NOAA Technical Memorandum NMFS-SEFSC-705

ALLOMETRIC RELATIONSHIPS FOR SPECIES CAPTURED IN LONGLINE FISHERIES FROM THE WESTERN NORTH ATLANTIC

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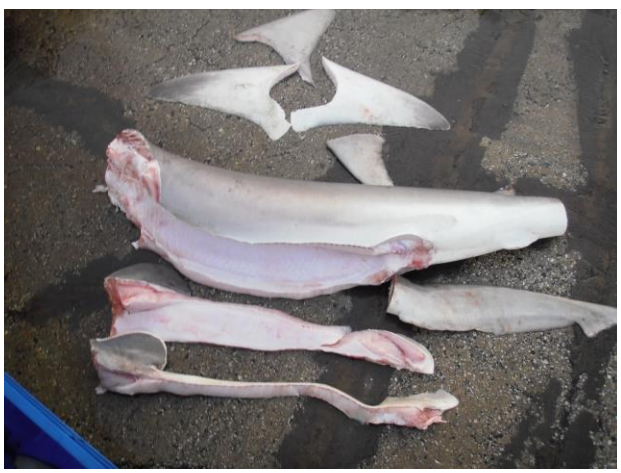

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NOTICE

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Introduction

Commercial landings data provide the platform upon which most research, assessments, and management plans are based. Data collection authorities obtain information from commercial records; however, commercial records are often in native units that are of limited use for data analysis. Conversion factors are used to convert landed condition weight or landed units of commercial seafood products to whole weight. Although many fisheries land product in whole form which does not require conversion, others record product in gutted, headed, carcass, fillet, tail, loins, fins or some other partial form of the fish. Conversion factors are also necessary for product landed in units other than weight in pounds, such as number, thousands, bushels or dozens. In addition, shellfish and crustacean fisheries generally land product as bushels, bags, baskets, numbers, shell on, shell off, or meat only. Conversion factors are then applied to these landed conditions or units with the resulting output of whole weight in pounds.

Standardizing reporting to whole weight in pounds has advantages for trend analysis and comparison between reporting agencies. Unfortunately, there is currently wide variation in conversion factors, and many of those conversion factors have not been verified in recent history. For example, Hesselman and Kemp (2006) analyzed conversion factors in use along the east coast and found that conversions factors for the same species differ from state to state. In general, states north of Virginia use standard historical NMFS conversion codes while states south of Virginia use different and unique conversions. Inconsistencies result in uncertainty when comparing landings among partners and can cause significant problems for species managed under state-by-state or regional quotas.

Herein, we update a variety of allometric relationships for species commonly captured in longline fisheries in the western North Atlantic.

Methods

Data sources

From 2011 to 2016, fisheries observers and field biologists collected length and weight data from a variety of fishery-dependent and –independent sources from the northern Gulf of Mexico and western North Atlantic Ocean. Observations were conducted aboard commercial bottom longline fishing vessels, targeting sharks and teleosts, from North Carolina to Texas along the U.S. Atlantic Coast (Enzenauer et al. 2015a). Fisheries observers from the SEFSC Panama City Laboratory also frequently acted as field biologists in cooperative projects with other National Marine Fisheries Laboratories and the fishing industry. In 2011 and 2012, observers were used by the SEFSC Beaufort Laboratory to study cryptic biomass of red snapper, *Lutjanus campechanus* (Mitchell et al. 2014). In 2013, a Marine Fisheries Initiative (MARFIN) grant initiated mandatory placement of fisheries observers in the southeastern U.S. Atlantic mid-shelf and deep-water reef fish fisheries with an overall target of 62 sea days (Enzenauer et al. 2015b). In 2015, the Beaufort Laboratory employed observers again for a deep-water survey focusing on blueline (gray) tilefish, *Caulolatilus microps* (Kellison 2016). Survey and fishing gears included vertical line or a combination of vertical line and bottom longline gears.

Fork length (FL) was measured (cm) in a straight line, using either Rhino Rulers[1] (Rhino Rulers, Switzerland), a NMFS provided fish board or a fiberglass tape measure. For those teleost species

[1] Mention of trade names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

that lack a forked tail, total length (TL) was recorded, while batoids were measured by disc width (DW). When possible, whole or gutted weights were taken (0.1 kg) at sea using Salter Brecknell scales (Avery Weigh-Tronix LLC, 1000 Armstrong Drive, Fairmont, MN 56031).

