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PLANT BIOMASS STRUCTURE OF ANTARCTIC TERRESTRIAL COMMUNITIES IN RELATION TO ENERGY FLOW[1]

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ABSTRACT

The structure of typical above-ground plant communities in the vicinity of the Arctowski Station (Admiralty Bay region, King George Island, cold maritime Antarctic, (φ = 62°09.9'S, λ=58°27.7'W) was analyzed in 1998. In the dominant type of ecosystems we assessed separately above-ground live biomass, dead biomass, as well as green and non-green biomass. Total above-ground biomass ranged from 60.0 to 1532.8, live biomass 60.0 to1289.6, and green biomass 60.0 to 675.5 g dry weight m^{-2}. Green biomass accounted for 27 to 100% of total above-ground biomass, and its contribution to above-ground biomass was positively correlated with the amount of energy subsidy from organic matter. We concluded that these Antarctic terrestrial ecosystems belong the subsidized ecosystem type (sensu Odum 1989) because they receive not only solar energy but also large amounts of organic matter transported from the sea by animals (birds and pinnipedes).

KEY WORDS: Antarctica - plant biomass - energy subsidy

INTRODUCTION

Studies of biomass and production of plant communities of polar regions go back the fifties Aleksandrova (1958), Bliss (1956), Pearsall and Nebould (1957). At the turn of the sixties and seventies the studies intensified. He results of those intensive studies have been put together in a number of extensive volumes edited often within the framework of IBP Tundra Biome Project by among other Wielgolaski (1975), Tieszen (1978), Sonesson (1980), Bliss et al. (1981), Laws (1984) Longton (1988). Those studies were a step forward toward understanding the structure of plant communities in relation to bioclimatic zones, the quantity and dynamics of primary production and the effect of habitat conditions on the efficiency of the primary production processes.

Studies concerning the above problems have been conducted on King George Island (Cold Maritime Antarctic), in particular in the coastal oasis situated in the Admiralty Bay region. Studies of the standing crop and production of plant communities and selected plant populations have been conducted there in the area of H. Arctowski Station since 1988 and still being continued. The main object of those studies has been answering the question in what way the habitat factors, varying in time and space, modify the primary production processes and the standing crop (Zarzycki, 1992, Barcikowski, 1994, Barcikowski, Gurtowska, 1999, Barcikowski et al., 1999).

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However, the primary and esential characteristic of Antarctic oases is the fact that the ecosystems in them run under conditions of energy subsidy. From the point of view of ecological energetics as understood by Odum (1998), there are four types of ecosystems. There are: unsubsidized natural solar-powered ecosystem, subsidized ecosystems, including naturally subsidized and human-subsidized ones, and finaly solely human subsidized ones without any contribution of direct solar energy. As energy subsidy Odum (l.c.) also considers solar energy transformed by ecosystems in another place or time. In response to a given quantity and quality of direct energy and energy subsidy a characteristics structure of the ecosystem plant biomass evolves, which is particularly evident in the ratio of the amount photosynthesizing (green) to non-photosynthesizing (non-green) tissue.

The Antarctic terrestrial ecosystems in the Admiralty Bay region (King George Island, Cold Maritime Antarctic) are typical naturally subsidized, since an important part in their development is played, besides solar energy absorbed in photosynthesis, also by the huge amounts of organic matter imported from the sea onto the land. That is matter actively transported by animals (fecal mass, pellets, mussels), matter produced by the animals (feathers, eggs, fur, dead animal bodies) and organic matter transported passively by physical processes (winds, sea waves, tides). The total quantity of organic matter supplied to the oasis under study is estimated at 1.8 kg m^{-2} rok^{-1} (Rakusa-Suszczewski, 1992). The matter is the main source of nutrients supplying the plant communities, thought it does not equally reach all the phytocenoses. The release of biologically active substances may also take place from paleornithogenic deposits (Tatur, Myrcha, 1988).

In the studies carried out so far in that region it has been found that the percentage of green parts of the above-ground biomass of phytocenoses is high compared with communities in other parts of world (Barcikowski, 1994). The objective of the present work was to assess the ratio of photosynthesizing to non-photosynthesizing tissue in the communities of the Antarctic oasis depending to various degrees on energy subsidy. For that purpose an assessment was made of the structure of the above-ground biomass of typical fresh-water a terrestrial plant communities. Basing on the results of the studies conducted in the vicinity of H. Arctowski Station in 1988 the above-ground standing crop in the dominant communities has been assessed, taking into consideration the total biomass, including living, dead, green and non-green biomass.

