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Research Article

**PREDRYING OF STRANDED WRACK MATERIAL AS AN
ASPECT OF THE LITTERBAG TECHNIQUES IN THE SANDY
BEACH STUDIES**

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Abstract

Methodological aspects of the arrangement of stranded wrack for the degradation rates within the litterbags were tested in a simple field experiment on temperate, fine/medium quartz sediment, sandy beach in Poland at the end of the Hel Peninsula (54°36'N, 18°49'E). Litterbags of the mesh size of 0.5 mm were used to construe and assess the role of the pre-drying of wrack before its placement into the bags.

The field station was established on the backshore, 15 m in width seaward from the crest of a dune. Three methods of predrying were done: (1) air drying, (2) oven drying, (3) freeze drying, as well as (4) non-dried fresh material was used as reference. The stranded seagrass wrack (*Zostera marina* L.), obtained directly from the beach, and then prepared in accordance with the procedures described above, was used as the study material.

Four trials were run with five repetitions of litterbags 7 cm long × 7 cm wide made from nylon mesh with 0.5 mm aperture widths. After exposition, bags were retrieved 5, 10, 50, 100, 150, 200 and 250 days post-placement. In the laboratory, samples of remaining material were

dried by the same method as earlier, respectively, and then weighed, and analysed using a CHNS Analyser.

It was shown that, under similar conditions of sediment composition, salinity and wave inundation, the method of predrying had little influence on the long-term process of decay. In the case of non-dried replicates, degradation rapidly proceeded in the initial stages and then stabilised to be linear, whereas, in dried samples it was done so linearly throughout the study period with only little differences. Such differences observed in the early part of the experiment were most likely the result of differences in material structure and the initial chemical composition of the plant material caused by a predrying-incurred disturbance in the chemical structure. Nevertheless, short-term environmentally driven sampling strategies fail to obtain conclusive results about degradation estimates of stranded wrack and should be avoided at least with the use of dried material.

INTRODUCTION

Originating from pedology, the litterbag method (Swift *et al.* 1979, Dziadowiec 1992) has also been used to investigate degradation in saltmarsh areas (Valiela *et al.* 1985, Harrison 1989, Newell and Fallon 1989, Blum 1993, Newell 1993) and in other types of shore (Newell *et al.* 1984, Williams 1984, Inglis 1989, Singh *et al.* 1991, Bermingham *et al.* 1996, Wachendorf *et al.* 1997). The use of litterbags has been, however, criticised for the artifacts that it can engender (Park 1974, Swift *et al.* 1979, St.John 1980), and attempts have been made to reduce errors associated with litterbag techniques (Newell *et al.* 1984, Buth and Voesenck 1987). Even so, this method is also employed in sandy beach studies (Inglis 1989, Wachendorf *et al.* 1997, Jędrzejczak 1999, 2002a, 2002c) to determine processing of organics, and using bags of different mesh apertures in order to estimate the role played by various faunal and non-faunal beach components in the decaying debris. Inglis (1989) and Jędrzejczak (2002b) have also used the litterbag technique to define how, when and where wrack has been colonised by invertebrates, with successive changes in wrack faunal assemblages.

The litterbag method assumes that the matter loss is detected after the material has been exposed in the field. Because of variable moisture content levels in samples, measurements with wet replicates may be responsible for errors in the analysis. Therefore, the dry weight of samples is needed in order to calculate the breakdown. Adequate preparation of material for detections is thus fundamental for the study. References recommend the use of substrata in two main ways: (1) fresh material or (2) pre-dried material using different desiccation methods (Robertson & Mann 1980, Josselyn & Mathieson 1980, Gallagher *et al.* 1984, Pelikaan 1984, Valiela *et al.* 1985, Harrison 1989, Inglis 1989, Singh *et al.* 1991, Blum 1993, Emery & Perry 1996). The use of fresh material requires a conversion formula thanks to which the original dry weight

prior to exposure can be estimated from a given wet weight. Initial weights are thus obtained by drying and scaling replicates of fresh wrack (Inglis 1989, Emery & Perry 1996). On the contrary, predrying is disregarded in this estimation due to the calculation of dry weight a priori before and after the exposition of each sample. This method, however, has the following drawback: the desiccated material is placed on the beach, instead of being naturally found there, since the material is usually freshly stranded and only later dries out when subjected to the regular processes observed in a beach environment. Placing of a pre-dried sample does not fully simulate the natural process of stranding of wrack material on the beach, which may increase its resistance to decomposition.

