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LENGTH-WEIGHT AND STANDARD LENGTH-FORK LENGTH RELATIONSHIPS OF DEEPSEA HANDLINE FISHES OF THE NORTHWESTERN HAWAIIAN ISLANDS

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ABSTRACT

Predictive and functional length-weight and standard length-fork (or total) length relationships were calculated from lengths and weights of eight major deepsea species caught by handline in the Northwestern Hawaiian Islands (NWHI). Data collected on RV *Townsend Cromwell* cruises from August 1978 to September 1981 were grouped by sex, cruise, and location of capture. Differences in slopes of regression lines between sexes, tested by ANCOVA for six species, were not significant. There were, however, significant differences among cruises for *Epinephelus quernus* and *Pristipomoides filamentosus*, the two most important species in the handline fishery. Among locations, differences in slopes were also not significant except for *E. quernus*. Pooling of data to calculate a single relationship representative of the whole population for each species, regardless of sex, cruise, or location of capture appeared justified. In this paper, length-weight relationships are given for eight major deepsea species caught by handline in the NWHI. These data represent conversion factors that should prove to be useful in the development of fishery management plans for the Hawaiian handline fishery.

bottomfish
length-weight
standard length-fork length
Northwestern Hawaiian Islands

INTRODUCTION

A deepsea handline fishery has been in existence in the Northwestern Hawaiian Islands since the mid-1940s. In 1976, the Magnuson Fishery Conservation and Management Act was enacted to extend U.S. jurisdiction over fishery resources out to 200 nautical miles from shoreline, and a management plan for the handline fishery resource in Hawaii was undertaken by the Western Pacific Regional Fishery Management Council. Between October 1976 and September 1981, the National Marine Fisheries Service (NMFS) conducted a series of resource survey and assessment cruises on the RV *Townsend Cromwell* and occasionally on a chartered commercial fishing vessel to collect data.

The catch of the deepsea handline fishery consisted primarily of eight species: greater amberjack, *Seriola dumerili*, pig ulua, *Pseudocaranx dentex* (= *Caranx cheilio*) (W.F. Smith-Vaniz, The Academy of Natural Sciences, 1981: personal communication), opakapaka, *Pristipomoides filamentosus* (= *P. microlepis*) (revised by Kami, 1973), kalekale, *P. sieboldii*, gindai, *P. zonatus* (= *Rooseveltia brighami*) (W.D. Anderson, College of Charleston, 1981: personal communication), ehu or ulaula, *Etelis carbunculus* (= *E. marshi*) (revised by Anderson, 1981), onaga, *E. coruscans* (= *E. carbunculus*) (revised by Anderson, 1981), and hapuupuu, *Epinephelus quernus*. These fishes were caught at the edge of banks between depths of 73 and 274 m.

There is no published life history information on any of these fishes from the NWHI and very little from elsewhere in the world. This report provides length-weight and standard length-fork length relationships of the eight major fish species caught on handline gear in the NWHI.

MATERIALS AND METHODS

Fork length (FL) or total length, standard length, weight, and sex were recorded for all fishes (Osteichthyes) caught at deepsea handline stations on the *Townsend Cromwell* survey cruises 78-03, 78-04, 79-02, 80-02, 80-03, 80-04, 80-05, 81-01, 81-02, 81-03, and 81-04 to the NWHI. Fork, total, and standard lengths were measured to the nearest millimeter with 1-m fish calipers according to Ricker (1980). Since the hapuupuu has a rounded tail, its total length was measured. The other fishes have forked tails. Although only fork length is mentioned in the balance of this manuscript, total length was used in place of fork length for hapuupuu. Weights were taken on a Maco (model 25) platform beam scale to the nearest 10 g. Prior to August 1978, weights were taken by spring scales and considered less accurate; these were not used in this study. Sex was determined by examining the gonads.

