Calorific value, lipid content and radioactivity of common species from Hornsund, Southwest Spitsbergen

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In the summer of 1981 the common flora and fauna of 28 species from Hornsund were collected, and the energy value, lipid content and global activity determined. It was found that the plants had low energy values, varying from 12.26 ± 0.42 kJ g^{-1} dry weight to 15.45 ±1.00 kJ^{-1} dry weight. The highest values in animals were noted in *Liparis liparis* (Pisces) 22.15 ± 0.89 kJ g^{-1} dry weight, and *Sagitta elegans* (Chaetognatha) 20.64 ± 0.49 kJ g^{-1}, the lowest being in *Orchomene minuta* (Amphipoda) 11.30 ± 0.74 kJ g^{-1} d.w. The lipid contents in the species studied were mostly low, the mean range from lowest to highest being 1.37–8.60% for plants and 7.14–31.93% for animals, and they were proportional to the energy value. Both the energy values and lipid contents were comparable to those in similar species from other waters. The global β activity in the organisms analysed was not high; at the same time plants had a higher content of radioactive isotopes, 1.97–61.9 pCi g^{-1} d.w., than animals, 5.2–17.8 pCi g^{-1} d.w.

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Biological investigations have been carried out on southwest Spitsbergen by the Institute of Oceanography of Gdańsk University since 1971 (Wiktor 1978). Initially the work concentrated on the basic problems of the biology and ecology of the common species (Amerski 1975; Żmijewska 1975; Pliński 1976; Węsławski 1980), this being followed by the determination of relationships between the various populations in the ecosystem of the region (Węsławski, in press). The present programme embraces elements which will enable studies of the manner of functioning of inshore ecosystems in southwest Spitsbergen (Opaliński & Węsławski, in press).

This region is of great interest, among other things for its isolation, its specific hydrological-meteorological conditions, and the general lack of data on polar marine ecosystems.

The purpose of this paper is to present the energy value and lipid content determinations in the common species of plants and animals in Hornsund. The data are of essential importance for studies of energy flow within the trophic chains of the polar ecosystems, as well as of their energy resources, in view of the low environmental temperatures and their narrow range, thus establishing the basic energy elements and determining their specifics in relation to ecosystems. The temperature zone for example, is of considerable importance.

Also, in view of the situation of Spitsbergen, far from industrialized regions, without the direct influence of man on the environment, a knowledge of the global β activity of 'clean' organisms may constitute a base line for further studies related to radioactive contamination and the protection of the natural environment.

Materials and methods

All the benthos samples taken in Hornsund (Fig. 1) were collected from July to September, 1981, by means of a dredge 40 × 40 cm with a mesh size of 1 × 1 mm. The energy values were determined for random samples of seven species of plants and 21 species of fauna. As relatively numerous samples were required for the determinations, all species could not be subjected to all the analyses.

Monospecies samples were dried to a constant weight at 55–60°C. The dried samples were then homogenized. Energy values, lipid content ash content, and global β activity were then determined. The energy value was determined by means of a KMB-2 type microbomb calorimeter (Klekowski & Bączkowski 1973), a modification of the Phillipson microbomb (Phillipson 1964). Prior to incineration the apparatus was calibrated, giving:

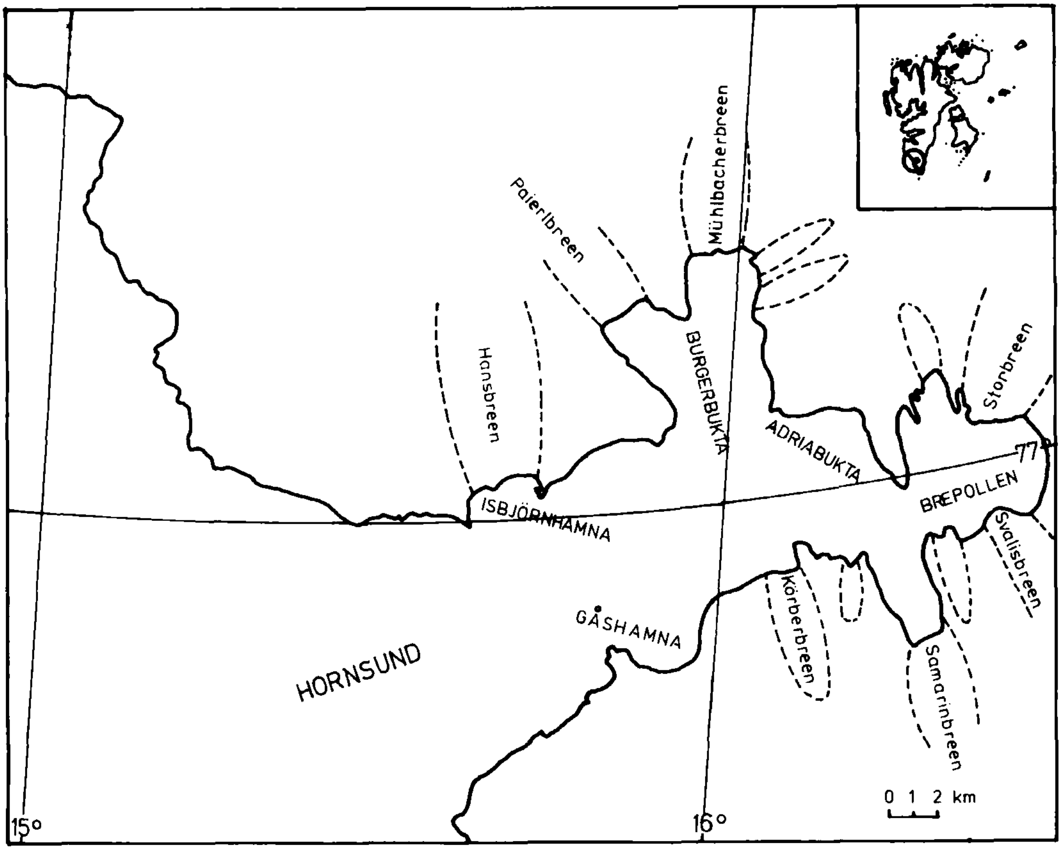

Fig. 1. Map of the investigation area.

— precision of the method (standard deviation) as ±0.25 J,
— percentage of error deviation 15.3%, and
— the range of burning for benzoic acid as 6.2–21.8 mg corresponding to 164.122–577.108 J.

From two to seven bombings were carried out on each type of material, before mean values were calculated.

For each sample the following were determined:

— the total energy value kJ g^{-1} dry weight (d.w.),
— the energy value of the organic mass kJ g^{-1} ash-free dry weight, and
— the percentage of ash contained from the microbomb after burning (but in this case there is always the possibility of loss of small quantities of ash at the time of burning).

To determine the lipid content the gravimetric method was used. A 100 mg sample of pre-dried and homogenized material was subjected to extraction by a chloroform + methanol mixture (2:1), then re-extraction by a mixture of chloroform + petroleum benzene (1:1), the lipid mass being presented as lipid as a % of dry material analyzed (Dowgiałło 1975).

To determine the global β activity, about 250 mg of the dry mass of the material examined was incinerated. Measurements were carried out in a No. 16 Polon ZAPKS apparatus. Each sample measurement took 20 minutes. The results were presented in pCi g^{-1} d.w.

Results and discussion

Caloric content

Energy values were calculated for seven plant species and nineteen animal species. Predominant among the flora were six species of Phaeophyta, and among the fauna, 14 species of Amphipoda. The results are presented as energy values of dry mass and organic matter.

The energy value of the dry mass is of greater importance from an ecological point of view, because all individuals are used as food. The energy values of the flora studied were much lower than those of the animals (Table 1). All the total energy values of plants were below 16.75 kJ g^{-1} d.w. and contained from 12.27 kJ g^{-1} d.w. in *Ptilota plumosa*, to 15.45 kJ g^{-1} d.w. in *Chorda filum*.

The highest energy values among the animals were noted in *Liparis liparis* (Pisces), 22.15 kJ g^{-1} d.w., *Sagitta elegans* (Chaetognatha), 20.64 kJ g^{-1} d.w., and *Mysis oculata* Fabricius, 19.43 kJ g^{-1} d.w. Amphipoda had lower energy values ranging from 11.30 kJ g^{-1} d.w. in *Orchomene minuta* to 19.47 kJ g^{-1} d.w. in *Onisimus caricus*. Percy (1979) indicates that the energy value of a related species, *Onisimus affinis*, fluctuates between 13.77 and 17.50 kJ g^{-1} d.w., the former value predominating over most of the year. The energy value of *Onisimus littoralis* from Hornsund was 16.87 kJ g^{-1} d.w., and that of *Onisimus edwardsi* 14.86 kJ g^{-1} d.w., both values being within the limits given for *Onisimus affinis* by Percy (1979).

