Energy contents and conversion factors for sea lion's prey[1]

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ABSTRACT

In order to understand the effect the diet of Steller sea lions may have had on their decline in the North West Pacific and the Gulf of Alaska, a database of the energetic contents of Steller sea lion's prey was compiled and added to the database of general conversions used by the students and researchers at the Fisheries Centre. Multiple conversions were compiled according to the group of prey, and (or) the availability of the data.

METHODOLOGY

General conversion factors in the carbon transfer food chain are given in Table 1. The general transfer of DOC produced by phytoplankton and the derivations of detritus biomass shown in Table 2 were obtained from Pauly et al. (1993). The conversion factors for elemental carbon are shown in Table 3. The conversion factors for crabs, birds and mammals were compiled in Joules per mg of dry weight ($J \cdot mg^{-1}$ DW), as shown in Tables 4, 5 and 6. Phytoplankton conversion factors taken from Cushing et al. (1958), were compiled in Table 7 and from other references in Table 8. Conversion factors for bacteria were compiled in kilocalories per gram of carbon ($kcal \cdot gC^{-1}$), as shown in Table 9. Macroalgae conversion factors were expressed in $J \cdot mg^{-1}$ DW, as well as per mg of wet weight (mg WW)and the percentage ash content (see Table 10).

Conversion factors for zooplankton varied according to functional groups and classes. General conversions from carbon to wet and dry weight as well as displacement volume are shown in Table 11. Copepod and ctenophore conversions were compiled in carbon as a percentage of dry weight or grams of carbon as kilocalories (Table 12). Conversion factors for different zooplankton families were compiled in all categories, such as dry weight to wet weight, dry weight to carbon, dry weight to proteins, dry weight to ash free dry weight, non specific energy density ($kJ \cdot g^{-1}$), protein to organic carbon and in joules per milligram of ash free dry weight ($J \cdot mg^{-1}$ AFDW, see Tables 13 and 14). Energy densities in five species of copepods (Table 15), protozoans, euphausiids, hyperiids, ctenophores and mysids were compiled in joules per mg of dry weight and in joules per mg of ash free dry weight (Table 16).

Energy densities for small and large cephalopods were expressed in kilojoules per gram (Table 17) and conversions for various species of squid are shown in joules per mg dry weight and in joules per mg ash free dry weight in Table 18. Pelecypods energy conversion factors were obtained in joules per milligram of dry weight, wet weight, ash free dry weight and the percent of water they contain (Table 19).

The energy density for invertebrates and benthos were converted from wet weight (WW) to dry weight, dry weight to ash free dry weight, wet weight to ash free dry weight, in joules per mg dry weight and in joules per mg wet weight (Tables 20, 21, 22). The conversion factors for sea cucumbers were compiled in joule per mg of dry weight and wet weight (Table 23). Similar measurements for sea urchins as well as the conversion to joules per mg of ash free dry weight are shown in Table 24. The conversion factors of the remaining groups of benthic species were classified in joules per mg of dry weight, wet weight, and of ash free dry weight (Table 25), while the conversion factors of nudibranchs were given in joules per milligram of dry weight and in mg of ash free dry weight (Table 26).

The energy content of various shrimp species in wet weight, dry weight, ash free dry weight, % water and % ash are given in Table 27, while the same conversions for various fish species are given in Table 28. Energy conversions were given separately for flatfish (Table 29), gadids (Table 30), salmon (Table 31), hexagrammids (Table 32), herring (Table 33) and forage fish (Table 34). We did not include recent analysis of energy densities for sea lion prey species in the Gulf of Alaska, including Southeast Alaska presented in a poster in October 2004 (Schaufler et al. 2004) as the complete results should be published soon (L. Schaufler, Auke Bay Lab. NOAA Juneau).

[1]Cauffopé, Geneviève and Sheila J.J. Heymans. 2005. Energy contents and conversion factors for sea lion's prey. In: Guénette, S., and V. Christensen (editors). 2005. Food web models and data for studying fisheries and environmental impacts on Eastern Pacific ecosystems. Fisheries Centre Research Reports 13(1):225-237

Table 1. General conversion factors in the carbon transfer food chain (McLusky 1981; Antonelis 1994)

Conversion
1gC ~ 10-12 kcal
1gC ~ 2 g ash-free dry weight
1 g ash-free dry weight ~ 23.7 kJ
1g organic C ~ 46 kJ
1 l O2 ~ 4.825 kcal

Table 2. Conversion factors and empirical relationship for detritus.

