Length-Weight Relationships, Biochemical Composition and Caloric Content of Selected Macrozooplankton from Frobisher Bay, N.W.T.

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Les numéros 1 à 25 de cette série ont été publiés à titre de Records statistiques, Service des pêches et de la mer. Les numéros 26-160 ont été publiés à titre de Rapports statistiques du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été modifié à partir du numéro 161.

Le titre exact paraît au haut du résumé de chaque rapport.

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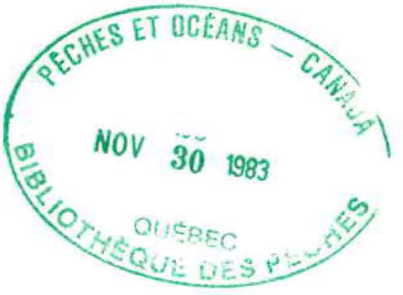

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LENGTH-WEIGHT RELATIONSHIPS, BIOCHEMICAL COMPOSITION AND CALORIC CONTENT OF SELECTED MACROZOOPLANKTON FROM FROBISHER BAY, N.W.T.

by

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ABSTRACT

Percy, J. A. and F. J. Fife. 1983. Length-weight relationships, biochemical composition and caloric content of selected macrozooplankton from Frobisher Bay, N.W.T. Can. Data Rep. Fish. Aquat. Sci. 418: vi + 74 p.

This report serves as a repository for tabular data pertaining to the length-weight relationships, biochemical composition and energy content at various times during the open water season of the ctenophore Mertensia ovum, the hyperiid amphipod Parathemisto libellula, the chaetognath Sagitta elegans and the euphausiid Thysanoessa inermis. Regression equations are developed that relate length to live weight, dry weight, ash-free dry weight and ash content. Data relating to the influence of size, sex and collection date on the water, ash, lipid, protein and caloric content are presented and statistically analyzed.

Key words: Arctic macrozooplankton, length, weight, caloric content, biochemical composition, Mertensia ovum, Sagitta elegans, Parathemisto libellula, Thysanoessa inermis.

RÉSUMÉ

Percy, J. A. and F. J. Fife. 1983. Length-weight relationships, biochemical composition and caloric content of selected macrozooplankton from Frobisher Bay, N.W.T.
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Ce rapport rassemble des données sous forme tabulaire reliées aux relations entre la longeur et le poids, à la composition biochimique et au contenu d'energie calorifique durant l'été pour le cténaire Mertensia ovum, l'amphipode hyperidée Parathemisto libellula, le chaetognath Sagitta elegans et l'euphausiacée Thysanoessa inermis. Des regressions reliant la longeur au poids humide au poids sec, au poids en matière organique et au contenu de cendre sont presentée. Les données reliées à l'influence de la taille, du sex et de la date d'echantillonage sur le contenu d'eau, de cendre, de protein et d'energie calorifique sont presentées et analysées.

ACKNOWLEDGEMENTS

We would like to thank the many summer students who assisted us in the field and laboratory during this study including M. deFeydeau, F. Paton and J. Shea. The field program was based at the Ikaluit Research Laboratory in Frobisher Bay and we are particularly grateful to A. Theriault of DIAND, Baffin Island Region, for his continuing support. We thank L. McMullon for typing the manuscript.

INTRODUCTION

This data report is one of a series of tabulations of results from studies on the ecological energetics of macrozooplankton species present in Frobisher Bay. A preliminary survey provided information about the general biochemical composition and caloric content of 15 of the most common species (Percy and Fife, 1980; 1981). It has since been shown that this macrozooplankton community is consistently dominated by a few species (Percy and Fife, 1983). The ctenophore Mertensia ovum, the hyperiid amphipod Parathemisto libellula and the chaetognath Sagitta elegans account for the bulk of the biomass, as well as of the caloric energy content, of the macrozooplankton present in the upper 50 m of the water column. In deeper water, these three species and the euphausiid Thysanoessa inermis account for most of the macrozooplankton caloric energy.

Because of this seeming importance in the Frobisher Bay ecosystem these four species have become the focus of more detailed ecological and physiological studies. To integrate effectively results from physiological and population ecology studies it is necessary that components and processes be expressed in the same or in compatible units. The most suitable and commonly used unit in energy flow studies is the calorie. It is frequently not practical or desirable to measure all components directly in calories. Often, non destructive techniques for estimating the energy content of preserved plankton samples, such as by the determination of mathematical relationships that permit interconversions of size, biomass and energy content, must be used.

Regression equations have been calculated for each of the above species that permit transformation of length or volume data into wet, dry, organic and inorganic biomass estimates. These in turn can be readily transformed into calories using appropriate conversion factors. In addition, differences in these length-weight relationships among different sexes and maturity stages and at different times in the open water season have been examined.

The earlier survey of the biochemical composition and caloric content of Frobisher Bay macrozooplankton (Percy and Fife, 1980) ignored the influences of size, sex and maturity. The present study looks at the effect of these factors on the composition and energy content of the four dominant species at various times during the open water season. This information not only provides a better understanding of the variations in organic composition and energy within the populations, but also permits a more precise estimation of population energy levels from size structure and biomass data.

METHODS

Macrozooplankton samples were collected at intervals during the open-water season by towing a 1-m ring net (1 mm mesh) at various depths at two stations in upper Frobisher Bay. Mertensia ovum, Parathemisto libellula and Sagitta elegans were collected between 10 and 30 m at station 5, while Thysanoessa inermis was collected between 60 and 120 m at station 51. The station locations and pertinent oceanographic data are provided in Grainger (1971) and Lovrity (1981).

Length-weight relationships

Length-weight relationships (length, live weight, dry weight, ash-free dry weight, percent ash and volume) were determined using macrozooplankton obtained in collections listed in table 1. Samples were obtained as early and as late in the open-water season as possible. Five collections of M. ovum were examined, including a winter one (8 Feb. 1982) obtained by suspending ½-m nets through the ice in a tidal current. Only one collection of T. inermis could be obtained.

Animals of interest were removed from the zooplankton collections immediately and transported to the laboratory in insulated containers of seawater.

The volume of individual M. ovum was measured by water displacement in an appropriately sized graduated cylinder (10-100 ml) after gently draining the animals in a scoop. Live weight was measured after again removing extraneous water. The animals were dried to constant weight at 60°C, cooled in a dessicator and weighed. Ash-free dry weight and

percent ash were determined after incinerating the animals at 500°C for 4 hours. For collections of ctenophores obtained in 1981 the body length and volume were measured in order to determine a regression equation for interconverting these two variables.

Both P. libellula and T. inermis were sexed. The maturity stage of S. elegans was determined according to the criteria outlined by Dunbar (1962). Lengths of the extended animals were measured to the nearest 0.1 mm with dial calipers. Animals were rinsed with isotonic ammonium formate, drained on plankton netting over vacuum for one minute and weighed. Dry weights and ash-free dry weights were determined as described above.

Regression equations relating the various length-weight measurements were calculated for each collection of animals using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) statistical package (SAS Institute Inc., 1982). The significance of differences in regressions of samples obtained at different times in the same open-water season was examined by analysis of covariance using the GLM procedure. Regressions for each of the relationships were also determined after combining the data for each species collected in the same open-water season. For M. ovum, the regressions for the combined samples obtained during the 1981 open-water season were compared with those for the winter sample (Feb. 1982) by analysis of covariance. For both P. libellula and T. inermis separate regressions were also calculated for juveniles, males and females and the significance of differences among them was determined by analysis of covariance. For

S. elegans, separate regressions were obtained for each of the three maturity stages. Differences were again examined by analysis of covariance.

Biochemical composition/caloric content

Samples used in the biochemical composition/caloric content study were obtained from collections listed in table 18. Animals for analysis were removed from the zooplankton collections and transported, in insulated containers of seawater, to the laboratory. P. libellula and T. inermis were sorted into males, females and juveniles. S. elegans was grouped into three maturity stages according to criteria outlined by Dunbar (1962). The animals were then counted and sorted into the size categories listed in table 19. Samples of the various size groups were drained over vacuum after rinsing with ammonium formate (except for M. ovum which was drained as described earlier). The wet weights of the samples were determined. They were then frozen, freeze dried and stored at -20°C until analyzed. Dry weight was determined after heating the samples at 60°C for two hours and cooling in a dessicator. The mean dry weights of individuals contained in the various size groups are presented in tables 20-23. Tissues were finely ground in a mortar and pestle or dental amalgamator before analysis.

The caloric content of pelletized 10 to 20 mg samples was measured with a Phillipson micro-bomb calorimeter (Phillipson, 1964), using standard procedures. In the case of ctenophore tissue, which has a high inorganic content (≈63% of dry weight), it was necessary to add 10-30%

calorimetric grade benzoic acid to ensure complete ignition.

The water content was determined from the difference between live and dry weights of the animals in the various size classes.

Ash content was estimated by incinerating 30 to 60 mg of dry tissue at 500°C for four hours and weighing the residue.

Protein was measured spectrophotometrically by the biuret method according to the procedure of Bamstedt (1974). Samples of 5 to 10 mg were analyzed with bovine albumin being used as a standard.

