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LENGTH-WEIGHT RELATIONSHIPS FOR *NEPHROPS NORVEGICUS* (L., 1758) OF THE NORTHERN TYRRHENIAN SEA IN RELATION TO SEX, SEASON, MOULT AND MATURITY

Riassunto — *Relazione taglia-peso per* Nephrops norvegicus *(L. 1758) del Tirreno settentrionale in relazione al sesso, stagione, muta e maturità.* Sono state stimate le relazioni taglia-peso, per entrambi i sessi di *Nephrops norvegicus,* in relazione alla stagione, allo stadio di muta, e per le femmine nello studio di intermuta in relazione al loro stadio ovarico. I campioni sono stati raccolti in primavera ed estate 1986 nel Tirreno settentrionale (Mediterraneo Centrale). Nessuna differenza significativa è stata osservata tra i pesi dei maschi raccolti nelle due stagioni considerate. I maschi pesano meno delle femmine raccolte in primavera e più di quelle in estate.

Il peso delle femmine con ovari maturi, a vari stadi (crema, pisello, verde scuro) e delle femmine ovigere è maggiore di quello delle femmine con ovari immaturi. Le femmine ovigere hanno lo stesso peso di quelle con ovari verde scuro, ma pesano più di quelle con ovari crema e pisello. Le femmine in intermuta con ovari pisello pesano meno di quello allo stadio di premuta con lo stesso tipo di gonade. I maschi in postmuta pesano meno di quelli negli stadi di intermuta e premuta. Il peso fresco degli individui è maggiore di quello degli individui scongelati. Viene infine discusso l'utilizzo delle relazioni taglia-peso sia per studi comparativi tra popolazioni che per la gestione degli stock di *Nephrops*.

Abstract — The length-weight relationships of Norway lobster, *Nephrops norvegicus* (L.), have been estimated for both sexes in relation to season and to moult stage, and for intermoult females in relation to maturity. Samples were collected in Spring and Summer 1986 from the Northern Tyrrhenian Sea (Central Mediterranean Sea). There was no significant difference between Spring and Summer weights for males of the same size, but males weighed less than females collected in Spring and more than the females collected in Summer. In the females, however, a decrease in weight was noticed from Spring to Summer, the difference being due to specimens with mature ovaries. Wet wei-

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In the intermoult stage, female with pale green ovaries weigh less than those in premoult stage of the same ovary category. Postmoulting males weigh less than those in the intermoult and premoult stages. The fresh specimens are heavier than those fully-thawed. The use of length-weight relationships for comparative studies among populations and for *Nephrops* stock assessment are discussed.

Key words — *Nephrops norvegicus*, lenght-weight relationship, Tyrrhenian Sea.

INTRODUCTION

The relationship between lenght and weight is an important information for fishery management (RICKER, 1980). The parameters of this relation, together with size at sexual maturity and fecundity, are also basic to intraspecific comparisons of discrete populations. As estimations of age-size relationships for crustacean populations are particularly difficult and time-consuming, many authors have used the aforesaid parameters to define similarities and/or differences among populations (WENNER *et al.*, 1974; SOMERTON and MACINTOSH, 1983; BOWERING and STANSBURG, 1984; BEYERS and GOSSEN, 1987).

A number of papers have dealt with lenght-weight relationships of *N. norvegicus*, but the results presented are conflicting. FARMER (1974a) and SARDÀ *et al.*, (1981) did not observe any differences in weight between sexes. Other authors pointed out differences in individual total weight between males and females (POULSEN, 1946; POPE and THOMAS, 1967; SYMONDS, 1972; FROGLIA and GRAMITTO, 1981; HOSSEIN *et al.*, 1986).