MATERIAL AND METHODS

Basing of the map of plant communities of the area round H. Arctowski Station (King George Island, South Shetlands, φ= 62°09.9' S, λ=058°27.7' W) by Furmańczyka and Ochyra (1982), nine sites were selected, representing typical terrestrial and fresh-water plants communities, depending to various degrees on energy subsidy. Those were:

1 – fragment of damaged moss carpet trodden by the staff of the Station (2 m asl)

2 – fresh-water community with *Phormidium* dominance, seasonally drying up puddle supplied by courses (2 m asl)

3 – community of nitrophilous alga *Prasiola crispa*, close vicinity of penguin rookery (25 m asl)

4 – community of benthic algae, small lake (2 m asl)

5 – moss carpet subformation with dominance of *Sanonia uncinata* and *Warnstorfia sarmentosa* (2 m asl)

6 – grass and cushion chamaephyte subformation with dominance *Deschampsia antarctica, Polytrichastrum alpinum* and *Sanonia uncinata* (25 m asl)

7 – grass and cushion chamaephyte subformation with dominance *Polytrichastrum alpinum Deschampsia antarctica* and *Colobanthus quitensis* (25 m asl)

8 – moss carpet subformation with dominance *Sanonia uncinata* and *Warnstorfia laculosa* (45 m asl)

9 – fruticose lichen and moss cushion subformation with dominance *Usnea antarctica* (55 m asl)

In each site the plant cover structure and the standing crop were assessed. The plant cover was estimated by means of hoop 0.1 m^2. In each site except the lake 100 random throws were executed. The plant cover was assessed, four groups of plants being distinguished: algae (for sites with *P. crispa* and *Phormidium*), lichens, bryophytes and vascular plants. In each site the biomass was assessed separately in each plant group. For each group 30 random samples were collected by means of metal mould 28.26 cm^2 in area. The material of each sample was segregated into dead, green and non-green parts. The segregated material was desiccated to steady weight at 85° C.

RESULTS AND DISCUSSION

The plant cover in all sites under study excepted the trodden one oscillated around 100%. The percentage of the particular plant groups depended on the habitat and topographic conditions. However, it is noteworthy that strongly subsidized sites (site 2) and those strongly disturbed by seasonal drying (sites 1) were dominated by algae (Fig. 1.).

The above-ground standing crop ranged from 60.0 to 1527.8 g dry weight m^{-2}. The lowest values were found in the fresh-water communities (site 1 and 2) and in the site damaged by treading (site A). The highest standing crop values were found in the community with the dominance of *Usnea antarctica* (site 8) and in the moss carpet subformation with the dominance *Sanonia uncinata* and *Warnstorfia sarmentosa* (site 4). Sites 4 and 7, similar in point of habitat conditions and species composition, showed the highest living biomass values: 1289 and 1244 g d.w. m^{-2} respectively (Fig. 2). The highest green biomass value was found in the site with the dominance of *U. antarctica* (Fig 2 and 3).

It is noteworthy thy that the analysis of the standing crop in plant communities, varying widely in point of the amount of standing crop as well as the size of photosynthesizing apparatus, does not demonstrated a pronounced effect of energy subsidy. None of the sites showing high total and green standing crop was clearly affected by matter import from the sea. On the other hand, the percentage of green biomass in the above-ground biomass of the communities clearly indicates that the effect of energy subsidy may be an increase in the percentage content of photosynthesizing tissue (Tab. 1).

That is particularly evident in site 2, were the photosynthesizing apparatus of the dominant species *P. crispa* constitutes 100 % of the above-ground biomass. Without doubt, the community situated close to the penguin rookery runs under high subsidy conditions. According to Tatur and Myrcha (1984), in the penguin rookery 10 kg d.w. m^{-2} of guano is accumulated each day. A similarly high green biomass content was found in the communities with the dominance of *Phormidium* and benthic algae, i.e. in disturbed communities. It seems that energy subsidy is another factor disturbing the functioning of plant communities; anyway it has the some effects for the biomass structure. It can be assumed that from the standpoint of ecological energetics, each disturbing factor is a source of additional energy affecting the ecosystem. As an example of the that notion can be regarded the moss carpet trodden by the staff of the Station. Primarily, it was probably similar to site 4. The site disturbed by man was characterized by an increasing index of green biomass content.