Lipid was measured gravimetrically following extraction of 50 to 100 mg of dry tissue with chloroform-methanol (2:1) in a microsoxhlet extractor. The resulting crude lipid extract was washed with 0.9% NaCl to remove non-lipid contaminants according to the method of Folch et al. (1957). The solvent was evaporated at 70°C and the lipid residue held overnight in a dessicator prior to weighing.

The mean values and elementary statistics for the various analyses were calculated for each species, size group, collection period and, where appropriate, each sex and maturity stage. The influence of these factors on each of the components was examined by analysis of variance using the GLM procedure of the SAS statistical package (SAS Institute Inc., 1982). Main effects and interaction effects were examined in the analysis. Pairwise t-tests were performed for all main-effect means using the GLM procedure. Because this procedure yields a more liberal test of significance when cell sizes are unequal the most appropriate test of significance is at the 1% level.

RESULTS

List of Tables

Table 1. Macrozooplankton collections used in the study of length-weight relationships and list of the variables measured.

Species	Collection date	n	Variables*
Mertensia ovum	27 July 1979	55	V, LW, DW, AFDW, % ash
	22 Sept. 1979	60	V, LW, DW, AFDW, % ash
	20-26 Aug. 1981	60	V, L, LW, DW
	6-12 Sept. 1981	60	V, L, LW, DW
	8 Feb. 1982	60	L, LW, DW
Parathemisto libellula	3-4 Aug. 1979	78	sex, L, LW, DW, AFDW, % ash
	14 Sept. 1979	72	sex, L, LW, DW, AFDW, % ash
Sagitta elegans	7 Aug. 1979	60	stage, L, LW, DW, AFDW, % ash
	22 Sept. 1979	51	stage, L, LW, DW, AFDW, % ash
Thysanoessa inermis	23 Aug. 1979	60	sex, L, LW, DW, AFDW, % ash

* V volume (ml)
LW live weight (g)
DW dry weight (g)
AFDW ash free dry weight (g)
L body length (mm)
% ash ash content (percent of dry weight)
sex Male (M), Female (F), juvenile (J)
stage maturity stages 1, 2 or 3. (Dunbar, 1962)

Table 2. Regression equations for length-weight relationships of M. ovum during two open-water seasons and in the winter. Symbols and units as in table 1 and below.*

Collection date	Relationship	a	b	r^2	SER	SD
27/7/79	LW = a+bV	0.123	0.855	0.826	0.054	0.990
(n = 55)	DW = a+bV	0.011	0.033	0.812	0.002	0.040
	AFDW = a+bV	0.008	0.009	0.748	0.001	0.014
	DW = a+bLW	0.008	0.038	0.966	0.001	0.017
	AFDW = a+bLW	0.008	0.011	0.867	0.001	0.010
	AFDW = a+bDW	0.005	0.289	0.941	0.010	0.007
	% ash = a+bV	55.866	2.178	0.300	0.457	8.376
	% ash = a+bDW	56.435	56.744	0.270	12.814	8.555
22/9/79	LW = a+bV	0.139	0.904	0.956	0.026	0.602
(n = 60)	DW = a+bV	0.011	0.039	0.953	0.001	0.027
	AFDW = a+bV	0.008	0.013	0.889	0.001	0.014
	DW = a+bLW	0.005	0.043	0.992	0.001	0.011
	AFDW = a+bLW	0.006	0.014	0.918	0.001	0.012
	AFDW = a+bDW	0.003	0.332	0.960	0.009	0.008
	% ash = a+bV	59.932	0.813	0.199	0.214	5.037
	% ash = a+bDW	60.010	19.197	0.177	5.425	5.104
26/8/81	logV = a+blogL	-3.121	2.453	0.889	0.114	0.117
(n = 60)	logL = a+blogV	1.299	0.362	0.889	0.017	0.045
	logLW = a+blogL	-3.162	2.468	0.874	0.123	0.126
	logDW = a+blogL	-3.670	1.924	0.666	0.179	0.184
6-12/9/81	logV = a+blogL	-2.863	2.281	0.927	0.084	0.095
(n = 60)	logL = a+blogV	1.273	0.407	0.927	0.015	0.040
	logLW = a+blogL	-3.299	2.529	0.918	0.099	0.113
	logDW = a+blogL	-4.215	2.261	0.931	0.081	0.092
8/2/82	logLW = a+blogL	-3.389	2.691	0.943	0.088	0.113
(n = 58)	logDW = a+blogL	-4.466	2.553	0.771	0.184	0.239
	DW = a+bLW	0.017	0.045	0.901	0.002	0.075

* a b coefficients of indicated regression equation.
r^2 coefficient of determination for the regression.
SER standard error of the regression coefficient b.
SD standard deviation of the regression.
n number of observations in data set.

Table 3. Analysis of covariance of regressions for length-weight relations of M. ovum collected during the open-water season and in the winter. Symbols and units as in table 1 and below.*

Collections compared	Relationship	F	p
27/7/79 and 22/9/79	LW = a+bV	2.02	0.158
	DW = a+bV	14.36	0.0002
	AFDW = a+bV	21.88	0.0001
	% ash = a+bDW	2.42	0.1227
	DW = a+bLW	29.85	0.0001
20-26/8/81 and 6-12/9/81	logLW = a+blogL	4.25	0.042
	logDW = a+blogL	1.75	0.189
	logL = a+blogV	0.00	0.976
20-26/8/81 } and 8/2/82 6-12/9/81 }	logLW = a+blogL	45.99	0.0001
	logDW = a+blogL	31.95	0.0001
	DW = a+bLW	3.32	0.070

* F F statistic
p level of significance of difference between regressions.

Table 4. Combined regressions for length-weight relationships of *M. ovum* collected during the open-water seasons of 1979 and 1981. Symbols and units as in tables 1 and 2.

Collections combined	n	Relationship	a	b	r^2	SER	SD
27/7/79	115	LW = a+bV	0.101	0.890	0.905	0.027	0.814
and		DW = a+bV	0.007	0.037	0.892	0.001	0.037
22/9/79		AFDW = a+bV	0.006	0.012	0.814	0.001	0.016
		DW = a+bLW	0.004	0.042	0.976	0.001	0.017
		AFDW = a+bLW	0.005	0.013	0.879	0.000	0.013
		AFDW = a+bDW	0.003	0.322	0.951	0.007	0.008
		% ash = a+bV	58.461	1.300	0.213	0.235	7.065
		% ash = a+bDW	59.059	29.689	0.172	6.135	7.247
20-26/8/81	120	logV = a+blogL	-2.979	2.359	0.907	0.069	0.107
and		logL = a+blogV	1.286	0.385	0.907	0.011	0.043
6-12/9/81		logLW = a+blogL	-3.249	2.511	0.896	0.079	0.121
		logDW = a+blogL	-3.979	2.116	0.805	0.096	0.147
		DW = a+bLW	0.064	0.031	0.637	0.002	0.094

Table 5. Regression equations for length-weight relationships of P. libellula collected on 3 Aug. and 14 Sept. 1979. Symbols and units as in tables 1 and 2.

Collection date	Relationship	a	b	r^2	SER	SD
3/8/79	logLW = a+blogL	-4.537	2.674	0.982	0.042	0.085
(n = 78)	logDW = a+blogL	-5.340	2.782	0.980	0.045	0.092
	logAFDW = a+blogL	-5.675	2.967	0.953	0.075	0.154
	DW = a+bLW	0.0002	0.212	0.964	0.005	0.002
	AFDW = a+bLW	0.0002	0.167	0.939	0.005	0.002
	AFDW = a+bDW	-0.0001	0.794	0.996	0.006	0.001
	% ash = a+bL	36.832	-0.819	0.252	0.162	8.977
	% ash = a+bDW	30.502	-475.62	0.203	108.07	9.267
14/9/79	logLW = a+blogL	-4.600	2.733	0.984	0.041	0.037
(n = 72)	logDW = a+blogL	-5.349	2.797	0.940	0.083	0.074
	logAFDW = a+blogL	-5.516	2.847	0.910	0.107	0.095
	DW = a+bLW	0.0002	0.214	0.953	0.006	0.002
	AFDW = a+bLW	0.0001	0.171	0.918	0.006	0.003
	AFDW = a+bDW	-0.0003	0.814	0.994	0.007	0.001
	% ash = a+bL	25.354	-0.229	0.052	0.116	4.129
	% ash = a+bDW	23.597	-143.56	0.144	41.917	3.925

Table 6. Analysis of covariance of regressions for length-weight relationships of P. libellula collected on 3 Aug. and 14 Sept. 1979. Symbols and units as in tables 1 and 3.

Relationship	F	p
logLW = a+blogL	0.57	0.451
logDW = a+blogL	0.31	0.580
logAFDW = a+blogL	0.40	0.530
DW = a+bLW	0.11	0.737
AFDW = a+bLW	0.32	0.575
AFDW = a+bDW	0.29	0.594
% ash = a+bL	2.31	0.131
% ash = a+bDW	5.06	0.023

Table 7. Combined regressions for length-weight relationships of P. libellula collected during the open-water season (3 Aug. and 14 Sept. 1979). Symbols and units as in tables 1 and 2.

