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

Juan Carlos Villaseñor-Derbez[1]

[1] Bren School of Environmental Sciences and Management, University of California Santa Barbara

Full postal address: 4312 Bren Hall, Santa Barbara, CA, 93106

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

Corresponding author information:

Juan Carlos Villaseñor-Derbez

4312 Bren Hall

Santa Barbara, CA

93106

jvillasenor@bren.ucsb.edu

+1 (207) 205 8435

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 (*Pterois volitans - miles* complex) are an invasive species in the North-Western Atlantic and the Caribbean. They are the first marine vertebrates to establish in North Atlantic (Schofield 2009: Schofield (2010)) and Caribbean coasts. Their presence in these waters has been labeled as a major marine invasion due to its threat to local biodiversity, the veolocity of its invasion, and the difficulty of management (Hixon et al. 2016).

Liofnish have been prooven to reduce recruitment of local reef fish species (Albins and Hixon 2008). Their diet focuses on small demersal reef-associated fish and crustaceans (Morris and Akins 2009; Villaseñor-Derbez and Herrera-Pérez 2014).

Lionfish were first recorded in Mexican waters in 2010 (Aguilar-Perera and Tuz-Sulub 2010).

Studies quantifying biomass from visual surveys / Ecosim simulations / stock assessments

Significant efforts have been made to understand the possible impacts of the invasion by X (cita de X), y (cita de Y) y z (cita de Z). An important pair of parameters often used in these studies are those which allow researchers to convert observed lengths into weights (*i.e.* weight-at-length parameters) to estimate biomass. Having presission of these parameters is important, because small changes in any of them can result in important over- or unnderestimation of biomass levels. This becomes particularly important when research involves, for example, identifying the total biomass available for harvest by fishers (as invasion management programs).

Objectives

The objectives of this study include providing site-specific weight-at-length parameters for the invasive lionfish in the Mexican Caribbean region. At the same time, we highlight the importance of using site-specific parameters by using those from other studies and comparing predicted weights to those found in this study. Finaly, we provide a review of and summarize other weight-at-length studies presented, making them readily accessible for future research.

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:

$$TW = aTL^b \tag{1}$$

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:

$$log_{10}(TW) = blog_{10}TL + log10(a) \tag{2}$$

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

$$Y = mX + c \tag{3}$$

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

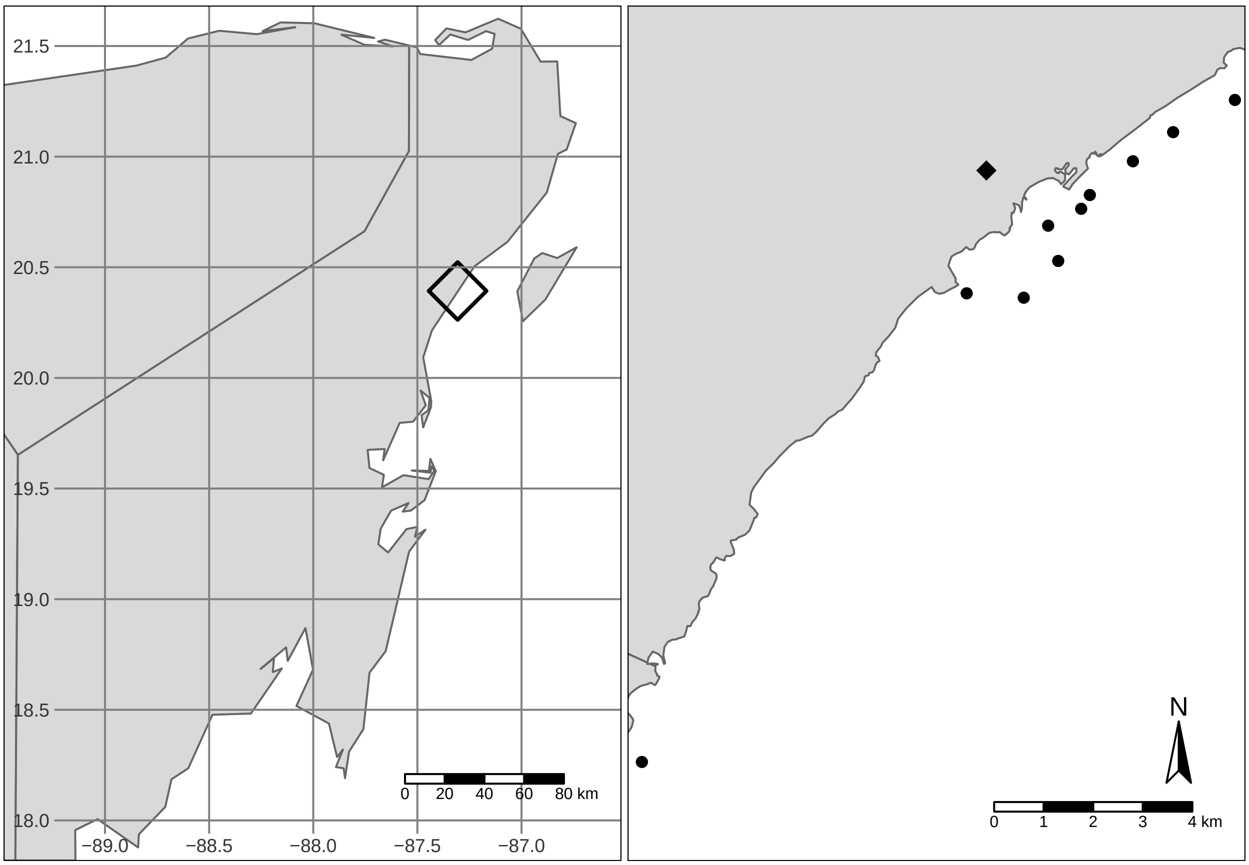
Review table

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.

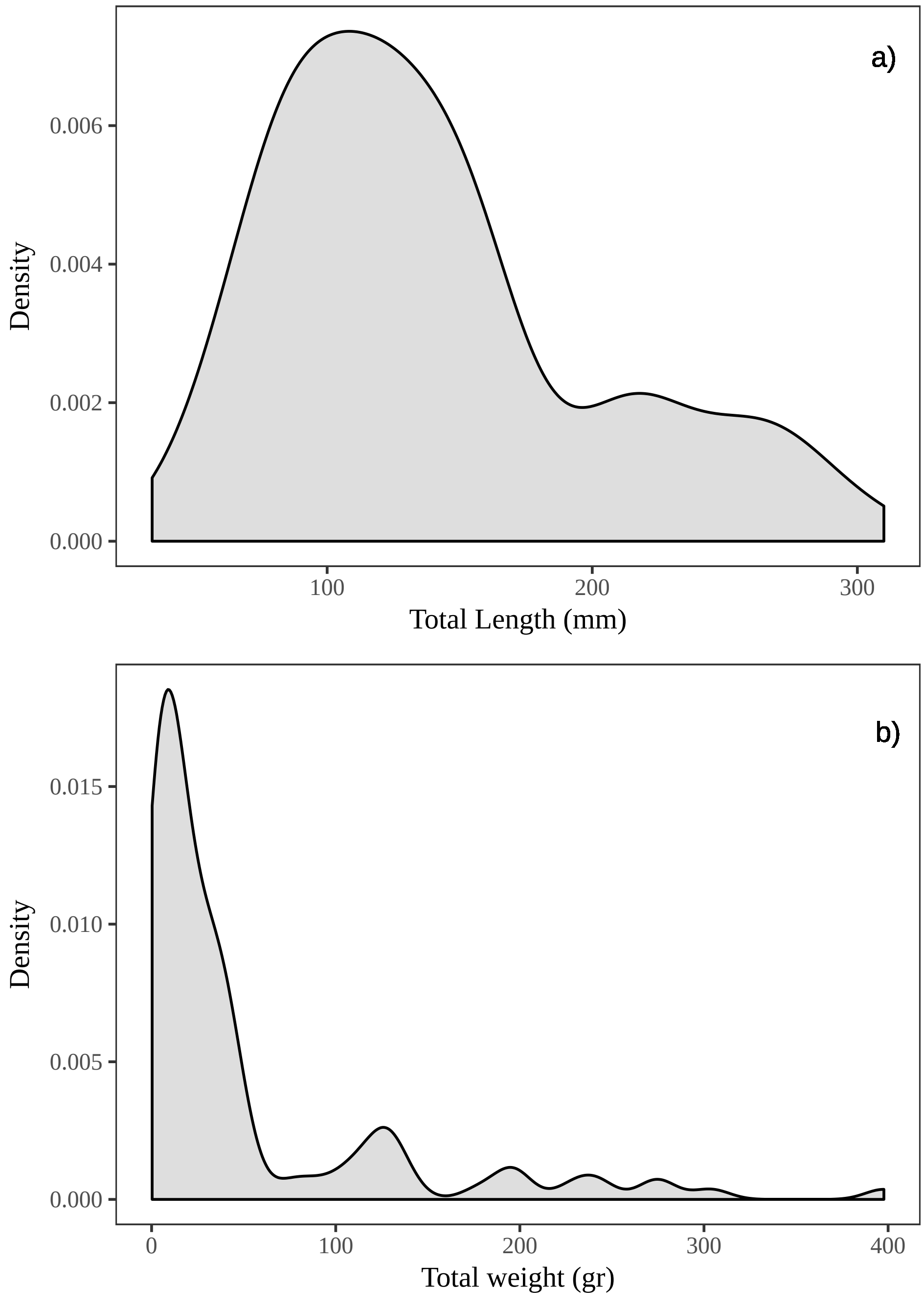
Reference	n	a	c	b	r2	Gender	minD	maxD
(Aguilar-Perera and Quijano-Puerto 2016)	472	0	-5.5400	3.3000	0.9500	Both	5.0	20.0
(Aguilar-Perera and Quijano-Puerto 2016)	67	0	-5.9300	3.4700	0.9500	F	5.0	20.0
(Aguilar-Perera and Quijano-Puerto 2016)	59	0	-5.3800	3.2300	0.9500	M	5.0	20.0
(Sandel et al. 2015)	458	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