Three different methods of drying are referenced to be employed in litterbag techniques. However, no data have been reported on this subject as yet. The aim of the present research was thus to compare these methods in sandy beach studies.

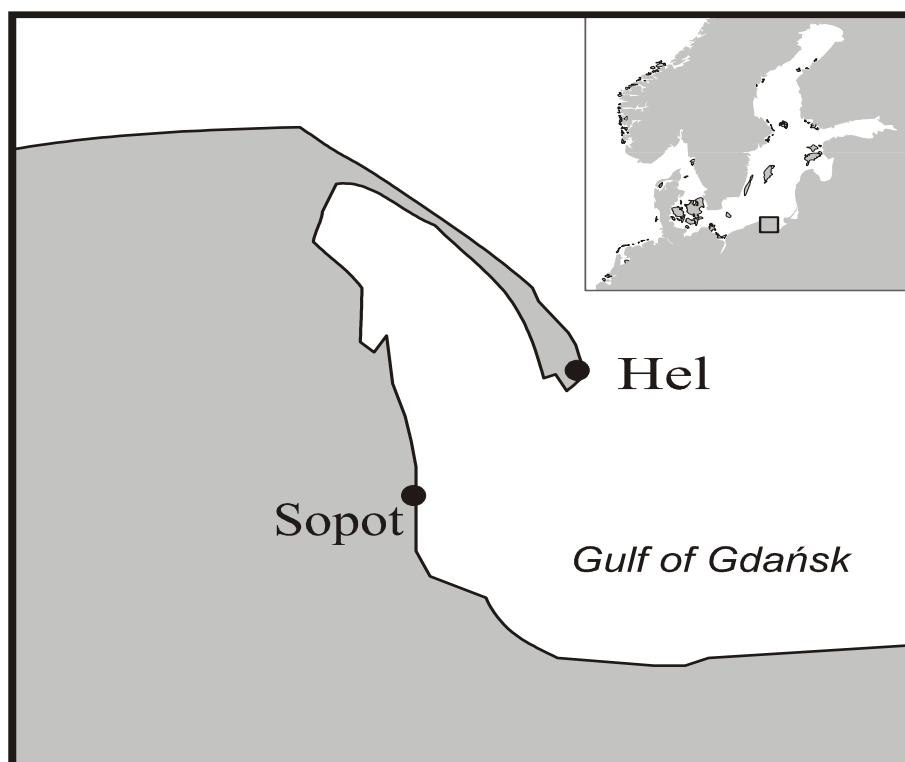


Fig. 1. Location of study beach site.

MATERIAL AND METHODS

Study site

Field experiments were undertaken on the temperate, medium to fine quartz sediment, sandy beach in Poland at the end of the Hel Peninsula (54°36'N, 18°49'E) from March 21 to November 25, 2000 (Fig. 1). Backed for most of its length by a well developed, stable dune system forming the upper limit of storm-accumulation, the Hel Great Beach is exposed to moderate to heavy wave action from the open Baltic Sea. The beach is situated in a former military area and visited by few people. However, the beach is also ideal for holidaymakers and a suitable area for recreational activities in the summer period.

Field study - litterbag design and placement

Litterbags, 7 cm long × 7 cm wide, were constructed of nylon mesh with a 0.5-mm aperture. The mesh was designed in order to give beach microbiota, meiofauna and small juvenile forms of macrofauna access to the enclosed material, as well as to achieve the leaching and fragmentation. Another goal was to exclude all the sandy beach fauna larger than 0.5 mm from the sample.

Freshly stranded seagrass wrack (*Zostera marina* L.), obtained directly from the beach and gently rinsed to remove the adhering sediment and surface fauna, was used as study material. The wrack was then prepared in the following way: (1) air drying, (2) oven drying, (3) and freeze-drying. In addition, (4) non-dried fresh material was used as reference. The air-dried replicates were moisture-devoid for 1 week to acquire constant weight. The oven-dried material was processed for 3 days at 60°C. The Alpha 2-4 freeze dryer (Christ) was used for 24 h to process the freeze-dried samples, with -80°C at a vacuum pressure of 400 bars.

Approximately 60 g ± 0.5 g (dry wt) or 6 g ± 0.5 g (wet wt) of material (and a plastic identification tag) was placed in each bag according to the method described by e.g. Valiela *et al.* (1985) and Blum (1993). After being filled, each bag was sewn up to isolate it from the beach sediment.