Relationship	a	b	r^2	SER	SD
logLW = a+blogL	-4.553	2.692	0.985	0.027	0.066
logDW = a+blogL	-5.348	2.793	0.978	0.034	0.083
logAFDW = a+blogL	-5.665	2.963	0.956	0.053	0.129
DW = a+bLW	0.0002	0.213	0.961	0.004	0.002
AFDW = a+bLW	0.0001	0.170	0.932	0.004	0.002
AFDW = a+bDW	-0.0002	0.806	0.995	0.005	0.0006
% ash = a+bL	34.533	-0.706	0.242	0.103	7.236
% ash = a+bDW	27.849	-330.535	0.186	56.851	7.499

Table 8. Regression equations for length-weight relationships of different sexes of P. libellula (3 Aug. and 14 Sept. 1979 data combined). Symbols and units as in tables 1 and 2.

Relationship	Sex	n	a	b	r^2	SER	SD
logLW = a+blogL	J	82	-4.536	2.675	0.972	0.051	0.081
	M	26	-4.972	3.002	0.968	0.111	0.030
	F	42	-4.704	2.815	0.931	0.121	0.046
logDW = a+blogL	J	82	-5.335	2.779	0.969	0.055	0.088
	M	26	-5.727	3.080	0.850	0.263	0.070
	F	42	-5.099	2.604	0.785	0.216	0.083
logAFDW = a+blogL	J	82	-5.335	2.779	0.969	0.055	0.088
	M	26	-5.857	3.105	0.784	0.333	0.088
	F	42	-5.123	2.543	0.678	0.277	0.106
% ash = a+bDW	J	82	32.880	-1355.767	0.283	241.015	8.409
	M	26	22.224	-101.014	0.060	81.476	3.742
	F	42	23.255	-101.748	0.048	71.733	4.344

Table 9. Analysis of covariance of regressions for length-weight relationships of different sexes of P. libellula (3 Aug. and 14 Sept. 1979 data combined). Symbols and units as in tables 1 and 3.

Relationship	F	p
logLW = a+blogL	0.74	0.477
logDW = a+blogL	0.14	0.869
logAFDW = a+blogL	0.13	0.878
% ash = a+bDW	0.06	0.946

Table 10. Regression equations for length-weight relationships of *S. elegans* collected on 7 Aug. and 22 Sept. 1979. Symbols and units as in tables 1 and 2.

Collection date	Relationship	a	b	r^2	SER	SD
7/8/79	logLW = a+blogL	-7.071	3.731	0.676	0.339	0.154
(n = 60)	logDW = a+blogL	-7.322	3.265	0.895	0.147	0.066
	logAFDW = a+blogL	-7.788	3.539	0.914	0.143	0.065
	DW = a+bLW	0.003	0.011	0.147	0.003	0.001
	AFDW = a+bLW	0.002	0.010	0.155	0.003	0.001
	AFDW = a+bDW	-0.0001	0.912	0.992	0.011	0.000
	% ash = a+bL	37.099	-0.801	0.404	0.128	3.763
	% ash = a+bDW	19.199	-1721.65	0.243	398.50	4.239
22/9/79	logLW = a+blogL	-5.879	2.991	0.895	0.147	0.047
(n = 51)	logDW = a+blogL	-7.277	3.265	0.889	0.165	0.052
	logAFDW = a+blogL	-7.854	3.604	0.884	0.186	0.059
	DW = a+bLW	-0.0002	0.109	0.927	0.004	0.000
	AFDW = a+bLW	-0.0005	0.102	0.920	0.004	0.000
	AFDW = a+bDW	-0.0003	0.939	0.990	0.013	0.000
	% ash = a+bL	42.271	-0.878	0.406	0.152	3.569
	% ash = a+bDW	21.801	-1697.72	0.359	324.5	3.709

Table 11. Analysis of covariance of regressions for length-weight relationships of S. elegans collected on 7 Aug. and 22 Sept. 1979. Symbols and units as in tables 1 and 3.

Relationship	F	p
logLW = a+blogL	1.84	0.178
logDW = a+blogL	11.80	0.008
logAFDW = a+blogL	5.10	0.026
DW = a+bLW	39.50	0.0001
AFDW = a+bLW	34.56	0.0001
AFDW = a+bDW	9.46	0.0027
% ash = a+bL	12.29	0.0007
% ash = a+bDW	9.07	0.0032

Table 12. Combined regressions for length-weight relationships of S. elegans collected during the open-water season (7 Aug. and 22 Sept. 1979). Symbols and units as in tables 1 and 2.

Relationship	a	b	r^2	SER	SD
logLW = a+blogL	-6.851	3.625	0.772	0.189	0.119
logDW = a+blogL	-7.566	3.443	0.916	0.100	0.063
logAFDW = a+blogL	-7.914	3.681	0.925	0.109	0.063
DW = a+bLW	0.003	0.020	0.198	0.004	0.002
AFDW = a+bLW	0.003	0.019	0.204	0.004	0.001
AFDW = a+bDW	-0.0002	0.913	0.993	0.008	0.0001
% ash = a+bL	34.270	-0.668	0.338	0.090	3.846
% ash = a+bDW	18.859	-1302.54	0.236	224.63	4.131

Table 13. Regression equations for length-weight relationships of different maturity stages of S. elegans (7 Aug. and 22 Sept. 1979 data combined). Symbols and units as in tables 1 and 2.

Relationship	Maturity	n	a	b	r^2	SER	SD
logLW = a+blogL	1	69	-7.051	3.762	0.912	0.143	0.073
	2	32	-6.515	3.397	0.419	0.730	0.196
	3	10	-6.394	3.304	0.972	0.197	0.049
logDW = a+blogL	1	69	-7.701	3.541	0.920	0.128	0.065
	2	32	-7.332	3.277	0.890	0.210	0.056
	3	10	-7.298	3.251	0.949	0.268	0.067
logAFDW = a+blogL	1	69	-8.069	3.744	0.926	0.129	0.066
	2	32	-7.995	3.681	0.919	0.199	0.053
	3	10	-7.637	3.434	0.944	0.295	0.074

Table 14. Analysis of covariance of regressions for length-weight relationships of different maturity stages of S. elegans (7 Aug. and 22 Sept. 1979 data combined). Symbols and units as in tables 1 and 3.

Relationship	F	p
logDW = a+blogL	0.09	0.913
logDW = a+blogL	1.60	0.207
logAFDW = a+blogL	1.30	0.277

Table 15. Regression equations for length-weight relationships of T. inermis collected on 23 Aug. 1979 (n = 60). Symbols and units as in tables 1 and 2.

Relationship	a	b	r^2	SER	SD
logLW = a+blogL	-5.912	3.527	0.927	0.129	0.086
logDW = a+blogL	-6.804	3.801	0.906	0.161	0.107
logAFDW = a+blogL	-6.954	3.883	0.903	0.168	0.111
DW = a+bLW	-0.001	0.323	0.951	0.010	0.003
AFDW = a+bLW	-0.001	0.299	0.945	0.010	0.003
AFDW = a+bDW	-0.0003	0.930	1.000	0.002	0.000
% ash = a+bL	15.708	-0.311	0.469	0.043	1.397
% ash = a+bDW	10.824	-82.221	0.434	12.314	1.433

Table 16. Regression equations for length-weight relationships of different sexes of *T. inermis* collected on 23 Aug. 1979. Symbols and units as in tables 1 and 2.

Relationship	Sex	n	a	b	r^2	SER	SD
logDW = a+blogL	J	16	-7.197	4.566	0.985	0.152	0.040
	M	9	-5.757	3.435	0.725	0.799	0.065
	F	35	-4.896	2.783	0.778	0.259	0.084
logDW = a+blogL	J	16	-8.026	4.786	0.953	0.285	0.075
	M	9	-6.049	3.547	0.670	0.941	0.076
	F	35	-5.656	2.961	0.707	0.331	0.108
logAFDW = a+blogL	J	16	-8.280	4.951	0.950	0.302	0.080
	M	9	-6.545	3.619	0.674	0.951	0.077
	F	35	-5.709	2.973	0.697	0.341	0.111
% ash = a+bDW	J	16	15.160	-469.910	0.821	57.943	1.120
	M	9	9.062	-35.960	0.490	13.870	0.436
	F	35	9.091	-33.577	0.244	10.302	0.787

Table 17. Analysis of covariance of regressions for length-weight relationships of different sexes of T. inermis collected on 23 Aug. 1979. Symbols and units as in tables 1 and 3.

Relationship	F	p
logLW = a+blogL	0.53	0.592
logDW = a+blogL	0.75	0.475
logAFDW = a+blogL	0.70	0.499
% ash = a+bDW	4.18	0.020

Table 18. Collection dates for macrozooplankton samples used in the biochemical composition/caloric content study.

Species	Collection date (1979)
Parathemisto libellula	31 July-2 August
	19-21 August
	7-9 September
	23-26 September
Mertensia ovum	25-27 July
	13 August
	28 August
	7-9 September
	17 September
Sagitta elegans	19-20 August
	14-17 September
Thysanoessa inermis	21-23 August

Table 19. Size group designations for macrozooplankton species used in the biochemical composition/caloric content study.