Some authors have stated that the individual weight of some decapods varies, depending upon the gonad and moult stages (OLMI and BISHOP, 1983; CADMAN and WEINSTEIN, 1985; ABELLO, 1986). In the Northern Tyrrhenian Sea *N. norvegicus* females with mature ovaries are present throughout the year, but they predominate between April and August. Moulting females occur throughout the year with monthly percentages ranging between 9-18%, reaching peaks of 27-32% between April and July (BIAGI *et al.*, 1990). Moulting males occur throughout the year, but mainly between August and December, i.e. when most females brood the eggs (BIAGI *et al.*, 1990; MORI, unpublished data).

The aim of the present research was to estimate the lenght-weight relationships for *N. norvegicus* of the Northern Tyrrhenian Sea (Central Mediterranean Sea) for both sexes in relation to season and stage of the moult cycle, and for intermoult females in relation to maturity.

Due to the long time of the trawl surveys, each sample must be

immediately freezed after its collection. In order to estimate weight loss caused by deep-freezing, the length-weight relationships for fresh and fully thawed specimens are investigated.

Material and Methods

The samples were collected between March and June, 1986 (Spring), and between 16 August and 11 September, 1986 (Summer) within a depth range of 200-500 m. The work was carried out as part of a trawl survey research project on the assessment of demersal resources, through a random stratified sampling desing, in the area lying between Elba and Giannutri Islands (Northern Tyrrhenian Sea, Central Mediterranean) (De Ranieri *et al.*, 1988).

Specimens were randomly placed in labelled plastic bags and transferred from the boat to a deep-freezer on landing, within twelve hours from the catch. Fifteen to twenty days after sampling, they were thawed in running water and drained for 30 minutes on absorbent paper. A sample of specimens collected in Spring were weighed immediately after landing (fresh weight) to estimate the loss due to dehydration in the deep-freeze.

Three measurements were made by the same person on those *Nephrops* which had a full set of appendages, and the following parameters were recorded: carapace length (CL), from the posterior margin of the orbit to the median posterior margin of the carapace; total wet weight of the whole fully-thawed animal; wet weight of the fully-thawed animal without the first pereiopods; fresh weight of animal without first pereiopods, within five hours after landing. The carapace length was measured to the nearest millimeter by a vernier caliper, and the weight, to the nearest gram, by Mettler PE200 electronic balance.

Each specimen, after being weighed and measured, was dissected; the gonad stage of females and the moulting stage of both sexes were determined. The gonad stage of females was established using Farmer's (1974b) colour scale: stage F1 (white), F2 (cream), F3 (pale-green), F4 (dark-green). Ovigerous females have not been included in the F1 stage; they are reported in the F6 stage. The following moult stages were considered for both sexes: a) intermoulting stage, characterized by the absence of gastrolites or any other moultin dicating marker; b) premoulting stage, characterized by the presence of gastrolites on the stomach wall; c) postmoulting stage on the basis of the shell condition, i.e, very soft, not or moderately calcificated, and harde-

ning (BERRY, 1969; SARDÀ, 1983a). The males in intermoult stage were denominated (M1), in premoult (M2), and in postmoult (M3). The females assigned to the F1, F2, F3, F4, and F6 stages were all specimens in intermoult stage. The females with pale green ovaries in premoulting stage were assigned to the stage F5. Unfortunately, it was possible to study only this group of specimens, since the premoulting and postmoulting females in the other gonad stages were too few to give statistically valid results.

The weight (Y) was assumed to be proportional to the carapace length (X), raised to a power, $Y=ax^b$, but was used in the logarithmic transformation, logY=loga+b logX. The parameters a and b were estimated using the least squares method of regression (Model I) (RICKER, 1980), as most authors who estimated these parameters for N. *norvegicus* utilized such a model. The statistical tests were performed using a package of statistical programs associated with the text *Biometry* by SOKAL and ROHLF (1981), distributed by Exeter Publishing of New York.