The length-weight data were examined for possible differences or changes due to sexual dimorphism, time of year (cruise), and area of capture (banks). For each species, the length-weight data were grouped by sex, cruise, and area of capture, and the slopes of the length-weight relationships for these groupings were compared by an analysis of covariance (ANCOVA) to test for equality of slopes among groups. When the group size was very small, <3, the data were not used. Computer program P1V from BMDP Statistical Software (Dixon, 1981) was used to perform the analyses. The decision to pool all data of the same species was made partially on the results of these tests. The relationship of weight to length is described by a power function of the form

$$W = aL^b$$

where

- W = weight in kilograms
- a = a constant (the Y-intercept)
- L = fork length in millimeters
- b = a constant (the regression coefficient or slope)

To fit a least square regression to the linear form of the length-weight power function, common log transformation of lengths and weights was required.

The predictive length-weight and standard length-fork length relationships were calculated by the BMDP computer program P6D (Dixon, 1981). The parameters for the functional length-weight, and standard length-fork length regression were calculated using the slopes of the predictive regression equations (Ricker, 1973).

RESULTS

Results of the ANCOVA comparing slopes and a tabulation of slopes for individual groups of six species of fish are listed by sex in Table 1, seven species by cruise in Table 2, and seven species by bank in Table 3. On the basis of these tests, all data were pooled for each species, so that single length-weight relationships would be representative of the whole NWHI population.

Parameters for the predictive and geometric mean (GM) functional length-weight regressions, sample size, correlation coefficients, and range of fork lengths for each species are tabulated in Table 4. Parameters for the predictive and GM functional standard length-fork length regressions are tabulated in Table 5. Functional length-weight curves for the eight deepsea fishes are illustrated in Figures 1 through 8.

TABLE 1. ANCOVA COMPARING EQUALITY OF SLOPES BETWEEN MALE AND FEMALE LENGTH-WEIGHT RELATIONSHIPS OF DEEPSEA HANDLINE FISHES

		Seriola dumerili	*Pseudocaranx dentex*	*Pristipomoides filamentosus*	*Pristipomoides sieboldii*	*Pristipomoides zonatus*	*Etelis carbunculus*
Males	Slope (b)	2.8539	2.9905	2.8340	3.1804	3.0732	2.9922
	Number (n)	106	128	194	27	34	238
Females	b	2.9577	2.9583	2.8727	3.0850	2.9657	3.0023
	n	71	132	240	89	45	496
All pooled	b	2.8986	2.9737	2.8584	3.1118	3.0121	2.9992
	n	177	260	434	116	79	734
	F value	1.7622	0.2621	1.6642	0.1295	0.2060	0.0326
	d.f.	1, 173	1, 256	1, 430	1, 112	1, 75	1, 730

TABLE 2. ANCOVA COMPARING EQUALITY OF SLOPES AMONG LENGTH-WEIGHT RELATIONSHIPS OF DEEPSEA FISHES GROUPED BY CRUISE

Cruise No.		*Seriola dumerili*	*Pseudocaranx dentex*	*Pristipomoides filamentosus*	*Pristipomoides sieboldii*	*Pristipomoides zonatus*	*Etelis carbunculus*	*Epinephelus quernus*
TC-78-03	Slope (b)	2.7759	2.9172	2.6880	2.4019	2.8394	2.9476	3.1833
	Number (n)	33	30	33	8	22	114	103
TC-78-04	b	2.9806	3.0941	2.7609	3.0276	—	2.3839	3.1245
	n	20	46	77	16	—	7	20
TC-79-02	b	—	2.1621	2.7696	3.2071	2.9855	3.0710	3.0748
	n	—	4	21	9	8	41	24
TC-80-02	b	3.2340	2.7391	2.8600	2.8953	2.7987	3.0275	3.0903
	n	9	15	43	15	6	98	75
TC-80-03	b	3.0348	2.6629	2.9790	3.6220	2.7675	3.0245	3.3476
	n	11	28	26	23	5	175	59
TC-80-04	b	2.9700	3.0016	2.7965	2.8786	3.5380	3.1853	2.9405
	n	12	22	71	11	7	22	45
TC-80-05	b	2.7615	2.8003	2.9636	3.3239	2.9335	3.0145	3.1002
	n	33	39	40	8	11	103	57
TC-81-01	b	3.1423	2.8631	2.8294	3.2541	—	3.0380	2.8785
	n	11	6	35	9	—	16	15
TC-81-02	b	2.8147	2.8850	2.8570	2.9673	2.1396	2.8549	3.0123
	n	11	9	5	3	3	57	38
TC-81-03	b	3.2171	2.8495	2.9983	4.7342	2.8351	3.4360	3.0373
	n	6	11	45	3	3	9	32
TC-81-04	b	2.8019	2.9873	2.7917	3.3846	3.0530	3.0465	2.9848
	n	35	57	75	23	19	112	79
All pooled	b	2.8626	2.9519	2.8281	3.1344	3.0000	3.0215	3.0662
	N	181	267	471	128	84	754	547
	F value	1.3214	1.2750	3.0654*	1.0638	0.4988	1.6198	3.3421*
	d.f.	9, 161	10, 245	10, 449	10, 106	8, 66	10, 732	10, 525