Species	Size group	Size range volume (ml)	Size range Length (mm)
Mertensia ovum	1	<0.9	(<18.6)*
	2	1.0 - 1.9	(19.3 - 24.7)
	3	2.0 - 2.9	(25.2 - 29.1)
	4	3.0 - 3.9	(29.5 - 32.6)
	5	4.0 - 4.9	(33.0 - 35.6)
	6	5.0 - 5.9	(35.9 - 38.3)
	7	6.0 - 6.9	(38.5 - 40.6)
	8	7.0 - 7.9	(40.9 - 42.8)
	9	8.0 - 8.9	(43.0 - 44.8)
	10	>9.0	(>45.0)
Parathemisto libellula} Thysanoessa inermis }	1		<4.9
	2		5.0 - 9.9
	3		10.0 - 14.9
	4		15.0 - 19.9
	5		20.0 - 24.9
	6		25.0 - 29.9
	7		30.0 - 34.9
	8		>35.0
Sagitta elegans	1		<9.9
	2		10.0 - 19.9
	3		20.0 - 29.9
	4		30.0 - 39.9
	5		>40.0

* lengths in parentheses calculated from volumes by the regression equation from table 4:

$$\log L = 1.286 + 0.385 \log V \quad (n = 120, r^2 = 0.91)$$

where: L = length in mm.
V = volume in ml.

Table 20. Mean dry weights of different size groups of M. ovum used in the biochemical composition/caloric content study. Symbols defined below.*

Size group	Nominal volume range (ml)	N (n)	Mean dry weight (mg)	SD
1	0.0 - 0.9	9 (263)	23.8	5.9
2	1.0 - 1.9	9 (112)	54.0	7.7
3	2.0 - 2.9	8 (72)	83.3	14.6
4	3.0 - 3.9	6 (47)	111.2	16.9
5	4.0 - 4.9	9 (50)	151.8	17.3
6	5.0 - 5.9	8 (31)	178.5	32.4
7	6.0 - 6.9	7 (25)	221.9	12.7
8	7.0 - 7.9	5 (17)	246.0	32.4
9	8.0 - 8.9	5 (9)	269.6	32.5
10	>9.0	7 (13)	346.3	64.7

* N number of subsamples used in analysis.
n total number of animals in all subsamples
SD standard deviation

Table 21. Mean live and dry weights of different size groups of *P. libellula* used in the biochemical composition/caloric content study. Symbols as in table 20.

Size group	Nominal length range (mm)	N (n)	Mean live weight (mg)	SD	Mean dry weight (mg)	SD
1	0.0 - 4.9	1 (10)	1.2	-	0.47	-
2	5.0 - 9.9	5 (272)	8.7	4.1	1.82	0.67
3	10.0 - 14.9	7 (283)	25.8	1.5	5.56	0.58
4	15.0 - 19.9	8 (216)	60.9	8.1	13.69	2.89
5	20.0 - 24.9	13 (134)	119.8	21.4	26.68	4.20
6	25.0 - 29.9	7 (30)	213.7	18.8	50.36	5.66
7	30.0 - 34.9	1 (2)	308.7	-	76.64	-
8	>35.0	1 (1)	330.4	-	63.89	-

Table 22. Mean live and dry weights of different size groups of *S. elegans* used in the biochemical composition/caloric content study. Symbols as in table 20.

Size group	Nominal length range (mm)	N (n)	Mean live weight (mg)	SD	Mean dry weight (mg)	SD
3	20.0 - 29.9	7 (153)	24.3	3.1	2.68	0.39
4	30.0 - 39.9	9 (306)	46.6	5.4	4.91	0.49
5	>40.0	5 (22)	94.3	10.6	9.74	1.55

Table 23. Mean live and dry weights of different size groups of *T. inermis* used in the biochemical composition/caloric content study. Symbols as in table 20.

Size group	Nominal length range (mm)	N (n)	Mean live weight (mg)	SD	Mean dry weight (mg)	SD
3	10.0 - 14.9	1 (22)	8.5	-	2.6	-
4	15.0 - 19.9	1 (25)	88.1	-	11.8	-
5	20.0 - 24.9	3 (110)	93.1	19.0	27.6	7.7
6	25.0 - 29.9	2 (36)	145.5	8.9	43.6	5.6
7	30.0 - 34.9	1 (3)	-	-	64.3	-

Table 24. Caloric content (calories/mg dry weight) of M. ovum of different sizes at different times during the open-water season. Symbols defined below.*

Date	Size group	n	$\bar{X}$ (calories/mg)	SD	CV
$\sum$	$\sum$	112	1.592	0.541	33.96
25-27/7	$\sum$	13	1.038	0.420	40.44
	3	3	1.620	0.151	9.32
	5	4	1.190	0.050	4.17
	7	2	0.720	0.042	5.89
	10	4	0.608	0.047	7.77
13/8	$\sum$	16	1.222	0.236	19.35
	3	5	1.528	0.135	8.86
	5	4	1.085	0.048	4.42
	7	2	1.085	0.163	14.99
	10	5	1.080	0.112	10.41
28/8	$\sum$	19	1.323	0.173	13.11
	3	5	1.528	0.212	13.89
	5	5	1.242	0.023	1.84
	7	3	1.270	0.020	1.58
	10	6	1.245	0.118	9.51
7-9/9	$\sum$	44	2.006	0.537	26.77
	1	4	2.495	0.227	9.10
	2	5	2.192	0.203	9.25
	3	5	2.884	0.203	7.02
	4	5	2.418	0.208	8.62
	5	5	1.670	0.118	7.05
	6	4	2.150	0.342	15.93
	7	4	1.558	0.310	19.92
	8	5	1.628	0.121	7.41
	9	2	1.310	0.028	2.16
	10	5	1.376	0.094	6.83
17/9	$\sum$	20	1.595	0.275	17.27
	3	5	1.990	0.090	4.52
	5	5	1.494	0.165	11.03
	7	5	1.576	0.092	5.84
	10	5	1.318	0.111	8.46

* $\sum$ indicates that the statistics apply to the combined subgroups of the particular variable.
n number of observations in data set.
$\bar{X}$ mean.
SD standard deviation.
CV coefficient of variation.

Table 25. Analysis of variance for the effect of date and size on the caloric content (calories/mg dry weight) of M. ovum during the open-water season. Symbols defined below.*

Source	df	SS	MS	F value
Model	25	30.30	1.212	48.62
Error	86	2.14	0.025	$p < 0.001$
Total	111	32.45		

$r^2 = 0.933$ CV = 9.916 SD = 0.158 $\bar{X}$ = 1.592 calories/mg

Source	df	SS	F value	p
Date	4	15.11	151.55	0.0001
Size	9	11.96	53.30	0.0001
Date X size	12	3.23	10.81	0.0001

Variable	n	$\bar{X}$ (calories/mg)	Significance $p < 0.05$	Significance $p < 0.01$
Date				
7-9/9	44	2.006	A	A
17/9	20	1.595	B	B
28/8	19	1.323	C	C
13/8	16	1.222	C	C
25-27/7	13	1.038	D	D
Size				
1	4	2.495	A	A
4	5	2.418	A	AB
2	5	2.192	B	BC
6	4	2.150	B	CD
3	23	1.935	C	D
8	5	1.628	D	E
5	23	1.354	E	F
7	16	1.346	E	F
9	2	1.310	EF	F
10	25	1.151	F	F

* df degrees of freedom.
SS sum of squares.
MS mean square.
r^2 coefficient of determination.
p significance level.
CV coefficient of variance.
SD standard deviation.
$\bar{X}$ mean.
n number of observations in data set.
A B C D E F means with the same letter not significantly different at level indicated; t-test on paired means.

Table 26. Caloric content (cal/mg dry weight) of P. libellula of different sizes at different times during the open-water season. Symbols as in table 24.

Date	Size group	Sex	n	$\bar{X}$ (calories/mg)	SD	CV
∑	∑	∑	73	4.950	0.372	7.51
31/7-2/8	∑	∑	14	4.673	0.254	5.44
	2	J	3	4.400	0.036	0.82
	3	J	3	4.543	0.127	2.80
	4	J	3	4.610	0.217	4.71
	5	F	5	4.952	0.096	1.93
19-21/8	∑	∑	22	4.928	0.358	7.26
	2	J	3	4.590	0.115	2.51
	3	J	3	4.410	0.072	1.64
	4	J	3	4.913	0.025	0.51
	5	∑	10	5.227	0.241	4.61
	5	F	5	5.080	0.250	4.93
	5	M	5	5.374	0.118	2.19
	6	F	3	4.800	0.131	2.73
7-9/9	∑	∑	24	5.083	0.427	8.40
	3	J	5	4.798	0.231	4.81
	4	J	5	4.976	0.260	5.23
	5	∑	9	4.979	0.410	8.23
	5	F	5	5.302	0.127	2.40
	5	M	4	4.575	0.187	4.10
	6	F	5	5.664	0.169	2.98
23-26/9	∑	∑	13	5.039	0.225	4.46
	5	∑	10	5.129	0.136	2.65
	5	F	5	5.048	0.084	1.67
	5	M	5	5.210	0.134	2.57
	6	F	3	4.740	0.214	4.51

Table 27. Analysis of variance for the effect of date, size and sex on the caloric content (calories/mg dry weight) of P. libellula during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	17	8.44	0.496	18.15
Error	55	1.50	0.027	$p < 0.001$
Total	72	9.94		

$r^2 = 0.849$ CV = 3.341 SD = 0.165 $\bar{X}$ = 4.950 calories/mg

Source	df	SS	F value	p
Date	3	1.62	19.71	0.0001
Size	4	2.89	26.46	0.0001
Sex	1	0.02	0.61	0.440
Date X size	7	2.49	12.99	0.0001
Date X sex	2	1.42	26.06	0.0001

Variable	n	$\bar{X}$ (calories/mg)	Significance $p < 0.05$	Significance $p < 0.01$
Date				
7-9/9	24	5.083	A	A
23-26/9	13	5.039	AB	AB
19-21/8	22	4.928	B	B
31/7-2/8	14	4.673	C	C
Size				
6	11	5.176	A	A
5	34	5.092	A	A
4	11	4.859	B	B
3	11	4.623	C	C
2	6	4.495	C	C
Sex				
F	31	5.124	A	A
M	14	5.087	A	A
J	28	4.688	B	B

Table 28. Caloric content (calories/mg dry weight) of S. elegans of different sizes and maturity stages at different times during the open-water season. Symbols as in table 24.

