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Morphometric Relationships of Marine Fishes Common to Central California and the Southern California Bight

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Length-weight relationships have several applications in fish stock assessments and ecological studies (e.g., Ricker 1975, Newman et al. 2006). Particularly, they are important for visual surveys of fish populations where the estimated total lengths are converted to weights to estimate fish biomass (e.g., Hamilton et al. 2010, Sala et al. 2012). The available information on length-weight relationships and length-length conversions for marine fishes in California are mostly limited to commercial catch (RecFIN 2009) or the occasional ecological survey (Miller et al. 2008), and a recent compilation of these parameters (Cailliet et al. 2000) demonstrated many species are lacking this basic information. Fishes used in this study were collected in various large- and small-scale projects by the Vantuna Research Group, Occidental College and California State University Northridge from 1984 to 2012. These included state-mandated programs dedicated to assessing the biological and economic impacts of its stocking efforts (ORHEP) and localized fisheries surveys (San Diego and Morro Bay) where a variety of species were caught. Measurements of lengths and weights provide the opportunity to generate information on morphometric relationships that will be useful to other researchers. Here we provide standard length (SL) to total length (TL) conversions (Table 1) for 32 near-shore marine fish species (Class Actinopterygii) and length-weight equation parameters (Table 2) for 71 near-shore marine fish species (57 from Class Actinopterygii and 14 from Subclass Elasmobranchii), common to central and southern California (Miller and Lea 1972).

Fishes were collected by several methods. (*White Seabass Gill Net Survey)* Collections using monofilament gill nets were made at 19 stations dispersed throughout the Southern California Bight from 1995–2005 in shallow (5–14 m) depths at the edge of rocky reefs as part of the Nearshore Gill Net Sampling Program for White Seabass (Age I-IV). For detailed methods see Pondella and Allen (2000). (*San Diego Bay Fisheries Inventory and Utilization Surveys*) Fish assemblages in San Diego Bay were assessed using a variety of methods (large seine, small seine, square enclosure, purse seine, beam trawl and otter trawl) (Allen et al. 2002). The bay is divided into four unique ecoregions that were sampled in April and July of 2005, 2008 and 2012, and by purse seine and square enclosure only in June 2009. (*Morro Bay Fish Survey*) Fish populations were surveyed in Morro Bay using methods similar to the San Diego Bay Fisheries Inventory and

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Table 1. Standard length (SL; in mm) to total length (TL; in mm) conversion parameters (see main text for equation description), sample size (N) and length characteristics of the sampled population for 32 fish species (Class Actinopterygii) common to southern and central California.

		length characteristics			parameters of the relationship		
Scientific Name	*Survey*	*N*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Clupeiformes							
Engraulidae - anchovies							
Anchoa compressa (Girard, 1858)	b	63	45	114	7.22	1.16	0.95
Anchoa delicatissima (Girard, 1854)	b	633	19	67	2.42	1.16	0.91
Aulopiformes							
Synodontidae - lizardfishes							
Synodus lucioceps (Ayers, 1955)	abc	20	68	193	−1.66	1.15	0.99
Batrachoidiformes							
Batrachoididae - toadfishes							
Porichthys myriaster Hubbs & Schultz, 1939	ab	23	16	327	−0.44	1.16	0.99
Atheriniformes							
Atherinopsidae - New World silversides							
Atherinops affinis (Ayers, 1860)	abc	1745	11	193	−0.02	1.19	> 0.99
Atherinopsis californiensis (Girard, 1854)	abc	11	31	282	−2.33	1.22	> 0.99
Leuresthes tenuis (Ayers, 1860)	bc	16	62	166	1.36	1.15	0.99
Beloniformes							
Hemiramphidae - halfbeaks							
Hyporhamphus rosae (Jordan & Gilbert, 1880)	b	14	24	127	−0.17	1.13	0.99
Belonidae - needlefishes							
Strongylura exilis (Girard, 1854)	ab	3	51	337	1.22	1.08	> 0.99
Cyprinodontiformes							
Fundulidae - topminnows							
Fundulus parvipinnis Girard, 1854	bc	195	14	78	1.91	1.11	0.99
Gasterosteiformes							
Syngnathidae - pipefishes							
Syngnathus leptorhynchus Girard, 1854	bc	799	33	248	1.20	1.02	> 0.99
Scorpaeniformes							
Scorpaenidae - scorpionfishes							
Scorpaena guttata Girard, 1854	abd	3	85	230	1.15	1.23	> 0.99
Cottidae - sculpins							
Leptocottus armatus Girard, 1854	abc	763	11	119	0.63	1.16	0.99
Perciformes							
Polyprionidae – wreckfishes							
Stereolepis gigas Ayers, 1859	ag	35	336	1450	−10.87	1.21	0.99
Serranidae – sea basses							
Paralabrax clathratus (Girard, 1854)	abcd	76	19	165	1.31	1.19	0.99
Paralabrax maculatofasciatus (Steindachner, 1868)	abd	348	32	306	1.71	1.22	0.99
Paralabrax nebulifer (Girard, 1854)	abd	154	43	180	4.77	1.15	0.98
Haemulidae - grunts							
Anisotremus davidsonii (Steindachner, 1876)	abde	623	20	328	5.78	1.23	0.99
Sciaenidae – drums and croakers							
Atractoscion nobilis (Ayers, 1860)	abf	6513	71	1220	11.29	1.15	0.99