*$P \leq 0.001$

TABLE 3. ANCOVA COMPARING THE SLOPES OF LENGTH-WEIGHT RELATIONSHIPS OF DEEPSEA FISHES GROUPED BY AREA OF CAPTURE

Location		*Seriola dumerili*	*Pseudocaranx dentex*	*Pristipomoides filamentosus*	*Pristipomoides sieboldii*	*Pristipomoides zonatus*	*Etelis carbunculus*	*Epinephelus quernus*
Nihoa	Slope (b)	2.0632	2.9491	2.7190	3.3226	2.8226	2.7018	3.1117
	Number (n)	6	17	6	11	4	9	11
Twin Banks	b	3.5030			—		—	2.4642
	n	4			2		2	3
Necker Island	b	3.1249	2.8444	2.8820	3.1665	3.3738	3.0851	2.9346
	n	27	23	138	23	8	62	25
French Frigate Shoals	b	3.0290	2.8800	2.8474	2.5694	2.9584	3.1620	3.0196
	n	10	29	189	25	11	27	70
Brooks Banks	b	—		2.5652				—
	n	1		7				1
St. Rogatien Bank	b	2.6158	2.9327	2.8740	4.2627	—	3.0025	2.7741
	n	4	12	16	3	2	17	21
Gardner Pinnacles	b	2.8590	3.0331	2.9417	3.0694	2.9069	3.0645	3.2203
	n	30	47	24	4	5	19	19
Raita Bank	b	3.0471	3.2211	2.7278	3.7351	3.1793	3.1094	3.0638
	n	15	23	17	16	8	24	47
Maro Reef	b	2.7612	2.9672	2.5130	—	2.6892	2.8013	3.0421
	n	19	29	35	2	9	24	53
Laysan Island	b	3.0085	3.1059	2.5450	3.5621	3.1261	3.0501	3.2619
	n	20	31	25	6	8	50	54
Northampton Seamounts	b		—	—	—	1.0547	2.4400	—
	n		1	1	2	6	6	2
Pioneer Bank	b							4.4152
	n							5

TABLE 3. ANCOVA COMPARING THE SLOPES OF LENGTH-WEIGHT RELATIONSHIPS OF DEEPSEA FISHES GROUPED BY AREA OF CAPTURE (continued)