Date	Size group	Stage	n	$\bar{X}$ (calories/mg)	SD	CV
∑	∑	∑	51	5.151	0.310	6.02
19-20/8	∑	∑	33	5.045	0.229	4.55
	3	∑	9	4.812	0.165	3.44
	3	1	5	4.816	0.078	1.62
	3	2	2	4.995	0.049	0.99
	3	3	2	4.620	0.226	4.90
	4	∑	14	5.127	0.126	2.46
	4	1	5	5.100	0.118	2.32
	4	2	4	5.223	0.109	2.08
	4	3	5	5.078	0.126	2.49
	5	∑	10	5.138	0.256	4.97
	5	1	2	5.485	0.049	0.90
	5	2	4	4.945	0.197	3.99
	5	3	4	5.158	0.160	3.10
14-17/9	∑	∑	18	5.347	0.348	6.52
	3	∑	11	5.401	0.416	7.70
	3	1	7	5.323	0.477	8.96
	3	2	4	5.538	0.287	5.19
	4	1	5	5.162	0.110	2.12
	5	2	2	5.510	0.170	3.08

Table 29. Analysis of variance for the effect of date, size and maturity stage on the caloric content (calories/mg dry weight) of S. elegans during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	12	2.69	0.22	4.02
Error	38	2.12	0.06	$p < 0.0005$
Total	50	4.81		

$r^2 = 0.559$ CV = 4.585 SD = 0.236 $\overline{X}$ = 5.151 calories/mg

Source	df	SS	F value	p
Date	1	1.06	19.06	0.0001
Size	2	0.28	2.48	0.097
Stage	2	0.10	0.94	0.399
Date X size	2	0.59	5.33	0.009
Date X stage	1	0.13	2.25	0.1418
Size X stage	4	0.53	2.35	0.0712

Variable	n	$\overline{X}$ (calories/mg)	Significance $p < 0.05$	$p < 0.01$
Date				
14-17/9	18	5.347	A	A
19-20/8	33	5.045	B	B
Size				
5	12	5.200	A	A
4	19	5.136	A	A
3	20	5.136	A	A
Stage				
2	16	5.239	A	A
1	24	5.151	AB	A
3	11	5.024	B	A

Table 30. Caloric content (calories/mg dry weight) of T. inermis of different sizes during the open-water season. Symbols as in table 24.

Date	Size group	Sex	n	$\bar{X}$ (calories/mg)	SD	CV
21-23/8	$\sum$	$\sum$	34	6.267	0.442	7.05
	3	J	5	5.476	0.178	3.26
	4	J	5	5.934	0.190	3.20
	5	$\sum$	10	6.385	0.236	3.69
	5	F	5	6.310	0.256	4.05
	5	M	5	6.460	0.214	3.31
	6	$\sum$	9	6.587	0.213	3.24
	6	F	4	6.678	0.120	1.79
	6	M	5	6.514	0.256	3.93
	7	F	5	6.580	0.138	2.10

Table 31. Analysis of variance for the effect of size and sex on the caloric content (calories/mg dry weight) of T. inermis during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	6	5.35	0.89	21.94
Error	27	1.10	0.04	$p < 0.0001$
Total	33	6.44		

$r^2 = 0.830$ CV = 3.216 SD = 0.202 $\bar{X}$ = 6.267 calories/mg

Source	df	SS	F value	p
Size	4	5.23	32.20	0.0001
Sex	1	0.00	0.00	0.979
Size X sex	1	0.12	2.85	0.103

Variable	n	$\bar{X}$ (calories/mg)	Significance $p < 0.05$	$p < 0.01$
Size				
6	9	6.587	A	A
7	5	6.580	A	A
5	10	6.385	A	A
4	5	5.934	B	B
3	5	5.476	C	C
Sex				
F	14	6.511	A	A
M	10	6.487	A	A
J	10	5.705	B	B

Table 32. Water content (percent of live weight) of P. libellula of different sizes at different times during the open-water season. Symbols as in table 24.

Date	Size group	Sex	N (n)	$\bar{X}$ (% water)	SD	CV
∑	∑	∑	40 (895)	77.32	2.24	2.90
31/7-2/8	∑	∑	8 (262)	78.85	2.06	2.62
	2	J	3 (151)	77.40	2.67	3.45
	3	J	3 (97)	79.36	1.45	1.83
	4	J	1 (13)	79.84	-	-
	8	F	1 (1)	80.66	-	-
19-21/8	∑	∑	6 (415)	77.70	1.35	1.74
	2	J	1 (120)	77.16	-	-
	3	J	1 (165)	80.25	-	-
	4	J	1 (77)	77.93	-	-
	5	∑	2 (42)	76.72	0.48	0.63
	5	F	1 (18)	77.06	-	-
	5	M	1 (24)	76.38	-	-
	6	M	1 (11)	77.41	-	-
7-9/9	∑	∑	15 (93)	77.62	2.11	2.71
	2	J	1 (1)	81.70	-	-
	3	J	3 (21)	76.79	0.86	1.12
	4	J	3 (49)	77.16	0.73	0.95
	5	∑	6 (19)	77.94	1.62	2.08
	5	F	3 (12)	78.15	0.61	0.78
	5	M	3 (7)	77.74	2.47	3.17
	6	F	2 (3)	76.54	4.91	6.41
23-26/9	∑	∑	11 (125)	75.60	2.05	2.71
	4	J	2 (39)	75.03	0.86	1.15
	5	∑	5 (68)	75.74	1.55	2.04
	5	F	3 (37)	75.82	2.11	2.78
	5	M	2 (31)	75.62	0.78	1.04
	6	∑	3 (16)	75.88	3.91	5.15
	6	F	2 (12)	77.78	3.01	3.86
	6	M	1 (4)	72.10	-	-
	7	F	1 (2)	75.17	-	-

Table 33. Analysis of variance for the effect of date, size and sex on the water content (percent of live weight) of P. libellula during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	21	119.16	5.67	1.32
Error	18	77.30	4.29	p = 0.2773
Total	39	196.46		

r^2 = 0.607 CV = 2.680 SD = 2.072 $\overline{X}$ = 77.32%

Source	df	SS	F value	p
Date	3	53.44	4.15	0.0212
Size	6	5.79	0.22	0.9635
Sex	1	4.44	1.03	0.3230
Date X size	8	39.91	1.16	0.3728
Date X sex	2	2.76	0.32	0.7289
Size X sex	1	12.82	2.99	0.1011

Variable	n	$\overline{X}$ (% water)	Significance p<0.05	Significance p<0.01
Date				
31/7-2/8	8	78.85	A	A
19-21/8	6	77.70	A	AB
7-9/9	15	77.62	AB	AB
23-26/9	11	75.60	B	B
Size				
8	1	80.66	A	A
3	7	78.38	AB	AB
2	5	78.21	AB	AB
4	7	77.04	AB	AB
5	13	76.91	B	AB
6	6	76.36	B	AB
7	1	75.17	B	B
Sex				
J	19	77.84	A	A
F	13	77.19	A	A
M	8	76.29	A	A

Table 34. Water content (percent of live weight) of S. elegans of different sizes and maturity stages at different times during the open-water season. Symbols as in table 24.

Date	Size group	Stage	N (n)	$\bar{X}$ (% water)	SD	CV
∑	∑	∑	20 (466)	89.37	0.50	0.56
19-20/8	∑	∑	8 (229)	89.63	0.23	0.26
	3	∑	3 (73)	89.65	0.32	0.36
	3	1	1 (52)	89.71	-	-
	3	2	1 (15)	89.30	-	-
	3	3	1 (6)	89.94	-	-
	4	∑	3 (146)	89.59	0.29	0.33
	4	1	1 (76)	89.90	-	-
	4	2	1 (31)	89.32	-	-
	4	3	1 (39)	89.56	-	-
	5	∑	2 (10)	89.64	0.02	0.02
	5	2	1 (5)	89.62	-	-
	5	3	1 (5)	89.65	-	-
14-17/9	∑	∑	12 (237)	89.20	0.57	0.64
	3	∑	4 (65)	88.99	0.79	0.89
	3	1	2 (45)	89.11	0.59	0.67
	3	2	2 (20)	88.86	1.20	1.35
	4	∑	6 (160)	89.44	0.35	0.39
	4	1	3 (70)	89.35	0.46	0.52
	4	2	3 (90)	89.53	0.26	0.29
	5	2	2 (12)	88.93	0.66	0.74

Table 35. Analysis of variance for the effect of date, size and maturity stage on the water content (percent of live weight) of S. elegans. Symbols as in table 25.