Sharks

Fishing vessels participating in the Highly Migratory Species Shark Research Fishery were required to bring up to three whole, large sharks per trip back to the dock to allow the fisheries observer to obtain whole, dressed, and fin weights using the fish house scales. For this fishery, the species of interest were the sandbar shark, *Carcharhinus plumbeus*, blacktip shark, *C. limbatus*, and the hammerhead sharks, *Sphyrna* spp. The cumulative fin weight was obtained from the four commonly sold fins: dorsal fin, two pectoral fins, and lower lobe of the caudal fin. Additional whole sharks were obtained from the Gulf of Mexico States Shark Pupping and Nursery Area (GULFSPAN) project (Deacy et al. in prep). In the U. S. Large Coastal Shark fishery, shark species are commonly dressed by removing head and entrails at sea, followed by removal of the fins, caudal peduncle and belly flaps at the dock. The remaining carcass or “log” is reported under the HMS grade code 39 (Table 1). In 2016, additional dressed shark weights were obtained with belly flaps still on the carcass (HMS grade code 25).

Teleosts

Teleost fishes were measured as described previously, and weighed whole or gutted at sea. The type of weight taken was determined by the observer’s sampling station, which was either before or after the crew member tasked with dressing the catch. As a result, the fish was weighed whole or gutted, respectively.

Caveats

Several possible sources of error should be noted: 1) obtaining fish weights using spring scales on a moving deck can create inconsistent scale readings; 2) the whole sharks that were brought back to the dock were often cut (live sharks are frequently “kill cut” or “naped” by cutting through the backbone just posterior to the cranial case) and thus bled before returning to the dock. This loss of fluid would have resulted in a marginal loss in whole weight; 3) the date of recent calibration of the dock scales was unknown, introducing the possibility of weighing errors; 4) the fins may have been weighed using scales of inappropriate precision, such as the dock scales, that may have limited accuracy for masses of less than two kilograms.

Analysis

Simple linear regression was used to define the relationships of fin weight, dressed weight code 39, and dressed weight code 25 to whole weight for shark species with $n \geq 10$. All analyses were conducted using the R statistical software version 3.2.0 (R Core Team 2014). Whole weight was modelled using Equation 1, where Wt is whole weight and X is fin weight, dressed weight code 39 or dressed weight code 25:

$$Wt = a + b * X$$

Equation 1

Length-weight analyses were also conducted on species with $n \geq 10$ per weight type (whole or gutted). The allometric length-weight model (Equation 2, where Wt = whole weight, FL = fork length, and a and b are constants) was transformed to a linear model by taking the natural logarithms of both sides.

$$Wt = a * FL^b$$

Equation 2

Simple linear regression was performed in the form presented in Equation 3, thus the regression slope = b and the regression intercept = log(a). Species with a log weight of less than -0.5 were eliminated from this analysis because of scale imprecision for these small fish.

$$\log(Wt) = \log(a) + b * log(FL)$$

Equation 3

The coefficient of determination (R^2) was calculated as an index of goodness of fit for all linear regressions.

Results and Discussion

Fin weight-whole weight models were estimated for six shark species and dress weight code 39-whole weight models were determined for five shark species (Table 2). Models for dress weight code 25 were only available for two species. The R^2 values were greater than 0.66 for all the dressed weight regressions, but there were low values for the fin weight models for four of the six species studied. This may reflect a precision error, discussed previously, where the dock scales were used to obtain fin weights instead of using the smaller, more precise, spring scales. It is also possible that extra fins may have been intermittently included for the lemon shark, *Negaprion brevirostris*, and the hammerhead sharks. We caution against the use of wet fin weight to estimate whole weights in these species.

The allometric length-weight model constants were determined for 40 teleost species and two teleost species complexes (Table 3), 12 shark species, one shark species complex and a single batoid species (Table 4). Both whole and gutted weight regressions were determined for 13 teleost species. Overall, the coefficient of determination suggested good model fits for most species ($R^2 > 0.7$), though 11 species had R^2 values of less than 0.5. The length-weight regressions for the sand perch, *Diplectrum formosum*, tomtate, *Haemulon aurolineatum*, clearnose skate, *Raja eglanteria*, and the sand diver, *Synodus intermedius*, had R^2 values of less than 0.2 and therefore should not be used for length-weight conversions. These extremely low R^2 values may reflect insufficient precision to distinguish weights of these small fish. Three shark species (sandbar, silky, *C. falciformis*, and scalloped hammerhead, *S. lewini*) have published length-weight relationships (Kohler et al. 1995) with larger sample sizes. However, this study adds conversion factors for 11 elasmobranch species.