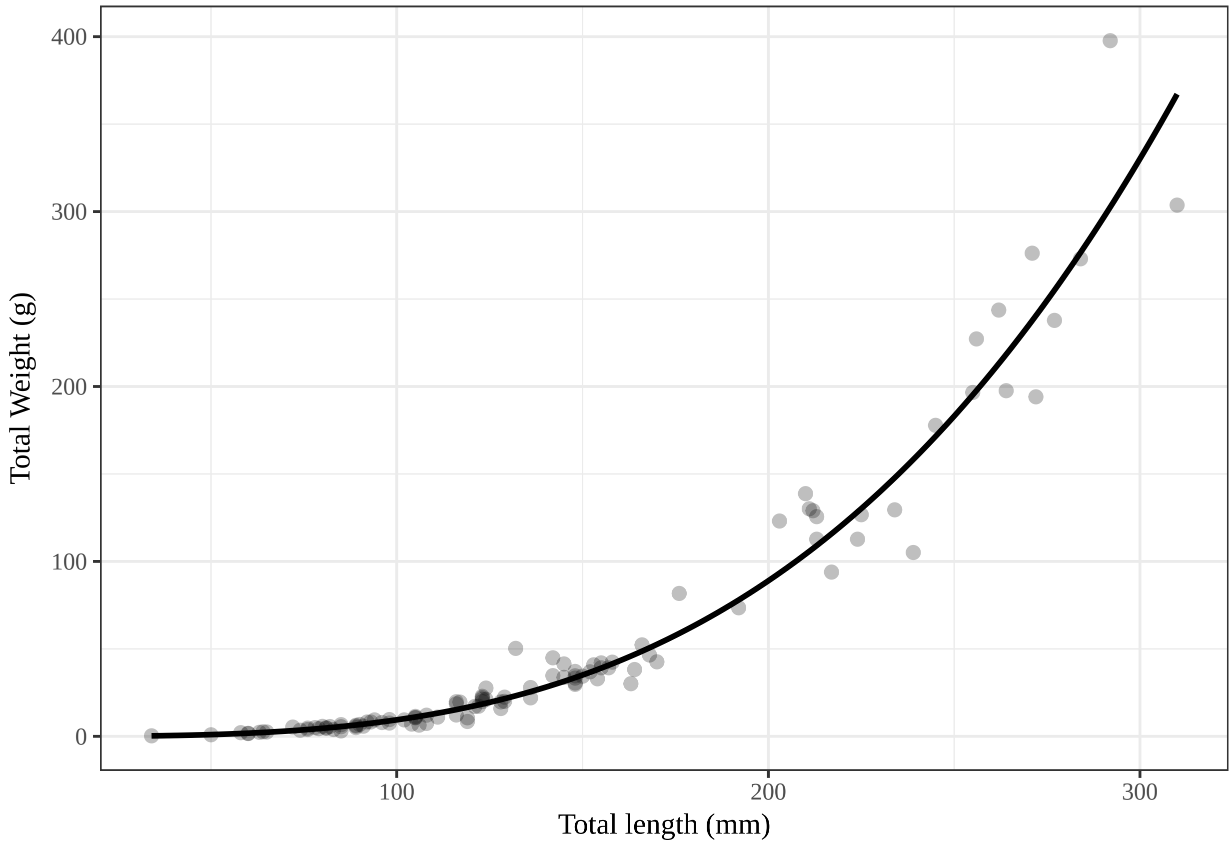
Map


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

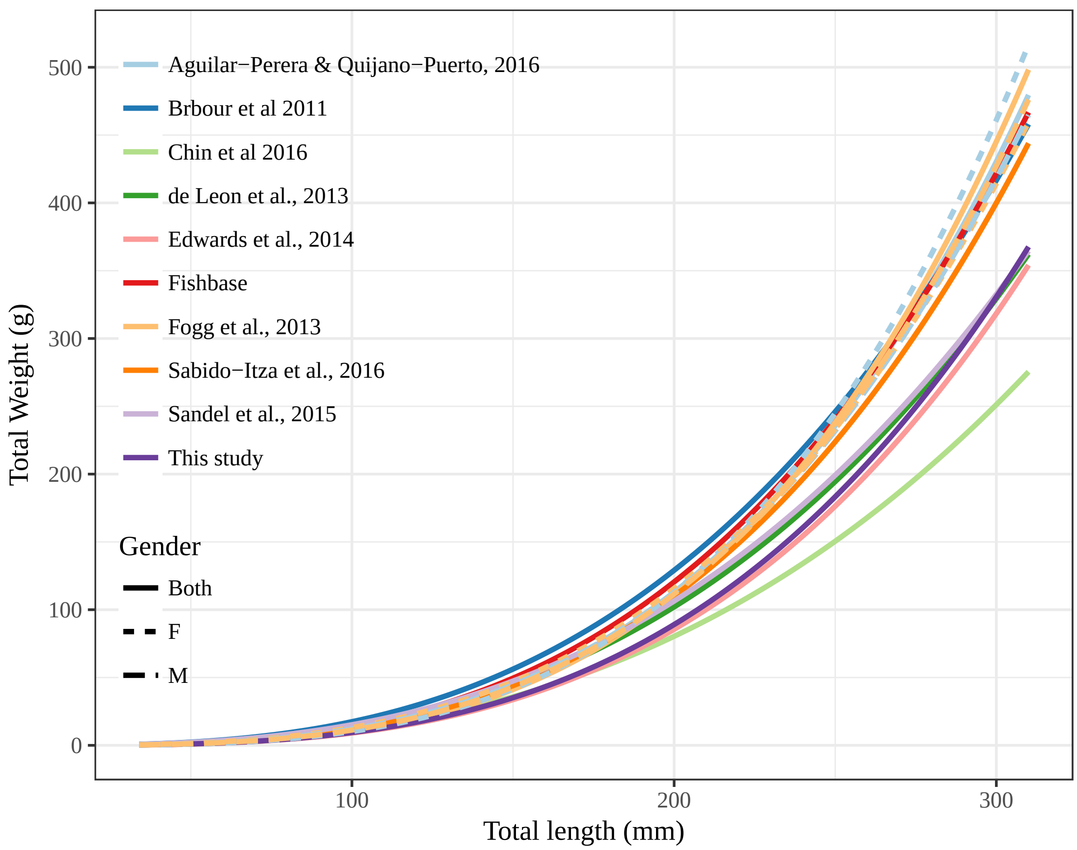
Histograms

