REVIEW OF LENGTH-WEIGHT RELATIONSHIPS FOR ANTARCTIC KRILL

V. Siegel*

Abstract

Length-weight relationships for krill, *Euphausia superba* (as well as relationships for other Antarctic euphausiid species), are listed for ash-free dry weight, dry weight, and wet weight. The accuracy of length-weight relationship calculations is improved when information on sex and dominant maturity stages is taken into account. The influence of seasonal changes on length-weight relationship parameters is discussed. Recommendations for possible uses of reviewed length-weight relationships are presented.

Résumé

Les relations longueur-poids du krill, *Euphausia superba*, (ainsi que les relations relatives aux autres espèces d'euphausiacés antarctiques) sont données pour le poids sec sans cendres, le poids sec et le poids humide. Toute information sur le sexe et les stades de maturité dominants permet d'améliorer la précision des calculs des relations longueur-poids. L'influence des variations saisonnières sur les paramètres des relations longueur-poids fait l'objet d'une discussion. Des recommandations sont présentées pour les utilisations possibles des relations longueur-poids révisées.

Резюме

Отношения "длина/вес" для криля, *Euphausia superba*, а также для других видов антарктических эвфаузиид, даны по категориям беззольного сухого веса, сухого веса и мокрого веса. Принятие во внимание информации о половой принадлежности и доминантных стадиях половозрелости улучшает точность вычислений отношений "длина/вес". Обсуждается влияние сезонных изменений в параметрах "длина/вес". Дается ряд рекомендаций по использованию приведенных отношений "длина/вес".

Resumen

Se presenta una lista de las relaciones talla-peso para el kril, *Euphausia superba* (así como las relaciones para otras especies de eufáusidos antárticos), en función del peso seco sin ceniza, peso seco, y peso húmedo. Los cálculos de estas relaciones son más fiables cuando se toman en cuenta la información sobre sexos y las fases de madurez predominantes. Se discute la influencia de los cambios estacionales en las variables de la relación talla-peso y se dan recomendaciones para el posible empleo de las relaciones talla-peso revisadas.

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* Institut für Seefischerei, Palmaille 9, 2000 Hamburg 50, Germany

1. INTRODUCTION

A knowledge of length-weight relationships of aquatic organisms is useful for a variety of studies related to fisheries biology. Biomass and production estimates from net samples and hydroacoustic surveys are expressed as wet weight and are derived from length frequency data. Physiological studies usually convert length into dry or ash-free dry weight. Length measurements can easily and rapidly be carried out on board vessels during surveys, while a direct precise measurement of weight of sorted species or specimens is often difficult and time-consuming. Various length-weight relationships have been established over the years for Antarctic krill *Euphausia superba*, but this information is widely spread throughout published scientific literature.

A comprehensive assessment of length-weight relationships has already been carried out by Morris *et al.* (1988), who also investigated the importance of maturity stages in improving the precision of calculating weight from length data. Since Morris *et al.* (1988) did not consider possible seasonal variations in weight, it would be helpful to summarise published length-weight relationships from the point of view of their seasonal variations.

2. DISCUSSION

Tables 1 to 4 summarise the available length-weight relationships for *E. superba* by season and contain information on the dominant maturity stages of krill. Table 5 lists the few data available for other Antarctic euphausiids. Most length measurements were made using total length AT (front of the eye to the tip of the telson), while other length categories are indicated in the respective tables. Another length measurement sometimes used is TT (tip of the rostrum to tip of the telson). Since this is not significantly different from AT (in *E. superba*), the results are directly comparable and are not listed separately in the tables. A few authors have used different kinds of length measurements (e.g., S1, S2, S7, BT; for definitions see Mauchline, 1980), but these are not included in Tables 1 to 4. Additional information was often collected during laboratory experiments and may be difficult to compare with field data, however the reader may refer to Morris *et al.* (1988) which contains a detailed reference list. Some data were published as the linearised logarithmic version of the regression function. These results have been re-calculated to facilitate direct comparison with other published coefficient values.