Conversion	**Reference**
DOC = 16% of total phytoplankton production	O'Reilly and Busch (1987)
The detritus biomass is estimated using an empirical relationship that relates detritus biomass to primary productivity and euphotic depth: $\log_{10} D = -2.41 + 0.954 \log_{10} PP + 0.863 \log_{10} E$ D = detritus standing stock ($gC \cdot m^{-2} \cdot year^{-1}$), PP = primary productivity ($gC \cdot m^{-2} \cdot year^{-1}$), E = euphotic depth (m). The euphotic depth is calculated from the Beer-Bouger Law where:, ln I(1) - ln I(2) = k (D(2)-D(1)) with: I (1) = 100% irradiance (at the surface), I(2) = 1% irradiance (at the euphotic depth), D (1) = depth at surface (0m), D(2) = euphotic depth, k = light attenuation coefficient.	Pauly et al. (1993)

Table 3. Energy content of organic carbon, carbohydrate, protein and lipid.

Substance	**Energy content ($J \cdot mg^{-1}$)**	**References**
mg organic carbon	45.7	Salonen et al. (1976)
mg carbohydrate	17.16	Brody (1945)
mg protein	23.65	Brody (1945)
mg lipid	39550	Brody (1945)

Table 4. Energy density from dry weight ($J \cdot mg^{-1}$ DW) for 2 species of crabs.

Species	**N samples**	**Energy content**	**References**
Uca pugilator	2	8.69	Cummins (1971)
Uca pugnax	2	10.53	Cummins (1971)

Table 5. Energy density from wet weight ($J \cdot mg^{-1}$WW) for birds. Transfer efficiency (or gross efficiency) is the ratio of production:consumption.

Conversion	**Energy density**	**Reference**
Birds	7.0	Hunt et al. (2000)
Seabirds	7.0	Hunt et al. (2000)
Transfer efficiency = 10%		Cohen and Grosslein (1987)

Table 6. Energy density in wet weight and conversion factors for marine mammals. Transfer efficiency (or gross efficiency) is the ratio of production:consumption.

Type	**Value**	**Reference**
Energy density ($J \cdot mg^{-1}$ WW)	7.0	Hunt et al. (2000)
Transfer efficiency	16 %	Cohen and Grosslein (1987)
Wet weight:kcal	1:1.25	Cohen and Grosslein (1987)

Table 7. Conversion factors for phytoplankton from wet weight to dry weight, carbon and oxygen equivalents Cushing et al. (1958).

Conversion factors	**Carbon**	**Dry organic matter**	**Oxygen equivalent**	**Wet weight**	**Dry weight**
	1 mg:	1 mg:	1 ml:	1 mg:	1 mg:
Carbon (mg)	1	0.43	0.53	0.024	0.3
Dry organic matter (mg)	2.3	1	1.2	0.055	0.69
Oxygen equivalents (ml)	1.9	0.83	1	0.046	0.57
Plankton biomass (mg)	42	18	22	1	13
Dry plankton (mg)	3.3	1.4	1.8	0.08	1

Table 8. Conversion factors for phytoplankton.

Conversion	**Reference**
1 gC = 11.4 kcal	Platt and Irwin (1973)
1 gC = 45% dry weight	Jorgensen et al. (1991)
DOC = 16% of total primary production	O'Reilly et al. (1987)
1 gC=9 g wet weight	Pauly and Christensen (1995)

Table 9. Conversion factor of bacteria from carbon to kilocalories.

Conversion	**Reference**
1 gC = 10 kcal	Cohen and Grosslein (1987)

Table 10. General data and conversion factors for carbon in 3 species of macroalgae.

Species	**Parameter**	**Value**	**Reference**
Laminaria spp.	Dry weight:wet weight	21%	Mackinson (1996)
Laminaria spp.	Annual P/B ratio	4.43	Brady-Campbell et al. (1984) in Mackinson (1996)
Ditylus brihtwelli	Energy ($J \cdot mg^{-1}$ DW)	7.84	Durbin and Durbin (1981)
Ditylus brihtwelli	Energy ($J \cdot mg^{-1}$ AF DW)	17.5	Durbin and Durbin (1981)
Ditylus brihtwelli	% ash	55%	Durbin and Durbin (1981)
Phaedactylus tricormutus	Carbon: dry weight	18.52%	Durbin and Durbin (1981)

Table 11. Conversion factors for zooplankton (Cushing 1958).