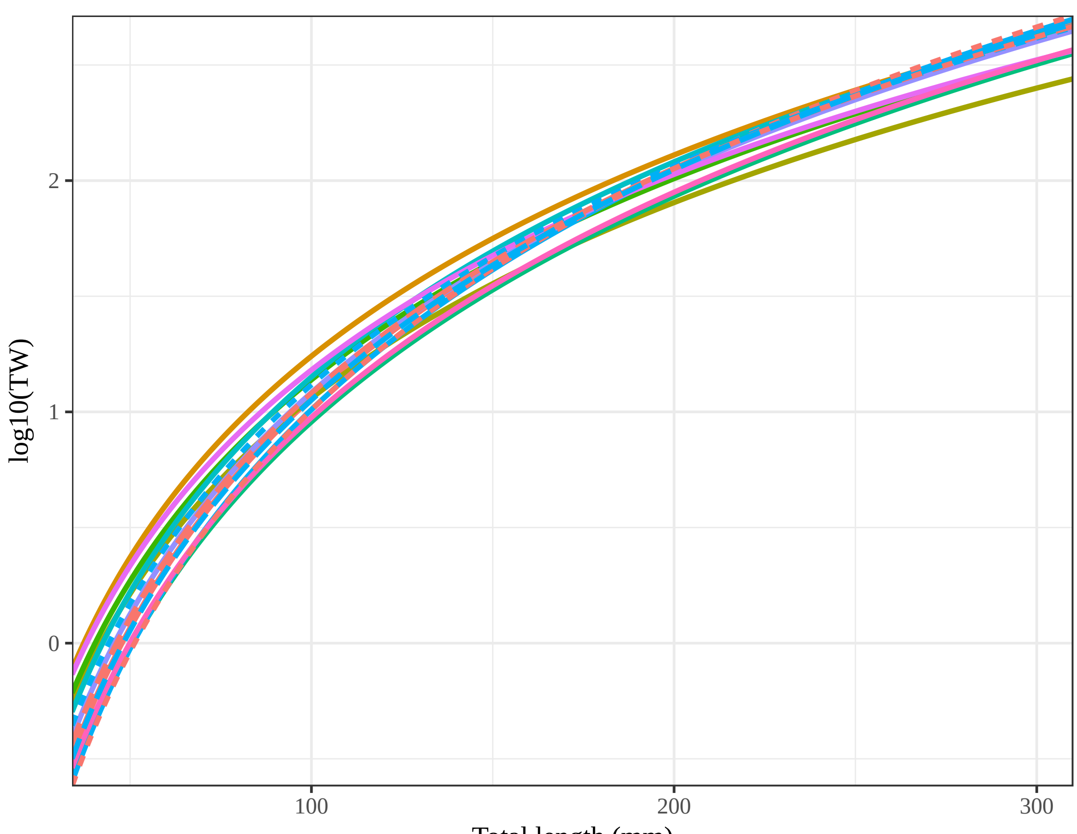

a)
Density
0.006
0.004
0.002
0.000
100
200
300
Total Length (mm)
b)
Density
0.015
0.010
0.005
0.000
0
100
200
300
400
Total weight (gr)