Several species are not adequately represented throughout their entire size ranges. The upper size limit can be directly affected by the height and physical strength of the fisheries observer, whereas the lower size limit may be a function of gear selectivity (varying among species). Specimens larger than 150 cm FL or 50 kg whole weight are less likely to have at-sea weights recorded and would require an at-dock weight. The silky shark, lemon shark, great hammerhead shark, *S. mokarran*, and scalloped hammerhead shark can all attain large sizes, which may complicate dockside weighing. Fisheries observers must obtain help from the crew with larger specimens. Dockside scales are often platform or floor scales, and large specimens may ground on both sides.

This study has successfully produced conversion factors from dressed weight to whole weight for sandbar, blacktip, scalloped and great hammerhead sharks respectively. Parameters ($n \geq 200$) were obtained for whole weight and gutted weight to FL for blueline tilefish, yellowedge grouper, *Epinephelus flavolimbatus*, red grouper, *E. morio*, red snapper, and scamp grouper, *Mycteroperca phenax*. The SEFSC Panama City Fisheries Observer Programs will continue to collect lengths and weights to further improve upon these data. Precision two kilogram scales would be a beneficial addition to a fisheries observer's field equipment.

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Table 1. Weight grade description codes used by Highly Migratory Species Division to describe shark products.

Grade code	Description
01	Round/Whole
08	Belly Flaps
11	Fins Fresh
12	Fins Dried
23	Gutted, Head On, Tail On, Belly Flaps NA
24	Gutted, Head Off, Tail On, Belly Flaps On
25	Gutted, Head Off, Tail Off, Belly Flaps On
38	Gutted, Head Off, Tail On, Belly Flaps Off
39	Gutted, Head Off, Tail Off, Belly Flaps Off
40	Loins
42	Chunks

Table 2. Fin weight and dressed weight linear relationships to whole weight (Wt) for the six species of sharks from the western North Atlantic: Wt = a + bX, where X is either fin weight (FIN) or dressed weight codes 39 or 25 (DW 39, DW 25). NA represents unavailable data due to *n* < 10.

Species	Weight type	*n*	a	b	R^2
Carcharhinus limbatus Blacktip shark	FIN	72	9.8408	22.3407	0.3670
	DW 39	71	6.6013	1.3142	0.6554
	DW 25	NA	NA	NA	NA
Carcharhinus plumbeus Sandbar shark	FIN	128	26.6263	12.4962	0.3332
	DW 39	127	7.3838	1.6759	0.6770
	DW 25	NA	NA	NA	NA
Rhizoprionodon terraenovae Atlantic sharpnose shark	FIN	44	0.5180	15.4161	0.2893
	DW 39	11	0.0679	1.7617	0.9934
	DW 25	33	0.0048	1.6795	0.9898
Sphyrna mokarran Great hammerhead shark	FIN	21	39.6275	19.3759	0.3121
	DW 39	18	12.1753	1.5613	0.9467
	DW 25	NA	NA	NA	NA
Sphyrna lewini Scalloped hammerhead shark	FIN	46	13.0493	28.9674	0.5987
	DW 39	41	0.8086	1.6494	0.9768
	DW 25	NA	NA	NA	NA
Sphyrna tiburo Bonnethead shark	FIN	20	0.2464	26.7765	0.6919
	DW 39	NA	NA	NA	NA
	DW 25	14	-0.0329	1.6633	0.9855

Table 3. Fork length (FL)-whole weight (Wt) relationships for the 40 species and 2 species complexes of marine teleosts from the western North Atlantic: Wt =aFL^b. Fork length and weight means and ranges were taken from data presented in this study. [TL]Species that were measured in total length.