Location		*Seriola dumerili*	*Pseudocaranx dentex*	*Pristipomoides filamentosus*	*Pristipomoides sieboldii*	*Pristipomoides zonatus*	*Etelis carbunculus*	*Epinephelus quernus*
Lisianski Island	b	3.0457	—	2.7858	—	—	2.9101	2.8368
	n	4	1	3	1	2	19	16
Bank No. 8	b	2.8226				2.5721	2.9802	3.3047
	n	6				12	46	15
Bank No. 9	b	2.6286	1.4618	—	3.2199	1.5433	2.9547	2.9476
	n	10	3	1	6	3	41	25
Pearl and Hermes Atoll	b	2.8353	2.9894	—	3.0234	2.4107	2.9689	3.0459
	n	19	46	2	12	7	212	111
Salmon Bank	b				2.7487	—	3.0449	—
	n				7	1	38	2
Ladd Seamount	b		-6.3426		0.5139		3.0938	3.5369
	n		3		6		55	18
Midway Islands	b	—	—				2.8397	2.9011
	n	2	1				17	8
Nero Seamount	b	1.0460	—	—	—		2.9148	2.8623
	n	3	1	2	1		77	10
Kure Atoll	b				—		3.3064	3.1142
	n				1		9	20
Bank No. 11	b							3.0171
	n							9
Group	b	2.9109	2.9868	2.8479	3.0656	2.9777	3.0135	3.0624
	n	177	263	460	119	81	752	540
	F value	1.5026	1.8598	1.8689	1.7048	0.9770	1.2153	3.4280*
	d.f.	13, 149	10, 241	9, 440	10, 97	10, 59	17, 716	18, 502

*P ≤ 0.001

TABLE 4. LENGTH-WEIGHT RELATIONSHIPS OF FISHES COMMONLY CAUGHT IN THE DEEPSEA HANDLINE FISHERY IN THE NORTHWESTERN HAWAIIAN ISLANDS

Species	Equation*	Y-axis Intercept	Regression Coefficient	N	Correlation Coefficient	Fork Length	
						Max. (mm)	Min. (mm)
Seriola dumerili	1	2.6069	0.3349	181	0.985	1,138	499
	2	-7.5280	2.8971				
	3	2.6026	0.3400				
	4	-7.6551	2.9412				
Pseudocaranx dentex	1	2.5860	0.3283	267	0.987	890	333
	2	-7.6624	2.9694				
	3	2.5832	0.3325				
	4	-7.7686	3.0074				
Pristipomoides filamentosus	1	2.5852	0.3455	471	0.995	779	234
	2	-7.4085	2.8670				
	3	2.5846	0.3471				
	4	-7.4453	2.8806				
Pristipomoides sieboldii	1	2.5741	0.2758	128	0.929	435	245
	2	-8.0845	3.1327				
	3	2.5772	0.2967				
	4	-8.6857	3.3702				
Pristipomoides zonatus	1	2.5580	0.3026	86	0.965	489	263
	2	-7.8524	3.0751				
	3	2.5559	0.3137				
	4	-8.1477	3.1878				
Etelis carbunculus	1	2.5864	0.3192	754	0.981	635	260
	2	-7.7930	3.0163				
	3	2.5850	0.3253				
	4	-7.9464	3.0740				
Etelis coruscans	1	2.5993	0.3376	44	0.979	880	480
	2	-7.3542	2.8399				
	3	2.5945	0.3448				
	4	-7.5248	2.9003				
Epinephelus quernus	1	2.5912	0.3187	547	0.989	1,106†	238
	2	-7.9342	3.0683				
	3	2.5886	0.3223				
	4	-8.0318	3.1028				

*Predictive equation 1: $\log X = \log a + b \log Y$
Predictive equation 2: $\log Y = \log c + d \log X$
Functional equation 3: $\log X = \log u + v \log Y$
Functional equation 4: $\log Y = \log w + x \log X$

where X = fork length (mm)
Y = weight (kg)
Y-intercept: a, c, u, w
regression coefficient: b, d, v, x

†Total length

TABLE 5. STANDARD LENGTH-FORK LENGTH RELATIONSHIPS OF FISHES COMMONLY CAUGHT I
SEA HANDLINE FISHERY IN THE NORTHWESTERN HAWAIIAN ISLANDS