Extensive studies of ecological succession demonstrated that also early succession stages characterized by a high content of photosynthesizing tissue in the biomass of phytocenoses compare with later, mature stages (Barcikowski, 1994). Early stages of ecological succession are often identicated with system running under disturbed conditions. It can therefore be assumed that biomass structure, understood as the ratio of the amount of photosynthesizing to that of non potosynthesizing tissue, is the function of energy flow, which produces similar effects in disturbed and subsidized systems and in early succession stages.

Considering the above findings, site 8 with the dominance of the lichen *U. antarctica* seems a kind of artefact. The community shows a comparatively high index of photosynthesizing tissue content in the above-ground biomass in spite of the fact that the effect of subsidy in the site was rather small. At most, there may be here some minor influences of paleornitogenic deposits. However, it seems that the results in question is due is the first place to an error in method, as in this case the total biomass of the lichens *U. antarctica* was considerated to be photosynthesizing tissue without subtracting from it the biomass of the non-photosynthesizing fugal hyphen.

We realise that the conclusions presented here cannot be considered to be fully proved, as, for one thing, the assessment of the amount of energy subsidy was highly subjective. However, we hope that the results of our studies will be an incentive for more studies in that field.

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Tab. 1 Percentage of green biomass in above-ground biomass of typical plant communities (King George Island, South Shetland Islands, January 1998)

Sites and communities	Above-ground biomass	Green biomass	Content of green biomass in above ground biomass
	g dry matter m^{-2}		%
A – damaged moss carpet, trodden by the staff of the Station	45.35	31.00	68.36
1 – fresh-water community with *Phormidium* dominance, seasonally drying up	70.00	70.00	100
2 – community of nitrophilous alga *Prasiola crispa*, close vicinity of penguin rookery	60.00	60.00	100
3 – community of benthic algae, small lake	60.00	60.00	100
4 – moss carpet subformation with dominance of *Sanonia uncinata* and *Warnstorfia sarmentosa*	1289.00	365.00	28.32
5 – grass and cushion chamaephyte subformation with dominance *Deschampsia antarctica*, *Polytrichastrum alpinum* and *Sanonia uncinata*	1023.00	468.00	45.75
6 – grass and cushion chamaephyte subformation with dominance *Polytrichastrum alpinum* *Deschampsia antarctica* and *Colobanthus quitensis*	756.00	270.00	35.71
7 – moss carpet subformation with dominance *Sanonia uncinata* and *Warnstorfia laculosa*	1244.00	336.00	27.01
8 – fruticose lichen and moss cushion subformation with dominance *Usnea antarctica*	963.00	675.00	70.09

