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Cover photo: Ehu (*Etelis carbunculus*) specimens. Photo credit: NOAA Fisheries.

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Executive Summary

Length-weight relationships are a valuable resource when working with survey data, and necessary input for many stock assessment models. Data from the CNMI Commercial Fisheries Biosampling Program were used to generate length-weight relationships for 11 bottomfish management unit species and 8 coral reef ecosystem component species. These represent entirely new estimates for 10 of the bottomfish species and considerable improvements over previously available values for most of the coral reef species, with much greater sample sizes and expanded size ranges.

Introduction

Length and weight are two fundamental metrics used in studying fishes and almost any other living organism. The allometric growth equation ($Weight = a * Length^b$) is typically used to define the relationship between increases in fish length and weight. Once developed, this formula can be used to estimate weight from length, or vice versa.

In the Commonwealth of the Northern Mariana Islands (CNMI), creel surveys conducted by the Department of Lands and Natural Resources, Division of Fish and Wildlife are a major source of fishery information (Ma et al., 2022). To limit the time requested of participating fishers, surveyors will often only measure the length of fish from the catch. Length-weight coefficients are then used to estimate the weight of the measured fish, allowing the total catch weight to be calculated. Length-weight coefficients are also used in other surveys (e.g., diver surveys (Ayotte et al., 2015)) and in stock assessments (Langseth et al., 2019). The availability of CNMI-specific length-weight coefficients can improve the reliability of estimates across these applications.

The 2023 Mariana Archipelago Stock Assessment and Fishery Evaluation report identifies species of particular interest to managers (WPRFMC, 2024). These include 13 bottomfish management unit species and 8 priority coral reef ecosystem component species, which are the subject of this report. CNMI-specific length-weight coefficients are available for 1 of the bottomfish species and 7 of the coral reef species (Matthews et al., 2019). With almost 8 years' worth of new length and weight data now available, it is possible to generate the first length-weight coefficients for the species without existing information and to update the coefficients for the species with existing information.

Materials and Methods

Data source

Data collected in the CNMI through the Pacific Islands Fisheries Science Center Commercial Fisheries Biosampling Program (Sundberg et al., 2015) were retrieved from a database maintained by the Western Pacific Fishery Information Network. The data were collected from October 2009 through July 2024. Over this period, 3,726 fishing trips were sampled. In most cases, the entire catch from these trips was identified to species, and fork-length measurements in centimeters were obtained for every fish; weight in grams was recorded for most specimens. Generally, weights of individual fish were not collected once a sufficient number of paired length-weight data were collected. Only paired length-weight measurements for fish identified to species were included in the present analysis.

Length-weight data for three species were filtered to account for potential species misidentifications. First, *Etelis carbunculus* is visually similar to a recently identified cryptic species, *E. boweni*, except that the newly identified species reaches much greater size (Andrews et al., 2021). A maximum length filter of 55 cm was applied to the *E. carbunculus* data to remove probable *E. boweni*. While this would retain smaller *E. boweni*, Dahl et al. (2024) demonstrated that *E. boweni* represent only about 8% of previously identified *E. carbunculus* samples from the Guam biosampling program and are disproportionately present in the larger size classes. Thus, very few *E. boweni* likely remain after the filtering.

Maximum length filters were also applied for *Pristipomoides flavipinnis* and *P. sieboldii* due to misidentification of *P. filamentosus*, which reaches greater size. Fishers have reported difficulty distinguishing *P. filamentosus* from large *P. flavipinnis* and all *P. sieboldii* (Iwane et al., 2023). A maximum length filter of 50 cm was applied to *P. flavipinnis* and 44 cm for *P. sieboldii*, representing values 20% greater than local estimates of their asymptotic length.

Data manipulation

Paired length-weight measurements were analyzed by species using the statistical language R (R Core Team, 2022). Code to automatically remove apparent outliers and produce parameters of the length-weight regressions used in a similar analysis of Guam biosampling data (Kamikawa et al., 2015) was replicated for the present CNMI biosampling data. The general methodology is described below.

For each species, paired length-weight measurements were fit to the model:

$$W = a * L^b$$

where *W* is the weight (g), *L* is the fork length (cm), and *a* and *b* are model parameters. To estimate the parameters via linear regression, a natural log transformation was applied, yielding:

$$\ln(W) = \ln(a) + b * \ln(L)$$

Linear regression of the logged weight onto the logged length measurements produced estimates of ln(*a*) and *b*.

After running the initial regression for each species, outliers were identified in ln-ln space as those points farther than four residual standard error measurements away from the regression line. Outliers were removed and the model was re-fit to the remaining paired length-weight measurements.