Species	Equation*	Y-axis Intercept	Regression Coefficient	N	Correlation	Range of Fork Length		Range of Standard Le	
						Max. (mm)	Min. (mm)	Max. (mm)	Min. (mm)
Seriola dumerili	1	3.5344	0.9391	74	0.996	1,494	524	1,367	504
	2	2.1377	1.0572						
	3	0.7493	0.9425						
	4	-0.7889	1.0610						
Pseudocaranx dentex	1	-0.1104	0.9448	129	0.997	830	464	772	431
	2	4.6975	1.0510						
	3	-2.2639	0.9481						
	4	2.4134	1.0547						
Pristipomoides filamentosus	1	2.5515	0.9012	200	0.997	779	268	723	242
	2	0.5081	1.1034						
	3	1.0884	0.9037						
	4	-1.1713	1.1065						
Pristipomoides sieboldii	1	4.2166	0.8983	70	0.987	435	245	403	225
	2	4.0474	1.0853						
	3	0.0356	0.9098						
	4	-0.0218	1.0992						

*Prediction equation 1: $X = a + b Y$
Prediction equation 2: $Y = c + d X$
Functional equation 3: $X = u + v Y$
Functional equation 4: $Y = w + y X$

where X = standard length
Y = fork length
Y-intercept: a, c, u, w
regression coefficient: b, d, v, y

TABLE 5. STANDARD LENGTH-FORK LENGTH RELATIONSHIPS OF FISHES COMMONLY CAUGHT IN THE DEEP-SEA HANDLINE FISHERY IN THE NORTHWESTERN HAWAIIAN ISLANDS (continued)

Species	Equation	Y-axis Intercept	Regression Coefficient	N	Correlation	Range of Fork Length		Range of Standard Length	
						Max. (mm)	Min. (mm)	Max. (mm)	Min. (mm)
Pristipomoides zonatus	1	-13.888	0.9506	42	0.985	489	282	452	256
	2	26.825	1.0207						
	3	-20.0176	0.9650						
	4	20.7707	1.0362						
Etelis carbunculus	1	-2.8201	0.9185	434	0.993	629	269	581	241
	2	9.8694	1.0728						
	3	-6.0045	0.9253						
	4	6.5023	1.0807						
Etelis coruscans	1	-0.5400	0.9169	40	0.998	480	876	440	810
	2	3.4976	1.0859						
	3	-1.8766	0.9189						
	4	2.0160	1.0883						
Epinephelus quernus	1	-13.152	0.8630	289	0.997	21,100	235	956	181
	2	18.896	1.1525						
	3	-14.758	0.8653						
	4	17.096	1.1556						

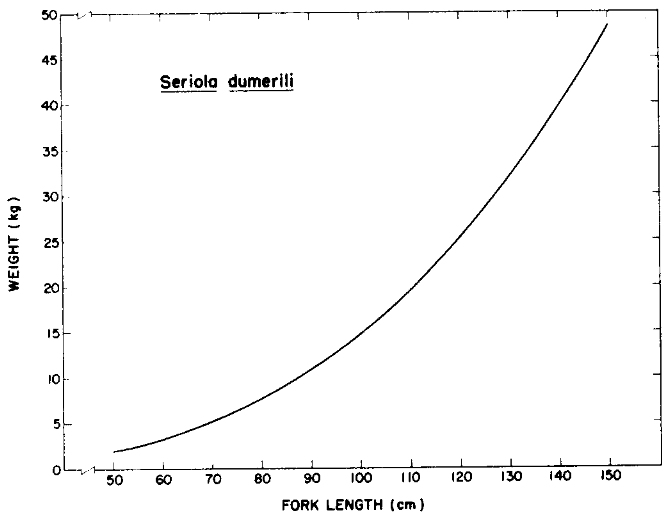

Figure 1. Functional length-weight relationship of the greater amberjack from the Northwestern Hawaiian Islands