RESULTS AND DISCUSSION

Total wet weight for each sex in relation to season

The paramerers of the relationships between total wet weight and carapace length of fully-thawed males and females (both in the intermoult stage) collected in Spring and Summer are given in Tab. 1, and the regression lines are drawn in Figs. 1A, B. The ovigerous females were not included in the Summer' sample. All the correlation coefficients are high and significant ($P<0.01$) (Tab. 1). Since the probability of detecting differences in the length-weight relationships increases with large animals (SOMERTON and MACINTOSH, 1983), all the comparisons dealt with Norway lobsters of the same size. Analysis of covariance shows that the regression coefficients of the four samples differ significantly ($P<0.01$). A t-test for homogeneity of the slopes indicates that the individual weights of males collected in Spring (Mspr) are not significantly different ($P>0.05$) from those collected in Summer (Msum), but males of either category weigh more ($P<0$ 01) than the females collected in Summer (Fsum) and less ($P<0.01$) than those collected in Spring (Fspr). The females collected in Spring weigh significantly more than those collected in Summer ($P < 0.01$).

The higher weight of males (Mspr and Msum) than that of females

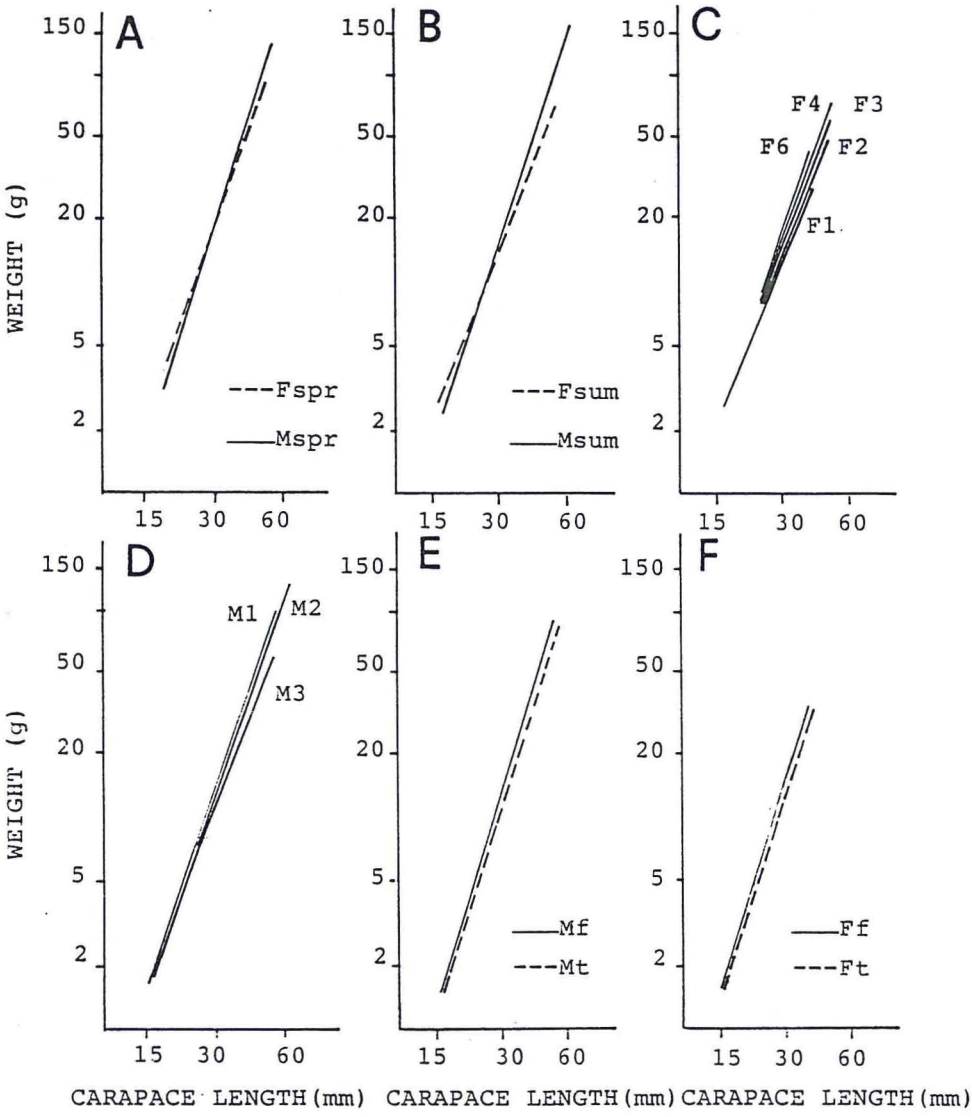

Fig. 1 - Log weight plotted against log carapace length (CL). (A) log total wet weight against log CL tor fully-thawed males and females, in intermoult stage, collected in Spring. (B) log total wet weight against log CL for fully-thawed males and females, in intermoult stage, collected in Summer. (C) log wet weight without first pereiopods against log CL for fully-thawed females in relation to maturity, F1=white ovaries, F2=cream ovaries, F3=pale green ovaries, F4=dark green ovaries, F6=specimens with embryos; (D) log wet weight without first pereiopods against log CL for fully-thawed males in relation to moult stage, M1=intermoult, M2=premoult, M3 =postmoult; (E) log wet weight without first pereiopods against log CL for fresh and fully-thawed males; (F) log wet weight without first pereiopods against log CL for fresh and fully-thawed females.

