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Benthic macroalgae of Admiralty Bay (King George Island, South Shetland Islands) and circulation of algal matter between the water and the shore*)

ABSTRACT: The occurrence of 18 species of algae was stated in the investigated region. Among them the following were predominant: *Himantothallus grandifolius, Desmarestia menziesii, Cystosphaera jacquinotii, Ascoseira mirabilis, Leptosomia simplex, Adenocystis utricularis, Monostroma hariotii, Iridaea obovata, Hildenbrandia lecannellieri, Plocamium coccineum* and *Phycodrys antarctica*. Vertical stratification of the distribution of three singled out communities of algae was observed downwards to the depth of 90 m, which is the limit of the occurrence of the algae in the Bay. The process of decomposition depends on the place where it occurs, the kind of the thalluses and the season of the year. The quickest decomposition of algae was observed on the shore, in the summer and spring.

The total quantity of algal matter washed ashore along 15.8 km of the coast line of Admiralty Bay, during the period between February and October 1979, was estimated at 279 metric tons of dry weight matter. From this quantity, in result of decomposition of the algae on the shore, 75 tons of the matter were released during an average time of 12 days. The remaining 204 tons of partially decomposed algal matter are driven by winds farther inshore or into the waters of the Bay or remain ashore among the stony rubble.

Key words: Antarctic, Admiralty Bay, benthic algae, distribution, decomposition

1. Introduction

Neushul (1965) carried out observations and collections of benthic algae along the coasts of the South Shetlands (Half Moon Island) and in littoral and sublittoral zones of the Antarctic Peninsula and has determined species composition and the regions of the occurrence of benthic algae

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depending on the depths of the waters. Perfunctory underwater observations along the coasts of South George Island showed poor algal vegetation with predominance of the genus *Desmarestia*. Neushul (1968) has mapped the distribution of benthic algae of the Antarctic regions in the form of charts for particular species. A comprehensive inventory of the species of the Antarctic algae with nomenclature, systematic position and distribution was given by Papenfuss (1964). All these studies, including Dell (1972), indicate that most characteristic for the South Shetlands are: *Desmarestia menziesii* J. Agardh, *D. willii* Reinsch, *D. anceps* Montagne, *D. ligulata* (Lightfoot) Lamouroux, *Monostroma hariotti* Gain, *Adenocystis utricularis* (Bory) Skottsberg, *Ascoseira mirabilis* Skottsberg, *Cystosphaera jacquinotii* (Montagne) Skottsberg, *Leptosomia simplex* (A. et. E. S. Gepp) Kylin, *Phyllogigas grandifolius* (A. et E. S. Gepp) Skottsberg, *Iridaea obovata* Kützing, *Plocamium secundatum* (Kützing) Kützing. Moe and DeLaca (1976) and DeLaca and Lipps (1976) made observations and collections of macroscopic algae in the region of King George Island (North-West coasts of the Fildes Peninsula, Maxwell Bay, Nelson Strait). In consequence of these studies a catalogue of the algae species and zonation of the plant-animal association were determined. Yet, there are no data referring to the Admiralty Bay itself. The abrasive action of ice is an important agent having a substantial influence upon the occurrence and distribution of algae in the Antarctic regions (Neushul 1965, Delepine, Lamb and Zimmermann 1966, Moe and DeLaca 1976, Gruzov 1978). Moe and DeLaca (1976) report that macroalgae occur in more aboundant quantities in open places exposed to the motion of the waves.

Accumulation of fragments of algae in the hollows of the bottom of the littoral zone washed ashore by the waves was observed also in other regions of the Antarctic (Bunt 1955, Neushul 1965, Gruzov 1978). The fate of brown algae thrown out from the sea onto the land and remaining in the tidal pools in the littoral zone of Macquarie Island was studied by Bunt (1955). The author declares that decomposition of seaweeds occurs in effect of the action of microorganisms more speedily in contact with the water surface or beyond the water environment than in the water. Benthic macroalgae are one of the very important elements of the littoral zones in the Antarctic (Bunt 1955, DeLaca and Lipps 1976) and play a significant role in the processes of exchange and circulation of matter between water and land (Rakusa-Suszczewski 1980a, 1980b).

The aim of this study is to determine the composition and distribution of the principal groups of phytobenthos of the Admiralty Bay, to investigate the ways and directions of the transport of algae and to examine throughly decomposition processes ashore and in sea water in a year-cycle.

2. Region of investigations and environmental conditions

Admiralty Bay is the largest bay of King George Island, South Shetlands Archipelago (Rakusa-Suszczewski 1980b). The boundary line of Admiralty Bay lies between Demay Point and Syrezol Rocks. The surface area of the Bay is 131 km^2 and the volume of water is about 18 km^3. A diversified shore line is in the western part of the Bay of a rocky, sandy and gravelly character and in the northern and eastern parts is icebound. The total length of the shore line is 84.8 km. The cross section of the basin of Admiralty Bay is U-shaped and its upper part opens out on both sides forming a shallower "microshelf", several score metres deep. The maximum depth of the central part of the Bay is about 530 m.

The region selected for investigations (Fig. 1) lies on the west coast of Admiralty Bay, between Point Thomas and Demay Point, and is 11.5 km long. It includes various types of shore line: icebound — 1.9 km, rocky — 2.4 km, sandy-gravelly — 7.2 km. The depth of the "microshelf" along the coast under investigation ranges from 0 to 100 metres.

The region of Admiralty Bay is characterized by strong winds; the mean wind speed in 1978 was 7 $m \cdot s^{-1}$ (Zubek 1980). The wind are southward through westward to northward increasing the waving of the waters. The surge of the sea and surf dash the algae and washed them ashore. The region between the Point Thomas and the Glacier of Ecology is most favoured as regards the quantity of the algal matter (Fig. 1) washed ashore. The weather-beaten algae appeared on the shore a day or a few days after a storm. Though westerly winds prevailed usually, the largest waves thrusting out the algae onto the shore were caused by northerly winds or infrequent northeasterlies and southerlies, generally concomitant with a huge dead wave and violent displacement of the waters from the Bransfield Strait towards Ezcurra Inlet. These waves tear off the thalluses from the bottom and carry them ashore. The westerly wind, likewise, caused the transfer of algae onto the investigated section of the coast, which was connected probably with whirls of water masses flowing out from Ezcurra Inlet southwards.

From early May till early October, despite the lack of a permanent ice cover, the whole shore line of Admiralty Bay was covered with ice pack spreading out over a distance of a few to several score metres toward the Bay. Near Shag Point and in the shallower areas between Shag Point and Point Thomas numerous fragments of algae were observed drifting along the coast. Ice covering the shore line prevented, as results from the observations, throwing of the algae up onto the shore though they were shoot out onto the top of ice cover by high billows of the surf. In mid-October, higher temperatures and increased intensity of the surf waves coused the removal of ice and disclosure of the shore line, on which the algae appeared again.

3. Material and methods

The investigations were conducted from December 1978 till December 1979 in the region of the Arctowski Antarctic Station, situated at Admiralty Bay (62°09 45" S., 58°27 45" W.).