Four trials with five repetitions for each bag were set up at the field station established on the backshore/foredune, 15 m in width, seaward from the crest of a dune (Fig. 2). At the station, a flat spade was inserted in the sediment to the requisite depth (approx. 2-5 cm) and a bag slid into the sediment along the blade of the spade. Having been assigned an identification number, each bag was inserted individually into the beach. The sediment was then pressed back around each bag.

Each trial was run for 250 days. In the first trial, the loss of air-dried dry weight was measured, and in the second the same was done with freeze-dried material; in the third, oven-dried samples were checked, as well as bags with fresh tissue in the fourth one. Bags were selected for sampling *a priori* using a random number table and, after exposition, bags were retrieved after 5, 10, 50, 100, 150, 200 and 250 days in the field.

All litterbags were returned to the laboratory, where the contents of each one were gently rinsed again to remove the adhering sediment and surface fauna. Next, each bag was weighed, frozen, and processed for a week.



Fig. 2. Schematic profile of the Hel Great Beach slope, showing the foredune zone sampled.

Laboratory experiments

In the laboratory, the samples of rinsed, refrigerated organic material were dried using the same method as earlier, respectively, to constant weight and then weighed on an Explorer analytical balance (OHAUS; min. wt 10 mg, $d=0.1$ mg; max. wt 42 g, $d=0.01$ mg or 210 g, $d=0.1$ mg; $e=1$ mg) to determine the dry weight. Drying and weighing five replicates of 6-g portions of fresh tissue of *Zostera marina* made it possible to obtain initial weights.

After each sample had been homogenised, carbon, nitrogen and sulphur were measured with a Carlo Erba Instruments EA1108 CHNS-O Analyser according to the method described by *e.g.* Newell *et al.* (1984) and Newell & Fallon (1989), using 5-chloro-4-hydroxy-3-methoxy-benzylisothiouria phosphate $C_9H_{11}ClN_2O_6PS$ (C 31.35%, H 4.09%, N 8.13%, S 9.30%, Cl 10.29%, O 27.85%, P 8.99%; ca 1-3.5 mg) as standard, and acetanilide C_8H_9NO (C 71.09%, H 6.71%, N 10.36%, O 11.84%; ca 1-2 mg) for reference. The maximum error of the Analyser was 0.3%.

Decomposition model and statistics

Decomposition data derived from litterbag studies (change in dry weight in time) were expressed as the percentage of initial dry weight of remaining tissue and were analysed using two-factor ANOVA (Underwood 1981, StatSoft Inc. 1995, Zar 1999) with time and method employed as main effects. To prevent a binomial distribution in ANOVA analysis, all data were transformed to their arcsine. Then the resultant data had an underlying distribution that was nearly normal (Zar 1999). This transformation is presented in Eq. (1):

$$p' = \arcsin(p)^{1/2} \quad (1)$$

where: p - data proportion.

However, the raw data for each of the methods, combined to form a common matrix, were analysed for methodological similarities in the way of hierarchical clustering, which takes a similarity matrix (common data table) as a beginning and successively fuses the samples into groups starting with the highest mutual similarities and gradually decreasing the similarities in which the groups form. At the lowest similarity a single cluster contains all groups. Thus, groups of methods with distinct semblances in predrying activities can be determined. The graphical result of this type of analysis is a dendrogram: the X-axis showing the full set of samples under consideration and the Y-axis defining the similarity level at which two groups are accepted to have coalesced (Field *et al.* 1982, StatSoft Inc. 1995, Fowler *et al.* 1998). Similarities between predrying methods were calculated and expressed as a dendrogram using group-average linking (UPGMA) provided by the Bray-Curtis Similarity Index and as determined by STATISTICA 5.0 (StatSoft Inc. 1995, Fowler *et al.* 1998) with Eq. (2):

$$\text{Euclidean distance } (x, y) = \{S_i (x_i - y_i)^2\}^{1/2} \quad (2)$$

The final results were evaluated with a single exponential decay model (Jenny *et al.* 1949, Petterson and Cummins 1974, Swift *et al.* 1979) according to Eq. (3):

$$W_t = W_0 \cdot e^{-kt} \quad (3)$$

where: W_t - dry weight (g) of litter sample remaining after time t; W_0 - initial dry weight (g) of litter sample; e - base of natural logarithm; k - decay coefficient (day^{-1}); t - time (days).

