Biometry of the invasive lionfish (*Pterois volitans*) in Playa del Carmen, Mexico and a review of length - weight parameters across the invasion range

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Running title: Length - weight parameters for *Pterois volitans*

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Title of the contribution: Biometry of the invasive lionfish (*Pterois volitans*) in Playa del Carmen, Mexico and a review of length - weight parameters across the invasion range

Abstract

300 words

Key words

lionfish, biometry, length-weight relationship, Mexico

Resumen

300 palabras

Palabras clave

pez león, biometría, relación lopngitud-peso, México

Introduction

Lionfish

Lionfish impacts

Studies quantifying biomass from visual surveys

Objectives

- Provide a new site-specific pair of growth parameters
- Highlight the relevance of using site-specific parameters
- Provide a review of existing growth parameters

Materials and Methods

Area of study

The present study took place off the coasts of Playa del Carmen, in the coasts of the Mexican Caribbean. The region represents the northernmost section of the Mesoamerican reef, which extends from coast of Cancun south to Honduras (**reference**). Coral reefs and mangroves are important habitats distributed along the cost, and represent important sources of income in terms of extractive (*e.g.* recreational fishing) and non-extractive (*e.g.* SCUBA diving) activities related to tourism (**reference**), the main source of income to the local economy.

Coral reefs in the region are characterized by X, Y, Z. Descripcion general de los arrecifes.

Fish sampling

The present study uses samples obtained by Villaseñor-Derbez & Herrera-Pérez (2014) for stomach content analysis between May and August of 2010. A total of 33 SCUBA immersions were performed in 10 sampling sites along 14 Km of coast between Puerto Aventuras and Akumal (Fig. 1, Table 1). All observed organisms (n = 109) were collected using hand nets -to avoid weight loss due to bleeding- and numbered collection bottles. Information on Depth and other comments were recorded in an underwater slide. Depth was recorded by dive gauges held by divers as safety procedures during the collections. Samples were frozen within 30 mins of completing the dive and stored for posterior analysis in the lab. Sampling locations included wall and carpet reefs at depths between 5.7 m and 38.1 m. For every organism Total Length (TL; mm) and Total Weight (TW; gr) were recorded in the lab.

Data analysis

The weight at length relationship between the observed variables was calculated with the allometric growth function:

$$TW = aTL^b$$

Where TW is the Total Weight (gr), TL is the observed Total Length (mm), a is the scaling parameter and b is the exponent (**revisar**). The dependent and independent variables were transformed via base-10 logarithms so that the equation is then:

$$log_{10}(TW) = blog_{10}TL + log10(a)$$

To simplify this equation, we can re-write it as:

$$Y = mX + c$$

Where $Y = log_{10}(TW)$, $X = log_{10}(TL)$, $m = b$, and $c = log_{10}(a)$. This equation was used to estimate the coefficients (a and b), which were estimated via an Ordinary Least Square Regression and heteroskedastic-robust; Standard Errors were calculated to account for **lo que sea que Olivier dijo que era importante**.

- Conversions to biomass

-Lit review

When reviewing other length-weight relationships, it was noticed that some papers indistinctly use a to report either the multiplying coefficient in **eq. 1** or the y-intercept (c) in **eq. 2**, which might sometimes be overlooked. Furthermore, some studies report their parameters as mm-to-gr conversions, but a rapid evaluation of such parameters indicates that they were estimated as cm-to-gr conversions (Fig. A1). Here, both parameters (a and c) are reported for the present findings and, when ever required, coefficients from other studies are converted. All coefficients are reported as mm to gr conversions.

Results

Length-weight relationship

Comparison of allometric parameters

Discussion and Conclusions

Not using spear poles allows us to have a full sample of fish with a wider range of sizes and weights, ideal for visual census. Also, there is no loss in body mass due to bleeding.

Aknowledgements

Tables

Location table

Table 1: Coordinates, minimum, maximum and mean depth (m), and number of samples for each location. n = sample size.