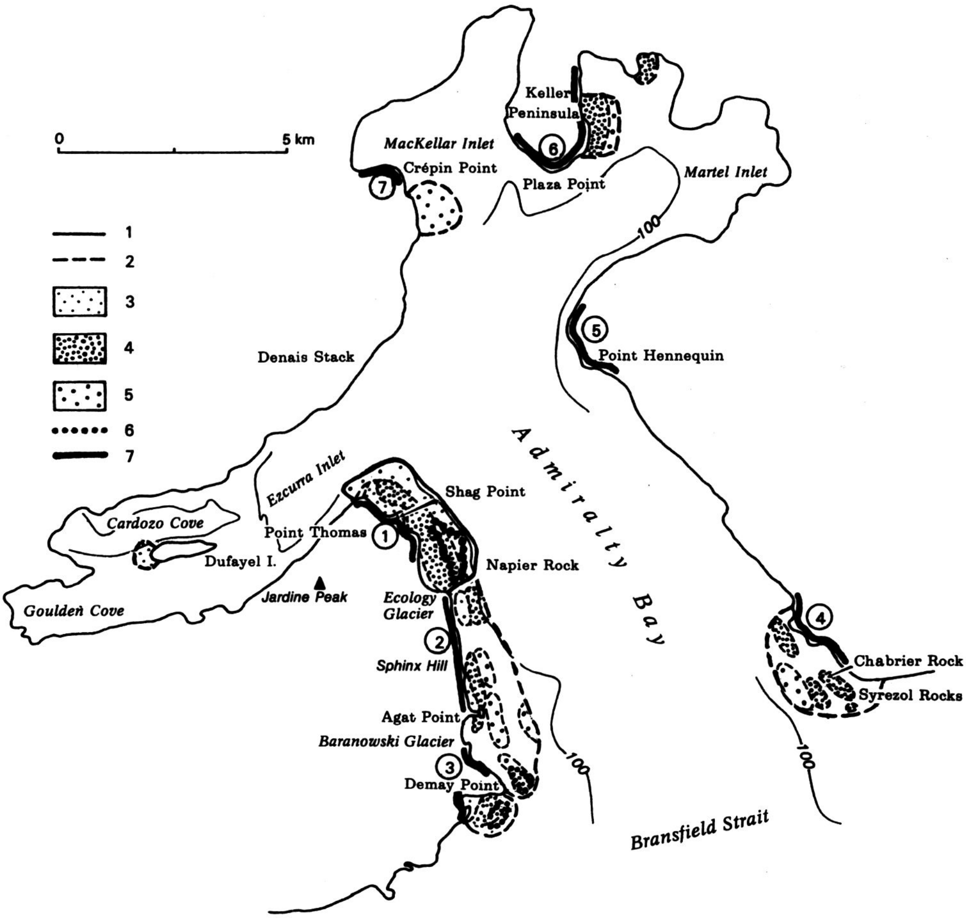

Fig. 1. Horizontal distribution of benthic macroalgae at Admiralty Bay (King George Island)

1 — the investigated range of agglomerations of algae; 2 — approximate range of algal agglomeration; 3 — areas of the bottom overgrown with algae: *Adenocystis utricularis, Monostroma hariotii, Leptosomia simplex, Desmarestia menziesii, Ascoseira mirabilis, Iridaea obovata;* 4 — areas of the bottom overgrown with algae: *Leptosomia simplex, Desmarestia menziesii, Ascoseira mirabilis, Himantothallus grandifolius, Hildenbrandia lecannellieri, Phycodrys antarctica, Desmarestia* sp.; 5 — areas of the bottom overgrown with algae: *Himantothallus grandifolius, Desmarestia* sp., *Plocanium coccineum*; 6 — areas overgrown with alga: *Cystophaera jacquinotii*, 7 — the investigated coasts.

Numbers in circles (1—7) — sections of the coast of Admiralty Bay, whereon algae are washed ashore. Total length of the sections of the coast, whereon algae were washed ashore (Sections 1—7) is 15.75 km. Section 1 — 2350 m long (from this section quantitative samples were collected), 2 — 2600 m, 3 — 800 m, 4 — 1400 m, 5 — 2400 m, 6 — 5600 m, 7 — 600 m.

Location of the places of the occurrence of benthic algae was carried out using dredging methods. A few observations of the bottom were made with a spyhole finder. Direct observations and collecting of algae were made mainly at ebb-tide. Several times algae were collected by two frogmen. Dredging was performed with rectangular metal dredges (inlet opening: longer side from 80 to 140 cm, shorter side from 30 to 40 cm). Each dredge was provided with four steel beams (140 cm long) and 0.5—2 cm mesh nylon net bags (10 to 90 cm long). Anchor-dredges, catching large specimens of algae complete, were also used. Dredging was made from a fishing boat downwards to the depth of 140 metres deep.

The quantities of the algal matter washed ashore at Admiralty Bay were determined from the beginning of February to the end of November. Samples were collected on the shore over a distance of about 2350 m of the shore line between Point Thomas and the foregrounds of the Glacier of Ecology. Observations of the shore line in the area under investigation were performed daily and decisions on the collection of samples were made at the moment when algae thrown out by the waves appeared on the shore. Samples were collected in two ways: at several points along the section of the shore where algal matter washed ashore was spread out evenly and at the places where accumulation of algae was markedly greater or where they were piled up in huge heaps. Single quantitative samples were collected by hand along a 1 m-long stretch of the shore or 0.5 m-long stretch in the case of a large amount of the algal matter. From large heaps algae were picked out within a 0.2 m $\times$ 0.2 m surface area down to the ground. Percentage content of red algae and brown algae was determined the samples representative for mass of algae washed ashore. The total length of the shore line where algae were washed ashore is 15.8 km (Fig. 1).

The effects of the wind, sweeping away fragments of the thalluses of the washed ashore algae and carrying them along inland or (and into the Bay), were established by observations.

Table I.

Place and duration of the exposure of the selected species of algae at Admiralty Bay in 1979

Species	Place of exposure	Duration of exposure
Leptosomia simplex	sea water	16 March — 1 May
	shore	16 March — 1 May
Cystosphaera jacquinotii	sea water	5 Nov. — 10 Dec.
	shore	5 Nov. — 10 Dec.
Himantothallus grandifolius	sea water	10 Jan. — 5 Feb. 22 March — 22 June 5 Nov. — 10 Dec.
	shore	27 Jan. — 20 March 22 March — 22 June 5 Nov. — 10 Dec.

Decomposition of algae was examined under natural conditions, during their exposure in water and ashore (Table I). The exposed species of algae represented substantive constituents of algal matter washed onto the shores of the Bay. A long-lasting exposure of the samples of algae in sea water is assured owing to an adequate system of equipment enabling to place the samples at a required depth. The system consisted of a light and a heavy anchor connected by a cable at the bottom and a buoy connected with light anchor on the surface of the water. Samples in nylon net-bags were hung on the cable connecting the buoy with light anchor. The site of the exposure ashore was situated on a stony shore at a distance of about 50 m from the mouth of the stream, near Shag Point.

Decomposition of algae was determined by measuring the dry weight content of the exposed thalluses. The samples of wet weight algae in the form of rings (20 mm in diameter) cut out from one specimen of the examined species were put into bolting-cloth bags and in a nylon net submerged in the waters of the Bay at the depth of 25 m (5 m above the bottom). The algae ashore were placed in an identical nylon net within the reach of the spray of the surf waves. The content of dry weight thalluses was determined, at intervals of 5 to 15 days.

Ash content was measured gravimetrically after combustion of the examined material in a muffle furnace at 550°C for 2 hours. Changes in caloricity was determined with two methods: wet combustion consisting in oxidation of organic matter in a mixture of bichromate of potassium and sulphuric acid (Zdanowski 1979) and direct combustion in a KL-5 calorimeter. Dry weight content was determined by weight after dessication of algae at 65°C to constant weight. Lipids content was determined gravimetrically double extraction from crumbled material with a mixture of chloroform: methanol (2:1) and chloroform: hexane (1:1) (Dowgiałło 1975).

4. Results

4.1. Benthic flora

Phytobenthos of Admiralty Bay is composed of about 18 species of algae. The following species are predominant:

Green algae — *Monostroma hariotti* Gain
Red algae — *Leptosomia simplex* (A. et E. S. Gepp) Kylin
— *Iridaea obovata* Kützing
— *Hildenbrandia lecanneieri* Hariot
— *Plocamium coccineum* (Hudson) Lynobye
— *Phycodrys antarctica* (Skottsberg) Skottsberg
Brown algae — *Himantothallus gradifolius* (A. et E. S. Gepp) Skottsberg
— *Desmarestia menziesii* J. Agardh
— *Desmarestia* sp. Lamouroux
— *Cystosphaera jacquinotii* (Montagne) Skottsberg

— *Ascoseira mirabilis* Skottsberg
— *Adenocystis utricularis* (Bory) Skottsberg.