Conversion factors	**Carbon** 1 mg	**WW** 1 mg	**DW** 1 mg	**Displacement volume** (1ml)
Carbon (mg)	1	0.12	0.6	96
Plankton wet weight (mg)	8.3	1	5	800
Dry plankton (mg)	1.7	0.2	1	160
Displacement volume (ml)	0.01	0.0012	0.006	1

Table 12. Conversion factors for copepods and ctenophores.

Conversion factors	**Reference**
1 g dry weight = 5.25 kcal	Laurence (1976)
1 gC = 10 kcal	Steele (1974)
Copepods C = 37% of dry weight	Table 1-793 in Jørgensen et al. (2000)
Ctenophora C = 6.4% dry weight	Table 1-793 in Jørgensen et al. (2000)

Table 13. Compilation of conversion factors for various types of zooplankton.

Taxon	WW: DW	DW: protein	DW: AFDW	DW: organic carbon	Protein : organic carbon	Energy content		References
						$kJ \cdot g^{-1}$ WW	$J \cdot mg^{-1}$ AFDW	
Gelatinous						3		Hunt et al. (2000)
Miscellaneous invertebrates						4		Hunt et al. (2000)
Miscellaneous invertebrates						3		Hunt et al. (1981)
Gelatinous	0.041	0.094	0.362	0.092	0.981			Hunt et al. (1981)
Ctenophora	0.042	0.109	0.304	0.05	0.460			Hunt et al. (1981)
Hydromedusae	0.041	0.144	0.373	0.100	0.881			Hunt et al. (1981)
Siphonophora	0.039	0.071	0.374	0.087	1.224			Hunt et al. (1981)
Thaliacea	0.04	0.058	0.361	0.088	1.523		24.12	Hunt et al. (1981)
Pteropoda	0.118			0.297				Hunt et al. (1981)
Polychaeta	0.138	0.347	0.862	0.38	1.097			Hunt et al. (1981)
Chaetognatha	0.115	0.295	0.658	0.35	1.186			

Table 14. Compilation of conversion factors for various groups of zooplankton (Hunt et al. 1981).

Taxon	WW: DW	DW: protein	DW: AFDW	DW: organic carbon	Protein: organic carbon	Energy density ($kJ \cdot g^{-1}$ WW)
Crustacea *	0.209	0.414	0.851	0.43	1.04	4
Rotifera			0.803	0.38	1.097	
Cladocera			0.795	0.426		
Copepoda	0.186	0.404	0.904	0.461	1.141	
Ostracoda			0.903			
Amphipoda	0.238		0.794	0.393		
Decapoda			0.791			
Euphausiacea	0.225	0.473	0.862	0.436	0.922	
Zooplankton				0.303		

* data also from Hunt et al. (2000);

Table 15. Energy densities for five species of copepods.

Copepods	Energy content ($J \cdot mg^{-1}$)		Other information	References
	DW	AFDW		
Acartia tonsa	17.91	22.39	DW = 10.86% WW	Durbin and Durbin (1981)
Calanus helgolandicus		22.61		Slobodkin and Richman (1961)
Cyclops vernalis *	23.82	24.36		Cummins and Wuycheck (1971)
Mesocyclops edax		22.94		Cummins and Wuycheck (1971)
Trigriopus californicus		23.09		Slobodkin and Richman (1961)

* total samples = 3

Table 16. Energy content for euphausiids, protozoans, hyperiids, ctenophores and mysids.

Species	Energy content ($J \cdot mg^{-1}$)			Other information	References
	DW	AFDW	WW		
Euphausia superba	19.76		3.73	81.0% water; lipid =7.4% DW	Tarverdiyeva (1972)
Tetrahymena pyriformis (Protozoan)		24.86			Slobodkin and Richman (1961)
Hyperiids		2.51			Tarverdiyeva (1972)
Ctenophores			0.17		Tarverdiyeva (1972)
Mysids			3.77		Tarverdiyeva (1972)

Table 17. Energy content (kJ g^{-1}WW) in small and large cephalopods.