Table 1. Continued.

Scientific Name	Survey	length characteristics N	Min. (mm)	Max. (mm)	parameters of the relationship a	b	R^2
Cheilotrema saturnum (Girard, 1858)	ab	6	35	178	1.40	1.19	> 0.99
Roncador stearnsii (Steindachner, 1876)	abe	493	138	542	11.85	1.20	0.99
Embiotocidae – sea perches							
Cymatogaster aggregata Gibbons, 1854	abc	828	26	112	1.83	1.24	0.98
Micrometrus minimus (Gibbons, 1854)	abc	43	21	113	3.35	1.19	0.99
Blenniidae – combtooth blennies							
Hypsoblennius gentilis (Girard, 1854)	bcd	20	44	109	3.99	1.15	0.99
Clinidae – kelp blennies							
Gibbonsia elegans (Cooper, 1864)	bd	10	23	106	−0.37	1.15	> 0.99
Heterostichus rostratus Girard, 1854	abcd	329	23	315	1.23	1.13	> 0.99
Gobiidae - gobies							
Clevelandia ios (Jordan & Gilbert, 1882)	bc	310	10	56	0.37	1.16	0.99
Quietula y-cauda (Jenkins & Evermann, 1889)	bc	64	22	64	1.17	1.16	0.97
Pleuronectiformes							
Paralichthyidae – sand flounders							
Citharichthys stigmaeus Jordan & Gilbert, 1882	abc	263	22	101	0.65	1.17	0.99
Paralichthys californicus (Ayers, 1859)	abc	62	57	430	8.26	1.16	0.98
Pleuronectidae – right-eyed flounders							
Pleuronicthys guttulatus Girard, 1854	abc	48	17	204	2.31	1.21	> 0.99
Pleuronichthys ritteri Starks & Morris, 1907	abd	24	78	156	0.17	1.25	0.97
Cynoglossidae - tonguefishes							
Symphurus atricaudus (Jordan & Gilbert, 1880)	ab	18	64	138	−0.88	1.08	> 0.99

a, White Seabass Gill Net Survey; b, San Diego Bay Fisheries Inventory and Utilization Survey; c, Morro Bay Fish Survey; d, Cryptic reef fish collections from King Harbor and Agua Hedionda; e, Heat Treatments from Encina Generating Station, Cabrillo Power Plant, and Huntington Beach Generation Station; f,Opportunistic non-scientific hook and line and spear catches; g, Data provided by Michael Domeier

Utilization Surveys in April, August and November of 2005–2007 and in May of 2008. (*Cryptic reef fish collections from King Harbor, Redondo Beach and Agua Hedionda, San Diego*) Collections of cryptic benthic fishes in King Harbor, Redondo Beach have been made periodically (1–12 times per year) since 1984 by divers using anesthetic and air lifts (Stephens et al. 1994). A similar collection was made from Agua Hedionda Lagoon in 2005. (*Heat Treat and Impingement Surveys*) Samples were also collected during heat treatments in 2005 at Encina Generating Station, Cabrillo Power Plant, and Huntington Beach Generating Station. For detailed methods see Pondella et al. (2008). Some white seabass (*Atractoscion nobilis*) specimens were also collected opportunistically by hook and line or spear. Additionally, data for giant sea bass (*Stereolepis gigas*) collected by hook and line was included (Michael Domeier, pers. comm.). While fishes caught during some of these studies were batch weighed by species, all individuals used here were measured individually: TL and/or SL or disc width (DW) were typically recorded to the nearest millimeter (mm) or occasionally centimeter (cm) and weight was recorded to the