The total area of the bottom overgrown with algae is 15.1 km², which is 11.5% of the total area of Admiralty Bay. The principal region most aboundant in algae stretches from Point Thomas to the end of the foreground of the Ecology Glacier spreading out farther inside the Bay over a distance of about 1500 m along the line between Point Thomas — Point Hennequin and Napier Rock at the Ecology Glacier (Fig. 1). This region occupies the surface of 3.5 km², which makes up about 2.7% of the total area of Admiralty Bay. The agglomerations algae were also found in the Bay beyond Demay Point on the microshelf extending towards Bransfield Straits and along the line between the Ecology Glacier and Demay Point, near Chabrier Rock and Syrezol Rocks. They spread out far inside the Bay over a distance of about 1500 m. Other large agglomerations of algae

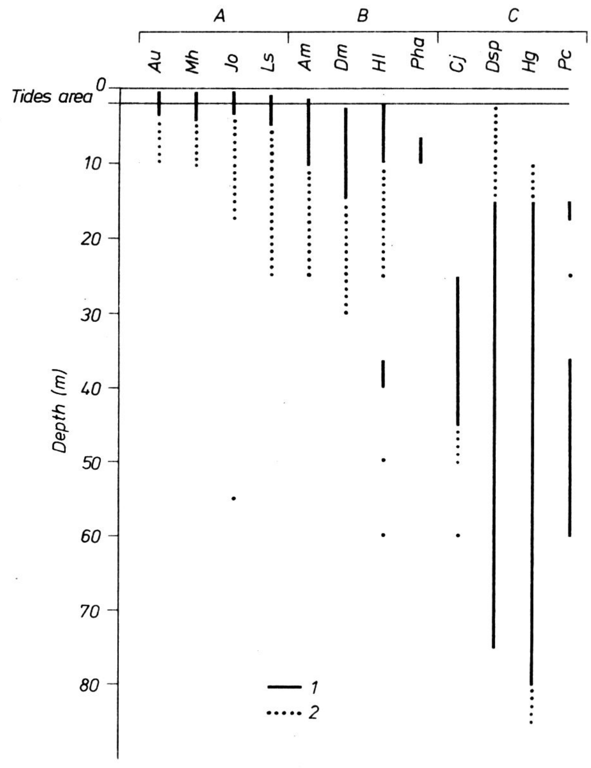

Fig. 2. Vertical distribution of benthic macroalgae at Admiralty Bay
A, B, C — communities of algae, Au — *Adenocystis utricularis*, Mh — *Monostroma hariotii*, Io — *Iridaea obovata*, Ls — *Leptosomia simplex*, Am — *Ascoseira mirabilis*, Dm — *Desmarestia menziesii*, Hl — *Hildenbrandia lecannellieri*, Pha — *Phycodrys antarctica*, Cj — *Cystosphaera jacquinotii*, Dsp — *Desmarestia* sp. (except *Desmarestia menziesii*), Hg — *Himantothallus grandifolius*, Pc — *Plocamium coccineum*.
1 — frequent occurence of algae, 2 — infrequent occurence of algae.

were observed in the regions along the eastern shores of Keller Peninsula in Martel Inlet. Agglomerations of algae were also noticed near Crepin Point and west promontory of Dufayel Island. An interesting region, besides Admiralty Bay, spreads out from the Bay beyond Demay Point to Potter Cove in the area of Maxwell Bay. Large agglomerations of algae grow on the rocky microshelf, full of submarine mounds and huge rocks.

In the investigated regions of Admiralty Bay three communities[1]) of algae were differentiated (Fig. 2). They were distributed in tiers depending on the depth and the character of substratum. The upper tier of algae occurs in the tidewater. The most characteristic for this community are: *Adenocystis utricularis, Monostroma hariotti, Iridaea obovata* and *Leptosomia simplex*. Here, *Adenocystis utricularis* and *Monostroma hariotti* prevail quantitatively, their biomass in the region between Point Thomas and Shag Point ranges from 0.7 to 1.3 kg 1 m^2, which from 0.4 km^2 area gives about 4 ton wet weight. The second community covers bottom areas from the lowest water level to the depth of 10—15 m. This community consists of the following species: *Desmarestia menziesii, Ascoseira mirabilis, Hildenbrandia lecannellieri, Phycodrys antarctica* and small quantities of representatives of the first community. The third community were at the depth ranging from 10—15 m to 70—90 m, which is the limit of the occurrence of algae. The largest brown algae enter into the composition of this community: *Himantothallus gradifolius* — measurements of the thallus of the largest specimen — length 10.2 m, width of the foliaceous part 0.78 m and 0.48 m, weight 15.4 kg; *Cystosphaera jacquinotii* — length 4.4 m, weight 4.3 kg; *Desmarestia* sp. — length 3.5 m, weight 2.7 kg. Among the red algae observed in this community there was also *Plocamium coccineum* as well as some other species of algae from the second community. It has been found that the thalluses of *Desmarestia* sp., *Himantothallus grandifolius* and *Hildenbrandia lecannellieri* were very often overgrown with epiphytes: *Adenocystis utricularis*, *Monostroma hariotti, Leptosomia simplex* and *Plocamium coccineum*.

Agglomerations of algae are associated with a hard rocky-stony substratum. Algae in the tidal zone and in deeper waters concentrate chiefly in bottom holes between submarine boulders, on the borders of bottom stones, in cracks and crevices of rocks. This type of substratum enables algae to attach themselves to the bottom and protects partially thalluses against destructive effects of icebergs and ice fields. The destructive effects of ice occur chiefly in the tidal zone. Large icebergs drift along west coasts of the Bay, from Demay Point to Point Thomas, rubbing against the bottom probably at the depth of 20—30 m, They tear off from the bottom huge brown alge, which are found washed ashore near the displacement of the floating icebergs. The thalluses of these algae were fresh and had distinct marks of mechanical action of ice (cracks, crushed fragments).

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[1]) The term community should not be compared with analogical term used in specialized botanical studies.

4.2. Seasonal evaluation of the intensity of the process of circulation of algal matter between the water and the shore

One of the most remarkable processes occurring in the tidal zone is certainly the washing ashore of algae by surf waves. The above-described, three communities of benthic plants are the source of algal matter. Throughout the summer season (February, March, April) large quantities of crumbled algae were observed floating on water and washed ashore in the tidal zone of the Bay. Despite considerable differences in the quantities of algal matter at various 1 metre-long sections of the shore and a considerable irregularity in its distribution on the shores the total monthly quantities of the matter cast ashore during February, March and April were comparable, remaining within the range of 56—57 ton of wet weight algae per month (Fig. 3). The largest quantities of algae were washed ashore in April, which was surely associated with a spell of very strong winds and displacement of the water masses and ice fields. In May, large agglomerations of algae were not observed on the shore. The total quantity of algal matter was twentyfold smaller as compared with the quantities noted in April. Numerous fragments of algae were observed in sea water, but they were raised sporadically by high surf waves and the wind up to the top of ice cover extending over the beach. A repeated increase of algal matter in the region under investigation was noted in October and its total quantity in November was estimated ot over 50 ton of wet weight algae.