Source	df	SS	MS	F value
Model	12	2.03	0.169	0.42
Error	7	2.79	0.399	p = 0.9081
Total	19	4.82		

r^2 = 0.421 CV = 0.707 SD = 0.632 $\overline{X}$ = 89.37%

Source	df	SS	F value	p
Date	1	0.857	2.15	0.186
Size	2	0.364	0.46	0.651
Stage	2	0.124	0.16	0.859
Date X size	2	0.297	0.37	0.702
Date X stage	1	0.141	0.35	0.571
Size X stage	3	0.187	0.16	0.9223
Date X size X stage	1	0.062	0.16	0.7049

Variable	n	$\overline{X}$ (% water)	Significance $p<0.05$	$p<0.01$
Date				
19-20/8	8	89.63	A	A
14-17/9	12	89.20	A	A
Size				
4	9	89.49	A	A
5	4	89.28	A	A
3	7	89.27	A	A
Stage				
3	3	89.72	A	A
1	7	89.41	A	A
2	10	89.24	A	A

Table 36. Water content (percent of live weight) of T. inermis of different sizes during the open-water season. Symbols as in table 24.

Date	Size group	Sex	N (n)	$\bar{X}$ (% water)	SD	CV
$\sum$	$\sum$	$\sum$	5 (149)	67.02	1.70	2.54
21-23/8	3	J	1 (22)	70.02	-	-
	5	$\sum$	2 (91)	66.40	0.23	0.35
	5	F	1 (63)	66.56	-	-
	5	M	1 (28)	66.23	-	-
	6	$\sum$	2 (36)	66.16	0.46	0.70
	6	F	1 (24)	66.48	-	-
	6	M	1 (12)	65.83	-	-

Table 37. Ash content (percent of dry weight) of M. ovum of different sizes at different times in the open-water season. Symbols as in table 24.

Date	Size group	n	$\bar{X}$ (% ash)	SD	CV
∑	∑	157	63.22	4.56	7.21
25-27/7	∑	29	64.76	6.52	10.07
	1	2	50.55	0.12	0.24
	2	3	55.75	0.42	0.75
	3	4	59.97	0.52	0.87
	4	3	65.21	0.74	1.13
	5	3	68.17	1.46	2.14
	6	3	64.73	0.26	0.40
	7	2	71.38	0.58	0.81
	8	3	71.64	0.42	0.59
	9	3	69.50	0.69	1.00
	10	3	69.74	4.28	6.13
13/8	∑	34	66.12	2.43	3.67
	1	4	63.67	0.37	0.58
	2	4	65.49	0.51	0.79
	3	3	66.79	0.52	0.77
	4	3	67.03	0.78	1.16
	5	4	67.66	0.22	0.33
	6	3	67.26	0.40	0.60
	7	3	64.29	5.71	8.87
	8	4	64.40	1.74	2.71
	9	2	67.65	0.05	0.07
	10	4	67.96	3.37	4.96
28/8	∑	25	60.68	5.07	8.36
	1	4	49.96	0.56	1.12
	2	4	60.00	0.32	0.54
	3	1	61.80	-	-
	5	4	61.54	1.60	2.59
	6	4	64.37	0.63	0.98
	9	4	63.85	0.31	0.49
	10	4	64.09	0.20	0.31

Table 37. Continued.

Date	Size group	n	$\overline{X}$ (% ash)	SD	CV
7-9/9	$\sum$	36	61.27	3.64	5.94
	1	4	58.31	0.27	0.46
	2	4	60.67	1.97	3.25
	3	4	60.55	2.47	4.08
	4	4	63.60	0.64	1.00
	5	4	64.19	2.02	3.14
	6	4	61.88	4.85	7.84
	7	4	64.52	1.38	2.14
	8	4	61.46	3.58	5.83
	10	4	56.28	4.74	8.42
17/9	$\sum$	33	62.94	1.91	3.03
	1	3	64.94	0.36	0.56
	2	3	62.11	0.44	0.71
	3	7	61.87	0.53	0.85
	4	3	60.59	0.71	1.18
	5	3	63.05	0.16	0.26
	6	2	63.23	1.87	2.96
	7	3	64.81	3.89	6.00
	8	3	62.01	0.17	0.27
	9	3	62.82	1.96	3.11
	10	3	65.48	0.04	0.06

Table 38. Analysis of variance for the effect of date and size on the ash content (percent of dry weight) of M. ovum during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	45	2799.84	62.22	15.77
Error	111	437.87	3.94	$p < 0.0001$
Total	156	3237.71		

$r^2 = 0.865$ CV = 3.142 SD = 1.986 $\overline{X} = 63.22\%$

Source	df	SS	F value	p
Date	4	654.86	41.50	0.0001
Size	9	819.44	23.08	0.0001
Date X size	32	1325.55	10.50	0.0001

Variable	n	$\overline{X}$ (% ash)	Significance $p<0.05$	$p<0.01$
Date				
13/8	34	66.12	A	A
25-27/7	29	64.76	B	B
17/9	33	62.94	C	C
7-9/9	36	61.27	D	D
28/8	25	60.68	D	D
Size				
7	12	65.68	A	A
9	12	65.63	AB	A
5	18	64.84	ABC	A
8	14	64.60	ABC	A
10	18	64.39	ABC	A
6	16	64.21	BC	A
4	13	64.07	C	A
3	19	61.96	D	B
2	18	61.01	D	B
1	17	57.86	E	C

Table 39. Ash content of P. libellula, S. elegans and T. inermis of different sizes at different times during the open-water season. Symbols as in table 24.

Species	Date	Size group	Sex/stage	n	$\bar{X}$ (% ash)	SD	CV
P. libellula	∑	∑	∑	31	19.36	2.43	12.57
	31/7-2/8	∑	∑	14	21.20	2.36	11.15
		1	J	2	24.17	0.42	1.74
		2	J	4	21.55	0.16	0.74
		3	J	4	18.24	1.27	6.96
		4	J	4	22.31	1.77	7.93
	19-21/8	∑	∑	10	17.19	0.88	5.13
		5	∑	8	17.06	0.94	5.54
		5	-	2	18.58	0.11	0.59
		5	M	6	16.56	0.13	0.79
		6	F	2	17.69	0.34	1.92
	23-26/9	∑	∑	7	18.80	0.48	2.57
		5	F	3	19.20	0.02	0.10
		5	M	4	18.50	0.44	2.38
S. elegans	∑	∑	∑	10	15.75	0.84	5.31
	19-20/8	∑	∑	3	16.03	0.91	5.69
		3	1	1	16.98	-	-
		4	∑	2	15.56	0.56	3.59
		4	1	1	15.95	-	-
		4	1	1	15.16	-	-
	14-17/9	∑	∑	7	15.63	0.85	5.41
		1	1	1	16.54	-	-
		4	∑	6	15.48	0.82	5.28
		4	1	3	15.80	1.14	7.22
		4	2	3	15.16	0.25	1.66
T. inermis	21-23/8	∑	∑	16	7.64	0.72	9.40
		4	J	4	8.76	0.18	2.06
		5	∑	8	7.44	0.07	0.96
		5	F	4	7.46	0.11	1.42
		5	M	4	7.42	0.01	0.18
		6	F	4	6.92	0.23	3.38

Table 40. Analysis of variance for the effect of date, size and sex on the ash content (percent of dry weight) of P. libellula during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	8	162.39	20.30	29.20
Error	22	15.30	0.70	$p < 0.0001$
Total	30	177.68		

$r^2 = 0.914$ CV = 4.306 SD = 0.834 $\overline{X}$ = 19.36%

Source	df	SS	F value	p
Date	2	96.70	69.54	0.0001
Sex	4	58.71	21.11	0.0001
Size	2	6.98	5.02	0.0160

Variable	n	$\overline{X}$ (% ash)	Significance $p < 0.05$	Significance $p < 0.01$
Date				
31/7-2/8	14	21.20	A	A
23-26/9	7	18.80	B	B
19-21/8	10	17.19	C	C
Size				
1	2	24.17	A	A
4	4	22.31	B	B
2	4	21.55	B	B
3	4	18.24	C	C
5	15	17.87	C	C
6	2	17.69	C	C
Sex				
J	14	21.20	A	A
F	5	18.59	B	B
M	10	17.33	C	B

Table 41. Analysis of variance for the effect of date, size and maturity stage on the ash content (percent of dry weight) of S. elegans during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	5	3.58	0.716	1.05
Error	4	2.72	0.679	p = 0.494
Total	9	6.29		

r^2 = 0.568 CV = 5.232 SD = 0.824 $\overline{X}$ = 15.75%

Source	df	SS	F value	p
Date	1	0.33	0.49	0.523
Size	2	2.31	1.70	0.291
Stage	1	0.92	1.36	0.308
Date X stage	1	0.01	0.01	0.919

Variable	n	$\overline{X}$ (% ash)	Significance $p < 0.05$	$p < 0.01$
Date				
19-20/8	3	16.03	A	A
14-17/9	7	15.63	A	A
Size				
3	1	16.98	A	A
1	1	16.54	A	A
4	8	15.50	A	A
Stage				
1	6	16.15	A	A
2	4	15.16	A	A

Table 42. Analysis of variance for the effect of size and sex on the ash content (percent of dry weight) of T. inermis during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	3	7.45	2.48	100.04
Error	12	0.30	0.02	$p < 0.0001$
Total	15	7.74		

$r^2 = 0.962$ CV = 2.062 SD = 0.158 $\bar{X}$ = 7.64%

Source	df	SS	F value	p
Size	2	7.44	150.02	0.0001
Sex	1	0.002	0.09	0.775

Variable	n	$\bar{X}$ (% ash)	Significance $p < 0.05$	$p < 0.01$
Size				
4	4	8.76	A	A
5	8	7.44	B	B
6	4	6.92	C	C
Sex				
M	4	7.43	A	A
F	8	7.19	B	A

Table 43. Lipid content (percent of dry weight) of M. ovum of different sizes at different times during the open-water season. Symbols as in table 24.

