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In situ primary production of Fucus vesiculosus and Cladophora glomerata*

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Abstract

The primary production of two of the most commonly distributed benthic algae in the Baltic proper was measured using different in situ methods (bottles, plastic bags, ^{14}C and O_2) during summer. Results on exudation and heterotrophic activity of these exudates have been worked out for *Fucus*. Low primary production and exudation values are found, while the total bacterial activity seems to be high compared to the net primary production.

Zusammenfassung

Primärproduktion von Fucus vesiculosus und Cladophora glomerata in situ

Die Primärproduktion der beiden am weitesten verbreiteten benthischen Algen der eigentlichen Ostsee wurde unter Verwendung verschiedener in situ Methoden (Flaschen, Plastiksäcke, ^{14}C und O_2) während eines Sommers gemessen. Bei *Fucus* wurde auch die Exudation und die heterotrophe Aktivität der Exsudate gemessen. Dabei ergaben sich geringe Primärproduktions- und Exsudationswerte, während die Gesamtbakterienaktivität, verglichen mit der Nettoprimärproduktion hoch erscheint.

Introduction

The metabolism of phytobenthic communities has been shown to be significant through the analysis of energy- and material flows in the Baltic ecosystem (JANSSON, 1972; in press). Information on primary production, distribution of benthic plants and their sensitivity to changes in the environment has become increasingly necessary in recent years as human pollution in the Baltic has increased (NORIN and WAERN, 1973; PEKKARI, 1973; NOTINI, 1978; WALLENTINUS, 1976b).

During joint investigations by Working Group 3 of the Baltic Marine Biologists in June 1975–1976 benthic algae production, as well as the structure and function of a particular *Fucus vesiculosus* community were studied.

This paper gives some results of the primary production of two of the most commonly distributed algae in the Baltic.

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Material and Methods

The experiments were carried out at the marine biological station of Kämpinge on the southcoast of Sweden (Fig. 1). The experimental site was located at the southern end of the Falsterbo channel, which is protected from storm by a concrete wall. The salinity here is around 10‰.

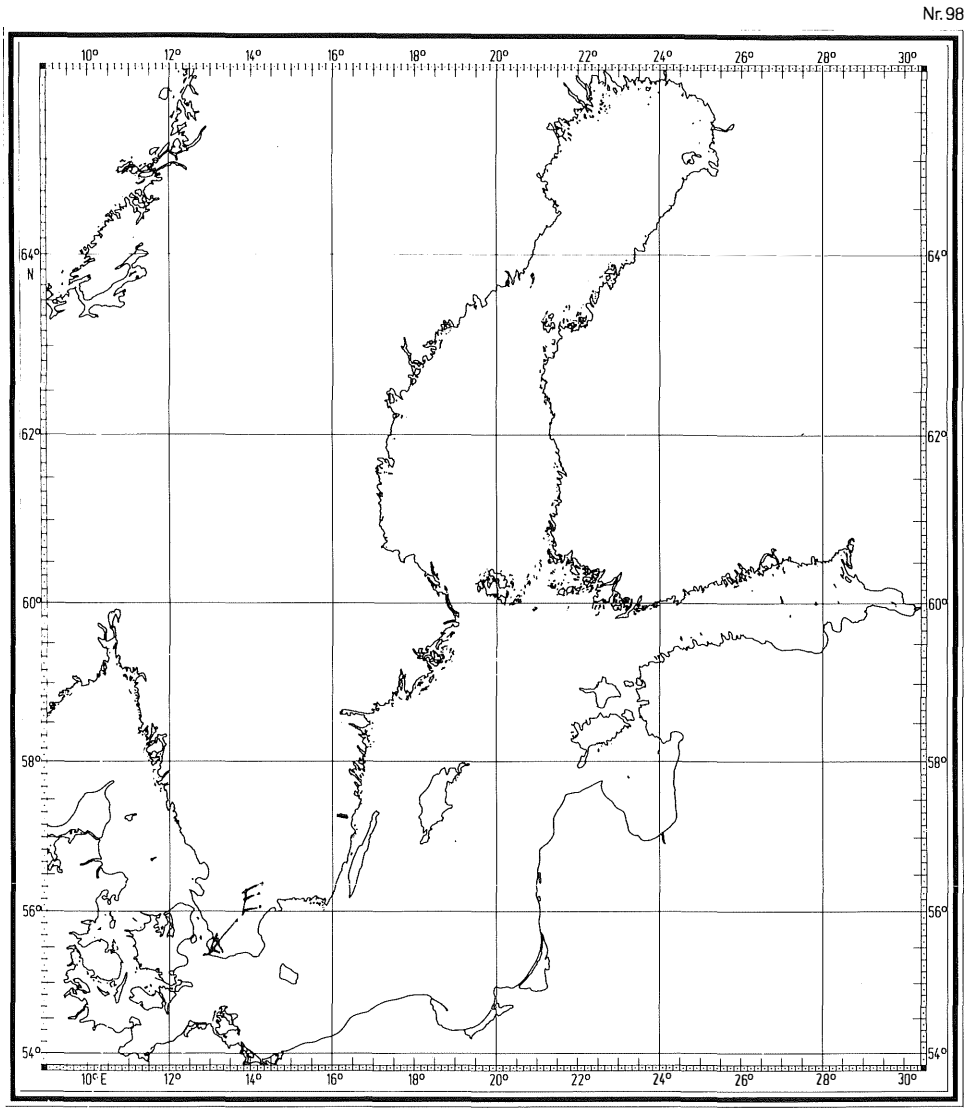

Figure 1
The Baltic Sea and the location of the experimental site (E)

In situ primary production was measured in bottles (1.2 l at 4 and 24 h periods, WALLENTINUS, 1976a) and in plastic bags (of sizes varying from about 50 to 100 l. for 1–2 days; Fig. 2, SCHRAMM and MARTENS, 1976; GUTERSTAM, 1977. In the former, parts of algae were incubated, while in the latter whole algae were enclosed.