Location	Latitude	Longitude	Minimum Depth (m)	Maximum Depth (m)	Mean Depth (m)	n
Canones	20.477	-87.233	15.0	31.2	21.6	11
Castillo	20.496	-87.220	12.5	30.5	27.5	18
Cuevitas	20.478	-87.244	7.4	12.8	11.2	4
Islas	20.490	-87.228	14.0	19.4	16.7	10
Paamul	20.513	-87.192	9.9	22.7	15.5	31
Paraiso	20.484	-87.226	9.4	38.1	17.7	16
Pared	20.502	-87.212	12.1	21.0	16.3	12
Pedregal	20.507	-87.204	14.4	14.9	14.7	3
Santos	20.493	-87.222	5.7	26.6	16.2	2
Tzimin-Ha	20.393	-87.307	21.2	24.6	22.9	2
Total			5.7	38.1	18.6	109

Summary table

Table 2: Summary statistics of Length and Weight of sampled organisms.

Statistic	N	Mean	St. Dev.	Min	Max
Length	109	140.22	62.41	34	310
Weight	109	52.56	76.58	0.30	397.70

Regression table

Table 3:

	Dependent variable:
	log10(Weight)
Constant	-5.494 $(-5.657, -5.331)^{***}$
log10(Length)	3.235 $(3.159, 3.311)^{***}$
F Statistic	6928.67^{***} (df = 1; 107)
Observations	109
Adjusted R^2	0.976
Residual Std. Error	0.096 (df = 107)
Note:	$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

