"This paper not to be cited without prior referance to the author"

International council
for the exploration of the sea. C.M. 1985/L:11

DENSITY IN SUB-ARCTIC ZOOPLANKTON

by

Stig Falk-Petersen, Jos W. Køgeler, Åge Kristensen
Fritz Pettersen & John Dalen

S. Falk-Petersen, Køgeler, J.W., Å Kristensen, F. Pettersen & J. Dalen 1985 00 00. Density in Sub-Arctic zooplankton.

Abstract

Seasonal variations in specific density were measured for *Thysanoessa inermis*, *Thysanoessa raschii*, *Meganyctiphanes norvegica*, *Calanus finmarchicus* and *Calanus hyperboreus*. The density of a 20 mm *T. inermis* was lowest in December (1,052 g/cm^3) and highest in February - March (1.065 g/cm^3). For a 20 mm *T. raschii* the minimal density was determined in December (1.059 g/cm^3) and the maximum in February - March (1.074 g/cm^3). *M. norvegica* individuals og 35 mm also had their lowest density i December (1.060 g/cm^3), but reached their maximum density in July (1,076 g/cm^3). The density of the euphausiids is found to be size dependent. The density increases as the size decreases.

C. finmarchicus and *C. hyperboreus* had densities less than seawater (1.026 g/cm^3) during most of the year. Just before spawning the density increased to 1.036 g/cm^3 and 1.028 g/cm^3 for *C. finmarchicus* and *C. hyperboreus* respectively. The seasonal variations of the density were closely related to the lipid content of the animals.

Stig Falk-Petersen, Institute of Fisheries, P.O. Box 3083, Guleng,
University of Tromsø, N-9001 Tromsø, Norway.
Jos W. Køgeler, Institute of Fisheries, P.O. Box 3083, Guleng
University of Tromsø, N-9001 Tromsø, Norway.
Åge Kristensen, Continental Shelf and Petroleum Technology Research
Institute Ltd., P.O.Box 1883 Jarlesletta, N-7001 Trondheim, Norway.
Fritz Pettersen, EISCAT, Ramfjord, University of Tromsø.
John Dalen, Electronic Research Laboratory, University of Trondheim,
N-7034 Trondheim.

Correspondation should be adressed to Stig Falk-Petersen.

INTRODUCTION

The majority of secundary production in the marine areas of the world is due to euphausiids (krill) and calanoid copepods (MAUCHLINE & FISHER 1967). This production forms the basis of the energy channelled onwards through the food-web to the major stocks of zooplanktivorous fish such as anchovetta, herring and capelin.

Estimation of zooplankton abundance har been dependent on net sampling, but the many disadvantages of this technique (CASSIE 1967 VANNUCEI 1969) have led to the development of remote acoustical sampling techniques (GREENLAW 1979, KRISTENSEN 1983). The major advantages of acoustic methods are their continous nature of observation to meet requirements of high sampling frequency, considerable observation volumes and the possibility to make rapid *in situ* biomass estimates from large geographical areas.

Two basic approaches can be used in acoustic estimation of zooplankton. In the first one an empirical relation between biomass and volume backscattering strength is used (PIEDER 1979, SAMEOTO 1980, FALK-PETERSEN and HOPKINS 1981). The other method is based on scattering models of the investigated zooplankton species. These models can be empirical or mathematical (ANDERSON 1950, JOHNSON 1977, GREENLAW 1977, 1979, KRISTENSEN 1983, FALK-PETERSEN and KRISTENSEN 1983. The backscattering cross section predicted by these models is generally dependent of the acoustic frequency, the density contrast and the sound speed contrast between the organism and seawater. The physical shape of the organisms may also be introduced as a parameter.

Little is known about densities of zooplankton (BEAMISH 1971, GREENLAW 1977, SUZUKI 1979, KILLS 1979a). From the North-Atlantic no information is available. As the biochemical composition of zooplankton is known to change during the year, density were measured for several sub-arctic zooplankton species over a yearcycle.

In the present study the seasonal variation of the density are presented. The variation of the density is discussed in relation to the biochemical content of the animals.

MATERIALS AND METHODS

Zooplankton was caught with a 1 m^2 rectangular midwater trawl (mesh size 1 mm) during 10 cruises with R.V. "Johan Ruud" in the Tromsø area (Northern Norway) between November 1982 and September 1983. The zooplankton was kept alive in big seawater filled containers until the measurements took place.

The density was determinded using a Pharmacia 50/1000 water cooled column filled with sea water having a linear salinity gradient of 80 cm total height (fig.1). Each column was calibrated using a series of glass floats of precisely known density (Martin Instrument Company Ltd., Herts, England) (fig.2). To make a continious density scale over the whole column, the density of the floats was regressed on depth using a first order linear model.