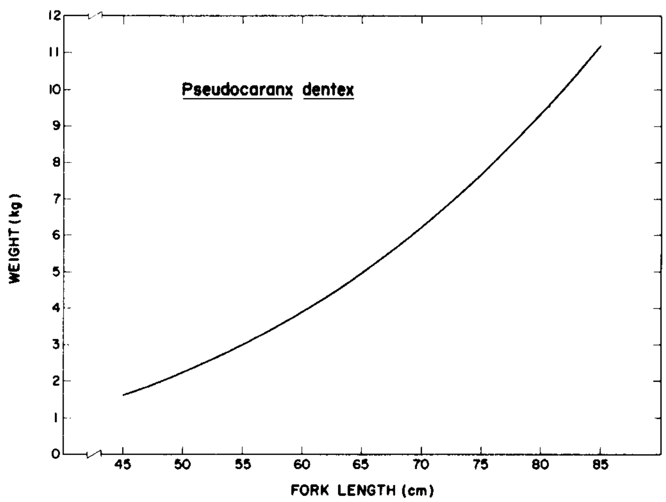

Figure 2. Functional length-weight relationship of pig ulua from the Northwestern Hawaiian Islands

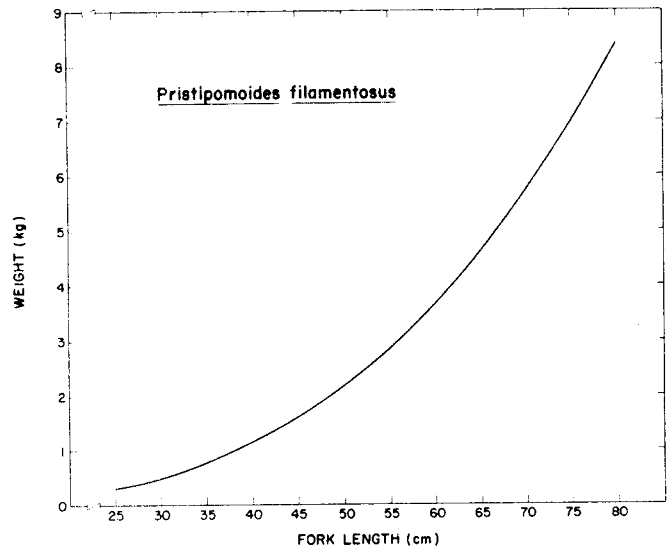

Figure 3. Functional length-weight relationship of opakapaka from the Northwestern Hawaiian Islands

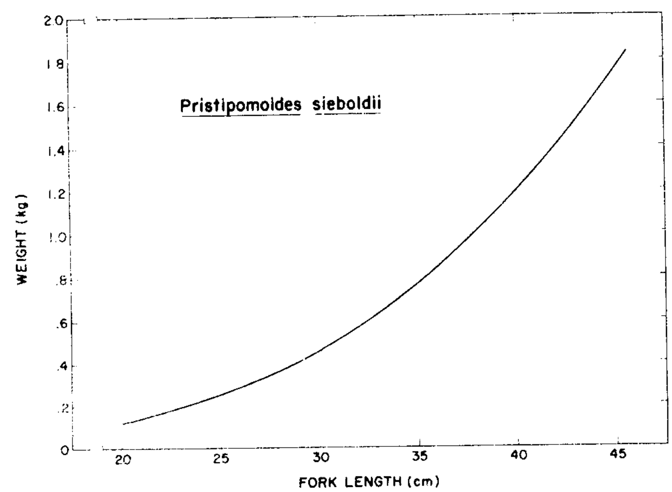

Figure 4. Functional length-weight relationship of kalekale from the Northwestern Hawaiian Islands