Table 2. Length and weight parameters, sample size (N), input length type, and length characteristics of the sample for 14 cartilaginous fish species (Subclass Elasmobranchii) and 57 ray-finned fish species (Class Actinopterygii) common to southern and central California.

			length characteristics			*parameters of the relationship*		
Scientific Name	*Survey*	*N*	*Type*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Heterodontiformes								
Heterodontidae - bullhead sharks								
Heterodontus francisci (Girard, 1855)	ab	651	TL	170	870	1.18E-05	2.94	0.98
Lamniformes								
Alopiidae - thresher sharks								
Alopias vulpinus (Bonnaterre, 1788)	a	16	TL	870	2560	3.11E-04	2.36	0.90
Carcharhiniformes								
Scyliorhinidae - cat sharks								
Cephaloscyllium ventriosum (Garman, 1880)	a	307	TL	335	950	3.00E-06	3.13	0.92
Triakidae - hound sharks								
Galeorhinus galeus (Linnaeus, 1758)	a	102	TL	250	1900	7.78E-06	2.93	0.95
Mustelus californicus Gill, 1864	ab	441	TL	345	1200	7.27E-07	3.22	0.95
Mustelus henlei (Gill, 1863)	a	387	TL	340	1100	8.07E-07	3.21	0.95
Triakis semifasciata Girard, 1855	a	736	TL	160	1545	5.95E-06	2.95	0.97
Hexanchiformes								
Hexanchidae - cow sharks								
Notorynchus cepedianus (Bonnaterre, 1788)	a	30	TL	1185	1900	8.61E-07	3.22	0.88
Squaliformes								
Squalidae - dogfish sharks								
Squalus acanthias Linnaeus, 1758	a	191	TL	320	1200	8.29E-08	3.57	0.94
Squatiniformes								
Squatinidae - angel sharks								
Squatina californica Ayers, 1859	ab	206	TL	320	1200	7.81E-06	3.02	0.94

Table 2. Continued.

			length characteristics			*parameters of the relationship*		
Scientific Name	*Survey*	*N*	*Type*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Rajiformes								
Rhinobatidae – guitarfishes								
Rhinobatos productus Ayres, 1854	ab	111	TL	225	1340	3.43E-06	3.01	0.95
Myliobatiformes								
Urotrygonidae - American round stingrays								
Urobatis halleri (Cooper, 1863)	abc	556	DW	74	275	5.73E-05	3.02	0.96
Gymnuridae - butterfly rays								
Gymnura marmorata (Cooper, 1864)	ab	26	DW	250	1010	2.74E-06	3.20	0.98
Myliobatidae - eagle rays and mantas								
Myliobatis californica Gill, 1865	abc	270	DW	180	1000	2.32E-05	2.94	0.95
Albuliformes								
Albulidae - bonefishes								
Albula gilberti Pfeiler & Van der Heiden, 2011	ab	42	SL	55	360	2.05E-07	3.77	0.98
Clupeiformes								
Engraulidae - anchovies								
Anchoa compressa (Girard, 1858)	b	63	SL	45	114	1.11E-05	3.05	0.94
Anchoa delicatissima (Girard, 1854)	b	637	SL	19	67	7.55E-06	3.09	0.90
Clupeidae - herrings								
Sardinops sagax (Jenyns, 1842)	abc	247	SL	75	280	1.19E-05	3.02	0.91
Aulopiformes								
Synodontidae – lizardfishes								
Synodus lucioceps (Ayres, 1855)	abc	80	SL	61	360	2.12E-06	3.26	0.98
Batrachoidiformes								
Batrachoididae - toadfishes								
Porichthys myriaster Hubbs & Schultz, 1939	ab	328	SL	16	490	1.38E-05	2.98	0.99
Porichthys notatus Girard, 1854	ab	77	SL	23	460	2.21E-05	2.92	0.92

Table 2. Continued.