Tables 1 and 2 show the regression parameters for ash-free dry weight and dry weight relationships respectively, while Tables 3 and 4 contain wet weight data. In most cases krill were separated according to sex. In their comprehensive study, Morris *et al.* (1988) analysed the improvement in the precision of predictions using length-weight relationships. They split their samples into single maturity stages or sexes and compared the goodness of fit tests of the regressions by examining their variances. They found that the simple classification of 'males', 'gravid females' and 'non-gravid females' increases the precision in prediction for both dry weight (Table 2) and wet weight (Table 3).

Morris *et al.* (1988) noted that 'surprisingly, the simple division of krill into male and female categories is of little practical use in improving the precision of any prediction of weight'. However, Morris *et al.* (1988) only analysed samples taken over a short period during the spawning season (end of February to beginning of March 1985), when most adult krill were still in the gravid maturity stage. The result they obatined was to be expected, because for the spawning season, covariance analyses of length-weight relationships indicated no differences between male and female krill (Siegel, 1986a and 1989). Gravid-stage males and females were of the same weight.

The situation changes throughout the year, i.e., during the annual maturity cycle of krill. Morris *et al.* (1988) applied various published length-weight relationships to data obtained from a single acoustic survey around South Georgia and found great differences in the estimated total biomass (25% for wet weight and a 35% deviation for dry weight between the results obtained for different length-weight relationships). However, they did not take into account the seasonal or dominant maturity stage composition factor which underlies length-weight relationships. A simple example which uses coefficients from overall length-weight relationships (see Table 4) demonstrates the seasonal change in krill weight. For different months (with different dominant adult maturity stages) a 50 mm krill would attain the following weights:

October	resting stage	787 mg
December	most gravid	927 mg
January	gravid + spent	913 mg
February	all gravid	931 mg
February	all spent	912 mg
March	spent	860 mg
June	resting stage	796 mg

Data for February were collected in different years and indicate the timing of spawning varies from year to year. The seasonal variation in krill weight clearly shows that the results may differ by 15% when using length-weight relationships for krill at different dominant maturity stages. Siegel (1986a and 1989) has already noted that length-weight relationships during the post-spawning and winter seasons are significantly different from those obtained during the spawning season, with minimum weight during winter. This seasonal variability partly explains the variation in estimated biomass obtained by Morris *et al.* (1988). Moreover, a difference in the weight of both sexes has been noted by Nemoto *et al.* (1981), Retama and Quintana (1982) and Siegel (1986a), with males being heavier than females at similar sizes. However, this difference in weight between males and females is statistically significant only during the post-spawning period, when females have shed their eggs (Siegel, 1989). After the ovaries had recovered and during the winter resting stage there was no significant deviation between the weight (length-weight relationship) of males and females.

Based on the above observations, it is recommended that:

(i) when data are available on stock composition by size, sex and maturity stage:

- (a) during the summer spawning period use separate length-weight relationships for males, gravid females and non-gravid females (Table 3);
- (b) during the post-spawning period use separate length-weight relationships for males, gravid females, non-gravid females and spent females (Table 3);
- (c) during the winter and pre-spawning periods use general length-weight relationships (Table 4, depending on month, although differences between months are not significant during this period);

(ii) when data are available on stock composition by size and sex, but no information can be obtained for maturity stages:

- (a) during the late spawning and post-spawning periods use separate length-weight relationships for males and females (Table 3);
- (b) for other periods use general length-weight relationships (Table 4); and

(iii) when data are available on population composition only by size:

- (a) for all periods use general length-weight relationships based on data collected during a minimum period of one month (Table 4).

Because spawning may occur in different months during different years, dominant maturity stage is more important than month in choosing the correct length-weight relationship.

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Table 1: Length-weight relationship for krill (*Euphausia superba*) males (M) and females (F), $W_{AFD} = a \bullet L^b$ for ash-free dry weight (in mg) and total length (AT in mm).