TAB. 1 - Estimated parameters of total wet weight (Y) and carapace length (X) relationships for fully-thawed males and females collected in Spring (Mspr and Fspr) and in Summer (Msum and Fsum). N=number of specimens; range=size range in carapace lenght (mm); a=intercept; b=slope; Se=Standard error of the slope; r=correlation coefficient.

Groups	N	Range	Parameters			
			a	b	Se	r
Mspr	185	18-56	-3.6236	3.2925	0.03	0.987
Fspr	171	19-55	-3.5747	3.2640	0.03	0.987
Msum	158	16-58	-3.6709	3.3381	0.02	0.994
Fsum	117	16-51	-3.3644	3.1294	0.04	0.986
M=Mspr+Msum	343	16-58	-3.6254	3.3014	0.02	0.991
F=Fspr+Fsum	289	16-55	-3.4444	3.1810	0.02	0.988
Tot=M+F	631	16-58	-3.5470	3.2496	0.02	0.990

collected in Summer (Fsum) could depend on the first pereiopods which are bigger in males than in females (SARDÀ *et al.*, 1981). To verify this assumption, the weights of both first pereipods (PerWW) for each sex were taken. The relative parameters of the relationship LogCL/LogPerWW are: Males, N=145, a=-4.9421, b=3.7586, r=0.987; Females, N= 126, a=-4.3341, b=3.3162, r=0.978). Regression coefficients differ significantly ($P<0.01$). The male first pereiopods are significantly heavier than the female ones.

The individual male weight of *N. norvegicus* in the intermoult stage remained costant in the two seasons, likely because there is no seasonal fluctuation in the male reproductive cycle (MORI, unpublished data).

The higher weights of females collected in Spring (Fspr) than those of females collected in Summer (Fsum) might be related to their gonade stage. In Spring the percentage of *N. norvegicus* with white ovaries was 15.7%, and, with mature ovaries (cream, pale green, dark green) 84.3%, whereas in Summer the percentages were 70.9% and 29.1% respectively. For other decapod species, some authors have stated that the individual weight of females varies, depending upon the gonad stage (ABELLO, 1986).

The females collected in Spring are heavier than males collected in both seasons (Mspr and Msum), but this fact cannot solely be ascribed to the maturing gonads of the females. Other factors can contribute to the higher female weight, e.g., the female tail flesh contains a higher proportion of water than that of the male (HOSSAIN *et al*, 1987).

Because of the lack of significant difference between males collec-

ted in Spring (Mspr) and in Summer (Msum) both data were combined (Tab. 1, M=Maspr+Msum).