The animals were anesthetized in a $60^0/00$ saltwater solution. Immediately thereafter each specimen was identified, and the lenght was measured before it was brought into the column. The lenght of the euphausiids was defined as the distance from behind the eye to the end of telson. For the copepods the lenght was defined as the lenght of the abdomen. Only specimen positively evaluated to be clearly alive prior to the anesthetation activity was used in the experiments. The specific density was determined by the depth where the organisms reached neutral buoyancy. The density contrast was obtained by dividing the observed value by the specific density of sea water. (1.026 g/cm^3).

RESULTS

The densities of the investigated euphausiids are found to decrease linearily with increasing size, Table 2, 3 and 4. Both slope and intercept of the calculated regression equation changed during the year. To make comparisons possible between the estimated values the density of a reference-sized animal was calculated. As a reference size, 20 mm for the *Thysanoessa spp*. and 35 mm for the *M. norvegica* was chosen. (Fig.3).

The density of *T. inermis* increased between November 1982 and March 1983 from 1.052 to 1.065 g/cm^3 before decreasing again during spring and summer period. *T. raschii* showed similar variation, but the densities were higher than those of *T. inermis*. The density of *T. raschii* increased from 1.059 g/cm^3 in December 1982 to 1.074 g/cm^3 in March 1983 before decreasing to 1.056 g/cm^3 in September 1983.

M. norvegica also had its lowest density (1.060 g/cm^3) in December 1982, but did not reach its maximum before August 1983 (1.076 g/cm^3)

The density of *C. finmarchicus* and *C. hyperboreus* also varied with the season (fig. 4). It is interesting to note that most of the year *Calanus spp.* are slightly lighter than sea water. *C. finmarchicus* had a density of 1.025 to 1.026 g/cm^3 from May to January, while *C. hyperboreus* had densities between 1.022 and 1.025 g/cm^3 in the same period. Only in March, just before spawning, both species had densities (respectively 1.029 and 1.036 g/cm^3) greater than sea water.

DISCUSSION

The mathematical models used in acoustical estimation of zooplankton are very sensitive to changes of density and contrasts (JOHSON 1977, GREELAW 1977, KRISTENSEN 1985). A one percent change thus parameters results in a 1.6 dB change of the backscattering cross section (KRISTENSEN 1983).

The largest source of error in determining the density of zooplankton by the applied method was to locate the exact position of the specimen in the colum as the animals not always reached a complete neutral buoyance. The high salinities caused death and a subsequent increase in density of the krill was probably induced by osmotic processes. Before these happened the animals did however reach a relatively stable position in the column, and this was measured as the point of neutral buoyance. In addition the gradient is very small and a 20 mm error in depth reading lead to an unaccuracy of the calculated density of less than 0.1%, i.e. a rather small error. (KRISTENSEN 1983). The difference in density between individuals of the same size was assumed to be due to differences in the biochemical composition among the organisms. The regression equations found for the densities of the euphausiids are therefore belived to express the mean density as a function of the size. The differences in density between the species, sizes and seasons is closly related changes in the lipid composition of the ivestigated species.

T. inermis contains more lipids and lipids of lower density (wax-esters), than _T. raschii_ wich contains mainly triacylglycerols (FALK-PETERSEN 1981, FALK-PETERSEN et al. 1981). It has also been shown that the lipid content is higher in large krill than in small krill (FALK-PETERSEN 1981). This will contribute to the observed in density with increasing length. The seasonal variations in density correspond with changes of the lipid composition of the investigated zooplankton species as described by FALK-PETERSEN (1981), FALK-PETERSEN el al 1981, and SARGENT et al. (1985).

GREENLAW (1977) calculated a mean density of 1.063 g/cm^3 for Euphausia pacifica of 19-23 mm total length, and BEAMISH (1971) reported a density of 1.06 g/cm^3 for Euphausia sperba. As season and size dependency of these values should also be taken into account, it is difficult to make a direct comparison with our results. KIILS (1979b) also found a length density relation for M. norvegica, but in contrast to our observations, he found the density to increase with increasing size. He calculated the density in January for a referece size animal (35 mm) to 1.057 g/cm^3. This is lower than our observation, 1.067 g/cm^3. These differences might be due to different composition of the animals, and the fact that he used nitrogen frozen krill while we used living animals.

C. finmarchicus and C. hyperboreus have densities of less than 1.026 g/cm^3 from June to January. Only in February these two species had higher densities than sea water. This means that both species have a slightly positive buoyance most of the year. This contradicts with observations of GREENLAW (1979) who found a density of 1.043 g/cm^3 for Acartia clausi and C. marshalle. The diiference can probably be explained by changes in the lipid levels.