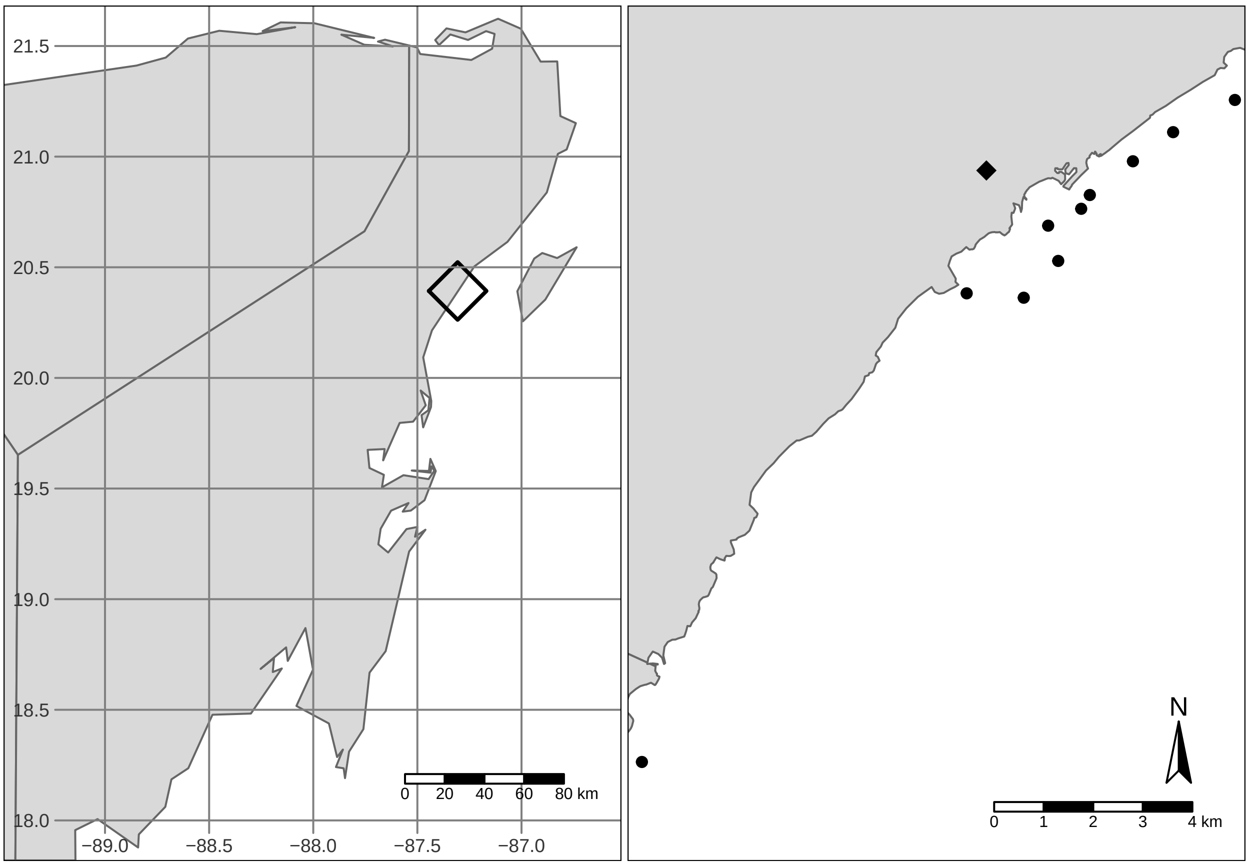
Review table

Table 4: Allometric growth parameters for eight published papers, Fishbase (Froese and Pauly 2016), and this study. All parameters have been adjusted to convert from millimiters to grams. n = Sample size, a = scaling parameter for eq. 1, c = y-intercept for eq. 3, b = exponent or slope for eq. 1 or eq. 2, respectively.

Reference	n	a	c	b	r2	Gender	minD	maxD
(Aguilar-Perera and Quijano-Puerto 2016)	472	0	-5.5400	3.3000	0.9500	Both	5.0	20.0
(Aguilar-Perera and Quijano-Puerto 2016)	67	0	-5.9300	3.4700	0.9500	F	5.0	20.0
(Aguilar-Perera and Quijano-Puerto 2016)	59	0	-5.3800	3.2300	0.9500	M	5.0	20.0
(Sandel et al. 2015)	458	0	-4.4400	2.8100	NA	Both	NA	NA
(Chin, Aiken, and Buddo 2016)	419	0	-4.5600	2.8500	0.8715	Both	18.3	18.3
(Barbour et al. 2011)	774	0	-4.5391	2.8900	NA	Both	27.0	45.0
(de Leon et al. 2013)	1450	0	-4.6411	2.8900	0.9600	Both	NA	NA
(Fogg et al. 2013)	582	0	-5.8600	3.4349	0.9900	Both	NA	NA
(Fogg et al. 2013)	119	0	-5.5700	3.3100	0.9700	M	NA	NA
(Fogg et al. 2013)	115	0	-5.1700	3.1437	0.9400	F	NA	NA
(Edwards, Frazer, and Jacoby 2014)	1887	0	-5.5229	3.2400	0.9700	Both	15.0	30.0
(Sabido-Itza et al. 2016)	2143	0	-5.2828	3.1832	0.9907	Both	0.5	57.0
(Froese and Pauly 2016)	NA	0	-5.0293	3.0900	NA	Both	NA	NA
This study	109	0	-5.4941	3.2347	0.9766	Both	5.7	38.1