			length characteristics			parameters of the relationship		
Scientific Name	*Survey*	*N*	*Type*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Mugiliformes								
Mugilidae - mullets								
Mugil cephalus Linnaeus, 1758	abc	40	SL	53	520	2.96E-05	2.93	0.99
Atheriniformes								
Atherinopsidae - New World silversides								
Atherinops affinis (Ayers, 1860)	abc	1756	SL	11	193	3.83E-06	3.24	0.99
Atherinopsis californiensis (Girard, 1854)	abc	420	SL	31	360	1.03E-05	3.01	0.94
Leuresthes tenuis (Ayers, 1860)	bc	17	SL	32	166	8.25E-07	3.52	0.98
Beloniformes								
Hemiramphidae - halfbeaks								
Hyporhamphus rosae (Jordan & Gilbert, 1880)	b	18	SL	24	127	6.23E-07	3.32	0.94
Belonidae - needlefishes								
Strongylura exilis (Girard, 1854)	ab	10	SL	51	760	1.36E-07	3.39	> 0.99
Cyprinodontiformes								
Fundulidae - topminnows								
Fundulus parvipinnis Girard, 1854	bc	198	SL	14	78	1.49E-05	3.08	0.99
Gasterosteiformes								
Syngnathidae - pipefishes								
Syngnathus leptorhynchus Girard, 1854	bc	814	SL	33	248	8.45E-08	3.35	0.95
Scorpaeniformes								
Scorpaenidae - scorpionfishes								
Scorpaena guttata Girard, 1854	abd	618	SL	30	305	3.66E-05	2.98	0.94
Sebastes atrovirens (Jordan & Gilbert, 1880)	a	102	SL	125	270	9.44E-06	3.22	0.92
Sebastes carnatus (Jordan & Gilbert, 1880)	a	36	SL	110	240	1.72E-04	2.68	0.91
Sebastes rastrelliger (Jordan & Gilbert, 1880)	ab	225	SL	52	350	2.93E-05	3.01	0.91

Table 2. Continued.

Scientific Name	Survey	N	length characteristics			parameters of the relationship		
			Type	Min. (mm)	Max. (mm)	a	b	R^2
Hexagrammidae - greenlings								
Oxylebius pictus Gill, 1862	ad	17	SL	27	150	1.52E-05	3.11	0.98
Cottidae - sculpins								
Artedius corallinus (Hubbs, 1926)	d	20	SL	12	59	3.19E-05	2.88	0.99
Leptocottus armatus Girard, 1854	abc	827	SL	11	190	2.32E-05	2.98	0.99
Ruscarius creaseri (Hubbs, 1926)	d	174	SL	10	44	1.49E-05	3.17	0.99
Scorpaenichthys marmoratus (Ayres, 1854)	ad	136	SL	44	390	2.06E-05	3.06	0.95
Perciformes								
Polyprionidae - wreckfishes								
Stereolepis gigas Ayers, 1859	ag	96	SL	125	2003	1.07E-04	2.80	0.99
Serranidae - sea basses								
Paralabrax clathratus (Girard, 1854)	abcd	636	SL	19	575	2.09E-05	3.01	0.98
Paralabrax maculatofasciatus (Steindachner, 1868)	abd	430	SL	32	350	2.16E-05	3.03	0.99
Paralabrax nebulifer (Girard, 1854)	abd	635	SL	27	410	2.89E-05	2.95	0.99
Haemulidae - grunts								
Anisotremus davidsonii (Steindachner, 1876)	abde	750	SL	20	330	1.64E-05	3.13	0.98
Sciaenidae - drums and croakers								
Atractoscion nobilis (Ayres, 1860)	abf	6548	SL	71	1220	2.97E-05	2.87	0.96
Cheilotrema saturnum (Girard, 1858)	ab	344	SL	35	365	3.83E-05	2.91	0.92
Cynoscion parvipinnis Ayres, 1861	b	10	SL	179	465	6.52E-05	2.74	0.99
Menticirrhus undulatus (Girard, 1854)	ab	432	SL	165	520	2.58E-05	2.91	0.94
Roncador stearnsii (Steindachner, 1876)	abe	577	SL	138	542	3.96E-05	2.91	0.96
Kyphosidae - sea chubs								
Hermosilla azurea Jenkins & Evermann, 1889	a	53	SL	165	310	1.14E-05	3.21	0.85

Table 2. Continued.