The observed seasonal changes of the density contrats of zooplankton are of surch magnitudes that when a mathematical model is used for acoustic estimation of zooplankton undances, the parameters of this model should be tuned for the actual seasons. The densities of the euphausiids are also so strongly size dependent that the relevant parameters of the model should reflect this.

ACKNOWLEDGEMENTS

The enthusiastic participation of the crew of R.V. "Johan Ruud" during the many surveys is gratly appreciated.

REFERENCES

ANDERSON, V.C. 1950. Soundscattering from a fluid sphere. *J.Acoust. Soc.Am.* 22, 426-431.

BEAMISH,P. 1971. Quantitative measurements of acoustic scattering from zooplanktonic organisms. *Deep Sea Res.* 18, 811-822.

R.M. CASSIE, 1968. "Sample design", in zooplankton sampling, edited by D.J. Tranter and J.H. Fraser. (Unesco Press, Paris).

FALK-PETERSEN, S. 1981. Ecological investigations on the plankton community of Balsfjorden, Northern Norway: Seasonal changes in body weight and main biochemical of *Thysanoessa inermis* (Krøyer), *T. raschii* (M.Sars) and *Meganyc* and *Meganyctiphanes NORVEGIA* (M.Sars) in relation to environmental factors. *J.Exp. Mar.Biol. Ecol.* 49, 103-120.

FALK-PETERSEN, S., GATTON, R.R., SARGENT, J.R., HOPKINS, C.C.E. 1981. Ecological investigations on the zooplankton community of Balsfjorden, Northern Norway: Seasonal changes in the lipid class composition of *Meganyctiphanes norvegia* (M.Sars), *Thysanoessa raschii* (M.Sars) and *T. inermis* (Krøyer). *J.Exp. Mar. biol. Ecol*. 54, 209-224.

FALK-PETERSEN, S. and HOPKINS, C.C.E. 1981. Zooplankton soundscattering layers in North Norwegian fjords. Intercation between fish and krill shoals in a wintersituation in Ullsfjorden and Øksfjorden. *Kieler Meeresforsch., Sonde* 5, 191-201.

FALK-PETERSEN, S. & A. KRISTENSEN 1985. Acoustic assesment of krill stocks in Ullsfjorden, North Norway. *Sarisa* 70: 83-90

GREENLAW, C.F. 1977. Backscattering spectra of preserved zooplankton. *J. Acoust. soc. Am.* 62, 44-52.

GREENLAW, C.F. 1979. Acustical estimation of zooplankton populations. *Limnol. Oceanogr.* 24, 226-242.

JOHNSON, R.K. 1977. Sound scattering from a fluid sphere revisited. *J. Acoust. Soc. Am.* 61, 375-377.

KIILS, U. 1979a. Aspects of physiological ecology of *Euphausia superba.* *Int. Coun. Expl. Sea.* CM. 9179/L:3.

KIILS, U. 1979b. Preliminary data on volume, density and cross section area of Antarctic krill. *Meeresforschn.* Bd 27(3) 207-209.

KRISTENSEN, Å. 1983. Acoustic classification of zooplankton. Dr.Ing. Thesis/ELAB report STF44 A83187, Univ. of Trondheim, Norway.

MAUCHLINE, J. and FISHER, L.R. 1969. The biology of euphausiids. *Adv Mar. Biol.* 7, 1-454.

SARGENT, J.R., FALK-PETERSEN & K. TANDE 1985. Lipid classes and fatty acid composition in some coppepods. (in prep)

SUZUKI, M. (1979). Thermal characteristics of the Antarctic krill (*Euphausia superba*). *Bull. Jap. Soc. Sci. Fish.* 54, 745-751.

M. VANNUCEI, 1969. "Loss of organisms throught the meshes", in zooplankton sampling, edited by D.J. Tranter an J.H. Fraser. (Unesco Press, Paris).

Table 2. *Thysanoessa enermis*. Specific density (s) and density contrasts (g). Linear regression between density/density contrasts, Y, and length (L); Y = aL ? b, b = regression coeffisient, a = intercept and r = correlation coeffisient.