Species	Wt type	*n*	Mean FL	FL Range	Mean WT	a	b	R^2
Balistes capriscus Gray triggerfish	Whole	421	39.9	20 - 61	1.4	4.2763E-05	2.8033	0.8021
Calamus bajonado Jolthead porgy	Whole	61	50.9	31 - 71	2.7	1.5463E-04	2.4687	0.8424
	Gutted	19	51.1	37 - 64	2.7	2.8303E-05	2.8955	0.9461
Calamus nodosus Knobbed porgy	Whole	21	34.4	30 - 40	0.9	1.0606E-04	2.5483	0.4840
Caranx crysos Bluerunner jack	Whole	19	36.3	24 - 42.5	0.9	6.4943E-05	2.6459	0.9021
Caulolatilus microps Blueline tilefish	Whole	2126	57.4	33 - 91	2.2	3.3265E-05	2.7301	0.8375
	Gutted	281	56.9	42 - 72	2.3	2.5343E-06	3.3727	0.9551
Centropristis striata[TL] Black sea bass	Whole	842	34.0	19 - 55	0.6	6.0936E-05	2.5876	0.6716
Coryphaena hippurus Dolphinfish	Whole	38	71.3	40 - 130	3.4	4.5051E-05	2.5759	0.8648
Diplectrum formosum Sand perch	Whole	21	22.0	10 - 27	0.2	4.6925E-01	-0.2659	0.0431
Echeneis naucrates Sharksucker	Whole	68	69.7	60 - 81	1.4	1.0088E-04	2.2362	0.5631
Epinephelus adscensionis Rock hind	Whole	13	40.5	35 - 49	1.2	3.4614E-03	1.5659	0.2638
Epinephelus drummondhayi Speckled hind	Whole	60	52.4	31 - 92	2.8	1.6389E-05	2.9949	0.9347
	Gutted	118	68.0	37 - 89	5.8	2.1863E-05	2.9371	0.9686
Epinephelus flavolimbatus Yellowedge grouper	Whole	1235	66.1	33 - 102	3.7	2.8900E-05	2.7898	0.9107
	Gutted	246	66.2	50 - 93	3.8	3.1031E-05	2.7815	0.9126
Epinephelus morio Red grouper	Whole	18980	46.6	18 - 86	1.7	1.8174E-05	2.9507	0.8566
	Gutted	4616	56.1	31 - 86	2.7	1.3866E-05	3.0090	0.8674
Epinephelus niveatus Snowy grouper	Whole	252	66.7	28 - 112	4.8	1.0773E-05	3.0546	0.9809
	Gutted	30	70.1	49 - 103	4.9	1.9178E-05	2.9097	0.9770
Euthynnus alletteratus Little tunny	Whole	75	64.8	43 - 98	4.3	4.6990E-03	1.6296	0.4768

Table 3 continued.

Species	Wt type	*n*	Mean FL	FL Range	Mean WT	a	b	R^2
Haemulon aurolineatum Tomtate	Whole	39	20.7	15 - 27	0.3	8.3723E+00	-1.1141	0.1152
Haemulon plumieri White grunt	Whole	97	34.3	22 - 47	0.8	1.6577E-04	2.3842	0.7884
Helicolenus dactylopterus Black bellied rosefish	Whole	165	31.2	21 - 44	0.5	3.5012E-05	2.7600	0.7694
Holocentridae Squirrelfishes	Whole	36	28.5	20 - 40	0.4	4.6851E-04	2.0247	0.4237
Lopholatilus chamaeleonticeps Tilefish	Whole	138	65.4	32 - 108	3.5	5.4675E-06	3.1506	0.9478
Lutjanus analis Mutton snapper	Whole	55	66.5	40 - 85	4.7	2.3687E-04	2.3469	0.8071
	Gutted	25	56.0	39 - 79	2.8	9.1053E-06	3.1103	0.8338
Lutjanus campechanus Red snapper	Whole	1763	58.6	4.5 - 89	3.3	2.3609E-04	2.3214	0.7249
	Gutted	381	61.0	36 - 83	3.6	3.4932E-05	2.7959	0.9012
Lutjanus griseus Gray snapper	Whole	46	50.3	33 - 78	2.1	5.8459E-05	2.6461	0.9523
	Gutted	24	48.7	39 - 59	1.7	1.2686E-04	2.4323	0.6092
Lutjanus synagris Lane snapper	Whole	89	32.7	24 - 42	0.6	7.4428E-05	2.5729	0.6292
	Gutted	10	35.5	31 - 38	0.7	1.7642E-06	3.5942	0.2817
Lutjanus vivanus Silk snapper	Gutted	19	53.1	40 - 63	2.3	3.4638E-05	2.7884	0.9557
Malacanthus plumieri Sand tilefish	Whole	10	53.3	46 - 60	1.1	1.0803E-07	4.0395	0.6805
Mycteroperca microlepis Gag grouper	Whole	333	77.7	43 - 140	6.0	3.0030E-05	2.7879	0.9122
	Gutted	85	81.6	63 - 109	7.2	2.0863E-05	2.8817	0.5995
Mycteroperca phenax Scamp grouper	Whole	711	55.2	31 - 90	2.3	1.1397E-05	3.0257	0.8687
	Gutted	245	54.5	39 - 77	2.1	2.0750E-05	2.8720	0.8764
Ocyurus chrysurus Yellowtail snapper	Whole	264	31.3	26 - 42	0.5	8.1962E-05	2.5450	0.7830
Opsanus pardus[TL] Leopard toadfish	Whole	43	33.8	19 - 47	0.9	4.3614E-03	1.5013	0.3653
Pagrus pagrus Red porgy	Whole	566	35.7	24 - 49	0.8	1.4224E-04	2.4136	0.5507
	Gutted	69	41.4	25 - 57	1.4	8.3528E-04	1.9934	0.7416

Table 3 continued.