Size	Energy content ($kJ \cdot g^{-1}$ WW)	References
Small	3.5	Hunt et al. (1981); Hunt et al. (2000)
Small	4.0 *	Hunt et al. (2000); Ashmole (1971)
Large	4.0	Hunt et al. (2000)
Large	4.0-6.0	Anthony and Roby (1997); Harris et al. (1986); Miller (1978);(Paul and Paul 1998) ; Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)

* Including metabolic digestion

Table 18. Energy conversion factors for squids.

Species	Energy content ($J \cdot mg^{-1}$)			% water	Other information	Reference
	DW	AFDW	WW			
Squids			3.81			Van Pelt et al. (1997)
Squids (5 spp)			3.85-6.53			Perez (1994)
Dosidicus gigas	23.73	24.88	4.22	82.2	beaks removed: lipid= 19.1% DW or 4.4% WW	Peterson (1979)
Loligo opalescens				76.8		Rachor et al. (1982)
Symplectoteuthis ovalaniensis	21.86	23.64	5.59	74.5	beaks removed	Peterson (1979)

Table 19. Energy conversion factors in various species of pelecypods (Cummins and Wuycheck 1971).

Species	N samples	Energy content ($J \cdot mg^{-1}$)			% water
		DW	AFDW	WW	
Ensis minor			14.65		
Clinocardium ciliatum	3	18.64		1.57	92.0
Modiolus sp.	3	19.26			
Scobicularis plana	60		21.34		
Yoldia sapotilla	3	20.01		2.88	
Yoldia thraciaeformis	3	20.03		2.13	89.0

Table 20. Conversion factors and energy content of various benthic invertebrates (Jangaard 1974; Bigg 1981; Brey 2001).

Family	WW: DW	DW: AFDW	WW: AFDW	Energy content ($J \cdot mg^{-1}$)	
				DW	AFDW
Mollusca	0.128	0.801	0.143	18.55	23.01
Bivalvia	0.087	0.831	0.057	18.85	22.79
Gastropoda	0.088	0.802	0.107	18.24	23.81
Nudibranchia	0.250	0.693	0.173	16.13	23.27
Cephalopoda	0.203	0.900	0.213	20.4	22.69
Annelida	0.187	0.623	0.157	14.53	23.33
Oligochaeta	0.174	0.323	-	7.54	23.33

Table 21. Conversion factors and energy content from dry weight, ash free dry weight and wet weight for various species of polychaetes obtained from Cummins and Wuycheck (1971).

Species	WW: DW	DW: ash free DW	WW: ash free DW	Energy content (J·mg^{-1})			% water
				DW	AFDW	WW	
Aphrodita hastata				14.39		2.03	
Axiothella sp.				14.86		2.32	84.0
Luabrinereis fragilis				28.34		4.43	78.0
Nethys ciliata				17.00		3.13	81.0
Niochamache sp.				14.91		2.59	83.0
Pectiinaria hypoborea				13.57		2.61	81.0
Pherusa plumosa				11.14		1.94	82.0
Phascolionn stroabi				14.19		2.49	82.0
Stemaspis fossor				8.91		2.25	75.0
Various species				16.91			
Polychaeta errantia	0.199	0.813	0.169	17.50	23.33		
Polychaeta sedentaria	0.188	0.732	0.145	14.19	23.33		

Table 22. Conversion factors and energy contents for various groups of benthic organisms obtained from Brey (2001).