Date	Size group	n	$\bar{X}$ (% lipid)	SD	CV
$\sum$	$\sum$	210	5.54	1.94	35.00
25-27/7	$\sum$	51	4.51	1.33	29.53
	1	5	6.40	0.66	10.29
	2	3	6.94	0.87	12.56
	3	9	5.22	0.69	13.30
	4	4	5.06	0.16	3.11
	5	4	3.94	0.13	3.26
	6	9	4.11	0.80	19.39
	7	4	2.32	0.15	6.52
	8	4	3.07	0.16	5.08
	9	4	3.51	0.16	4.69
	10	5	4.35	0.36	8.20
13/8	$\sum$	40	4.39	0.94	21.46
	1	4	6.03	0.41	6.74
	2	4	4.71	0.69	14.55
	3	4	4.10	0.08	1.92
	4	4	4.01	0.81	20.31
	5	4	3.37	0.08	2.28
	6	4	4.32	0.50	11.56
	7	4	3.19	0.13	3.98
	8	4	3.78	0.56	14.87
	9	4	5.11	0.19	3.71
	10	4	5.28	0.15	2.86
28/8	$\sum$	35	5.04	1.21	23.94
	1	4	7.25	0.26	3.54
	2	4	6.67	0.44	6.64
	3	4	4.79	0.11	2.26
	5	4	4.55	0.32	6.94
	6	4	5.06	0.49	9.62
	7	4	3.33	0.13	3.87
	8	4	5.03	0.19	3.80
	9	3	4.08	0.12	2.83
	10	4	4.39	0.10	2.20

Table 43. Continued.

Date	Size group	n	$\bar{X}$ (% lipid)	SD	CV
7-9/9	$\sum$	39	6.43	2.29	35.61
	1	4	7.69	0.18	2.30
	2	5	8.88	1.22	13.68
	3	3	10.85	0.17	1.58
	4	4	8.11	0.20	2.49
	5	4	5.26	0.20	3.83
	6	4	6.37	0.23	3.66
	7	4	4.46	0.06	1.40
	8	4	5.32	0.08	1.57
	9	3	2.84	0.06	2.20
	10	4	4.10	0.19	4.64
17/9	$\sum$	45	7.36	1.65	22.42
	1	4	6.53	0.62	9.44
	2	4	10.57	0.74	7.01
	3	4	8.93	0.03	0.30
	4	5	7.91	0.48	6.04
	5	4	6.96	0.22	3.19
	6	4	4.97	0.53	10.70
	7	7	7.09	0.22	3.06
	8	5	8.77	0.53	6.10
	9	4	6.46	0.47	7.30
	10	4	5.10	0.13	2.63

Table 44. Analysis of variance for the effect of date and size on the lipid content (percent of dry weight) of M. ovum during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	48	751.92	15.67	73.30
Error	161	34.41	0.21	$p < 0.0001$
Total	209	786.32		

$r^2 = 0.956$ CV = 8.341 SD = 0.462 $\bar{X}$ = 5.54%

Source	df	SS	F value	p
Date	4	294.55	344.58	0.0001
Size	9	238.28	123.89	0.0001
Date X size	35	219.09	29.29	0.0001

Variable	n	$\bar{X}$ (% lipid)	Significance $p < 0.05$	Significance $p < 0.01$
Date				
17/9	45	7.36	A	A
7-9/9	39	6.43	B	B
28/8	35	5.04	C	C
25-27/7	51	4.51	D	D
13/8	40	4.39	D	D
Size				
2	20	7.65	A	A
1	21	6.76	B	B
4	17	6.36	C	C
3	24	6.28	C	C
8	21	5.36	D	D
5	20	4.82	E	E
6	25	4.80	E	E
10	21	4.63	EF	E
9	18	4.50	F	E
7	23	4.47	F	E

Table 45. Lipid content (percent of dry weight) of P. libellula of different sizes at different times during the open-water season. Symbols as in table 24.

Date	Size group	Sex	n	$\bar{X}$ (% lipid)	SD	CV
∑	∑	∑	77	24.61	5.32	21.61
31/7-2/8	∑	∑	13	17.69	1.64	9.25
	2	J	3	16.08	0.63	3.90
	3	J	4	19.15	0.50	2.63
	4	J	4	18.50	0.94	5.07
	8	M	2	15.57	0.23	1.45
19-21/8	∑	∑	26	25.84	4.44	17.18
	2	J	3	18.03	0.35	1.92
	3	J	3	18.82	0.72	3.81
	4	J	4	26.66	0.32	1.21
	5	∑	8	27.90	2.36	8.47
	5	F	4	25.70	0.30	1.18
	5	M	4	30.09	0.33	1.10
	6	∑	8	28.94	1.06	3.66
	6	F	4	29.71	0.84	2.81
	6	M	4	28.18	0.59	2.10
7-9/9	∑	∑	14	23.46	3.23	13.77
	3	J	2	19.32	1.57	8.13
	4	J	4	22.02	0.26	1.19
	5	∑	6	24.37	2.08	8.54
	5	F	4	23.67	2.29	9.66
	5	M	2	25.78	0.23	0.91
	6	F	2	27.73	5.22	18.82
23-26/9	∑	∑	24	27.69	5.02	18.14
	4	J	3	24.13	0.81	3.36
	5	∑	8	26.68	1.68	6.28
	5	F	4	25.12	0.20	0.81
	5	M	4	28.25	0.08	0.30
	6	∑	8	28.82	8.29	28.77
	6	F	4	21.07	0.40	1.90
	6	M	4	36.56	0.32	0.88
	7	F	5	29.64	0.89	3.00

Table 46. Analysis of variance for the effect of date, size and sex on the lipid content (percent of dry weight) of P. libellula during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	21	2088.28	99.44	90.24
Error	55	60.61	1.10	$p < 0.0001$
Total	76	2148.88		

$r^2 = 0.972$ CV = 4.266 SD = 1.050 $\overline{X}$ = 24.61%

Source	df	SS	F value	p
Date	3	907.92	274.64	0.0001
Size	6	551.77	83.46	0.0001
Sex	1	212.83	193.14	0.0001
Date X size	7	91.23	11.83	0.0001
Date X sex	2	136.50	61.93	0.0001
Size X sex	1	20.82	18.89	0.0001
Date X size X sex	1	167.22	151.75	0.0001

Variable	n	$\overline{X}$ (% lipid)	Significance $p < 0.05$	$p < 0.01$
Date				
23-26/9	24	27.69	A	A
19-21/8	26	25.84	B	B
7-9/9	14	23.46	C	C
31/7-2/8	13	17.69	D	D
Size				
7	5	29.64	A	A
6	18	28.75	A	A
5	22	26.49	B	B
4	15	22.74	C	C
3	9	19.08	D	D
2	6	17.06	E	E
8	2	15.57	F	E
Sex				
M	20	28.75	A	A
F	27	26.10	B	B
J	30	20.50	C	C

Table 47. Lipid content (percent of dry weight) of S. elegans of different sizes at different times during the open-water season. Symbols as in table 24.

Date	Size group	Stage	n	$\bar{X}$ (% lipid)	SD	CV
∑	∑	∑	16	21.86	1.79	8.20
19-20/8	∑	∑	8	21.44	1.33	6.22
	3	1	1	18.17	-	-
	4	∑	7	21.90	0.20	0.93
	4	1	3	22.05	0.21	0.93
	4	2	2	21.79	0.21	0.94
	4	3	2	21.81	0.12	0.55
14-17/9	∑	∑	8	22.28	2.17	9.73
	3	∑	3	20.37	0.75	3.69
	3	1	2	19.95	0.24	1.21
	3	2	1	21.22	-	-
	4	∑	3	22.20	0.16	0.70
	4	1	1	22.11	-	-
	4	2	2	22.25	0.19	0.86
	5	2	2	25.27	1.70	6.72

Table 48. Analysis of variance for the effect of date, size and maturity stage on the lipid content (percent of dry weight) of S. elegans during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	8	45.06	5.63	12.66
Error	7	3.12	0.44	$p < 0.0016$
Total	15	48.17		

$r^2 = 0.935$ CV = 3.052 SD = 0.667 $\overline{X}$ = 21.86%

Source	df	SS	F value	p
Date	1	2.86	4.44	0.0388
Size	2	38.99	43.81	0.0001
Stage	2	0.20	0.22	0.8073
Date X size	1	1.99	4.47	0.0722
Date X sex	1	0.59	1.32	0.2844
Size X sex	1	0.43	0.96	0.3587

Variable	n	$\overline{X}$ (% lipid)	Significance $p < 0.05$	$p < 0.01$
Date				
14-17/9	8	22.28	A	A
19-20/8	8	21.44	B	A
Size				
5	2	25.27	A	A
4	10	21.99	B	B
3	4	19.82	C	C
Stage				
2	7	22.83	A	A
3	2	21.81	AB	AB
1	7	20.90	B	B

Table 49. Lipid content (percent of dry weight) of T. inermis of different sizes during the open-water season. Symbols as in table 24.