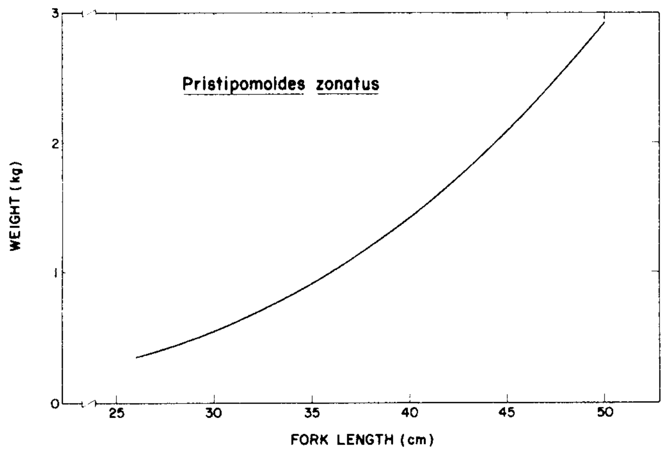

Figure 5. Functional length-weight relationship of gindai from the Northwestern Hawaiian Islands

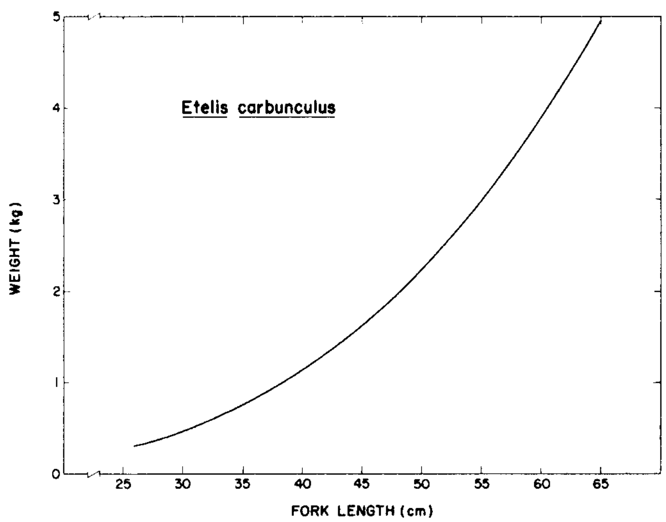

Figure 6. Functional length-weight relationship of ehu from the Northwestern Hawaiian Islands

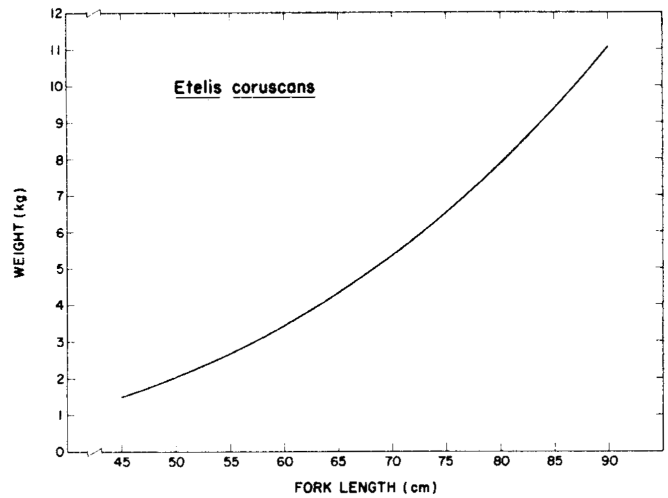

Figure 7. Functional length-weight relationship of onaga from the Northwestern Hawaiian Islands

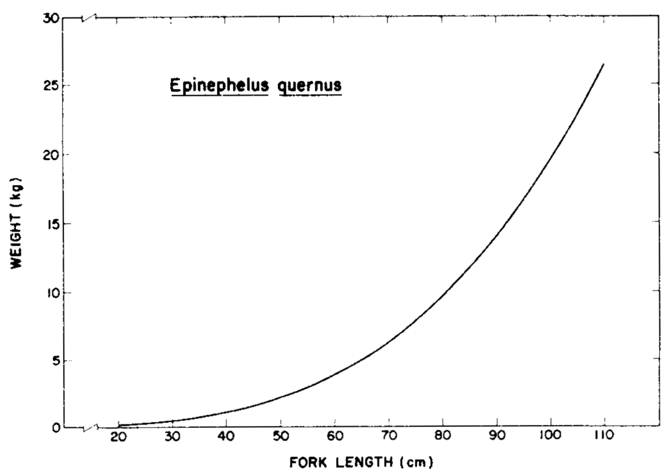

Figure 8. Functional length-weight relationship of hapuupuu from the Northwestern Hawaiian Islands