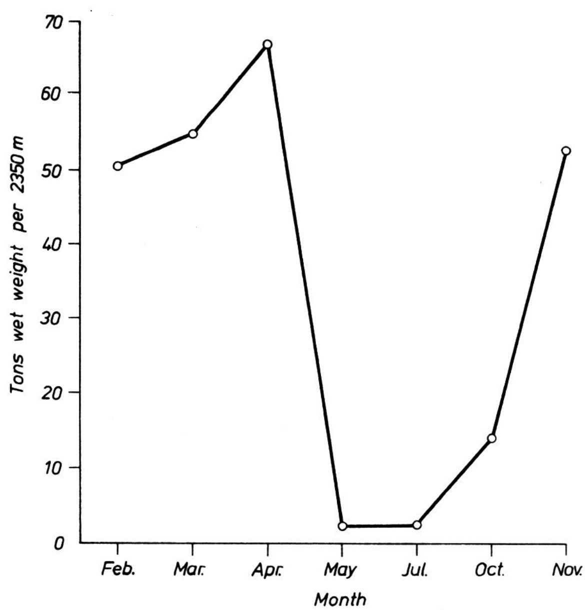

Fig. 3. Total monthly quantity of wet algal matter washed ashore in the investigated section of the coast of Admiralty Bay, in the period from February to November 1979

A gradual decrease of the quota of red algae in the total amount of algae washed ashore was noted in the period between February and October (Fig. 4). This is consistent with the observed seasonal decrease of the quantity of red algae at that time and in particular with a complete disappearance of *Leptosomia simplex*, which in the early April was still predominant among the red alga thalluses washed ashore. In October the heaps of algae were composed mainly of the thalluses of brown algae, however in November there was again an increase of the quantity of red algae in the algal matter washed ashore.

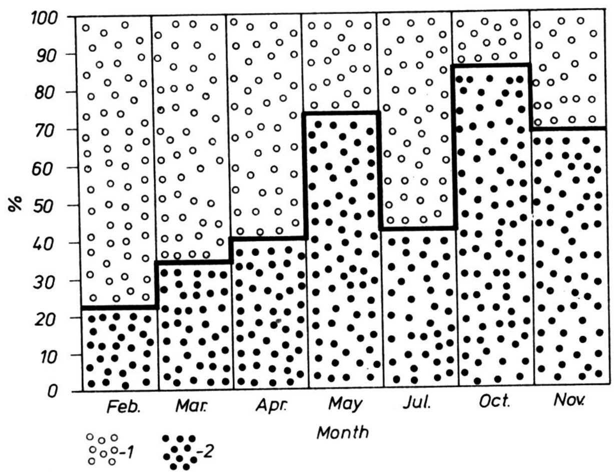

Fig. 4. Frequency of brown algae and red algae in algal matter washed ashore at Admiralty Bay during consecutive months (February — November 1979)
1 — red algae, 2 — brown algae

The time during which algae remain on the shore depends on the distance from the waterside. Algae washed ashore in the tidal zone were swept away back into the water by the subsequent flood-tide. Fragments of the thalluses cast off beyond the reach of the waves remained ashore several months. Algae cast off at the maximum tide subsisted on the shore the longest time. Regular observations showed that the mean duration of the remaining of algae ashore is 12 days.

On the whole, from February till November, 245 ton of wet weight algal matter (115 ton of brown algae, 130 ton of red algae) were cast off onto the investigated section of the coast, i.e. on the average 104 kg of algal matter per 1 metre-long stretch of the shore, during the whole season.

Finally, it has been calculated that throughout the period between February and November, 1643 ton of wet algal matter (775 ton of brown algae and 868 ton of red algae) were cast off by the sea into the accessible shores in the region of Admiralty Bay, which gives 279 ton of dry weight algal matter (123 ton of brown algae and 156 ton of red algae).

4.3. Decomposition of algae

The analysed algal material shows a high dry weight content in the investigated species, ranging from 8.8% to 18.1% of wet weight. The ash content in the dry weight matter of the investigated species ranges from 19.3% to 48.4%. The high ash content has an effect on low calorific values of the algal material, ranging from 9629.6 J (2.3 kcal) to 13816.4 J (3.3 kcal) per one gramme of dry weight.

The rate of decomposition of algal matter in water and ashore showed during the autumn considerable differences in morphologically different species of algae, i.e. *Leptosomia simplex* and *Himantothallus grandifolius* (Figs. 5 and 6). Decomposition of Leptosomia simplex was about twelvefold quicker in water and about fivefold quicker ashore as compared with the

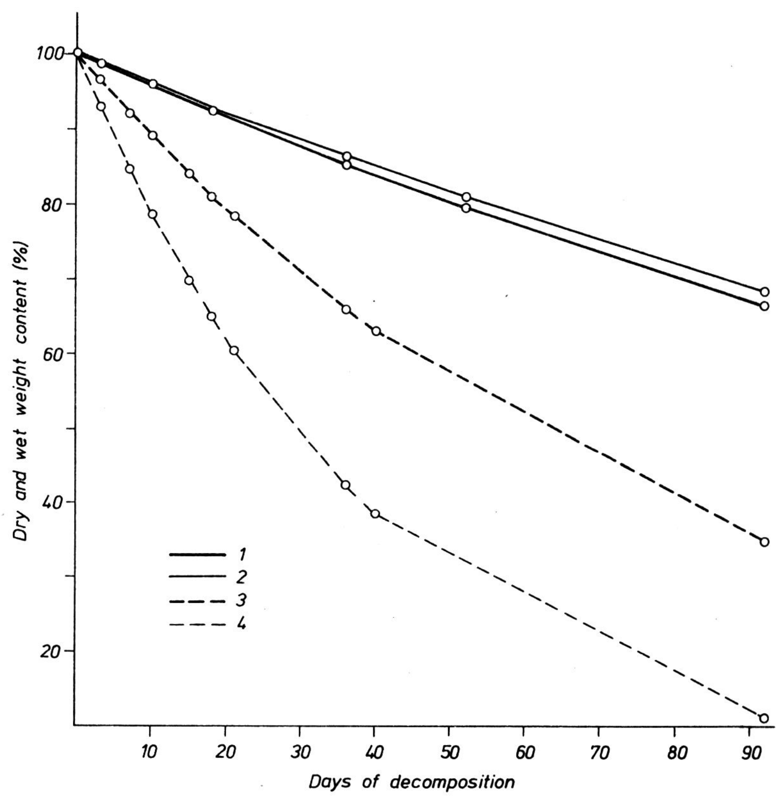

Fig. 5. Decomposition of *Himantothallus grandifolius* in sea water and ashore, during the autumn

Curves were traced with the least squares method, adjusting the function of the type

$$y = 100 \cdot e^{-bt}$$

Changes in the content of: 1 — dry weight material during the exposure in water, 2 — wet weight material during the exposure in water, 3 — dry weight material during the exposure ashore, 4 — wet weight material during the exposure ashore.

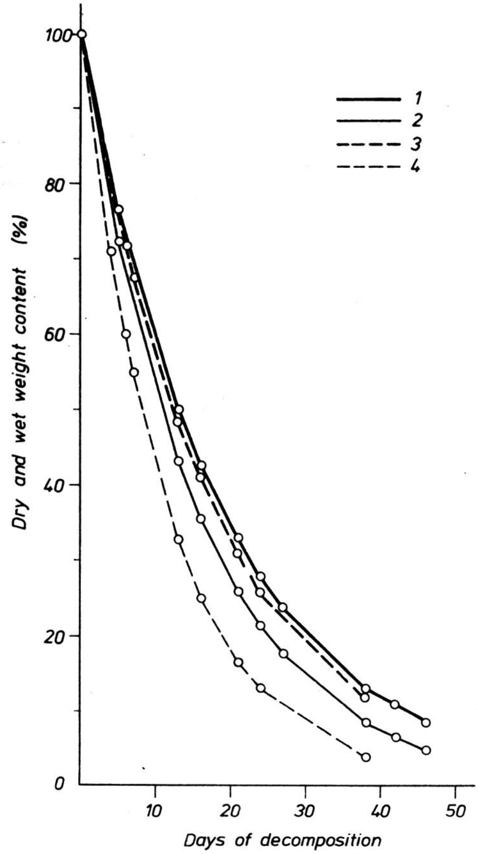

Fig. 6. Decomposition of *Leptosomia simplex* in sea water and ashore, during the autumn. Curves were traced with the method of the least squares, adjusting the function of the type

$$y = 100 \cdot e^{-bt}$$

Changes in the content of: 1 — dry weight material during the exposure in water, 2 — wet weight material during the exposure in water, 3 — dry weight material during the exposure ashore, 4 — wet weight material during the exposure ashore.

rate of decomposition of *Himantothallus grandifolius*. Differences in the rate of decomposition of algal matter in water and ashore were noted in the species *Himantothallus grandifolius* and *Cystosphaera jacquinotii* during spring exposures (Figs. 7 and 8).