Benthic organisms	WW: DW	DM: AFDW	WW: AFDW	Energy content (J·mg^{-1})	
				DW	AFDW
Crustacea (excluding Cirripedia)	0.226	0.742	0.169	16.75	22.57
Amphipoda	0.2	0.72	0.160	16.37	22.74
Cirripedia	0.066	0.79	0.039	17.96	22.74
Cumacea	0.173	0.63	0.075	14.33	22.74
Decapoda	0.258	0.680	0.18	15.14	22.26
Euphausiacea	0.254	0.883	0.224	20.08	22.74
Isopoda	0.200	0.640	0.142	14.55	22.74
Insecta Larvae	0.210	0.942		22.44	23.81
Chironomidae		0.931		21.83	23.44
Ephemeroptera		0.847		22.07	26.07
Odonata	0.226	0.888		20.99	23.65
Trichoptera		0.942		21.52	24.12
Echinodermata	0.324	0.306	0.091	6.70	21.5
Asteroidea	0.283	0.438	0.124	9.11	20.81
Crinoidea	0.432	0.238	0.080	5.1	21.44
Echinoidea	0.333	0.165	0.049	3.40	20.53
Holothuroidea	0.110	0.476	0.112	11.27	22.95
Ophiuroidea	0.460	0.211	0.09	4.6	21.75
Porifera	0.186	0.372	0.075	7.75	24.99
Actinaria	0.161	0.855	0.138	18.42	21.54
Bryozoa	0.199	0.402	0.080	9.28	23.09
Nemertea	0.208	0.816	0.211	19.04	23.33
Priapulida	0.095	0.861	0.065	20.09	23.33
Sipunculida	0.177	0.654	0.111	15.26	23.33
Ascidiae	0.063	0.358	0.023	6.81	19.01

Table 23. Energy contents (J·mg^{-1}) from wet and dry weight, and percentage of water in 3 species of sea cucumbers obtained from Cummins and Wuycheck (1971).

Species	DW	WW	% water
Chirodota laevis	10.76	1.11	90
Cucumaria frondosa	12.87	0.94	93
Malpadia oolitica	7.05	0.74	90

Table 24. Energy content from wet and dry weight in 2 species of sea urchins.

Sea urchins	Energy content (J·mg⁻¹)			% water	Other information	References
	DW	AFDW	WW			
Strongylocentrus drombachiensis	3.70		1.20	68	3 samples	Cummins and Wuycheck (1971)
Various species	9.46	22.74			25+20 species	Brey et al. (1988)

Table 25. Energy conversion factors for wet and dry weight and percentage of water in various groups of benthic zooplankton.

Benthic zooplankton	Energy content (J·mg⁻¹)			% water	Other information	References
	DW	AFDW	WW			
Anisogammarus pugettensis	12.54		2.46		DW =19.6% WW	Smith et al. (1986)
Crangonyx richmondensis	16.27	22.12			5 samples	Cummins and Wuycheck (1971)
Gammarus duebeni	18.47	21.50		74.0	6 samples	Cummins and Wuycheck (1971)
Gammarus minus		22.50			2 samples	Cummins and Wuycheck (1971)
Porifera	6.10				8 species	Brey et al. (1988)
Oligochaeta	22.36				5 species	Brey et al. (1988)
Ascidians	7.13	19.66			11 species	Brey et al. (1988)
Salps		0.17				Tarverdiyeva (1972)
Hydrozoans						
Chlorohydra viridissima		23.99				Slobodkin and Richman (1961)
Hydra littoralis		25.26				Slobodkin and Richman (1961)
Anthozoans						
Duva multiflora	12.88		2.07	83.0	2 species	Cummins and Wuycheck (1971)
Star fishes						
Asteria vulgaris	10.68		2.65	75.0	3 species	Cummins and Wuycheck (1971)
Ctenodiscus crispatus	7.65		2.55	67.0		Cummins and Wuycheck (1971)
Cumaceans						
Diastylis rathkei		16.4-18.7				Rachor et al. (1982)
Gastropods						
Natica clausa	18.39		3.31	82.0		Cummins and Wuycheck (1971)
Thais lamellosa		24.47				Cummins and Wuycheck (1971)
Thais lapillus	19.24		1.85	82.0		Cummins and Wuycheck (1971)
Various species	18.24	23.27			shells removed	Brey et al. (1988)
Opistobranchs						
Scaphander punctostriatus	13.97		1.75	90.0		

Table 26. Energy contents (J·mg⁻¹) from dry and ash free dry weight for nudibranchs obtained from Cummins and Wuycheck (1971).

Nudibranchs	DW	AFDW
Acanthodoris rhodoceras		22.77
Aegires albopunctatus		22.23
Aglaja diomeddea		23.26
Bulla gouldiana		26.6
Dendrodoris albopunctata		21.60
Dirona picta		27.95
Flabellina iodinea		20.70
Haminea virescens		22.34
Hermissenda crassicornis		26.99
Hopkinsia rosacea		25.15
Navanax inermis	3.86	25.09
Polycera atra		23.78
Triopha maculata		23.62

Table 27. Percentage of air and ashes, and energy content of various shrimp species from wet, dry and ash free dry weight, percentage of water and ash.