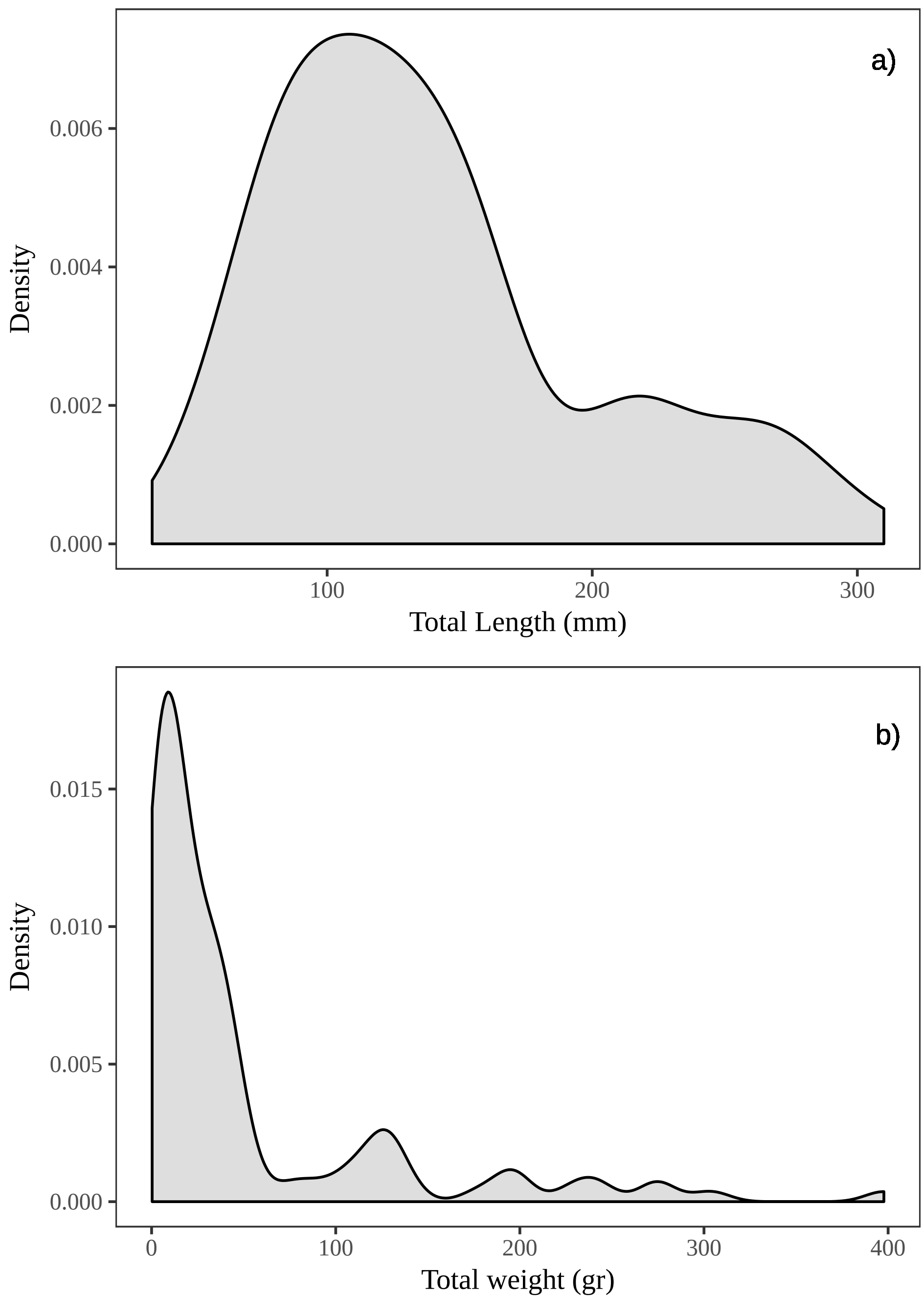
Figures

Map

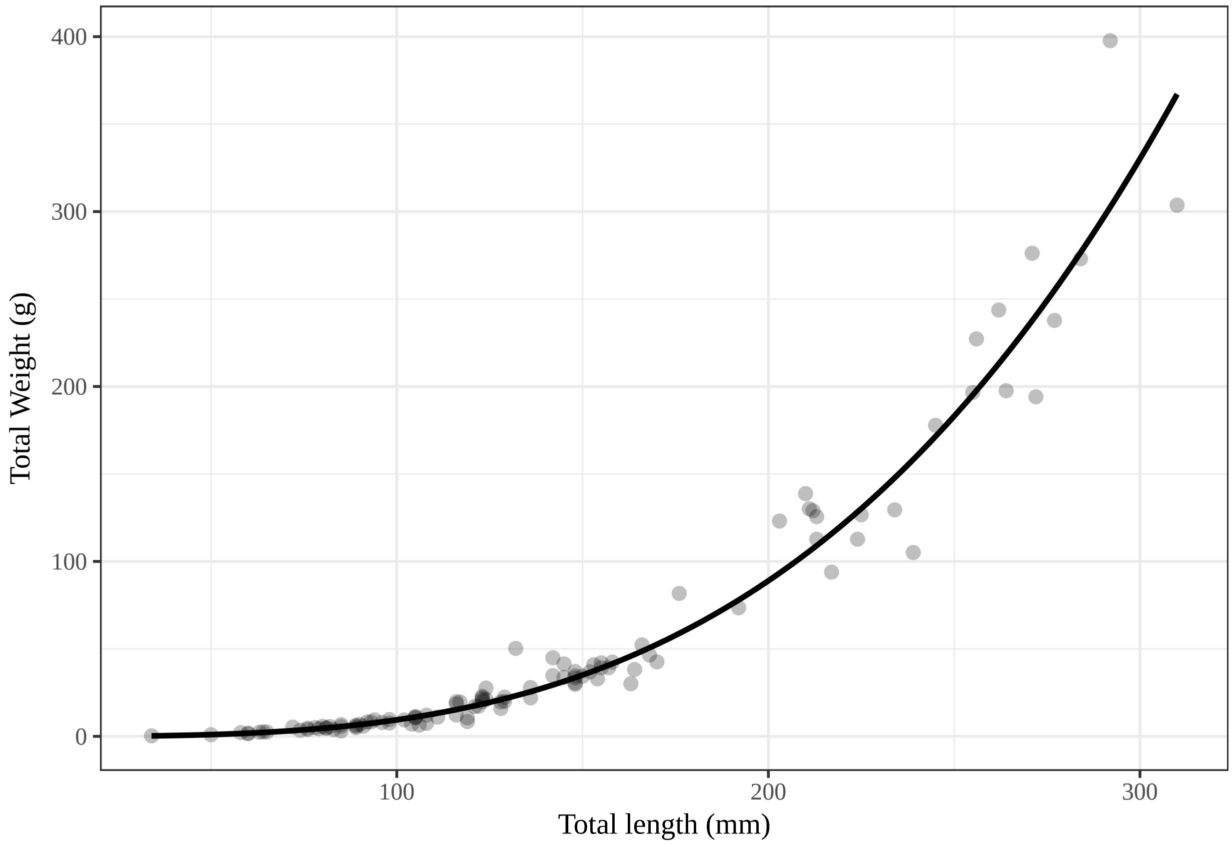


21.5
21.0
20.5
20.0
19.5
19.0
18.5
18.0
−89.0
−88.5
−88.0
−87.5
−87.0
0 20 40 60 80 km
N
0 1 2 3 4 km