Differences in the rate of decomposition between water and land environments were also observed. In the case of *Himantothallus grandifolius* the rate of decomposition under the conditions prevailing ashore was two to eight times faster in relation to the rate of decomposition in sea water (Figs. 5 and 7). Decomposition of *Leptosomia simplex* ashore was identical with that in water (Fig. 6). In the case of *Cystosphaera jacquinotii* decomposition occurred practically only in land environment (Fig. 8).

Seasonal differences in the rate of decomposition of the thalluses of *Himantothallus grandifolius* (Fig. 9) were observed between land and water

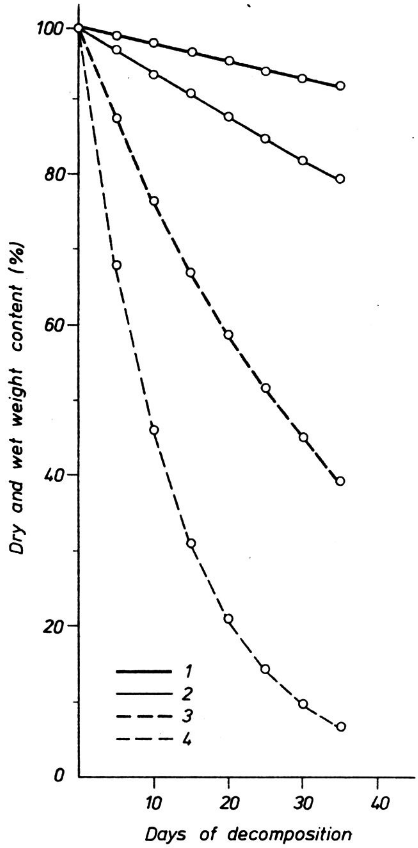

Fig. 7. Decomposition of *Himantothallus grandifolius* in sea water and ashore, during the spring.
Curves were traced with the least squares method, adjusting the function of the type

$$y = 100 \cdot e^{-bt}$$

Changes in the content of: 1 — dry weight material during the exposure in water, 2 — wet weight material during the exposure in water, 3 — dry weight material during the exposure ashore, 4 — wet weight material during the exposure ashore.

environments. The rate of decomposition ashore was quicker in the summer and spring. Differences in decomposition in various seasons of the year were relatively in water environment, a slightly quicker rate of decomposition was noted in the autumn.

In summer, the loss of dry weight matter was more than four times higher ashore than in water, which confirms the fact that the exposure of algae to the open air intensifies the rate of their decomposition.

During decomposition in water a decrease in dry weight matter and lipids content and in caloricity of the thalluses of *Himantothallus grandifolius* were observed simultaneously with a slight increase in ash content (Fig. 10). During decomposition ashore a marked decrease in dry weight matter, lipids and ash content and an increase in caloricity of the thal-

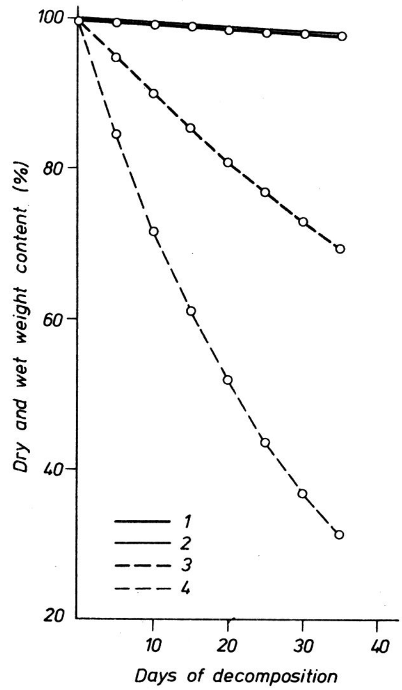

Fig. 8. Decomposition of *Cystosphaera jacquinotii* in sea water and ashore, during the spring Curves were traced with the least squares method, adjusting the function of the type $y = 100 \cdot e^{-bt}$

Changes in the content of: 1 — dry weight material during the exposure in water, 2 — wet weight material during the exposure in water, 3 — dry weight material during the exposure ashore, 4 — wet weight material during the exposure ashore.

luses were noted (Fig. 10), which indicates that ashore mineral compounds are liberated into the environment quicker than in water.

5. Discussion

Neushul (1965) exploring agglomerations of benthic algae along the shores of the South Shetland Islands reported scanty benthic flora in the regions of King George Island with predominance of algae of the genus *Desmarestia*. The results from studies indicate that algae of the genus *Desmarestia* are, indeed, one of the dominant forms of benthic flora. Besides *Desmarestia* the presence of the following species: *Monostroma hariotti*, *Adenocystis utricularis*, *Leptosomia simplex*, *Iridaea obovata*, *Ascoseira mirabilis*, *Cystosphaera jacquinotii* in other regions of the South Shetland Islands (Livingston Island, Half Moon Island, Harmony Cove) was also recorded by Neushul (1963).

The occurrence of the algae of the species *Himantothallus grandifolius* at Admiralty Bay is confirmed in further reports by Neushul (1968). In

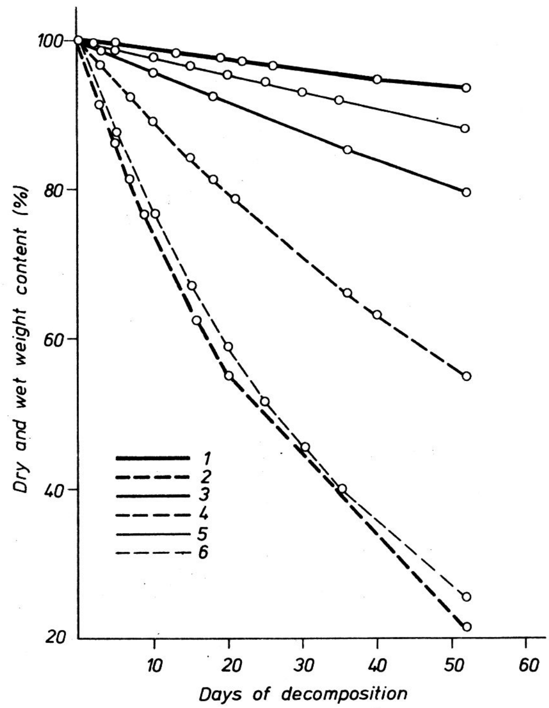

Fig. 9. Decomposition of Himantothallus grandifolius in water and ashore, in various seasons of the year.

Curves were traced with the least squares method, adjusting the function of the type $y = 100 \cdot e^{-bt}$.

Changes in the content of: 1 — dry weight material during the summer exposure in sea water, 2 — dry weight material the summer exposure ashore, 3 — dry weight material during the autumn exposure in sea water, 4 — dry weight material during the autumn exposure ashore, 5 — dry weight material during the spring exposure in sea water, 6 — dry weight material during the spring exposure ashore.

the Papenfuss (1964) systematic catalogue of Antarctic algae there are no data referring to the presence of the algae *Himantothallus gradifolius* and *Hildebrandia lecannellieri* in the regions of the South Shetland Islands. Delepine (1966) presented a schema of geographic distribution of the selected Antarctic species of algae, confirming the presence of *Himantothallus grandifolius* in the South Shetland Islands. Moe and DeLaca (1976), on the other hand, report that not only *Himantothallus grandifolius* but also *Hildebrandia lecannellieri* enters into the composition of algal benthic flora of the north-west coasts of Fildes Peninsula and Maxwell Bay (South Shetland Islands). Thus, the species of algae found at Admiralty Bay are consistent with the hitherto data on the composition of benthic flora of the South Shetland Islands.