Date	Number	Range (mm)	Density (g/cm^3)			Density contrast (g)	
			b	a 10^{-3}	r	b	a 10^{-3}
05.11.82	33		1.093	-1.81	-0.766	1.665	-1.76
17.11.82	21	16-25	1.091	-1.91	-0.951	1.063	-1.86
15.12.82	17	11-25	1.074	-0.90	-0.752	1.047	-0.88
20.01.83	12	12-23	1.101	-2.05	-0.899	1.073	-2.00
28.02.83	17	11-25	1.101	-1.77	-0.920	1.073	-1.73
28.05.83	15	17-25	1.060	-0.01	-0.140	1.033	-0.01
28.07.83	15	10-23	1.106	-2.50	-0.895	1.078	-2.48
21.09.83	17	12-22	1.088	-1.35	-0.765	1.060	-1.32

Table 3. *Thysanoessa raschii*. Specific density (s) and density contrast (g). Lineas regression between density/density contrast, Y, and length (L); Y = aL + b, b = regression coeffisient, a = intercept and r = correlation coeffisient.

Date	Number	Range (mm)	Density (g/cm^3)			Density contrast (g)	
			b	$a\cdot10^{-3}$	r	b	$a\cdot10^{-3}$
05.11.82	17		1.083	-0.87	-0.503	1.056	-0.85
17.11.82	12	16-21	1.080	-0.71	-0.687	1.053	-0.69
15.12.82	11	10-24	1.079	-0.99	-0.714	1.053	-0.96
20.01.83	10	11-20	1.097	-1.49	-0.729	1.069	-1.45
28.02.83	6	10-23	1.105	-1.52	-0.743	1.077	-1.48
28.05.83	15	13-22	1.086	-0.92	-0.420	1.058	-0.90
21.09.83	9	14-24	1.077	-0.810	-0.593	1.049	-0.79

Table 4. *Meganyctiphanes norvegica*. Specific density (s) and density contrasts (g). Linear regressions between density/density contrasts, Y, and length (L); Y = aL + b, b = regression coeffisient, a = intercept and r = correlation coefficient.

Date	Number	Range (mm)	Density (g/cm^3)			Density contrast (g)	
			b	$a\ 10^{-3}$	r	b	$a\ 10^{-3}$
05.11.82	12		1.098	-0.87	-0.865	1.07	-0.87
17.11.82	11	23-45	1.080	-0.47	-0.719	1.053	-0.45
15.12.82	13	27-45	1.070	-0.33	-0.429	1.045	-0.32
20.01.83	11	24-44	1.091	-0.57	-0.622	1.063	-0.56
28.05.83	10	25-41	1.086	-0.27	-0.330	1.058	-0.28
28.07.83	6	29-41	1.087	-0.28	-0.603	1.059	-0.27
21.09.83	6	22-44	1.090	-0.90	-0.965	1.070	-0.88

FIGURS

Fig.1. The water cooled density gradient column with the filling ellvice.

Fig.2. Density of the calibrated glass floats.

Fig.3. The seasonal variation in density of a standard sized animal. *Thysanvessa mermis*, *T. raschii* (20 mm), *Meganyctiphanes norvegica* (35 mm).

Fig.4. The seasonal variation in density of *Calanus finmarchicus* and *C. hyperboreus*.

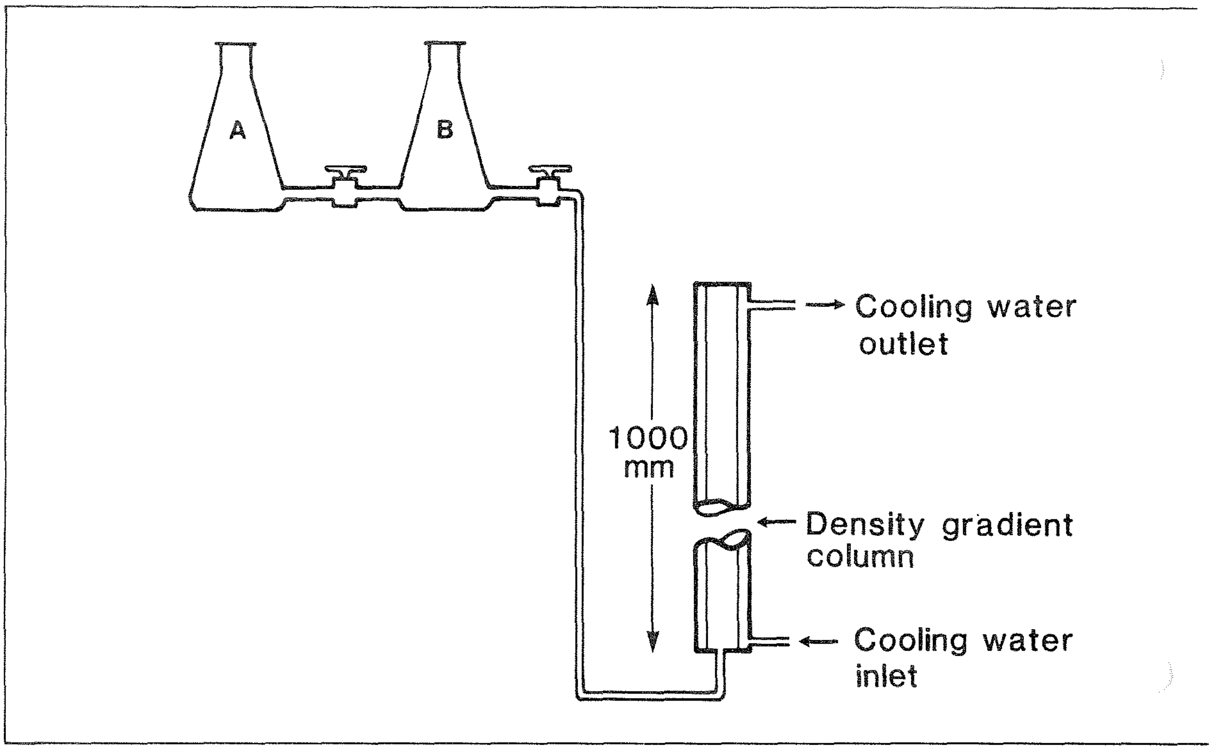
A
B
1000 mm
Cooling water outlet
Density gradient column
Cooling water inlet