Month	Sex	Regression Coefficient a	b	Size Range (mm)	Number of Krill	Dominant Adult Maturity Stages	Reference
October	M	0.0005	3.022	13-58	138	3A resting stage	Siegel (1986a)
	F	0.0008	2.906	13-59	141	3A resting stage	
December	M	0.00011	3.527	23-60	114	3B gravid	Siegel (1986a)
	F	0.00014	3.460	23-60	114	3C, D gravid	
January	M	0.00029	3.277	23-60	114	3A, B gravid-spent	Siegel (1986a)
	F	0.00066	3.041	23-60	114	3D/E gravid-spent	
February	M	0.00007	3.720	16-58	129	3A spent	Siegel (1986a)
	F	0.00026	3.205	16-59	132	3E spent	

Table 2: Length-weight relationship for krill (*Euphausia superba*) males (M) and females (F), and total ALL, $W_D = a \bullet L^b$ for dry weight (in mg) and total length (AT in mm).

Month	Sex	Regression Coefficient a	b	Size Range (mm)	Number of Krill	Dominant Adult Maturity Stages	Reference
Feb/Mar	ALL	0.00010	3.799		145		Jazdzewski *et al.* (1978)
Jan/Feb	ALL	0.00007	3.760	28-58	114	prespawning-gravid	Kils (1979)
October	M	0.00060	3.030	13-58	138	3A resting stage	Siegel (1986a)
	F	0.00080	2.971	13-59	141	3A resting stage	
November	M	0.00076	3.071	10-57	406	3A resting stage	Siegel (unpubl. data)
	F	0.00105	2.965	10-57	458	3A resting stage	
December	M	0.00019	3.435	23-60	114	3B gravid	Siegel (1986a)
	F	0.00025	3.357	23-60	114	3C, D gravid	
January	M	0.00036	3.277	23-60	114	3A, B gravid-spent	Siegel (1986a)
	F	0.00075	3.066	23-60	114	3D/E gravid-spent	
February	M	0.00009	3.694	16-58	129	3A spent	Siegel (1986a)
	F	0.00031	3.306	16-59	132	3E spent	
Feb/Mar	M	0.00238	2.93	34-57	1861	gravid	Morris *et al.* (1988)
	F	0.00024	3.55	37-58	1404	gravid-spent	
	(F)	0.00139	3.0737	37-58	933	only non-gravid females	
	(F)	0.00199	3.0438	41-58	471	only gravid females	
	ALL	0.00106	3.15	31-58	3265	gravid-spent	

Table 3: Length-weight relationship for krill (*Euphausia superba*) males (M) and females (F), $W_W = a \cdot L^b$ for wet weight (in mg) and total length (AT in mm). Length classes indicated by * refer to Standard 2 body length of Mauchline (1980).

Month	Sex	Regression Coefficient a	b	Size Range (mm)	Number of Krill	Dominant Adult Maturity Stages	Reference
Several years	M	0.0034	3.1761	3-61		all stages	Lockyer (1973)
	F	0.0009	3.5792	3-61		all stages	
Several years	M	0.00128	3.428			all stages	Nemoto *et al.* (1981) (one example out of several stations)
	F	0.00352	3.144			all stages	
Jan/Feb	M	0.00423	3.170	31-55	92	3B gravid	Retamal and Quintana (1982)
	F	0.00573	3.080	31-55	58	3B prespawning	
Dec/Feb	M	0.0019	3.36				Strelnikova (1985)
	F	0.0009	3.56				
Feb/Mar	M	0.00265	3.464	23-47*	2325		Rojas *et al.* (1981)
	F	0.00531	3.256	23-46*	2757		
October	M	0.00236	3.251	13-58	138	3A resting stage	Siegel (1986a)
	F	0.00242	3.247	13-59	141	3A resting stage	
November	M	0.00315	3.207	10-57	406	3A resting stage	Siegel (1989)
	F	0.00430	3.102	10-57	458	3A resting stage	
December	M	0.00083	3.561	15-59	114	3B gravid	Siegel (1986a)
	F	0.00115	3.457	15-59	114	3C, D gravid	
January	M	0.00156	3.403	23-60	114	3A, B gravid-spent	Siegel (1986a)
	F	0.00282	3.234	23-60	114	3D/E gravid-spent	
February	M	0.00111	3.507	16-58	129	3A spent	Siegel (1986a)
	F	0.00211	3.302	16-59	132	3E spent	
June	M	0.00328	3.176	21-59	380	3A resting stage	Siegel (1989a)
	F	0.00441	3.084	21-55	340	3A resting stage	
Feb/Mar	M	0.00613	3.0776	34-57	1882	gravid	Morris *et al.* (1988)
	F	0.00289	3.270	31-58	1417	gravid + spent	
	(F)	0.01088	2.9077	31-58	940	only non-gravid females	
	(F)	0.00975	2.9809	41-58	477	only gravid females	
	(F)	0.03548	2.590	39-56	65	only spent females	