A substantial divergence of energy values was

Table 1. The energy and ash content of some common species from Hornsund

Species	No of bombings	kJ g^{-1} dry weight mean ± SD	kJ g^{-1} ash free mean ± SD	Ash content % dry weight mean ± SD
Phaeophyta				
Chorda filum	5	15.48 ± 1.00	19.13 ± 1.64	19.8 ± 3.9
Chorda tomentosa	5	12.81 ± 0.78	17.71 ± 0.12	28.4 ± 3.2
Laminaria saccharina	3	12.98 ± 0.38	13.94 ± 0.56	6.9 ± 1.1
Laminaria digitalis	4	13.35 ± 0.31	15.32 ± 0.21	12.8 ± 1.3
Desmarestia aculeata	5	14.19 ± 0.73	19.24 ± 0.58	21.4 ± 5.8
Fucus serratus	5	14.40 ± 0.57	16.03 ± 0.35	10.6 ± 2.0
Rhodophyta				
Ptilota plumosa	7	12.26 ± 0.42	14.36 ± 0.98	14.4 ± 2.6
Polychaeta				
Harmatoë sp.	6	19.97 ± 0.73	23.57 ± 0.81	15.2 ± 0.7
Gastropoda				
Limacina helicina	5	15.40 ± 0.76	18.88 ± 3.04	21.8 ± 4.2
Mysidaceae				
Mysis oculata	4	19.42 ± 0.42	22.90 ± 1.45	15.1 ± 3.5
Amphipoda				
Themisto libellula	4	13.64 ± 0.51	15.57 ± 0.75	12.2 ± 2.1
Onisimus edwardsi	6	14.86 ± 0.53	20.72 ± 2.06	25.6 ± 0.6
Onisimus littoralis	5	16.87 ± 0.41	22.10 ± 0.42	22.5 ± 0.8
Onisimus caricus	5	19.46 ± 1.12	24.15 ± 0.25	19.5 ± 0.9
Gammarus setosus	3	15.40 ± 0.92	19.76 ± 0.42	22.3 ± 2.1
Gammarus oceanicus	3	16.62 ± 0.53	21.56 ± 1.32	22.4 ± 1.8
Orchomene minuta	2	11.30 ± 0.74	15.23 ± 0.11	25.9 ± 1.2
Anonyx nugax	4	14.52 ± 0.06	16.49 ± 0.07	17.6 ± 5.3
Anonyx sarsi	5	13.52 ± 0.72	17.87 ± 1.28	24.4 ± 1.6
Gammarellus homari	6	16.99 ± 1.45	21.60 ± 2.01	21.2 ± 0.8
Caprella septentrionalis	3	12.30 ± 0.74	15.70 ± 0.88	21.5 ± 1.7
Ischyrocerus anguipes	6	13.02 ± 0.70	21.85 ± 2.12	30.1 ± 2.2
Paraoediceros lynceus	5	16.45 ± 1.01	21.52 ± 0.97	25.8 ± 1.4
Calliopius laeviusculus	5	14.94 ± 0.25	20.34 ± 2.31	24.8 ± 5.8
Chaetognatha				
Sagitta elegans	5	20.64 ± 0.48	23.52 ± 1.41	14.2 ± 2.9
Pisces				
Liparis liparis	3	22.14 ± 0.88	26.54 ± 1.29	20.1 ± 5.7

noted in the genus *Themisto* caught in various regions. The total energy value of *Themisto libellula* from Hornsund, amounted to 13.65 kJ g^{-1} d.w. and ash-free 15.57 kJ g^{-1} d.w., whereas for the same species from the Arctic Sea, the corresponding values were respectively 17.67 kJ g^{-1} d.w. and 21.77 kJ g^{-1} d.w. (Percy & Fife 1981). The energy value of *Parathemisto quaichandi* from the NE Atlantic amounts to 21.51 ± 5.48 kJ g^{-1} d.w. ash-free (Williams & Robins 1979) and is much higher than that of *Themisto libellula* from Hornsund.