Species	N samples	Energy content (J·mg^{-1}) DW	AFDW	WW	% water	% ash	References
Artemia sp.			28.21				Slobodkin and Richman (1961)
Metapenaeus monoceros	69	22			75.6		Ramadhas and Sumitra (1979)
Palaemon debilis		17.90				24.5	Fonds et al. (1987)
Palaemon elegans	6					22	Fonds et al. (1987)
Palaemon elegans	26	18.60				17	Cummins and Wuycheck (1971)
Pandalus hypsinotus		21.36		4.98			Smith et al. (1986)
Pandalus platyceros		20.59		5.02			Smith et al. (1986)

Table 28. Energy content of various fish from wet and dry weight, percentage of water.

Species	N animals	Energy content (J·mg^{-1}) DW	AFDW	WW	% water	Other information	References
Auxis thazard	2	22.48	24.03	4.83	70.6	bones removed	Peterson (1979)
Brevoortia tyrannus		26.12	29.32	8.34			Durbin and Durbin (1981)
Canthidermis maculatus	2	23.68	25.11	3.84	74.8	bones removed	Peterson (1979)
Clupea harengus	1	26.63					Cummins and Wuycheck (1971)
Clupea harengus pallasi		25.90				DW =32.2% WW	Smith et al. (1986)
Coryphaena equisalis	2	22.27	23.81	4.81	72.9	bones removed	Peterson (1979)
Cubiceps panciradiatus	7	19.92	22.67	4.80	75.8		Peterson (1979)
Epinephelus aeneus					77.8		Mikhail et al. (1982)
Euthynnus lineatus	2	21.97	23.30	4.27	72.4	bones removed	Peterson (1979)
Exocoetus volitans	6	19.72	23.33	5.35	73.8		Peterson (1979)
Hypomesus pretiosus	4				76.2	lipid=23.6% DW or 5.5% WW	Olson and Boggs (1986)
Lactoria diaphanus	2	20.74	24.26	5.28	74.6		Peterson (1979)
Lethrinus nebulosus							Aldonov and Druzhinin (1978)
Oxyporhamphus micropterus	6	19.96	23.21	5.34	72.2		Peterson (1979)
Raja oricana			23.45	8.07			Cummins and Wuycheck (1971)
Remora remora	2	19.93	24.18	5.27	73.6		Peterson (1979)
Scomber japonicus	7				73.7	lipid=30.7% DW or 8.1% WW	Olson and Boggs (1986)
Stolephorus purpureus	4				76.2	lipid=18.0% DW or 4.3% WW	Olson and Boggs (1986)
Tautogolabrus adspersus	1	20.43					Cummins and Wuycheck (1971)
Vinciguerria lucetia	3	22.12	24.35	5.15	76.1		Peterson (1979)

Table 29. Energy content for flatfish and forage fish from wet weight. See table 35 for latin names.

Species	Energy content (J·mg^{-1} WW)	References
Flatfish	3.0-5.0	Anthony and Roby (1997); Harris et al. (1986); Miller (1978); (Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)
Arrowtooth flounder	5.15	Perez (1994)
English sole	4.9 (March) 5.95 (October)	Dygert (1990)
Yellowfin sole	3.3-3.5 (May) 4.4 (June)	Paul et al. (1993)
Pleuronectidae	2.86-3.95	Anthony et al. (2000)
Forage fish	7.5 (4.0-11.0)	Anthony and Roby (1997); Harris et al. (1986); Miller (1978);(Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)

Table 30. Energy content from wet weight for gadids. See table 35 for latin names.