If the length weight relationships are utilized for *Nephrops* stock assessment, the samples of the females collected in spring and in summer can be pooled (Tab. 1, F=Fspr+Fsum), because the error is small if compared to the effect of varying other inputs such as growth or mortality costants (see RICKER, 1980). For the same reason it is possible to combine the data of both sexes (Tab. 1, Tot=M+F).

Wet weight without first pereiopods for intermoult females in relation to maturity.

The length-weight relationships of females in different gonad stages were analyzed in order to verify whether the weight of the females of *N. norvegicus* depends upon the gonad stage.

All specimens were weighed without the first pereiopods (WWP) to nullify any possible error due to regenerated chelae of some specimens (SARDÀ, 1983b). The parameters for the relationships between WWP and CL for fully-thawed females are given in Tab. 2, and plotted in Fig. 1C.

TAB. 2 - Estimated parameters of wet weight without first pereiopods (Y) and carapace length (X) relationships for fully-thawed females (F1..F6) and males (M1..M3), in relation to moult and maturity. See Table 1 for the symbols.

Stages		N	Range	Parameters			
				a	b	Se	r
Mspr	(F1)	120	16-10	-3.1560	2.8993	0.08	0.957
Crean	(F2)	78	26-46	-3.2437	2.9752	0.09	0.966
Pale green	(F3)	106	27-49	-3.2570	2.9998	0.05	0.985
Dark green	(F4)	63	29-51	-3.3956	3.0941	0.07	0.981
F3 premoult	(F5)	71	26-55	-3.1024	2.9102	0.06	0.983
Ovigerous	(F6)	70	27-44	-3.7777	3.3456	0.15	0.935
Intermoult	(M1)	203	15-55	-3.5817	3.1973	0.03	0.990
Premoult	(M2)	52	15-62	-3.3423	3.0514	0.05	0.992
Postmoult	(M3)	60	25-48	-3.0348	2.3137	0.08	0.974

in Fig. 1C. All the correlation coefficients are high and significant ($P < 0.01$), except that for ovigerous females (F6), wich has a low value. This may be due to the fact that we included in the same stage (F6) specimens belonging to different substages, e.g., the ovigerous females in the stages A, B and C (sensu FIGUEIREDO, 1971). It is known that the number of embryos decreases with the incubation time (MORIZUR *et al.*, 1981), consequently causing a decrease of individual weight of F6 females.

Analysis of covariance indicates that the regression coefficients of the five kinds of females do not differ ($P > 0.05$), but the intercepts, assuming a common slope, differ significantly ($P<0.01$). Pair-wise multiple comparisons of the intercepts (Bonferroni t-test, MILLER, 1966) show that specimens with white ovaries (F1) have similar weights to that of the F2 females ($P>0.01$), but weigh significantly less ($P<0.01$) than females with mature ovaries or ovigerous ones (F3, F4 and F6). The individual weights of females with cream ovaries (F2) are not significantly different ($P>0.05$) from those of females with pale green (F3) and dark green ovaries (F4). In addition, the females with cream (F2) or pale green (F3) ovaries weigh less than ovigerous ones ($P<0.01$), whilst females with dark-green ovaries (F1) show the same weights as those of ovigerous ones ($P>0.05$).

Wet weight whitout first pereiopods for each sex in relation to stage of moult cycle

The stage of moult is known to affect the length-weight relationships (OLMI and BISHOP, 1983; CADMAN and WEINSTEIN, 1985; ABELLO, 1986). The parameters of the length-weight relationships for premoulting females with pale green ovaries (F5) are shown in Tab. 2. Analysis of covariance shows no statistical difference between the regression coefficients of F3 and F5 females ($P>0.05$), while their intercepts, assuming a common slope, differ significantly ($P<0.01$). The F5 females are heavier than the F3 ones for all sizes examined. OLMI and BISHOP (1983) obtained the same finding for *Callinectes sapidus,* but for this species, as for *N. norvegicus,* no plausibile explanation was found.