Table 4: Length-weight relationship for krill (*Euphausia superba*) not separated for males and females, $W_W = a \bullet L^b$ for wet weight (in mg) and total length (AT in mm). Length classes indicated by * refer to Standard 2 and ** to Reference body length of Mauchline (1980).

Month	Regression Coefficient a	b	Size Range (mm)	Number of Krill	Dominant Adult Maturity Stages	Reference
Several months	0.00056	3.62	24-58	30/mm		Chekunova and Rynkova (1974)
Jan/March	0.00229	3.35	22-42**	49	mostly adolescent	Clarke (1976)
April	0.0018	3.3436	20-61	1085	spent	Sahrhage (1978)
Feb/March	0.0018	3.3831		145		Jazdzewski *et al.* (1978), identical to Rakusa-Suszczewski (1981)
Jan/Feb	0.00158	3.40	28-58	114	prespawning-gravid	Kils (1979)
Feb/March	0.00298	3.4232	23-47*	5082		Rojas *et al.* (1981)
Feb/March	0.00385	3.20	26-59	3299	gravid-spent	Morris *et al.* (1988)
April	0.0017	3.4327	20-60	708	probably spent	Miller (1986)
October	0.00236	3.251	13-58	279	resting stage	Siegel (1986b)
December	0.00086	3.551	15-59	250	gravid	Siegel (unpubl. data)
January	0.00205	3.325	23-60	228	gravid-spent	Siegel (unpubl. data)
February	0.00083	3.561	13-60	228	gravid	Siegel (unpubl. data)
February	0.00165	3.380	16-59	261	spent	Siegel (1986a)
March	0.00193	3.325	30-62	143	spent	Siegel (1986b)
June	0.00353	3.151	21-59	339	resting stage	Siegel (unpubl. data)

Table 5: Length-weight relationship for other Antarctic euphausiid species than krill (*Euphausia superba*). $W_W = a \cdot L^b$ for wet weight (in mg) and total length (in mm).

Month	Sex	Regression Coefficient a	b	Size Range (mm)	Number of Krill	Dominant Adult Maturity Stages	Reference
Thysanoessa macrura							
Dec-Feb	ALL	0.00482	3.063	11-28	68	(resting?)	Rakusa-Suszczewski and Stepnik (1980)
Euphausia crystallorophias							
Dec-Feb	M F	0.0113 0.0055	2.79 3.04		118 129	(spent-resting?)	Rakusa-Suszczewski and Stepnik (1980)
November	ALL	0.0017	3.373	17-37	150	prespawning-gravid	Siegel (unpubl. data)
Euphausia frigida							
March	ALL	0.040	2.339	8-23	80	resting stage	Siegel (unpubl. data)
Euphausia triacantha							
May	ALL	0.0383	2.495	13-38	115	resting stage	Siegel (unpubl. data)

Légende des tableaux

Tableau 1: Relation longueur-poids pour le krill (*Euphausia superba*) mâle (M) et femelle (F), $W_{AFD} = a \cdot L^b$ pour le poids sec sans cendres (en mg) et la longueur totale (AT en mm).