Species	Energy content ($J \cdot mg^{-1}$ WW)	Other information	References
Gadids	4.0 (3.0-5.0)		Anthony and Roby (1997); Harris et al. (1986); Miller (1978); (Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)
Pacific cod	3.0		Hunt et al. (2000)
Pacific cod	3.93		Perez (1994)
Pacific cod	2.94		Van Pelt et al. (1997)
Pacific cod	3.65	age 0	Anthony et al. (2000)
Pacific cod	3.54	age >0	Anthony et al. (2000)
Pacific cod	4.00-4.30	March	Smith et al. (1990)
Pacific cod	3.33-3.38	July	Smith et al. (1990)
Pacific cod	4.13-4.49	December	Smith et al. (1990)
Pacific cod	3.0		Hunt et al. (2000)
Pollock	4.54-4.72		Rosen and Trites (2000)
Pollock	7.0		Hunt et al. (2000)
Pollock	4.64		Perez (1994)
Pollock	2.73		Van Pelt et al. (1997)
Pollock	5.89		Miller (1978)
Pollock	3.47	age = 0	Anthony et al. (2000)
Pollock	3.24	age >0	Anthony et al. (2000)
Pollock	3.93		Payne (1999)
Pollock	2.7	June	Paul et al. (1998b)
Pollock	3.4	August	Paul et al. (1998b)
Pollock	3.6	October	Paul et al. (1998b)
Pollock	3.4-4.0	March	Paul et al. (1998b)
Pollock	4.0	May	Paul et al. (1998b)
Pollock	3.68-4.03	Ripe	Smith et al. (1988)
Pollock	3.26-3.41	Spent	Smith et al. (1988)
Pollock	5.45		Harris et al. (1986)

Table 31. Energy content for various species of salmon. See table 35 for latin names.

Species	Energy content ($J \cdot mg^{-1}$ WW)	Other information	References
Salmon	5.0-9.0		Anthony and Roby (1997); Harris et al. (1986); Miller (1978); (Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)
Chinook	6.06	300 g	Stewart and Ibbarra (1991)
	8.72	3 kg	Stewart and Ibbarra (1991)
Coho	6.06	300 g	Stewart and Ibbarra (1991)
	8.72	3 kg	Stewart and Ibbarra (1991)
Pink	3.41	Age 0	Anthony et al. (2000)
	3.73	Age >0	Anthony et al. (2000)
	3.2-4.4		Paul and Willette (1997)
Sockeye	4.35		Anthony et al. (2000)
	6.68	300 g	Brett (1983)
	7.77	2.1 kg	Brett (1983)
	6.89-7.69		Hendry and Berg (1999)
			Hendry and Berg (1999)

Table 32. Energy density for various species of Hexagrammids. See Table 35 for latin names.

Species	Energy content ($J \cdot mg^{-1}WW$)	References
Hexagrammids	3.0-6.0	Anthony and Roby (1997); Harris et al. (1986); Miller (1978); (Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)
Atka Mackerel	4.02	Van Pelt et al. (1997)
Greenlings	3.45	Van Pelt et al. (1997)
Lingcod	3.98	Anthony et al. (2000)

Table 33. Energy density for herring.

Species	Energy content ($J \cdot mg^{-1}WW$)	Other information	References
Clupea spp.	7.0	Includes metabolic digestion	Hunt et al. (2000)
Clupea pallasii	6.40-7.58		Rosen and Trites (2000)
Clupea pallasii	7.0		Hunt et al. (2000)
Clupea pallasii	5.44	bomb cal.	Perez (1994)
Clupea pallasii	11.72	gulf	Perez (1994)
Clupea pallasii	3.69	age 0	Anthony et al. (2000)
Clupea pallasii	5.84	age > 0	Anthony et al. (2000)
Clupea pallasii	3.43		Payne et al. (1999)
Clupea pallasii	5.7	age 0, fall	Paul et al. (1998a)
Clupea pallasii	8.0	age 1, fall	Paul et al. (1998a)
Clupea pallasii	9.4-10.2	age 2, fall	Paul et al. (1998a)
Clupea pallasii	4.4	Age 0-1, spring	Paul et al. (1998a)
Clupea pallasii	5.2-6.3	Age ≥2 spring	Paul et al. (1998a)
Clupea pallasii	5.23.4-3.8	December	Calkins (1998)
Clupea pallasii	3.4-3.8	March	Calkins (1998)
Clupea pallasii	7.95		Stansby (1976)
Other	3-6		Anthony and Roby (1997); Harris et al. (1986); Miller (1978); Paul and Paul [, 1998 #40]; Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)

Table 34. Energy density for forage fishes. See Table 35 for latin names.