The length-weight relationships of the males in the intermoult (M1), premoult (M2) and postmoult (M3) stages, were estimated. The weights were taken without first pereiopods for the aforesaid reasons. The estimated parameters are shown in Tab. 2, and the regression lines drawn in Fig. 1D. All the correlation coefficients are high and significant ($P<0.01$). The correlation coefficient of M3 males is lower than those of M1 and M2 males. The low correlation coefficient of M3 males may be due to the fact that we included in the same stage (owing to their small number) specimens belonging to three different substages, that is, A1 (newly moulted), A2 (soft), and B2 (papershell). Analysis of covariance shows that the slopes of the three different types of males (M1, M2, M3), related to the moulting stage, differ significantly ($P<0.01$). A t-test for homogeneity of the slopes indicates, that premoulting (M2) and intermoulting (M1) specimens do not differ in weight ($0.05>P>0.01$), while the weights of M1 and M2 males differ significan-

tly from those of postmoulting specimens ($P<0.01$). Thus, premoulting males (M2) have similar weights to that intermoulting males (M1), while postmoulting males (M3) weigh significantly less than M1 and M2 males. This could be due to the fact that in postmoulting specimens there is an absorption of water and an initial mineralization which increase from A_1, to B_2 stages. Such physiological processes end in the intermoult stage (Stages C_1-C_4) (PASSANO, 1960), thus rendering the specimens in intermoult and premoult stages heavier than in the postmoult stage.

Wet weight without first pereiopods for fresh and fully-thawed specimens.

Till now we have dealt with weight-size relationship of fully-thawed specimens. In order to estimate possible weight loss caused by deep-freezing, one sample of 138 females and 178 males, collected during Spring, was weighed fresh, without first pereiopods. The length-weight relationships for fresh and fully thawed specimens of both sexes are shown in Tab. 3, while the regression lines are drawn in Figs. 1 E, F.

TAB. 3 - Estimated of weight without first pereiopods (Y) and carapace length (X) relationships, for fresh (Mf and Ff) and fully-thawed specimens (Mt and Ft), of both sexes, collected in Spring. See Table 1 for the symbols.

Groups	N	Range	Parameters			
			a	b	Se	r
Ff	138	16-43	-3.7488	3.3352	0.05	0.985
Ft	138	16-43	-3.6170	3.2304	0.04	0.972
Mf	178	16-53	-3.6426	3.6489	0.03	0.990
Mt	178	16-53	-3.5708	3.1925	0.03	0.989

The correlation coefficients of the fresh specimens are more significant than those of fully-thawed specimens (Tab. 3). This can be due to a different percentage of water loss by each single specimen during deep freezing. The relative position of the specimens in the plastic bags may be important since the specimens surrounded by other specimens are less liable to water loss, while those externally located are liable to greater water loss. Wet weights of fresh males (Mf) and females (Ff) were compared with those of fully-thawed specimens. Analysis of covariance shows no statistical difference between the regression coefficients ($P>0.05$), while the intercepts of fully-thawed and fresh specimens for both sexes, assuming a common slope, differ significantly ($P<0.01$). The fresh specimens are heavier than those fully-thawed.

This weight loss after freezing has been reported for other decapod species, e.g. *Pandalus borealis* (DUPOUY *et al.*, 1981).

CONCLUSIONS

Since length-weight relationships of Norway lobster, *N. norvegicus*, differ significantly in relation to sex, moult stage, maturity and season, comparison among samples may lead to erroneous conclusions if these variables are not considered.

If the length-weight relationships are utilized for *Nephrops* stock, assessment, the data of both sexes, also if collected in different months of the year, can be pooled, because the error is small if compared to the effect of varying other inputs such as growth or mortality costants.

A general rule correlating weight loss and freezing time cannot be formulated since many factors can influence this relationship, as for example the use of plastic bags for each specimen or group of individuals, the method of thawing, the time elapsing between thawing and measuring, the type of freezer etc.

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