The decay coefficient k permits a comparison of decomposition rates between organic material types and among studies. The single-exponential model does not, however, discriminate between soluble versus refractory material, nor does it distinguish microbial contributions (Wieder and Lang 1982).

RESULTS AND DISCUSSION

Significant weight loss occurred in all bags. ANOVA tests proved that time and methods of desiccation used in the experiment have a significant influence on breakdown rates. Other ANOVA proportions were not statistically significant (Table 1). Within 250 days, the material in bags lost from 16 to 18 % of its initial dry weight in the case of all data from each method of predrying. It may suggest that the use of fresh vs dried material therefore appeared to have had little significant effect on the breakdown. However, the seagrass disintegrated in two different ways for the majority of the experimental period. Fresh material decay was initially rapid but then became stable, whereas dried material degradation was approximately linear (Fig. 3). F-tests, conducted to determine the significance of decomposition rate differences for each type of predrying, showed the regression of mass loss versus time resulted in k -values (Fig. 4). The initial reduced model utilised all data within a type of predrying, lumped and regressed using a single exponential model. The full model treated each bag as an individual k -value. Decomposition rates (k) during 250 days varied both in the fresh and dried types of material. The fresh wrack generally decomposed faster than the dried tissue during first 70 days after start, whereas decomposition rates after Day 50 were more similar for both types. However, the Tukey tests did not reveal significant variability in three types of dried samples. Differences were due probably to the different chemical processing of the material.

Table 1

Analysis of the proportion (arcsine transformation) of seagrass dry weight loss in the litterbags on seven sampling occasions (Days) using four different methods of predrying (Method). Significant effects are highlighted.

Source of variation	Trial			
	df	MS	F ratio	P
Days	6	0.621	87.248	<0.01
Method	3	0.025	4.022	0.023
Days x Method	18	0.007	0.124	0.945
Bartlett's statistic	27	$\chi^2 = 9.542$		0.487
Cochran's statistic		C = 0.340		

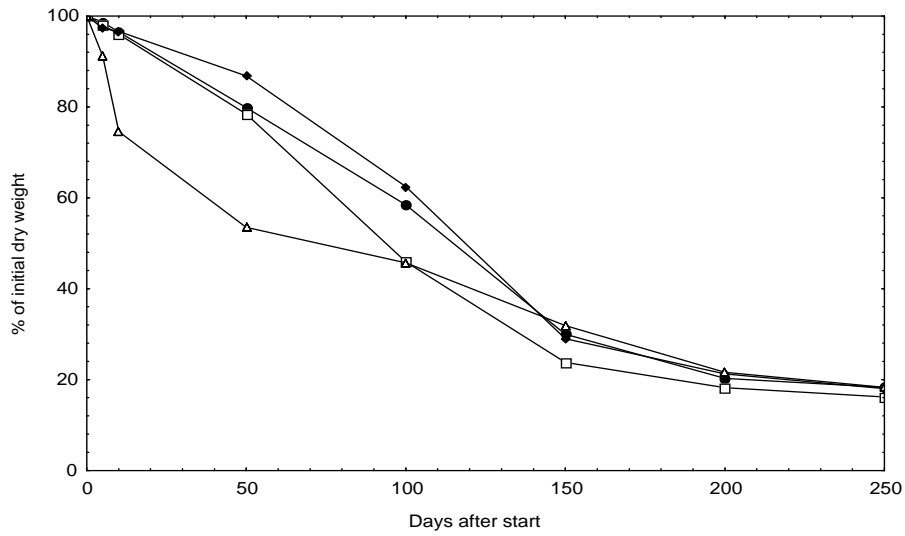


Fig. 3. Changes in the mean dry weight of *Zostera marina* leaves in litterbags secured in the foredune zone of Hel Great Beach: ●, air-dried; ◆, freeze-dried; □, oven-dried; △, fresh material.