Species	Number	Energy content ($J \cdot mg^{-1}$ WW)	Other information	References
Forage fish		7.5 (4.0-11.0)		Anthony and Roby (1997); Harris et al. (1986); Miller (1978); (Paul and Paul 1998); Paul et al. (1993); Paul et al. (1998a); Paul et al. (1998b); Perez (1994); Smith et al. (1988); Smith et al. (1990); Van Pelt et al. (1997)
Capelin		7.03		Perez (1994)
Capelin		5		Hunt et al. (1981)
Capelin		4.84	Age =1	Van Pelt et al. (1997)
Capelin		3.54-4.67	Age = 2	Van Pelt et al. (1997)
Capelin		5.50		Miller (1978)
Capelin		4.17	Age =1	Anthony et al. (2000)
Capelin		6.7	Age ≥1, June	Anthony et al. (2000)
Capelin		3.7	Age ≥1, September	Anthony et al. (2000)
Capelin		5.26	Gulf	Payne et al. (1999)
Capelin		6.48	Bering Sea	Payne et al. (1999)
Capelin		5.0		Hunt et al. (2000)
Eulachon		11.05	August	Perez (1994)
Eulachon		10.96	March	Perez (1994)
Eulachon		7.49		Anthony et al. (2000)
Eulachon		10.10	February-March	Payne et al. (1999)
Eulachon		10.62-10.86	June-September	Payne et al. (1999)
Pacific sandlance		4.95	Age 1	Van Pelt et al. (1997)
Pacific sandlance		5		Hunt et al. (1981)
Pacific sandlance		3.18	Age 0	Van Pelt et al. (1997)
Pacific sandlance		5.67	Age ≥ 2	Van Pelt et al. (1997)
Pacific sandlance		6.5	Age 0, June	Anthony et al. (2000)
Pacific sandlance		4.8	Age 0, June	Anthony et al. (2000)
Pacific sandlance		5.3	Age 0, August	Anthony et al. (2000)
Pacific sandlance		5.6	Age > 0, June	Anthony et al. (2000)
Pacific sandlance		4.9	Age > 0, sep	Anthony et al. (2000)
Pacific sandlance		5.20	Gulf	Payne (1999)
Pacific sandlance		6.11	bomb cal	Payne et al. (1999)
Pacific sandlance		3.40-3.55	Age 0, 6 cm	Robards et al. (1999)
Pacific sandlance		4.62-4.86	Age 0, 9 cm	Robards et al. (1999)
Pacific sandlance		3.22-3.32	Age ≥ 1, November	Robards et al. (1999)
Pacific sandlance		3.23-3.25	Age ≥ 1, February	Robards et al. (1999)
Pacific sandlance		5.0		Hunt et al. (2000)
Pacific sandlance		5.46-5.75	Age ≥ 1, June-July	Robards et al. (1999)
Pricklebacks		5.40		Payne et al. (1999)
Pricklebacks	6	4.11-4.90		Anthony et al. (2000)
Rockfish		2.97		Van Pelt et al. (1997)
Rockfish		3		Hunt et al. (2000)
Rockfish	3	5.77-6.23		Perez (1994)
Northern rockfish		5.56	Bering Sea, July	Perez (1994)
Northern rockfish		6.85	Gulf, February	Perez (1994)
Sculpins	4	3.51-5.19		Perez (1994)
Sculpins	12	3.05-5.26		Anthony et al. (2000)
Myctophids		7		Hunt et al. (2000)
Saury		7		Hunt et al. (2000)
Epipelagic fishes		7.0		Hunt et al. (2000)
Mesopelagic fishes		7.0		Hunt et al. (2000)

Table 35. Common and latin names for fish species presented in tables 29-34

Common name	**Latin name**
Arrowtooth flounder	*Reinhardtius stomias*
Atka mackerel	*Pleurogrammus monopterygius*
Capelin	*Mallotus villosus*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
English sole	*Parophrys vetulus*
Eulachon	*Thaleichythus pacificus*
Flatfish	Pleuronectidae
Greenling	*Hexagrammos spp.*
Lingcod	*Ophiodon elongatus*
Pacific cod	*Gadus macrocephalus*
Pacific herring	*Clupea pallasii*
Pacific sandlance	*Ammodytes hexapterus*
Pink salmon	*Oncorhynchus gorbuscha*
Pollock	*Theragra chalcogramma*
Pricklebacks	Stichaeidae
Rockfish	Sebastidae
Saury	*Cololabis saira*
Sculpins	Cottidae
Sockeye salmon	*Oncorhynchus nerka*
Yellowfin sole	*Limanda aspera*

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