The hitherto charts of the distribution of benthic algae in the Antarctic (Delepine 1966, Neushul 1968) are only simple schemata with marked down places of catches of the most frequently occurring species. The

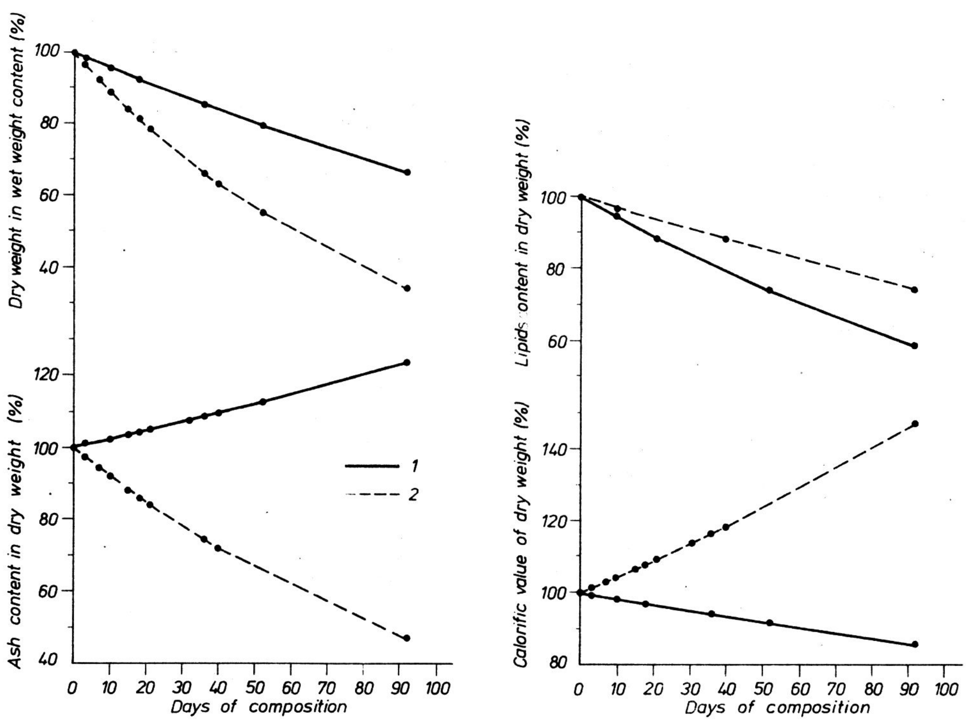

Fig. 10. Changes in the content of dry weight matterial, ash, lipids, and calorific values in *Himantothallus grandifolius* during the autumn exposure in sea water and ashore

1 — exposure in sea water, 2 — exposure ashore.

Curves were traced with the least squares method, adjusting the function of the type $y = 100 \cdot e^{-bt}$, except the curves of the changes in the ash content during decomposition in sea water and the changes in calorific values during decomposition ashore, were the function of the type $y = 100 \cdot e^{+bt}$ was adjusted.

As 100% absolute values were taken relating to undecayed (fresh) thalluses, successively: 13% — dry weight content of wet weight, 32% — ash content in dry weight matter, 14% — lipids content in dry weight matter, 12.1 J (2.9 kcal) — calorific value of 1 g of dry weight material.

map presented in this study is the first chart of this type worked out for the region of Admiralty Bay. The existence of the identified bottom areas with agglomerations of algae was confirmed on the basis of the interpretation of the bird's s-eye-view colour-photographs of Admiralty Bay (Furmańczyk and Zieliński in press).

Zaneveld (1968) declares that the main factor limiting the occurrence of benthic algae is an inadequate type of substratum. A hard rocky-stong bottom makes favourable conditions for a secure attachement of algae. Analogical situation was observed at Admiralty Bay. The abundance of seaweeds in the open places of the bottom and in the vicinity of the run-offs from the land (streams, run-offs from rookeries of penquins, seals, etc.) suggests favourable effects of continuous displacement of water masses and contiguity of run-offs rich in nutritive substances. Scantiness of algae along south coast of the Ezcurra Fiord may by explained by the character of the substratum of loose rocks and quicksand, differing from other regions of the Bay, e.g. Shag Point, or it may be associated with the phenomenon of a decrease in the quantity of seaweeds on the steep slopes of the bottom in the Antarctic, as described by Gruzov (1978).

Besides the substratum, ice is also an important limiting factor restricting the occurrence of algae. DeLaca and Lipps (1976), in result of their observations carried out along Antarctic Peninsula and the South Shetland Islands, reported that large algae, such as: *Desmarestia manziesii* or *Himantothallus grandifolius*, are particularly liable to the destructive effects of ice and waves. Moreover, it was observed that algae growing in the areas of a continuous inflow of ice are dwarfish and form smaller agglomerations (Moe and DeLaca 1976). At Admiralty Bay algae with large thalluses, e.g. *Desmarestia* sp., *Himantothallus grandifolius, Cystosphaera jacquinotii* and *Ascoseira mirabilis*, were subject to the abrasive action of ice most of all at the depths ranging from the minimum sea level to 20—30 m deep. In the regions of Half Moon Island, as reported by Neushul (1965) vast areas of the tidal zones were devoid of algae, except in ebb-tide pools, whereas the shores of the investigated island were covered by productive glaciers. At Admiralty Bay along the rocky-stony stretches of the shores only a several-metre-wide belt in the higher part of the tidal zone was devoid of algae. Inshore rocks, e.g. Shag Point, provide perfect shelter for the species of algae growing there — *Ascoseira mirabilis, Desmarestia menziesii, Adenocystis utricularis* and *Iridaea obovota*. Even small pieces of ice from ice fields are not able to get between the rocks overgrown with algae. Moe and DeLaca (1976) suggest that the effect of ice on algae depends on the shape and number of the rocks at the bottom and proximity of glaciers. At Admiralty Bay algae grow in unusual abundance at the front of Ecology Glacier and Baranowski Glacier, which are supported glaciers, of low activity not producing large icebergs. Merely the immediate, several-score-metre-wide forefront of the front of the glaciers is cleared af algae. The picture of the bottom of the lower part of the sublittoral zone in front of the above-mentioned glaciers and in other parts of the Bay, where the bottom is overgrown with algae, is consistent with the description by Skottsberg (Neushul 1965). The observed among algae at Admiralty Bay epiphytic phenomenon of various species of algae, e.g. *Leptosomia simplex, Adenocystis utricularis* or *Monostroma hariotii* growing on stipes and attachment organs of brown algae *Desmarestia* sp., *Himantothallus grandifolius* and on thalluses of red algae *Hildenbrandia lecannellieri,* confirms the reports from Half Moon Island (Neushul (1965) and from Petrel Island (Adelie Land) (Delepine and Hureau 1963).

At Admiralty Bay three zones of agglomeration of algae were defferntiated, depending on the depth of their occurrence. Each zone has a characteristic community of species zonation of algae at Admiralty Bay is similar to that in Half Moon Island (Neushul 1965), where the tidal zone is in many places devoid of vegetation, whereas the sublittoral zone is abundant in algae. Large quantities and great variety of algae in the lower part of the tidal zone (the littoral) and in the sublittoral (depth ranging from

10—15 m to 70—90 m) of Admiralty Bay may be compared with the situation in the infralittoral zone of the regions of Melchior Island (Delepine, Lamb and Zimmermann 1966) and Petrel Island (Delepine and Hureau 1963). The lower limit of the occurrence of agglomerations of algae at Admiralty Bay is at the depth of 70—90 m. Delepine, Lamb and Zimmermann (1966) determined lower limits of occurrence for particular species of algae, e.g. *Desmarestia* sp. — 30 m, *Ascoseira mirabilis* — 8 m, *Iridaea obovata* — 17 m, *Leptosomia simplex* — 9 m deep. Delepine (1976) reports that the lower limit of the occurrence of algae *Durvillea antarctica* and *Macrocystis pyrifera* in Morbihan Bay (Kerguelen Islands) is consistent with the isobath at the depth of 20 m. DeLaca and Lipps (1976) observed algae in Arthur Harbour to the depth of 43 m and declared that the limit of the occurrence of algae depends on the type of substratum, wave effects and penetration of light. Zaneveld (1968) asserts that the lower limit of the occurrence of algae in the Ross Sea is probably at the depth of 668 m. Several times algae were collected at Admiralty Bay below the limit depth of 90 m, but these were only fragments of thalluses, which were probably wrenched away by icebergs from the bottom in shallower places and carried along to deeper regions of Bay. Transport of algae by icebergs in the region of Hope Bay was described by Neushul (1965), Zaneveld (1965), however, asserts that in the regions of Ross Island and Victoria Land transport by icebergs plays but an insignificant part in the displacement of algal material.