Fig. 1.

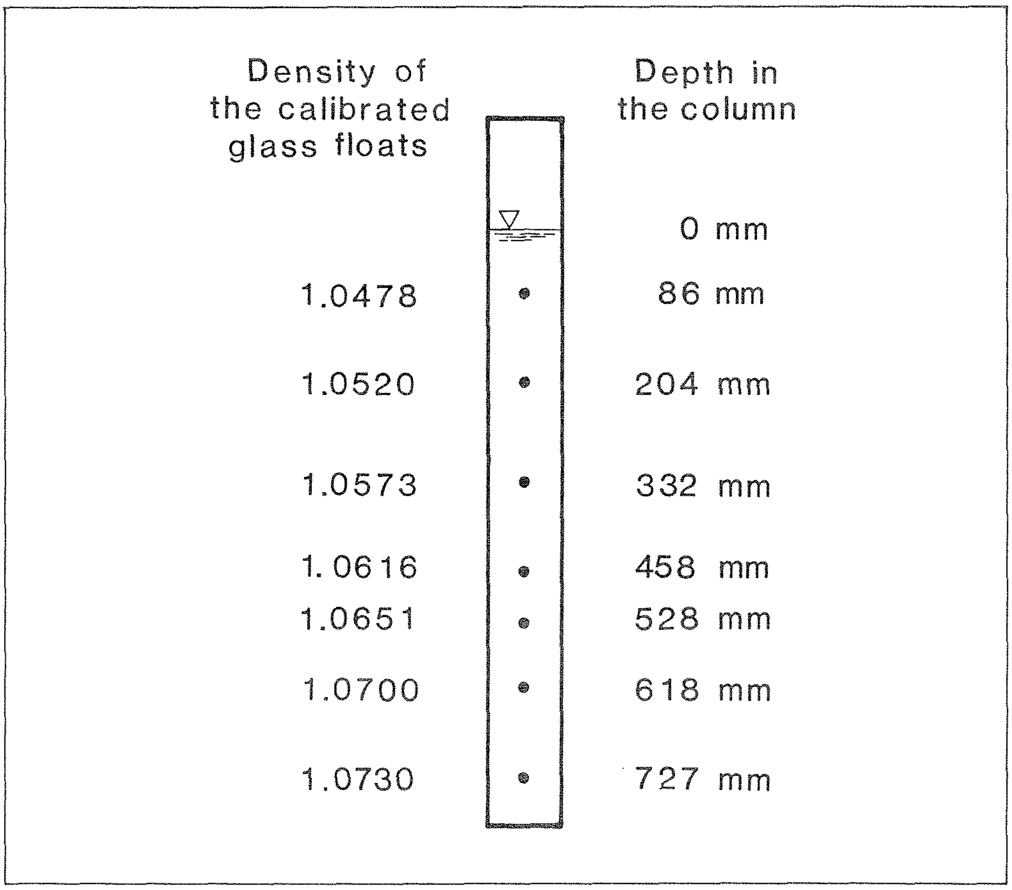
Density of the calibrated glass floats
Depth in the column
0 mm
1.0478
86 mm
1.0520
204 mm
1.0573
332 mm
1.0616
458 mm
1.0651
528 mm
1.0700
618 mm
1.0730
727 mm

Fig. 2.