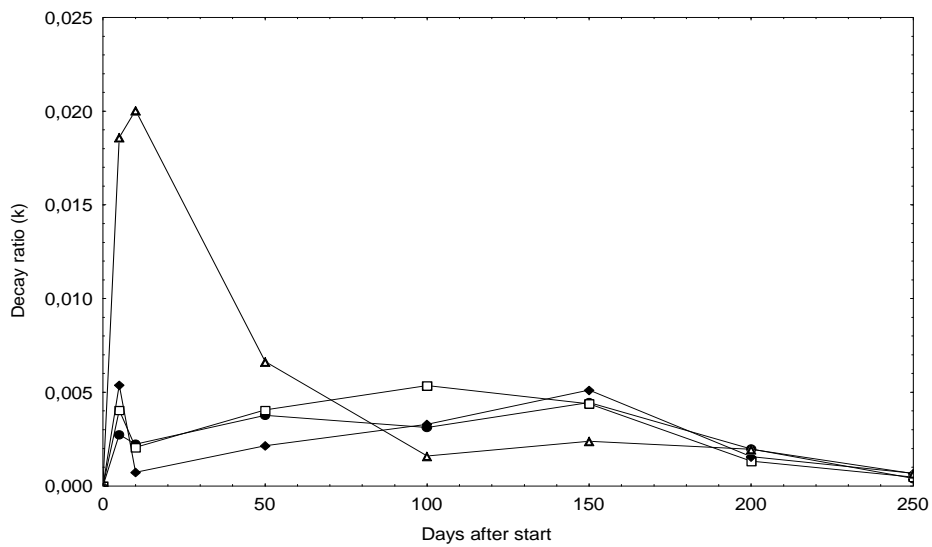


Fig. 4. Changes in the mean decay ratio (day^{-1}) of *Zostera marina* leaves in litterbags secured in the foredune zone of Hel Great Beach: ●, air-dried; ◆, freeze-dried; □, oven-dried; △, fresh material.

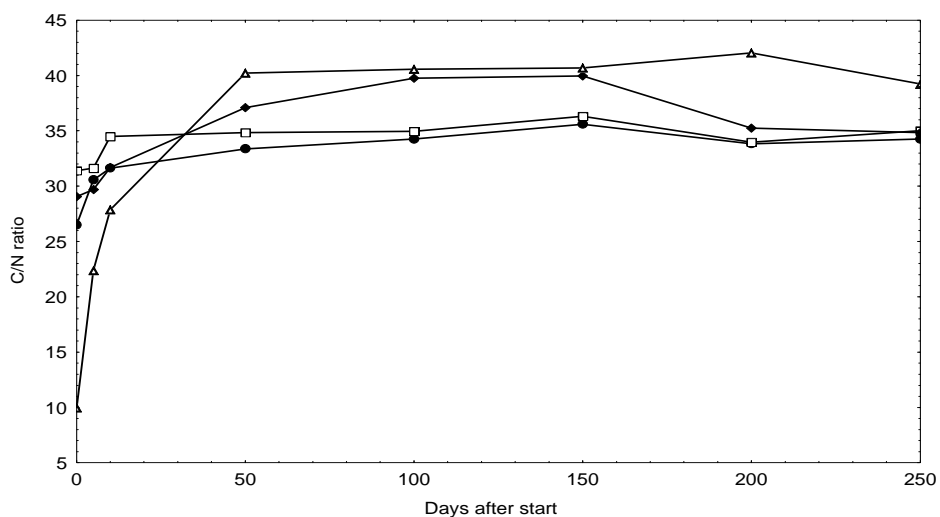


Fig. 5. Changes in the mean C/N ratio of *Zostera marina* leaves in litterbags secured in the foredune zone of Hel Great Beach: ●, air-dried; ◆, freeze-dried; □, oven-dried; △, fresh material.