Percy & Fife (1981) state that the energy value of epibenthic Amphipoda from the Arctic Sea varies from 14.82 to 20.14 kJ g^{-1} d.w., whereas that from N. Carolina varies from 12.18 kJ g^{-1} to 18.41 kJ g^{-1} d.w. (Thayer et al. 1973). This is a similar range to that found in the amphipods from Hornsund, 12.31 to 19.47 kJ g^{-1} d.w., in this study.

The energy values of flora or fauna from Hornsund were not found to differ markedly from those of related species from waters with different hydrological conditions.

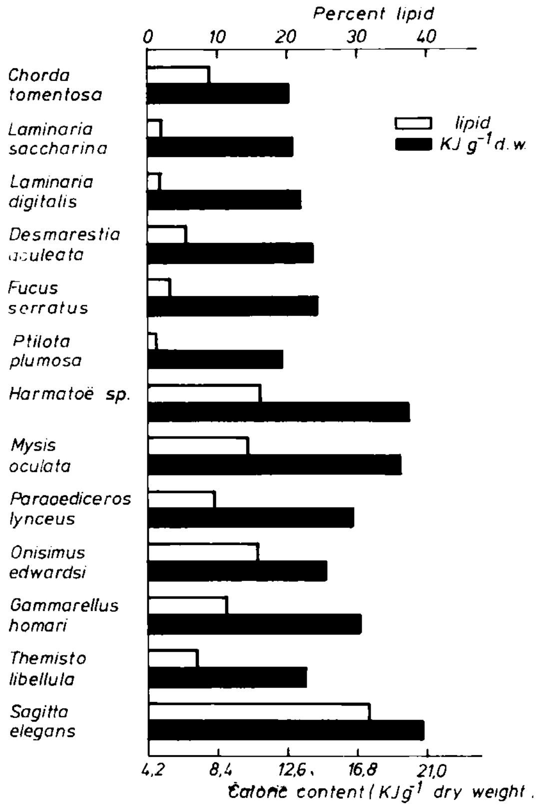

Fig. 2. Lipid and caloric contents of common animal and plant species from Hornsund in the summer.

Lipid content

The lipid content of an organism plays a central role in the determination of its energy content. The lipid content of six species of plants and eight species of animals from Hornsund was determined (Fig. 2). In the material studied, the plants had the lowest lipid content, fluctuating between 1.37 and 8.60% of dry weight, the mean being 3.85%.

The mean lipid content in all the animals studied was much higher, amounting to 14.63%. The lowest lipid content was noted in *Themisto libellula*, 7.14%, with an energy value of 13.65 kJ g^{-1} d.w. The highest lipid content, 31.93%, was found in *Sagitta elegans*, with an energy value of 20.64 kJ g^{-1} d.w. As in the examples mentioned, the lipid content of the remaining organisms analyzed was proportional to the energy value (Fig. 2).

The lipid content in *Sagitta elegans* from Hornsund is much higher than in that previously cited from the Arctic Sea, 17.23% (Percy & Fife 1981), or from the Bering Sea, 6.7% (Ikeda 1972); Lee (1975) found a lipid content of 13% in *Eukronia hamata* from the Arctic Ocean. The lipid content of the Chaetognaths varies greatly.

In amphipod, the lipid content fluctuated between 7.0% and 15.0%, the mean being 10.85%. These are not very high values, particularly when compared with results presented by Percy & Fife (1981), where planktonic amphipods (Hyperiidae) had lipid contents of 18.35% and epibenthic ones varied from 7.0% to 22.0%.

Percy (1979) cites a lipid content of 14–27% for *Onisimus affinis* while we found 15.87% in *Onisimus edwardsi* in our study from Hornsund. The content is highest in the spring and during the reproductive period.

Substantial differences are noted in the lipid content of the genus *Themisto* from various regions. *Themisto libellula* from Hornsund had a lipid content of 7–14%, which is very low compared with *Parathemisto* sp. from other regions, for example, the Sea of Japan, which contains as much as 39.6% lipid (Nakai 1955), or *Themisto libellula* from the Arctic Sea, with 18.2% in the summer (Percy & Fife 1981).

Probably there are several reasons for the low lipid content in amphipods from Hornsund. One of them is that the epibenthic species lives in stable trophic conditions, hence there is no necessity to accumulate energy stores for the winter, as in the case of the plankton species. During this time the water temperature fluctuated between −1.2°C and 1.3°C, and the salinity from 34.7% to 35.2%. Our study shows that the lipid content of individuals depends on the species itself as well as the water basis from which the material originates.