			length characteristics			*parameters of the relationship*		
Scientific Name	*Survey*	*N*	*Type*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Embiotocidae - surfperches								
Cymatogaster aggregata Gibbons, 1854	abc	879	SL	26	140	2.08E-05	3.07	0.97
Micrometrus minimus (Gibbons, 1854)	abc	88	SL	21	135	2.91E-05	3.02	0.96
Pomacentridae – damselfishes								
Chromis punctipinnis (Cooper, 1863)	ad	148	SL	24	210	2.69E-05	3.02	0.98
Hypsypops rubicundus (Girard, 1854)	a	139	SL	90	220	3.07E-05	3.11	0.88
Labridae - wrasses and parrotfishes								
Semicossyphus pulcher (Ayres, 1854)	a	194	SL	45	455	8.45E-05	2.80	0.92
Blenniidae - combtooth blennies								
Hypsoblennius gentilis (Girard, 1854)	bcd	30	SL	34	109	1.58E-05	3.10	0.95
Hypsoblennius jenkinsi (Jordan & Evermann, 1896)	d	73	SL	13	80	8.64E-06	3.20	0.98
Clinidae - kelp blennies								
Gibbonsia elegans (Cooper, 1864)	bd	115	SL	16	107	4.80E-06	3.24	0.99
Heterostichus rostratus Girard, 1854	abcd	521	SL	23	400	3.97E-06	3.17	0.99
Labrisomidae - labrisomid blennies								
Paraclinus integripinnis (Smith, 1880)	bcd	489	SL	9	58	1.11E-05	3.10	0.98
Gobiesocidae - clingfishes								
Gobiesox rhessodon Smith, 1881	d	42	SL	7	25	2.11E-05	3.04	0.96
Gobiidae - gobies								
Clevelandia ios (Jordan & Gilbert, 1882)	bc	329	SL	6	56	2.55E-06	3.42	0.95
Quietula y-cauda (Jenkins & Evermann, 1889)	bc	64	SL	22	64	1.22E-05	3.05	0.95
Rhinogobiops nicholsii (Bean, 1882)	d	58	SL	24	86	6.28E-06	3.26	0.99
Sphyraenidae - barracudas								
Sphyraena argentea Girard, 1854	ab	436	SL	300	965	2.46E-05	2.76	0.94
Scombridae - mackerels								
Scomber japonicus Hottuyn, 1782	ab	274	SL	160	395	1.93E-05	2.93	0.92

Table 2. Continued.

			length characteristics			parameters of the relationship		
Scientific Name	*Survey*	*N*	*Type*	*Min. (mm)*	*Max. (mm)*	*a*	*b*	R^2
Pleuronectiformes								
Paralichthyidae - sand flounders								
Citharichthys stigmaeus Jordan & Gilbert, 1882	abc	285	SL	22	135	8.33E-06	3.20	0.98
Paralichthys californicus (Ayers, 1859)	abc	623	SL	57	810	2.55E-05	2.91	0.95
Xystreurys liolepis Jordan & Gilbert, 1880	ab	36	SL	105	400	3.07E-06	3.36	0.94
Pleuronectidae - right-eye flounders								
Pleuronicthys guttulatus Girard, 1856	abc	118	SL	17	340	5.80E-05	2.85	0.99
Pleuronichthys ritteri Starks & Morris, 1907	abd	107	SL	17	230	2.95E-05	2.98	0.96
Cynoglossidae - tonguefishes								
Symphurus atricaudus (Jordan & Gilbert, 1880)	ab	32	SL	34	185	1.07E-05	3.00	0.94

a, White Seabass Gill Net Survey; b, San Diego Bay Fisheries Inventory and Utilization Survey; c, Morro Bay Fish Survey; d, Cryptic reef fish collections from King Harbor and Agua Hedionda; e, Heat Treatments from Encina Generating Station, Cabrillo Power Plant, and Huntington Beach Generation Station; f,Opportunistic non-scientific hook and line and spear catches; g, Data provided by Michael Domeier nearest gram (g) either in the field or from frozen specimens that were brought back to the laboratory.

All statistical analyses were performed using R (R Core Development Team 2012). Standard length to total length conversion equations were established using linear regression analyses. Length-length models were fitted to the equation $TL = a+bSL$ where SL is standard length (mm) and TL is total length (mm) (Table 1). Length-weight models were fitted to the equation $W = aL^b$, where W is the wet body weight (g) and L is the total length (mm) or disc width (mm) (Table 2) by log-transforming both the length and weight data, performing linear regression analyses. Estimated parameters were then back-transformed to the original scale for reporting. Obvious outliers were removed prior to model fitting. While some species had a low sample size ($N < 30$), we report parameters here for those where 1) the naturally occurring size range was adequately represented in the sample, 2) the models fit the data well (Tables 1, 2), and 3) the lack of published information on the species made the parameter estimates of high value (Froese 2006). Parameters for some species described here have been previously published (e.g. Miller et al. 2008, Love 2011). However, there is value in including parameters for all species that we had sufficient data for where sampling locations differ across studies and/or larger sample sizes were available, permitting future users of the parameters more options depending on their intended use.

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