Date	Size group	Sex	n	$\bar{X}$ (% lipid)	SD	CV
21-23/8	∑	∑	23	42.68	6.41	15.01
	3	J	1	24.51	-	-
	4	J	5	34.97	0.42	1.21
	5	∑	7	45.00	2.39	5.31
	5	F	4	43.54	2.17	4.99
	5	M	3	46.95	0.32	0.68
	6	∑	8	46.54	2.18	4.69
	6	F	4	48.35	1.01	2.10
	6	M	4	44.72	1.14	2.54
	7	-	2	47.54	2.01	4.22

Table 50. Analysis of variance for the effect of size and sex on the lipid content (percent of dry weight) of T. inermis during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	5	825.78	165.16	112.29
Error	15	22.06	1.47	$p < 0.0001$
Total	20	847.85		

$r^2 = 0.974$ CV = 2.872 SD = 1.213 $\bar{X}$ = 42.22%

Source	df	SS	F value	p
Size	3	779.56	176.67	0.0001
Sex	1	0.55	0.37	0.5514
Size X sex	1	45.67	31.05	0.0001

Variable	n	$\bar{X}$ (% lipid)	Significance $p < 0.05$	$p < 0.01$
Size				
6	8	46.54	A	A
5	7	45.00	A	A
4	5	34.97	B	B
3	1	24.51	C	C
Sex				
F	8	45.95	A	A
M	7	45.67	A	A
J	6	33.23	B	B

Table 51. Protein content (percent of dry weight) of selected macrozooplankton species of different sizes at different times during the open-water season. Symbols as in table 24.

Species	Date	Size group	Sex/stage	n	$\bar{X}$ (% protein)	SD	CV
M. ovum	∑	∑	-	95	18.92	3.50	18.50
	25-27/7	3	-	7	21.36	1.25	5.87
	13/8	3	-	7	16.23	0.14	0.85
	28/8	3	-	7	14.68	0.61	4.14
	7-9/9	∑	-	11	21.54	1.17	5.42
		1	-	7	24.17	0.61	2.51
		2	-	7	20.10	1.21	6.02
		3	-	7	25.56	0.95	3.71
		4	-	7	17.40	0.94	5.43
		5	-	7	16.62	1.94	11.66
		6	-	7	20.02	1.43	7.16
		7	-	7	20.24	1.04	5.12
		8	-	7	14.38	0.22	1.50
		10	-	7	16.12	1.08	6.73
	17/9	3	-	7	17.31	0.75	4.34
P. libellula	∑	∑	∑	86	46.28	8.90	19.23
	19-21/8	5	∑	14	39.62	1.30	3.27
		5	F	7	39.85	1.59	3.99
		5	M	7	39.39	0.99	2.52
	7-9/9	∑	∑	37	51.88	9.60	18.51
		3	J	11	60.04	4.84	8.07
		4	J	14	52.83	4.47	8.46
		5	∑	12	43.30	10.43	24.08
		5	F	10	39.05	2.77	7.11
		5	M	2	64.53	6.74	10.44
	23-26/9	5	∑	35	43.01	6.02	14.00
		5	F	21	42.77	3.86	9.03
		5	M	14	43.37	8.46	19.51

Table 51. Continued.

Species	Date	Size group	Sex/stage	n	$\bar{X}$ (% protein)	SD	CV
S. elegans	Σ	Σ	Σ	27	53.94	5.46	10.12
	19-20/8	Σ	Σ	18	55.46	6.07	10.95
		3	Σ	5	57.18	2.14	3.75
		3	1	3	58.12	0.20	0.35
		3	2	2	55.77	3.42	6.12
		4	Σ	9	52.98	7.74	14.61
		4	1	7	56.79	1.74	3.07
		4	3	2	39.64	1.79	4.51
		5	Σ	4	58.88	1.99	3.38
		5	2	2	60.29	0.81	1.35
		5	3	2	57.47	1.81	3.15
	14-17/9	4	Σ	9	50.91	1.76	3.46
		4	1	3	51.45	2.99	5.82
		4	2	6	50.65	1.06	2.09
T. inermis	21-23/8	Σ	Σ	47	57.82	5.19	8.97
		4	-	4	55.50	2.07	3.73
		5	Σ	19	55.99	5.88	10.50
		5	-	6	61.21	1.82	2.98
		5	F	6	54.58	0.35	0.64
		5	M	7	52.73	7.70	14.60
		6	Σ	19	61.30	3.00	4.90
		6	-	7	64.32	2.70	4.21
		6	F	5	60.60	1.01	1.67
		6	M	7	58.78	0.74	1.27
		7	-	3	51.90	0.42	0.81

Table 52. Analysis of variance for the effect of date and size on the protein content (percent of dry weight) of M. ovum during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	12	1062.50	88.54	82.07
Error	82	88.46	1.08	$p < 0.0001$
Total	94	1150.96		

$r^2 = 0.923$ CV = 5.490 SD = 1.039 $\overline{X}$ = 18.92%

Source	df	SS	F value	p
Date	4	282.58	65.48	0.0001
Size	8	779.91	90.37	0.0001

Variable	n	$\overline{X}$ (% protein)	Significance $p < 0.05$	Significance $p < 0.01$
Date				
25-27/7	11	21.54	A	A
7-9/9	63	19.40	B	B
17/9	7	17.41	C	C
13/8	7	16.23	D	C
28/8	7	14.68	E	D
Size				
1	7	24.17	A	A
7	7	20.24	B	B
2	7	20.07	B	B
6	7	19.93	B	B
3	39	19.36	B	B
4	7	17.39	C	C
5	7	16.62	CD	C
10	7	16.12	D	C
8	7	14.38	E	D

Table 53. Analysis of variance for the effect of date, size and sex on the protein content (percent of dry weight) of P. libellula during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	8	5119.92	639.99	30.58
Error	77	1611.75	20.93	$p < 0.0001$
Total	85	6731.67		

$r^2 = 0.761$ CV = 9.887 SD = 4.575 $\bar{X}$ = 46.28%

Source	df	SS	F value	p
Date	2	2157.96	51.55	0.0001
Size	2	1629.09	38.91	0.0001
Sex	2	403.19	9.63	0.0002
Date X sex	2	926.68	22.21	0.0001

Variable	n	$\bar{X}$ (% protein)	Significance $p<0.05$	$p<0.01$
Date				
7-9/9	37	51.88	A	A
23-26/9	35	43.01	B	B
19-21/8	14	39.62	C	B
Size				
3	11	60.04	A	A
4	14	52.83	B	B
5	61	42.29	C	C
Sex				
J	7	48.63	A	A
M	23	44.00	B	B
F	38	42.51	B	B

Table 54. Analysis of variance for the effect of date, size and maturity stage on the protein content (percent of dry weight) of S. elegans during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	7	714.31	102.04	31.98
Error	19	60.63	3.19	$p<0.0001$
Total	26	774.94		

$r^2 = 0.922$ CV = 3.312 SD = 1.786 $\bar{X}$ = 53.94%

Source	df	SS	F value	p
Date	1	123.73	38.78	0.0001
Size	2	116.84	18.31	0.0001
Stage	2	386.12	60.50	0.0001
Date X stage	1	29.56	9.26	0.0067
Size X stage	1	58.06	18.19	0.0004

Variable	n	$\bar{X}$ (% protein)	Significance $p<0.05$	Significance $p<0.01$
Date				
19-20/8	18	55.46	A	A
14-17/9	9	50.91	B	B
Size				
5	4	58.88	A	A
3	5	57.18	A	A
4	18	51.95	B	B
Stage				
1	13	55.87	A	A
2	10	53.60	B	A
3	4	48.55	C	B

Table 55. Analysis of variance for the effect of size and sex on the protein content (percent of dry weight) of T. inermis during the open-water season. Symbols as in table 25.

Source	df	SS	MS	F value
Model	7	791.25	113.04	9.89
Error	39	445.67	11.43	$p < 0.0001$
Total	46	1236.92		

$r^2 = 0.640$ CV = 5.847 SD = 3.380 $\overline{X} = 57.81\%$

Source	df	SS	F value	p
Size	3	431.23	12.58	0.0001
Sex	2	341.90	14.96	0.0001
Size X sex	2	18.12	0.79	0.4597

Variable	n	$\overline{X}$ (% protein)	Significance $p < 0.05$	Significance $p < 0.01$
Size				
6	19	61.30	A	A
5	19	55.99	B	B
4	6	55.50	BC	B
7	3	51.90	C	B
Sex				
F	11	57.32	A	A
M	14	55.76	A	A

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