DISCUSSION

The slopes of length-weight regressions were compared among groups by ANCOVA to test for equality of slopes in the data. There were no significant differences between the slopes of male and female groups for any species (Table 1). Sex comparison for hapuupuu was not conducted due to the small sample size for males. No significant differences occurred in the comparison of slopes among cruises except for opakapaka and hapuupuu (Table 2). Large opakapaka caught on cruises 78-03 and 80-03 and small opakapaka caught on cruise 81-03 appeared to have been responsible for the significant difference. The slope of the length-weight regression of opakapaka of cruise 78-03 was lower than the rest of the cruises and the slopes for cruises 80-03 and 81-03 were higher than the other cruises. Likewise, large hapuupuu caught on cruise 80-03 appeared to be responsible for the significant difference among cruises. These cruises occurred during different months of the year, so the nonsignificance may also have implied that there were no significant seasonal differences in their length-weight relations. No significant differences were found in the comparison of slopes among banks for all species except hapuupuu (Table 3). Hapuupuu has a stout body compared with the more elongated body type of the snappers and greater amberjack or the laterally compressed body of pig ulua, and its length-weight relations may reflect changes in size structure in its population more than the other bottomfishes.

Forster et al. (1970) estimated the length-weight relationship of ehu from the western Indian Ocean. They found that females grew larger than males, calculated the length-weight relationship separately for males and females, and provided 95 percent confidence limits of the exponent of L (length). Although most of the Indian Ocean specimens were larger than Hawaiian forms (largest: 111 cm in the Indian Ocean, 63 cm in the NWHI), the estimates of the exponent of L for the two areas agreed well for males (3.07) and were well within the confidence limits ($P = 0.05$) of the exponent of L for females. Female fish in Hawaii also grew slightly larger, but the difference was not statistically significant.

Ralston (1981) calculated the length-weight relationship of opakapaka from the NWHI, from data collected on a commercial fishing vessel using a spring scale to weigh the fish. The parameters could not be directly compared, so curves derived from the parameters were compared and found to be only slightly different. Weights estimated for lengths <70 cm FL were slightly larger by Ralston's parameters.

Burch (1979) calculated the length-weight relationship of the greatest amberjack caught by sport fishing boats at Miami, Florida. Hawaii data could not be compared directly because different units of measurements were used, so curves derived from the parameters were compared and found to be slightly different. Weights estimated by Burch's formula tended to be lower than Hawaiian estimates, with the difference increasing as length increased. The weight difference estimated for a 130-cm FL fish by the two formulae was about 2.5 kg. The difference in length-weight relationships may have been due to unequal fish sizes in the two studies. The catch in the NWHI consisted mostly of fish under 100-cm FL, whereas the catch in Florida consisted primarily of fish greater than 100-cm FL. Other possible reasons for the difference in length-weight relationships may have been real morphometric differences between populations in different geographical areas or unequal dehydration due to sampling methods. Burch weighed his samples at the dock after a day's fishing trip, whereas Hawaiian samples were weighed within 2 hours after being caught.

SUMMARY

Length-weight data for each species except onaga were separated into groups by sex, cruise, and area of capture. The slope of length-weight relationship of a group was compared with others within their grouping by ANCOVA to test for heterogeneity in the data. Results of the tests appeared to justify the pooling of all data for each species.

Parameters of both the functional and predictive equations of length-weight relationship and standard length-fork length relationship were calculated for greater amberjack, pig ulua, opakapaka, kalekale, gindai, ehu, and onaga. For hapuupuu, the parameters for standard length-total length and length-weight relationships were calculated. In this paper, length-weight relationships are given for eight major deepsea species caught by handline in the NWHI. These data represent conversion factors that should prove to be useful in the development of fishery management plans for the Hawaiian handline fishery.

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