Although the code produced length-weight regression parameters for all species, only species deemed to have sufficient data for a reliable regression are reported. This was determined based on two criteria, as previously adopted when deriving length-weight relationships from CNMI biosampling data (Matthews et al., 2019):

- There must be a minimum of 100 paired length-weight measurements.
- The coefficient of determination (r^2) of the linear regression must be greater than or equal to 0.9.

Results

Nineteen species had sufficient paired data to produce reliable length-weight regressions (Table 1). This includes 11 of the 13 bottomfish management unit species and all of the coral reef ecosystem component species. Only *Caranx ignobilis* and *Variola louti* had insufficient data.

Table 1. Length-weight relationships for 19 bottomfish management unit species and coral reef ecosystem component species from the CNMI. Sample size (n), minimum and maximum fork lengths (L_{min}, L_{max}), minimum and maximum weights (W_{min}, W_{max}), allometric growth parameters (a, b), 95% confidence intervals for the growth parameters ([$a_{0.025}$, $a_{0.975}$] and [$b_{0.025}$, $b_{0.975}$]), and the coefficient of determination (r^2) are given.

Scientific Name	n	L_{min} (cm)	L_{max} (cm)	W_{min} (g)	W_{max} (g)	a	b	$a_{0.025}$	$a_{0.975}$	$b_{0.025}$	$b_{0.975}$	r^2
Bottomfish species												
Aphareus rutilans	473	26.0	109.0	290	13400	0.0354	2.76	0.0322	0.0389	2.74	2.79	0.99
Caranx lugubris	426	21.3	82.5	206	9394	0.0253	2.94	0.0227	0.0282	2.91	2.97	0.99
Etelis carbunculus	2145	15.7	53.5	62	2940	0.0159	3.03	0.0152	0.0166	3.01	3.04	0.99
Etelis coruscans	1499	24.8	99.5	254	13538	0.0512	2.70	0.0469	0.0559	2.68	2.72	0.98
Lethrinus rubrioperculatus	1611	17.8	38.1	107	982	0.0180	3.00	0.0167	0.0194	2.98	3.02	0.98
Lutjanus kasmira	888	15.5	35.7	67	806	0.0113	3.16	0.0100	0.0128	3.12	3.20	0.96
Pristipomoides auricilla	1735	17.8	39.5	112	1224	0.0154	3.07	0.0140	0.0170	3.04	3.09	0.96
Pristipomoides filamentosus	203	24.4	65.0	227	4164	0.0224	2.93	0.0188	0.0267	2.88	2.98	0.99
Pristipomoides flavipinnis	571	20.7	45.7	156	1846	0.0145	3.06	0.0131	0.0161	3.03	3.09	0.99
Pristipomoides sieboldii	451	19.5	37.6	112	874	0.0151	3.04	0.0127	0.0180	2.99	3.09	0.97
Pristipomoides zonatus	892	17.5	45.4	106	1864	0.0183	3.04	0.0168	0.0198	3.01	3.06	0.99
Coral reef species												
Acanthurus lineatus	5864	12.0	23.5	48	366	0.0413	2.85	0.0386	0.0442	2.82	2.87	0.91
Lethrinus harak	778	11.3	33.6	30	652	0.0190	3.00	0.0175	0.0206	2.97	3.02	0.99
Mulloidichthys flavolineatus	2851	8.3	31.4	7	469	0.0139	3.05	0.0135	0.0143	3.04	3.06	0.99
Naso lituratus	5293	14.0	30.1	56	552	0.0165	3.11	0.0156	0.0174	3.09	3.13	0.95
Naso unicornis	4641	10.8	53.6	24	2848	0.0271	2.91	0.0265	0.0278	2.90	2.91	0.99
Scarus rubroviolaceus	1893	17.7	52.6	112	3278	0.0087	3.25	0.0083	0.0091	3.23	3.26	0.99
Scarus ghobban	1685	14.9	38.1	60	1228	0.0127	3.12	0.0120	0.0133	3.11	3.14	0.99
Siganus argenteus	4103	10.0	34.3	16	864	0.0128	3.11	0.0125	0.0132	3.10	3.12	0.99

Discussion

These 19 length-weight relationships represent entirely new estimates for 10 bottomfish management unit species and one coral reef ecosystem component species, and notable improvements for the other species. Considerably greater sample sizes were available than during the previous assessment by Matthews et al. (2019), particularly for the bottomfish management unit species. Increased availability of particularly small and large specimens expanded the size range over which the regression coefficients should be applied. However, caution should be exercised for *Mulloidichthys flavolineatus*, which appears to exhibit biphasic growth. Its regression coefficients should only be applied to lengths greater than 11 cm.

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