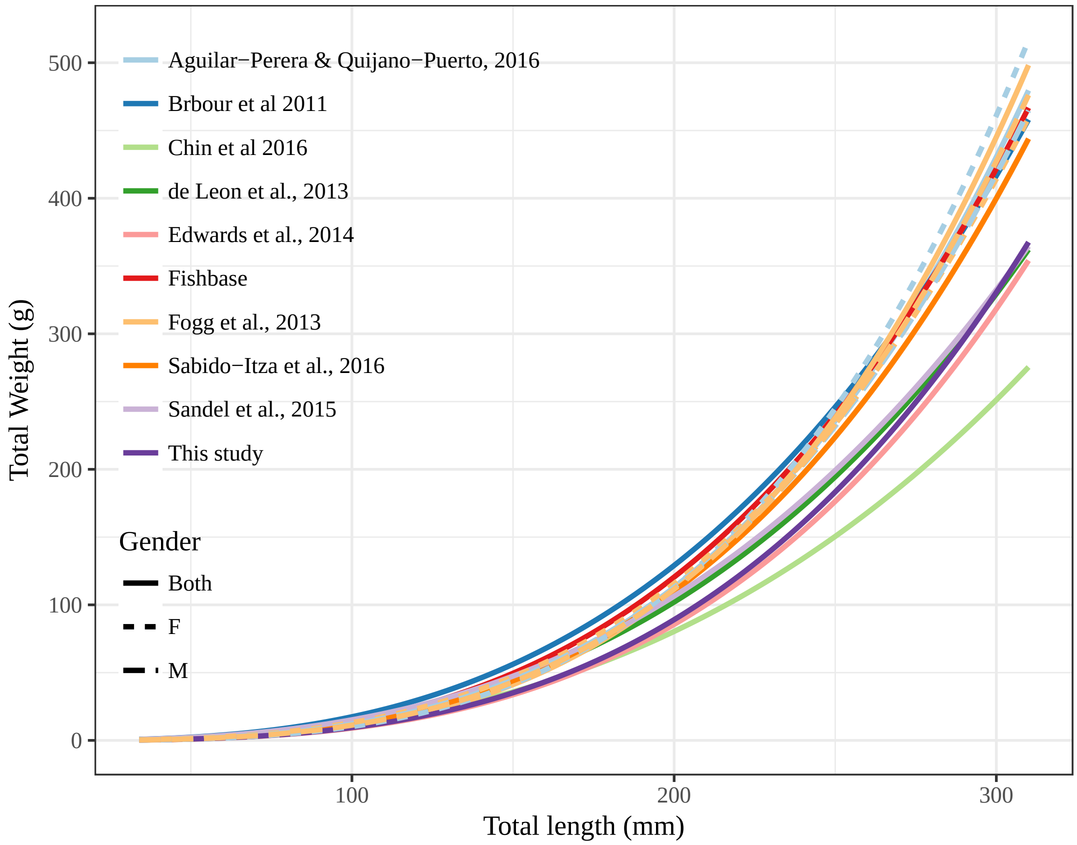
Histograms

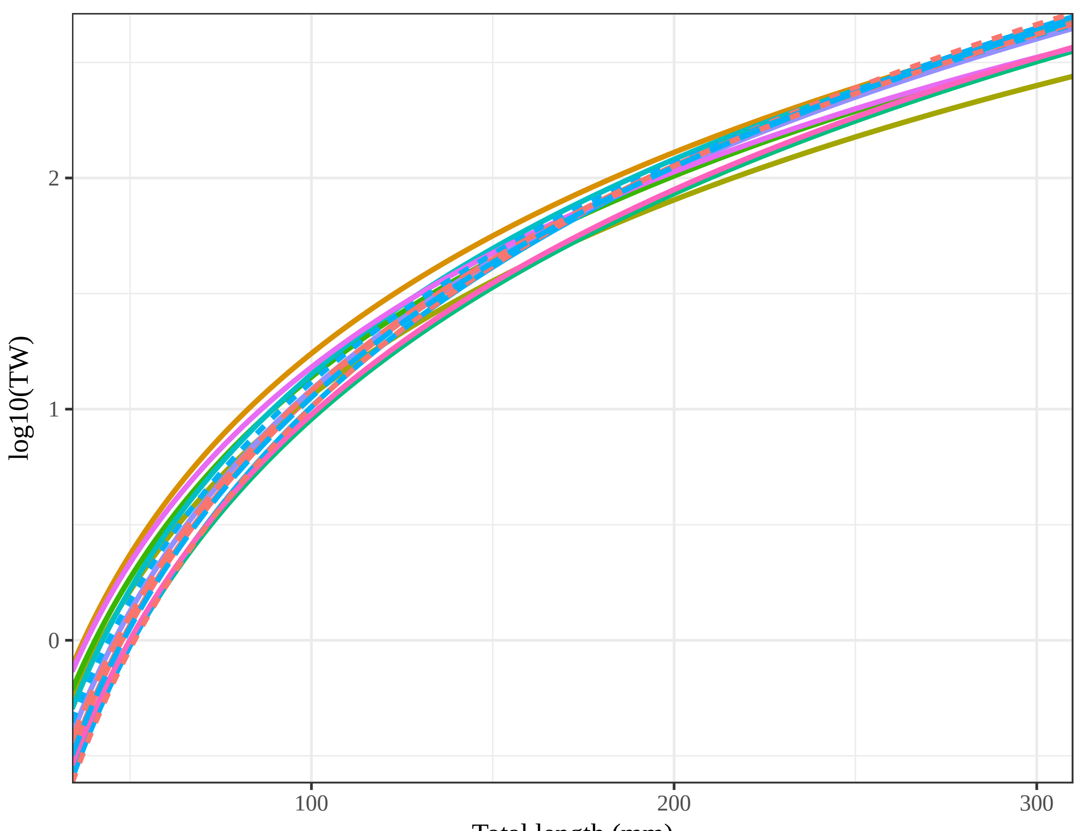

a)
Density
0.006
0.004
0.002
0.000
100
200
300
Total Length (mm)
b)
Density
0.015
0.010
0.005
0.000
0
100
200
300
400
Total weight (gr)

Scatter plot



Review plots





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