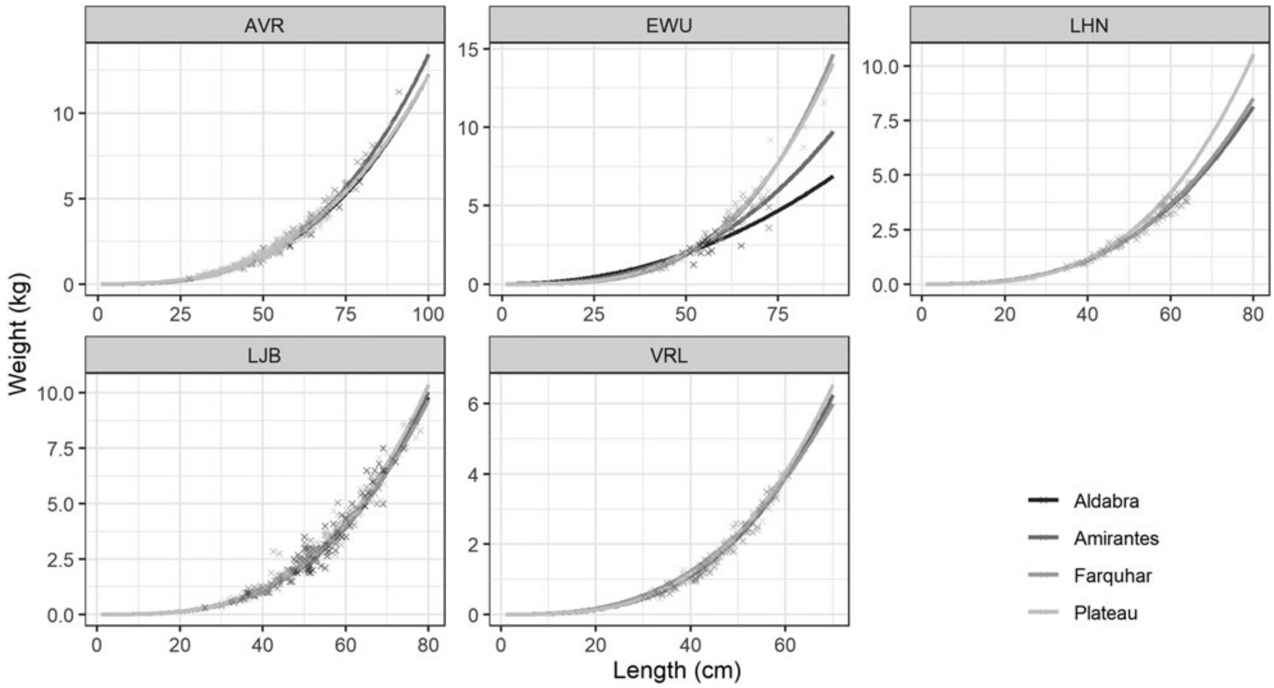

Fig. 5. Length–weight relationships estimated for five fish species from four different areas in the Seychelles EEZ: Mahé Plateau, Farquhar group, Amirantes group and Aldabra group (see Figure 1). The species code and related names are provided in Table 1. Measured weight data correspond to total weight (WT, kg); Measured length data correspond to Total length (TL, cm) for EWU, and to Fork length (FL, cm) for the other four species.

and thus contributes to the improvement of fish stock assessments and fisheries research management in the Seychelles and neighbouring countries.

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