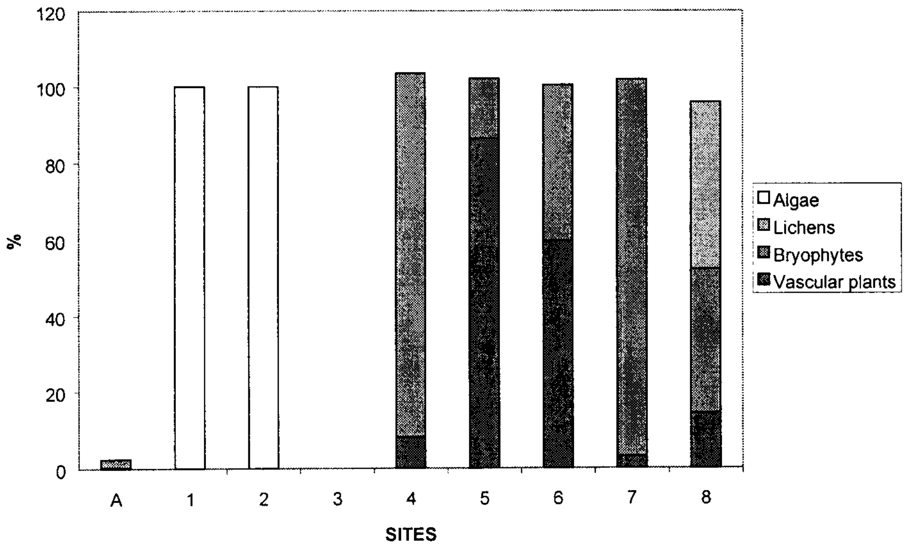

Fig. 1 Plant cover of selected sites in dominant communities affected to different degrees by energy subsidy (colonies of mammals and birds), (H. Arctowski Station, King George Island, January 1988), A – fragment of damaged moss carpet trodden by the staff of the Station (2 m asl), 1 – fresh-water community with *Phormidium* dominance, seasonally drying up puddle supplied by courses (2 m asl), 2 – community of nitrophilous alga *Prasiola crispa*, close vicinity of penguin rookery (25 m asl), 3 – community of benthic algae, small lake (2 m asl), 4 – moss carpet subformation with dominance of *Sanonia uncinata* and *Warnstorfia sarmentosa* (2 m asl), 5 – grass and cushion chamaephyte subformation with dominance *Deschampsia antarctica, Polytrichastrum alpinum* and *Sanonia uncinata* (25 m asl) 6 - grass and cushion chamaephyte subformation with dominance *Polytrichastrum alpinum Deschampsia antarctica* and *Colobanthus quitensis* (25 m asl), 7- moss carpet subformation with dominance *Sanonia uncinata* and *Warnstorfia laculosa* (45 m asl), 8 – fruticose lichen and moss cushion subformation with dominance *Usnea antarctica* (55 m asl).

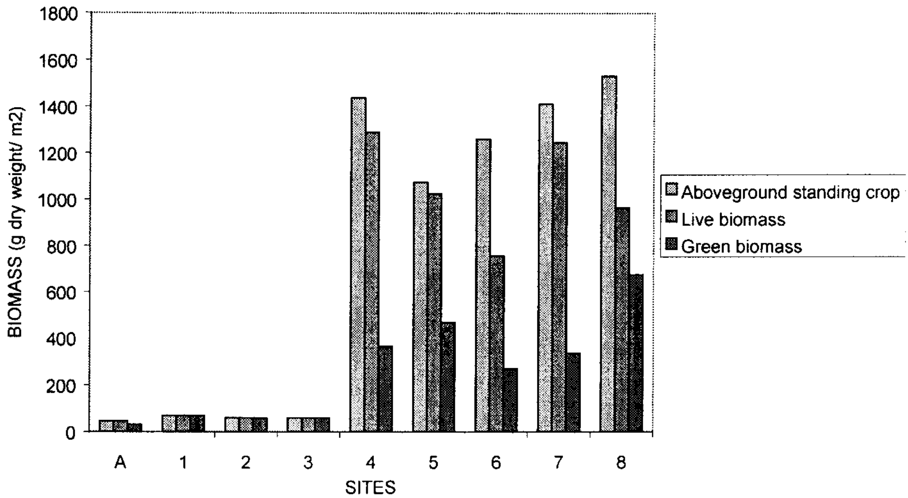

Fig. 2 Above-ground biomass of selected communities (H. Arctowski Station, King George Island, January 1988).

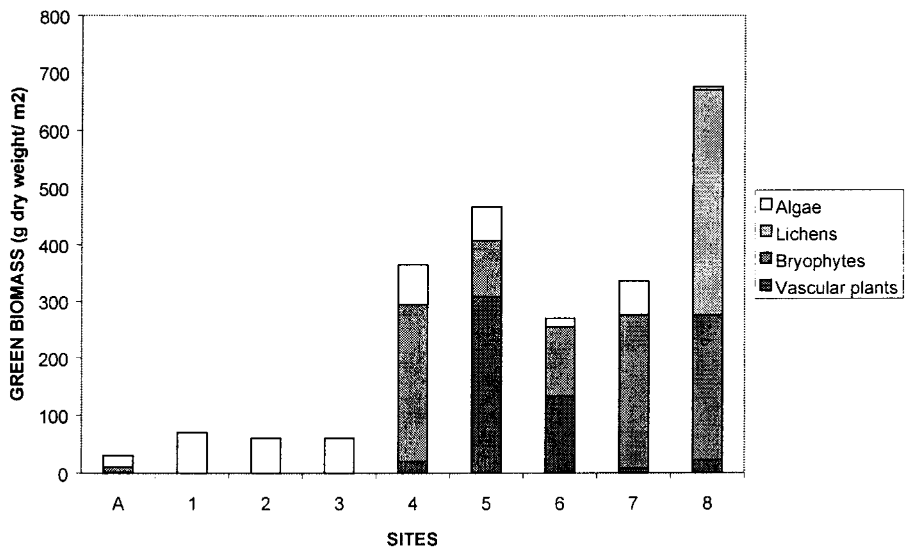

Fig. 3 Percentage of particular plant groups in the green biomass of the communities under study (H. Arctowski Station, King George Island, January 1988).