Scatter plot

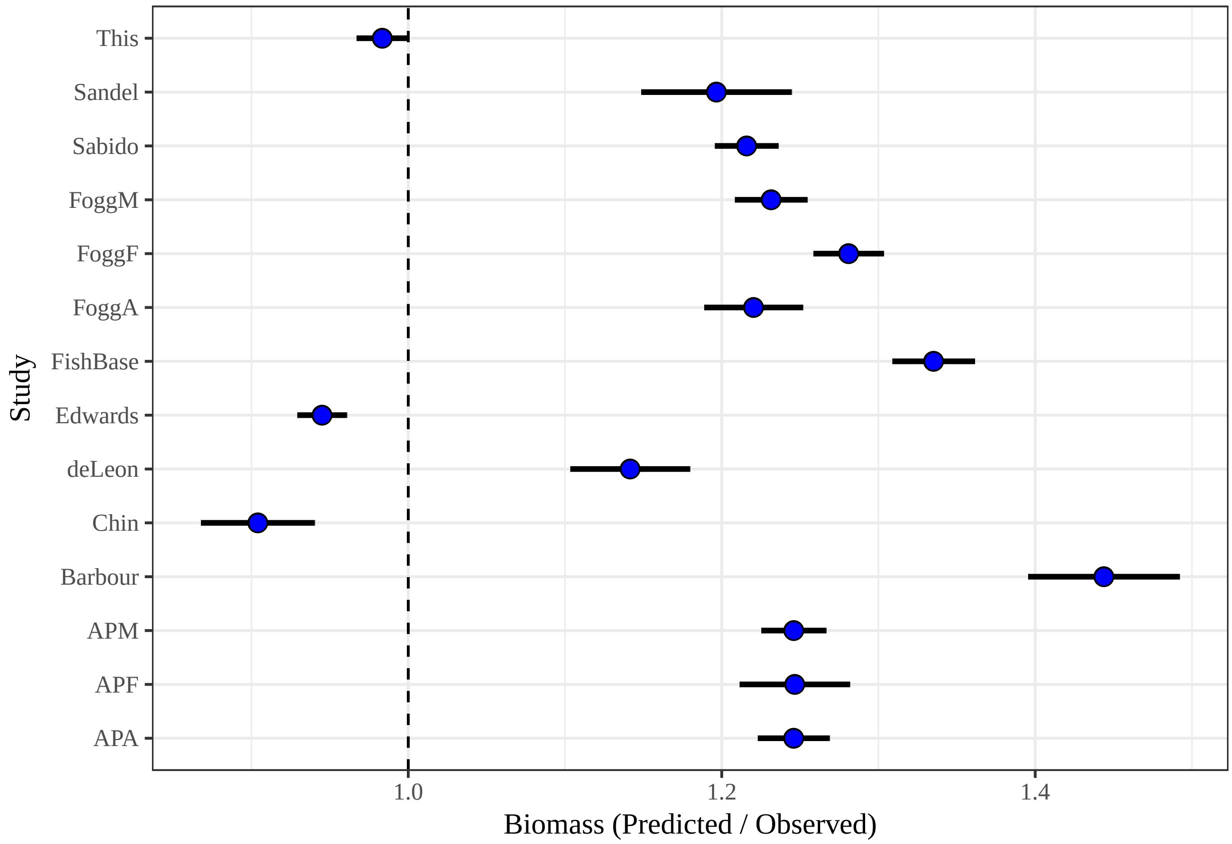


Review plots





Predictions plot



References

Aguilar-Perera, Alfonso, and Luis Quijano-Puerto. 2016. "Relations Between Fish Length to Weight, and Otolith Length and Weight, of the Lionfish Pterois Volitans in the Parque Nacional Arrecife Alacranes, Southern Gulf of Mexico." *Rev. Biol. Mar. Oceanogr.* 51 (2): 469–74. doi:10.4067/S0718-19572016000200025.

Aguilar-Perera, Alfonso, and Armin Tuz-Sulub. 2010. "Non-Native, Invasive Red Lionfish (Pterois Volitans [Linnaeus, 1758]: Scorpaenidae), Is First Recorded in the Southern Gulf of Mexico, Off the Northern Yucatan Peninsula, Mexico." *AI* 5 (Supplement 1): S9–S12. doi:10.3391/ai.2010.5.S1.003.

Albins, MA, and MA Hixon. 2008. "Invasive Indo-Pacific Lionfish Pterois Volitans Reduce Recruitment of Atlantic Coral-Reef Fishes." *Mar. Ecol. Prog. Ser.* 367 (September): 233–38. doi:10.3354/meps07620.

Barbour, Andrew B, Micheal S Allen, Thomas K Frazer, and Krista D Sherman. 2011. "Evaluating the Potential Efficacy of Invasive Lionfish (Pterois Volitans) Removals." *PLoS ONE* 6 (5): e19666. doi:10.1371/journal.pone.0019666.