Seaweeds in many seas are successively torn off from the substratum and washed ashore (Bunt 1955). Icebergs and ice fields in the Antarctic cause the formation of algal matter detached from the bottom and dispersed in water or raised by the waves and washed ashore onto the accessible beaches (Gruzov 1978). Observations carried out at Admiralty Bay showed that algae are torn away from the substratum by ice and waves to the depth of about 30 m deep e.e. in the region between Thomas Point and Demay Point. Most of the algae were into fragments and crushed. Futher fragmentation occurrs under the effects of water currents and waves hurling the mass of thalluses across the rough, rocky-stony bottom especially in shallower places, sometimes concomitantly with the ice spread over the littoral zone. The last stage of the drumbling of algae occurs ashore on the continually moving stony rubble. Neushul (1965) observed in Half Moon Island pieces of ice accumulated frequently inshore scrubbing the bottom in the tidal zone. The ice-action upon the bottom intensified by comulation of ice by waves and tides is, according to Neushul (1965), the main cause of the absence of algae in the tidal zone and agglomeration of algal matter in the depressions in the bottom and on the shores. Obviously, such a source of algal matter as the seasonal decay of the thalluses of algae cannot be ignored (Delepine, Lamb and Zimmermann 1966).

Bunt (1955) asserts that in the littoral zone of Macquarie Island the thalluses of seaweeds undergo decomposition in water as well as on beaches and among the rocks above the maximum sea level. The investigations at Admiralty Bay confirm the occurrence of decomposition of algae in water and ashore. The processes of decomposition are probably controlled by mechanical effects of the environment and bacterial action of microorganisms, which is confirmed by Bunt (1955). The acceleration of algae decomposition in contact with air is produced through a quicker development of microorganisms. Further course of decomposition of algae described by Bunt (1955) was similar to that observed on the coasts of Admiralty Bay. The algal material piled up on the shores of Macquarie Island mixes with shore sediments or accumulates among rocks. In both cases algal material was crushed and mixed with seal excrement, promoting development of microorganisms. Tidal pools were a particular sort of "pockets" for decomposing algae, where from they could be carried out back into the sea.

Taking into account the above results and the fact of a strongly

Table II.

Dry weight, ash, and lipids content and calorific value of the thalluses of some species of algae at Admiralty Bay

Species	Dry weight content in wet weight %		Calorific value kJ·$^{-1}$ dry weight (kcal·g^{-1} dry weight)	Calorific value kJ·g^{-1} dry weight without ash (kcal·g^{-1} dry weight without ash)	Lipids content in dry weight % with ash without ash
Adenocystis utricularis	15.1	48.4	9.6 (2.3)	18.4 (4.4)	2.6 5.0
Leptosomia simplex	8.8	32.4—43.3	13.0—11.3 (3.1— 2.7)	18.8—19.7 (4.5— 4.7)	
Monostroma hariotii	16.8				
Ascoseira mirabilis	13.3				
Desmarestia sp.	16.0—17.9	19.3—29.7	12.6—13.8 (3.0—3.3)	17.6—17.2 (4.2—4.1)	
Cystosphaera jacquinotii	18.1	24.7	12.1 (2.9)	16.3 (3.9)	
Himantothallus grandifolius	13.0	32.2	12.1 (2.9)	17.6 (4.2)	1.4 2.1
stipe beginning	16.5	24.6	12.6 (3.0)	16.7 (4.0)	
beginning part of thallus	11.3	32.4	11.7 (2.8)	17.2 (4.1)	
middle part of thallus	10.8	33.1	11.7 (2.8)	17.6 (4.2)	
upper part of thallus	15.7	26.0	13.0 (3.1)	17.2 (4.1)	

marked activity of cellulolytic bacteria in the waters of Admiralty Bay (Zdanowski, personal communication) it may be expected that bacteria play a considerable role in decomposition of the remains of algae, especially those exposed to open air, ashore. The analysis of algal material after various duration of decomposition processes ashore indicates simultaneous loss of organic and mineral substances. The highest intensity of liberation of those substances occurs on the shores of the Bay during the summer season, which is caused by great intensity of the changes in environmental conditions, such as: variations of temperature, sun radiation warming up the remnants of the thalluses on the shore, waves caused by strong winds, contact with fresh water flowing in from the land or from rainfalls and snow.

Bunt (1955) suggest that the process of decomposition of algae is doubtlessly one of the links in matter and energy circulation in the Antarctic near-shore ecosystem, enriching it in nutrients derived from marine benthic algae. This proves true at Admiralty Bay, especially in the summer and spring seasons, when the inflow of algae washed ashore intensifies.

The speed of decomposition of algae in water was lower at Admiralty Bay due to the fact that the samples of thalluses were exposed in bolting-cloth bags, which made impossible to contact of the thalluses with necrophagous fauna (amphipodes).

An attempt was made to estimate the quantity of the matter released from algae undergoing decomposition on the shores of the Bay. During the time from February to November 1979, 1643 tons of wet algal matter were washed ashore at Admiralty Bay, or 279 tons of dry algal matter, assuming

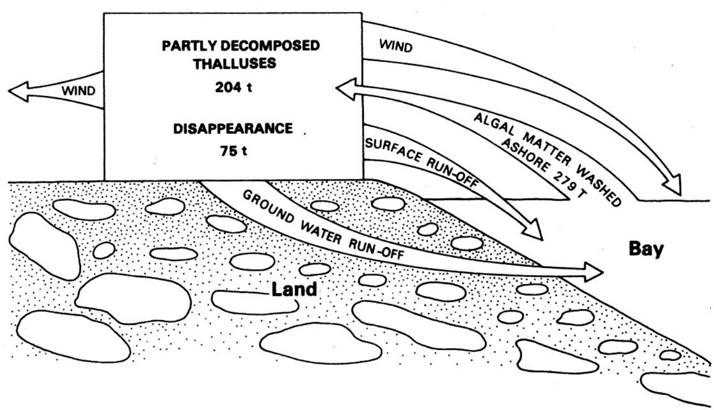

Fig. 11. Schema of algal matter circulation between water and land in the coastal zone of Admiralty Bay

279 t — total quantity of dry weight algal matter (in tons) washed ashore at Admiralty Bay from February till November 1979.

75 t — total quanity of dry weight algal matter (in tons) released in the form of organic and mineral compounds on the shores of Admiralty Bay from February till November 1979.

204 t — total quantity of dry weight partially decomposed algal matter (in tons) remaining ashore or getting back into the waters of Admiralty Bay during the time from February to November 1979.

that the average ratio of dry weight to wet weight of the exposed species (Table II) is 0.13. Presuming that washed ashore algae remained over there 12 days, the average loss of dry weight matter of three investigated thalluses amounted to 26,9%, or 75 tons of released matter in the form of organic and mineral compounds. A part of the released matter got back into the waters of the Bay carried along with the waves washing the coast and water flowing from the land, the remaining part was left ashore (Fig. 11).