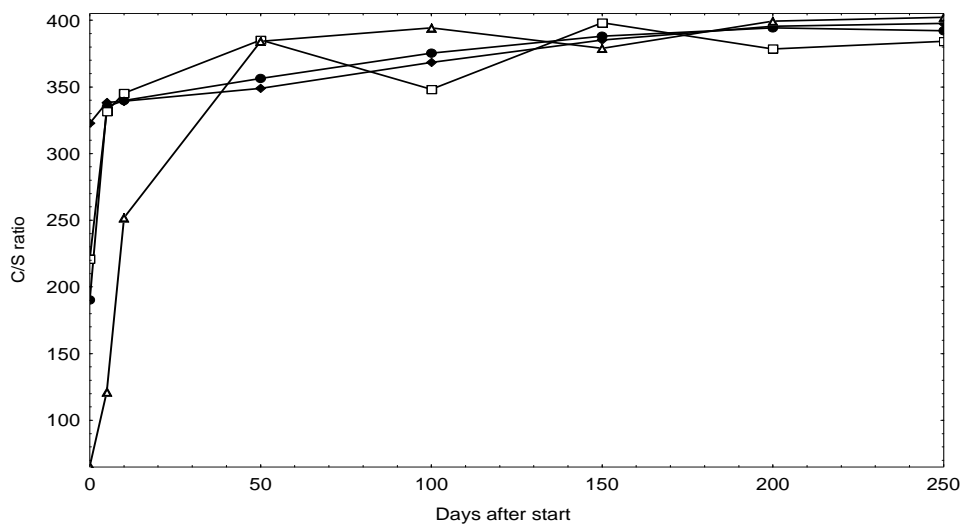


Fig. 6. Changes in the mean C/S ratio of *Zostera marina* leaves in litterbags secured in the foredune zone of Hel Great Beach: ●, air-dried; ◆, freeze-dried; □, oven-dried; △, fresh material.

Table 2

Details of published field study of *Zostera marina* leaves decay. Rates are expressed as loss of organic material or ([†]) total dry weight.

Age (state)	Treatment	Decay conditions				Decay rate [% day ⁻¹]	Reference
		Time [days]	Litter bag mesh [mm]	Location	Buried		
Old	Fresh	90	1	Subtidal		0.4	Robertson & Mann (1980)
			9	Subtidal		0.6	
Mixed (living)	Fresh	150	2.5	Subtidal		1.8	Josselyn & Mathieson (1980)
				Intertidal		0.7	
Green	Fresh	210	1	Subtidal		0.4 [†]	Pelikaan (1984)
Dead	Fresh	365	1	Subtidal		0.3	Gallagher <i>et al.</i> (1984)
				Intertidal		0.2	
Green, stranded	Fresh	27	0.048	Supralittoral		3.2	Jędrzejczak (2002a)
			0.5			3.5	
			12			3.8-4.4	
Green, stranded	Fresh	150	5	Intertidal		2-20	Jędrzejczak (2002c)
				Supralittoral		6-14	
					+	1-7	
				Backshore		0.2-4.5	
					+	0.5-3	
				Dune		1.5-6	
Green, stranded	Air-dried	250	0.5	Backshore		0.04-0.44	Present study
	Oven-dried					0.05-0.53	
	Freeze-dried					0.07-0.54	
					+	0.5-6	
	Fresh					0.06-2.00	

A similar situation was observed in the chemical analysis, which has demonstrated changes in CNS-losses during degradation in the bags (Fig. 5 and 6). The different CN-losses from fresh vs dried replicates indicated that the chemical composition of the remaining material could have changed. The C/N ratio subsequently increased in bags with both types of method used, however this rise was significantly lower towards approx. Day 40 in the case of fresh material decay.

Mass losses of different materials at the same site vary widely and are often explained by the chemical composition of litter. Differences in the mass loss of the same litter under identical climatic conditions, but at different sites, are normally minor. The rate of decomposition depends on the composition of flora and fauna, activity of microorganisms, temperature and moisture regime, litter quality and quantity, and the nutrient status of the soil (Swift *et al.* 1979). These conditions may manifest themselves not only in the abiotic fragmentation of the matter, but also in the structure and function of the local consumer assemblage and in the rate at which the material is decomposed by microbial components at a specific site. Jędrzejczak (1999, 2002b) reported that, aside from consumption, the feeding activities of detrital consumers could accelerate the decomposition of material through the spread of microorganisms or by maintaining the surface microbial community in a youthful state. Grazing of other detritivores accelerates the rate of decomposition of organic material by reducing its particle size, by presenting a greater surface area to microbial action, and through the excretion of nitrogen-rich materials that enhance microbial growth (Robertson and Mann 1980). Furthermore, fragmentation increases rates of leaching and saprophytic decay of detritus (Harrison and Mann 1975a, 1975b; Robertson and Mann 1980). The present results of organic material breakdown, achieved by simulating measurements of biological as well as physical and chemical activity under similar environmental conditions, are generally in accordance with the results of other studies focusing on the decomposition of *Zostera marina* (Table 2). However, k-value patterns depend on the initial conditions of each experiment presented in Table 2. Temperature plays a significant role in determining the decay rates. Furthermore, the importance of temperature varies depending on the phase of decay (Valiela *et al.* 1985). It has little effect on the rate of weight loss during the leaching phase. During the decomposition phase, however, weight loss increases when the temperature does so. This suggests that, as expected, higher temperatures enhance decomposing activity. Finally, temperature has no discernible effect on the low rate of weight loss during the refractory stage.