Chin, Denise A., Karl A. Aiken, and Dayne Buddo. 2016. "Lionfish Population Density in Discovery Bay, Jamaica." *International Journal of Scientific & Engineering Research* 7 (12): 1327–31.

de Leon, Ramon, Kim Vane, Paulo Bertuol, Valerie C. Chamberland, Fernando Simal, Eseld Imms, and Mark J. A. Vermeij. 2013. "Effectiveness of Lionfish Removal Efforts in the Southern Caribbean." *Endanger Species Res* 22 (2): 175–82. doi:10.3354/esr00542.

Edwards, Morgan A, Thomas K Frazer, and Charles A Jacoby. 2014. "Age and Growth of Invasive Lionfish (Pterois Spp.) in the Caribbean Sea, with Implications for Management."

BMS 90 (4): 953–66. doi:10.5343/bms.2014.1022.

Fogg, Alexander Q., Eric R. Hoffmayer, William B. Driggers, Matthew D. Campbell, Gilmore J. Pellegrin, and William Stein. 2013. “Distribution and Length Frequency of Invasive Lionfish (Pterois Sp.) in the Northern Gulf of Mexico.” *GCR* 25 (January). doi:10.18785/gcr.2501.08.

Froese, R, and D Pauly. 2016. “FishBase.” WEBSITE. *FishBase*. http://www.fishbase.org/.

Hixon, MA, SJ Green, MA Albins, JL Akins, and JA Morris. 2016. “Lionfish: A Major Marine Invasion.” *Mar. Ecol. Prog. Ser.* 558 (October): 161–65. doi:10.3354/meps11909.

Morris, JA, and JL Akins. 2009. “Feeding Ecology of Invasive Lionfish (Pterois Volitans) in the Bahamian Archipelago.” *Environ. Biol. Fishes* 86 (3): 389–98. doi:10.1007/s10641-009-9538-8.

Sabido-Itza, MM, A Medina-Quej, A De Jesus-Navarrete, JM Gomez-Poot, and MDC Garcia-Rivas. 2016. “Uso de La Estructura de Tallas Como Evidencia Del Establecimiento Poblacional Del Pez Le?n Pterois Volitans (Scorpaeniformes: Scorpaenidae) En El Sur Del Caribe Mexicano.” *RBT* 64 (1): 353. doi:10.15517/rbt.v64i1.18943.

Sandel, Vera, Damian Martinez-Fernández, Daniel Wangpraseurt, and Luis Sierra. 2015. “Ecology and Management of the Invasive Lionfish Pterois Volitans/Miles Complex (Perciformes: Scorpaenidae) in Southern Costa Rica.” *Rev Biol Trop* 63 (1): 213–21. http://www.ncbi.nlm.nih.gov/pubmed/26299126.

Schofield, Pamela. 2009. “Geographic Extent and Chronology of the Invasion of Non-Native Lionfish (Pterois Volitans [Linnaeus 1758] and P. Miles [Bennett 1828]) in the Western North Atlantic and Caribbean Sea.” *AI* 4 (3): 473–79. doi:10.3391/ai.2009.4.3.5.

———. 2010. “Update on Geographic Spread of Invasive Lionfishes (Pterois Volitans [Linnaeus, 1758] and P. Miles [Bennett, 1828]) in the Western North Atlantic Ocean, Caribbean Sea and

Gulf of Mexico.” *AI* 5 (Supplement 1): S117–S122. doi:10.3391/ai.2010.5.S1.024.

Villaseñor-Derbez, Juan Carlos, and Rogelio Herrera-Pérez. 2014. “Brief Description of Prey Selectivity and Ontogenetic Changes in the Diet of the Invasive Lionfish Pterois Volitans (Actinopterygii, Scorpaenidae) in the Mexican Caribbean.” *PANAMJAS* 9 (2): 131–35. https://www.researchgate.net/publication/265293117/_Brief/_description/_of/_prey/_selectivity/_and/_ontogenetic/_changes/_in/_the/_diet/_of/_the/_invasive/_lionfish/_Pterois/_volitans/_Actinopterygii/_Scorpaenidae/_in/_the/_Mexican/_Caribbean.