As a general rule the water temperature is the most important influence on lipid content in marine individuals. It is a fact that euphausiids living in high latitudes generally have higher lipid content than the animals from an area of higher environmental temperature. Another explanation is that they have a particularly active system for synthesizing fatty acids de novo from non lipid precursors (Mauchline & Fisher 1969). Henderson et al. (1982) noticed in vitro that *Thysanoessa inermis* from Balsfjorden (N. Norway) could biosynthesize lipid very fast. *Thysanoessa raschi* from Clyde Estuary, Scotland (Henderson et al. 1982) and from Balsfjorden (Falk-Petersen et al. 1981) have the same lipid level because of inner mechanisms. The amount of lipid of animals from Hornsund is smaller than we could expect knowing the Arctic environmental conditions, especially the low water temperature. It is possible that these animals have a similar active system to *Thysanoessa raschi* which makes the lipid content depend on lipid amount in the phytoplankton. It is necessary to remember that the concentration of phytoplankton in water influences the energy value and lipid content in animals. *Mytilus edulis* from Gdańsk Bay has the maximum of lipid in its body at the end of the autumn's phytoplankton bloom (Pazikowska & Szaniawska, in press).

The animal's trophic position seems to have a very great influence on the animal's lipid content. Copepods from high latitudes have phytoplankton as main food, which is characteristic for the higher lipid content (Lee et al. 1971). Omnivore like *Thysanoessa raschi* is not so rich in lipid as herbivores copepods (Falk-Petersen & Hopkins 1981). Probably omnivore and carnivore animals have less lipid content in their body than herbivore animals.

Ash content

The ash content in the material studied fluctuated between 6.9% and 30.1%. Only in the molluscs was this value substantially exceeded. For example, the ash value of *Thyasira sarsi* was 75% and that of *Littorina littorea* almost 90%. Hence, the total energy values for the whole organisms are very low and amount to 4.19–8.37 kJ g^{-1} d.w.

The mean ash content in the animals was 20.9% (excluding the molluscs) whereas it was 16.3% in plants. The majority of the animals studied were amphipods. The ash content in these organisms is high and amounts to 21.9% on the average. Percy & Fife (1981) found the ash content of arctic pelagic amphipods fluctuating between 12.5% and 20.7%. This is slightly lower than what is found in the material studied in Hornsund, where the lowest content was noted in *Themisto libellula* 12.2%, and the highest in *Ischyrocerus anguipes*, 30.1%. Omori (1969) gives an approximate ash content of 13.4% for *Parathemisto japonica*. *Onisimus affinis* had an ash content of 21.3–27.2% (Percy 1979), whereas *Onisimus edwardsi* from Hornsund had a mean ash content of 25.6%, *Onisimus littoralis* 22.5%, and *Onisimus caricus* 19.5%. The values are thus generally similar. *Sagitta elegans* had a mean value of 14.2% ash whereas *Eukrohnia hamata* from W. Norway had 14–21% ash (Bamstedt 1978).

Table 2. Total β radioactivity of dominant species from Hornsund.

Species	Radioactivity pCi g^{-1} dry weight
Phaeophyta	
Chorda filum	31.37
Chorda tomentosaa	19.77
Laminaria saccharina	61.91
Laminaria digitalis	36.19
Desmarestia aculeata	58.47
Rhodophyta	
Ptilota plumosa	48.26
Amphipoda	
Gammarellus homari	7.23
Paraoediceros lynceus	17.89
Gammarus sp.	16.47
Gastropoda	
Littorina littorea	10.53
Bivalvia	
Thyasira sarsi	10.96
Chaetognatha	
Sagitta elegans	5.20

Radioactivity

Recent observations on radioactivity in marine organisms constitute an essential element in radio-ecological studies. In many regions of the world, the natural content of radioactive atoms is disrupted by human activities. In the Spitsbergen region this influence is restricted, which is confirmed by the studies on global activity β in several species of plants and animals dominating in Hornsund. The global β activity in the organisms analyzed was low (Table 2). Characteristic of the algae is the higher content of radioactive isotopes which is understandable, as radioactive atoms are probably taken up directly from the water. Hiyama (1956) found the highest contents in algae and diatoms, rather than invertebrates, and the lowest levels in fish.

Gileva (1965) also observed that Chlorophyceae occupy a first place as regards the accumulation of various elements.

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