Tableau 2: Relation longueur-poids pour le krill (*Euphausia superba*) mâle (M) et femelle (F), et total (ALL), $W_D = a \cdot L^b$ pour le poids sec (en mg) et la longueur totale (AT en mm).

Tableau 3: Relation longueur-poids pour le krill (*Euphausia superba*) mâle (M) et femelle (F), $W_W = a \cdot L^b$ pour le poids humide (en mg) et la longueur totale (AT en mm). Les classes de longueur indiquées par * se rapportent à la longueur du corps Standard 2 de Mauchline (1980).

Tableau 4: Relation longueur-poids pour le krill (*Euphausia superba*), mâle et femelle combinés, $W_W = a \cdot L^b$ pour le poids humide (en mg) et la longueur totale (AT en mm). Les classes de longueurs indiquées par * se rapportent au Standard 2 et ** à la référence de longueur du corps de Mauchline (1980).

Tableau 5: Relation longueur-poids pour les espèces d'euphausiacés antarctiques autres que le krill (*Euphausia superba*). $W_W = a \cdot L^b$ pour le poids humide (en mg) et la longueur totale (en mm).

Список таблиц

Таблица 1: Отношение "длина/вес" для самцов (M) и самок (F) криля (*E.superba*), $W_{AFD} = a \cdot L^b$ в случае беззольного сухого веса (в мг) и общей длины (AT в мм).

Таблица 2: Отношение "длина/вес" для самцов (M), самок (F) и обоего пола (ALL), криля (*E. superba*), $W_D = a \cdot L^b$ в случае сухого веса (в мг) и общей длины (AT в мм).

Таблица 3: Отношение "длина/вес" для самцов (M) и самок (F) криля (*E. superba*), $W_w = a \cdot L^b$ в случае мокрого веса (в мг) и общей длины (AT в мм). Размерные классы, обозначенные *, относятся к измерениям Стандартной длины 2 (Mauchline, 1980).

Таблица 4: Отношение "длина/вес" для криля (*E. superba*) обоего пола, $W_w = a \cdot L^b$ в случае мокрого веса (в мг) и общей длины (AT в мм). Размерные классы, обозначенные *, относятся к измерениям Стандартной длины 2, и ** - Контрольной длины (Mauchline, 1980).

Таблица 5: Отношение "длина/вес" для видов антарктических эвфаузиид помимо криля (*E. superba*). $W_w = a \cdot L^b$ в случае мокрого веса (в мг) и общей длины (AT в мм).

Lista de las tablas

Tabla 1: Relación talla-peso del kril (*Euphausia superba*) macho (M) y hembra (F), $W_{AFD} = a \cdot L^b$ para peso seco libre de ceniza (en mg) y longitud total (AT en mm).

Tabla 2: Relación talla-peso del kril (*Euphausia superba*) macho (M) y hembra (F), y combinados (ALL), $W_D = a * L^b$ para peso seco (en mg) y longitud total (AT en mm).

Tabla 3: Relación talla-peso del kril (*Euphausia superba*) macho (M) y hembra (F), $W_W = a \cdot L^b$ para peso húmedo (en mg) y longitud total (AT en mm). Las clases de talla indicadas con un * se refieren a la talla estándar 2 de la talla corporal de referencia de Mauchline (1980).

Tabla 4: Relación talla-peso del kril (*Euphausia superba*) combinada para machos y hembras, $W_W = a \cdot L^b$ para peso húmedo (en mg) y longitud total (AT en mm). Las clases de talla indicadas con un * se refieren a la talla estándar 2, mientras que las marcadas con dos ** , a la talla corporal de referencia de Mauchline (1980).

Tabla 5: Relación talla-peso de otras especies de eufáusidos antárticos aparte de kril (*Euphausia superba*). $W_W = a \cdot L^b$ para peso húmedo (en mg) y longitud total (en mm).