A joint examination of the cluster analysis (Loss mode) with mean values of dry matter loss for each method of predrying allowed recognition of two

main groups of methods (dissimilarity level of 20%), which can be treated as distinct analytical activities (Fig. 7a): Group 1 comprised methods with use of some drying activities, and Group 2 only clustered the method of non-drying. Both groups were linked at a level close to 39%. The cluster analysis based on the C/N mode also determined two groups of methods at a level of 10% (Fig. 7b), the same as in the latter case. Both were linked at a level close to 25%.

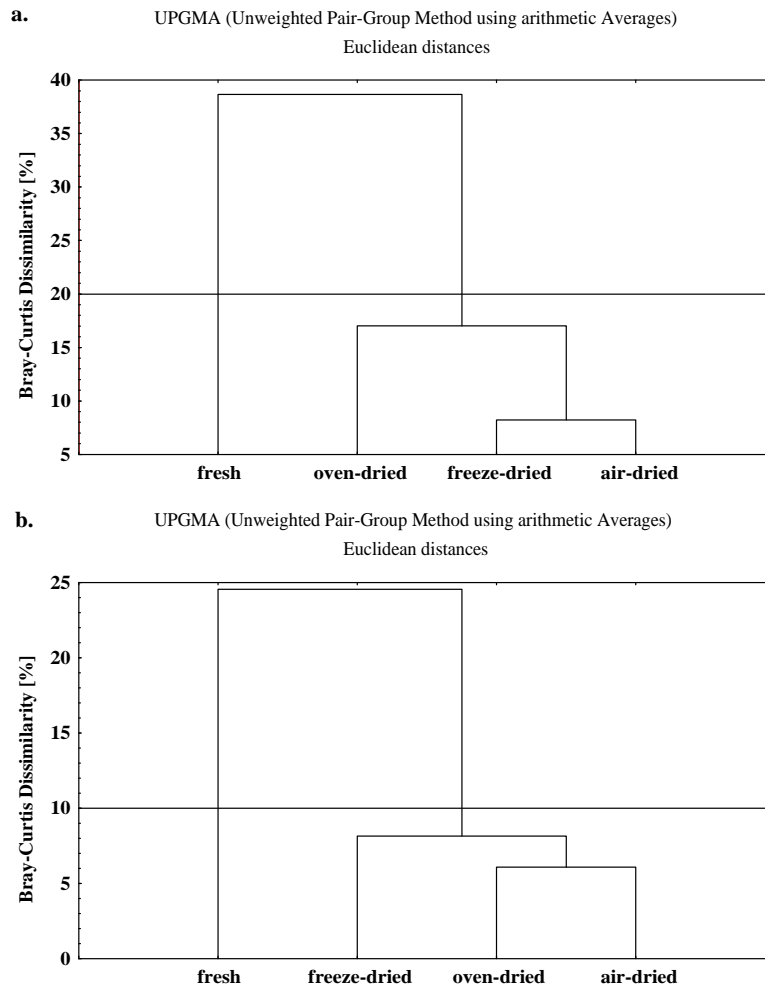


Fig. 7. Cluster analysis of predrying methods based on (a) dry weight loss and (b) C/N ratio variability, using the Bray-Curtis dissimilarity index (method names on X-axis are called as in “Material and Methods”).

The results obtained in present investigations are in excellent agreement with the previous study of Jędrzejczak (1999, 2002a, c). Long-term studies have led to suggestions that the method of predrying had little influence on the process of decay (Jędrzejczak 1999, 2002c). However, shorter-term experiments indicate that differences, apparent in the early part of the recent experiment, were also present in a similar study (Jędrzejczak 2002a). This was probably a result of differences in material structure and initial chemical composition of plant material, caused by some disturbance in chemical structure done by predrying activity. Elsewhere, this further implied that more refractory-becoming material prevents any fast degradation by decomposer assemblages in the short term. A detailed consideration of the problem revealed that short-term environmentally driven sampling strategies with pre-dried material fail to obtain conclusive results about degradation estimates of stranded wrack and faunal colonisation strategies, and should be avoided at least with the use of dried material. However, the use of pre-dried material is allowed within litterbag techniques in long-term sandy beach studies.

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