Species	Wt type	*n*	Mean FL	FL Range	Mean WT	a	b	R^2
Phycidae[TL] Hakes	Whole	43	45.8	19 - 57	0.9	1.5128E-05	2.8678	0.9696
Rachycentron canadum Cobia	Whole	13	90.4	55 - 121	9.2	9.3106E-07	3.5130	0.8945
Rhomboplites aurorubens Vermillion snapper	Whole	1524	35.3	17 - 51	0.6	7.8970E-06	3.1460	0.6961
Scomberomorus cavalla King mackerel	Whole	66	86.1	56 - 135	5.9	2.1313E-03	1.7640	0.5080
Seriola dumerili Greater amberjack	Whole	177	89.7	33 - 127	11.1	1.2955E-05	3.0072	0.9405
Seriola rivoliana Almaco jack	Whole	119	67.1	34 - 98	5.2	1.0701E-04	2.5383	0.8880
Seriola zonata Banded rudderfish	Whole	43	47.5	34 - 54	1.9	3.2241E-02	1.0553	0.2735
Sphyraena barracuda Great barracuda	Whole	15	91.5	48 - 117	4.7	1.9959E-04	2.2181	0.9219
Synodus intermedius Sanddiver lizardfish	Whole	17	30.9	27 - 35	0.3	3.9905E-03	1.2103	0.0608
Thunnus atlanticus Blackfin tuna	Whole	29	73.2	33 - 81	7.8	9.0036E-06	3.1697	0.9921
Urophycis floridana[TL] Southern hake	Whole	12	52.3	38 - 63	1.2	6.7062E-05	2.4614	0.9195

Table 4. Fork length (FL; in cm)-whole weight (Wt; in kg) relationships for the 14 species of elasmobranch from the western North Atlantic: $Wt = aFL^b$. Fork length and weight means and ranges were taken from data presented in this study. [DW]The clearnose skate, *Raja eglanteria*, was measured using disc width.

Species	*n*	Mean FL	FL Range	Mean Wt	a	b	R^2
Carcharhinus acronotus Blacknose shark	87	69.7	40.5 - 124	3.5	1.1568E-04	2.3939	0.8146
Carcharhinus falciformis Silky shark	13	84.9	54 - 222	11.0	2.2732E-05	2.7915	0.9339
Carcharhinus limbatus Blacktip shark	109	118.1	51 - 156	21.2	2.3782E-05	2.8487	0.9057
Carcharhinus plumbeus Sandbar shark	148	151.0	75 - 183	41.8	2.8635E-05	2.8204	0.7444
Hexanchus cf. nakamurai Bigeye sixgill shark	10	56.7	48 - 71	1.6	2.3835E-05	2.7406	0.9613
Negaprion brevirostris Lemon shark	13	63.7	56 - 80.5	2.4	2.5116E-06	3.2968	0.9888
Raja eglanteria [DW] Clearnose skate	31	44.4	41 - 47	1.7	1.0259E-02	1.3491	0.1465
Rhizoprionodon terraenovae Atlantic sharpnose shark	295	70.0	33 - 108	2.3	1.9882E-04	2.1789	0.7401
Sphyrna lewini Scalloped hammerhead shark	58	133.2	37 - 243	37.1	7.8796E-06	3.0529	0.9829
Sphyrna mokarran Great hammerhead shark	25	192.0	145 - 242	76.9	1.4786E-05	2.9275	0.8154
Sphyrna tiburo Bonnethead shark	21	68.7	51 - 85.5	2.6	2.5441E-06	3.2544	0.9547
Squalus cubensis Cuban dogfish	10	51.2	47 - 58	0.9	2.6559E-05	2.6536	0.8698
Squalus mitsukurii Shortspine dogfish	11	56.6	38 - 78	1.3	3.7523E-05	2.5465	0.9630
Mustelus spp. Smooth-hounds	221	102.7	59 - 139	4.3	2.4197E-05	2.5988	0.7697