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6. Summary

Phytobenthos of Admiralty Bay (King George Island, South Shetland Islands) consists of about 18 species of algae. The following are predominant: *Monostroma hariotii, Adenocystis utricularis, Leptosomia simplex, Iridaea obovata, Hildenrandia lecannellieri, Plocamium coccineum, Phycodrys antarctica, Himantothallus grandifolius, Desmarestia menziesii, Desmarestia* sp., *Cystosphaera jacquinotii, Ascoseira mirabilis*. The total surface area of the bottom overgrown with agglomerations of algae is 15.1 km^2, which makes up 11.5% of the total surface area of Admiralty Bay (Fig. 1). The main region of the occurrence of algae lies in the area of the microshelf, extending from Point Thomas to the end of the forehead of the Ecology Glacier. This region has an area of 3.5 km^2, which makes up 2.7% of the total area of the Bay. A zonal distribution of algal vegetation was observed, depending on the depth of water and character of the substratum (Fig. 2).

Three communities of algal agglomeration were differentiated: 1) in the tidal area, 2) from the minimum sea level to the depth of about 10—15 m, 3) from depth of 10—15 m to 70—90 m deep, which is the lower limit of the occurrence of algae in this region. The occurrence of algae is closely associated with a hard, rocky-stony substratum, displacement of water masses and proximity of the run-offs from the land, having a favourable effect on the agglomeration of algae. The largest brown algae occur in the middle and the lowest water layer, e.g. *Himantothallus grandifolius* is over 10 m in length and reaches the weight of over 15 kg. An epiphytic phenomenon was observed of some algae, e.g. *Adenocystis utricularis* and *Leptosomia simplex* growing on the thalluses of other species, e.g. *Desmarestia menziesii*.

The quantity of algal matter cast off by ice, water currents and the waves onto the shores of the whole Admiralty Bay, during the period from February to November 1979, was 279 ton of dry weight (Fig. 3). The largest quantities of algae were washed ashore in the section extending from Point Thomas to the forehead of the Ecology Glacier (Fig. 1). Decomposition of algae was caused by mechanical washing out of the organic and mineral substances under the effect produced by microorganisms. The speed of decomposition depends on the type of thalluses, the place of occurrence (sea water, seashore) (Figs. 5—8) and the season of the year (Fig. 9). The progress of decomposition was quickest ashore, in summer. It is estimated that from February till November 1979 in the processes of decomposition of algae 75 tons of dry, organic and mineral, algal matter were released on the shores of Admiralty Bay, in the average time of 12 days. A part of

algal matter got back into the waters of the Bay, another part remained on the shores. Further decomposition of the remaining 204 tons of partially decomposed algal matter followed a similar course.

7. Резюме

Фитобентос Острова Кинг Джорж Залива Адмиралты, Южные Шетланды образует около 18 водорослей. Преобладают следующие: *Monostroma hariotii*, *Adenocystis utricularis*, *Leptosomia simplex*, *Iridaea obovara*, *Hildenbrandia lecannellieri*, *Plocamium coccineum*, *Phycodrys antarctica*, *Himantothallus grandifolius*, *Desmarestia menziesii*, *Desmarestia* sp., *Cystosphaera jacquinotii*, *Ascoseira mirabilis*. Вся поверхность дна обростая скопленями водорослей, становит 15,1 км^2, а это составляет 11,5% всей поверхности Залива Адмиралты (рис. 1) Главный район выступления водорослей расположен в микрошельфе от Point Thomas до конца передней барьеры ледника Экологии, занимая поверхность 3,5 км^2 что составляет 2,7% всей поверхности залива. Констатировано этажность выступления водорослей: в зависимости от глубины и характера почвы (рис. 2).

Выделено 3 группы скоплений водорослей: 1) в сфере влияния, 2) от минимального уровня воды до около 10—15 м глубины, 3) с 10—15 м до 70—90 м глубины которая является нижней границей заселения водорослями. Выступление водорослей связано с твёрдым породистокаменистым грунтом, а также с течением масс вод и контактом со стоками воды из суши оказывающими полезное влияние на скопления водорослей. Самые большие бурые водоросли выступают в среднем и нижнем этаже и это нп. *Himantothallus grandifolius* достигающий свыше 10 м длины и массу 15 кг. Констатировано явление эпифонтичного порастания плех некоторых видов нп. *Desmarestia menziesii* другими водорослями нп. *Adenocystis utricularis*, *Leptosomia simplex*. Констатировано, что количество материи водорослей выброшенных льгом у барьера ледника, течений и волнования на берегах Залива Адмиралты с февраля до ноября 1979 достигло 279 тонн сухой массы (рис. 3).

Наибольше водорослей было выбросленных на отрезке от Поинт Томас до передней части ледника Экологии (рис. 1). Декомпозиция водорослей была вызвана механическим вымыванием огранических и минеральных субстанций и действованием микроорганизмов. Темп декомпозиции зависит от рода плехы, места в котором она проходила (морская вода, берег) (рис. 5—8), а также времени года (рис. 9).

Быстрее всего распад происходил на берегу лктом. Оценено что в процессе декомпозиции освобождено было на берега Залива Адмиралты с февраля до ноября 1979 г. 75 тонн сухой материи водорослей органичной и минеральной. Часть освобожденной материи вернулась в воды Залива, часть осталась на берегах, похожие были судьбы остальных 204 тонн частично распадшейся материи водорослей.

8. Streszczenie

Fitobentos Zatoki Admiralicji (Wyspa Króla Jerzego, Południowe Szetlandy) tworzy około 18 gatunków, glonów. Dominują: *Monostroma hariotii, Adenocystis utricularis, Leptosomia simplex, Iridaea obovata, Hildenbrandia lecannellieri, Plocamium coccineum, Phycodrys antarctica, Himantothallus grandifolius, Desmarestia menziesii, Desmarestia* sp., *Cystosphaera jacquinotii, Ascoseira mirabilis*. Całkowita powierzchnia dna porosła skupiskami glonów wynosi 15,1 km^2, co stanowi 11,5% całkowitej powierzchni Zatoki Admiralicji (rys. 1). Główny rejon występowania glonów leży w obszarze mikroszelfu od Point Thomas do końca czoła Lodowca Ekologii, zajmując obszar 3,5 km^2, co stanowi 2,7% całkowitej powierzchni Zatoki. Stwierdzono

piętrowość występowania roślinności glonowej w zależności od głębokości i charakteru podłoża (rys. 2).

Wyróżniono trzy zespoły skupisk glonów: 1) w obszarze pływów, 2)) od minimalnego poziomu wody do około 10—15 m głębokości, 3) od 10—15 m do 70—90 m głębokości, która jest dolną granicą zasiedlania przez glony. Występowanie glonów związane jest ściśle z twardym skalisto-kamienistym podłożem jak również z przepływem mas wód i kontaktem ze spływami z lądu wywierającymi korzystny wpływ na skupiska glonów. Największe brunatnice występują w środkowym i najniższym piętrze i są to np. *Himantothallus grandifolius* osiągający ponad 10 m długości i masę 15 kg. Stwierdzono zjawisko epifitycznego porastania plech pewnych gatunków np. *Desmarestia menziesii* przez inne glony np. *Adenocystis utricularis, Leptosomia simplex*.

Stwierdzono, że ilość materii glonowej wyrzuconej przy udziale lodu, prądów i falowania na brzegi całej Zatoki Admiralicji od lutego do listopada 1979 roku wynosiła 279 ton suchej masy (rys. 3). Najwięcej glonów wyrzuconych było na odcinku od Point Thomas do czoła Lodowca Ekologii (rys. 1). Dekompozycja glonów powodowana była mechanicznym wymywaniem substancji organicznych i mineralnych i działaniem mikroorganizmów. Tempo dekompozycji zależało od rodzaju plechy, miejsca w którym przebiegała (woda morska, brzeg) (rys. 5—8) oraz pory roku (rys. 9). Najszybciej rozkład zachodził latem na brzegu. Oszacowano, że w procesie dekompozycji uwolnione zostało ny brzegi Zatoki Admiralicji od lutego do listopada 1979 roku 75 ton suchej materii glonowej organicznej i mineralnej w średnim czasie 12 dni. Część uwolnionej materii wróciła od wód Zatoki, część zaś została na brzegach. Podobne były losy pozostałych 204 ton częściowo rozłożonej materii glonowej.

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