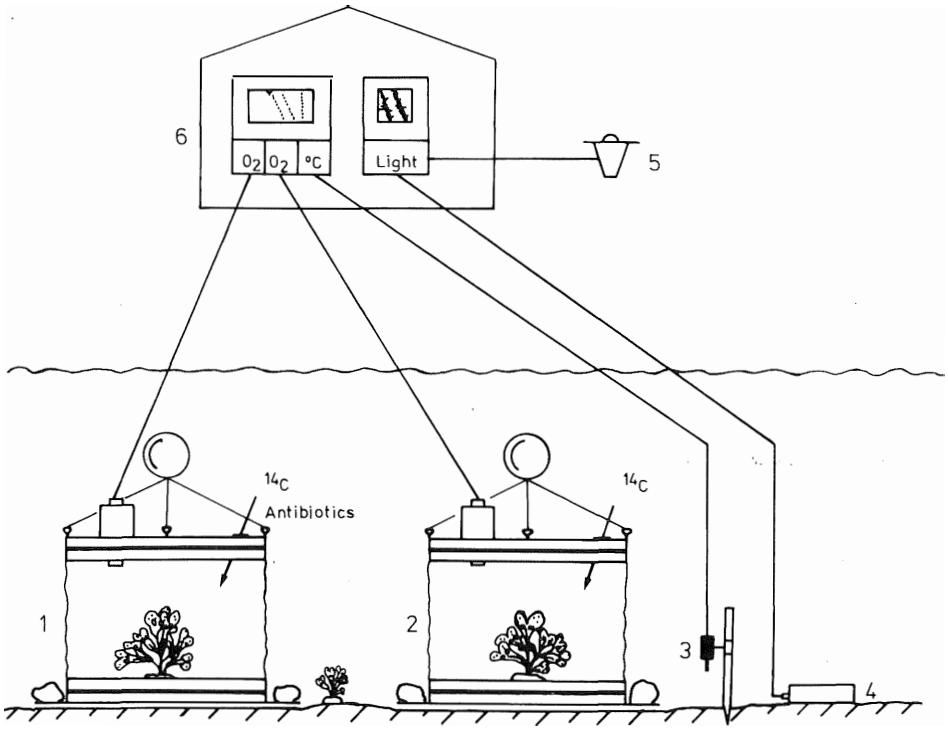

Figure 2

The experimental set-up for in situ studies of benthic algal metabolism.
1–2. Plastic bag (50 l, 50 cm diam.) with continuously registering O_2-electrodes.
3. Thermistor
4. Underwater light sensor
5. Solarimeter
6. The electrical supply to the sensors and the recording of data on land

For the bottles the ^{14}C method was used (5 μ Ci/l of NaH $^{14}CO_3$, no correction for dark fixation was made; WALLENTINUS, 1976a) and in the plastic bags the net O_2-output was measured by continuously recording O_2-electrodes (SCHRAMM and MARTENS, 1976).

In June 1976 both ^{14}C- and O_2-methods were used simultaneously in two 50 l plastic bags. Two similar specimens of *F. vesiculosus* (about 10 g dry wt.), cleaned of most of the epifauna, were incubated for a 7 h period (12–19 h, 13th June 1976).

A concentration of about 40 μ Ci/l of Na H $^{14}CO_3$ was used in the plastic bags in order to measure plant photoassimilation and release of extracellular compounds (FOGG, in: VOLLENWEIDER, 1974).

The contribution from the phytoplankton to primary production in the plastic bags was measured separately in 50 ml water samples.

In one of the plastic bags heterotrophic activity on the exudates produced by the algae was measured using 50 ml water samples taken after the incubation period. The water samples were mixed 1 : 1 with natural bacterial populations and incubated in situ for 2 h (ITURRIAGA and HOPPE, 1977). In the other plastic bag the bacterial activity was considered to have been arrested by injection of a broad spectrum antibiotic (Gentamycin 40 mg/l).

Analysis of the amount of exudates, the phytoplankton ^{14}C-assimilation and the heterotrophic uptake of exudates was done by the liquid scintillation technique (ITURRIAGA and HOPPE, 1977).

Analysis of carbon assimilated by the benthic algae was done by the liquid scintillation technique after washing in sea water, freezing to – 18 °C, freeze-drying and dry combustion (WALLENTINUS, 1976a).

The algae used for only the O_2-method were dried at 60 °C until constant weight.

Light was measured continuously above the water surface with a solarimeter (KIPP and ZONEN, 300–2500 nm). The photosynthetically active part of the spectrum (400–700 nm) was calculated as 45% of the measured insolation (v. BRÖCKEL, 1975).

Results

The net primary production of *C. glomerata* and *F. vesiculosus* are given in Table 1. For comparison between the ^{14}C- and the O_2-method both were considered to measure net primary production (a PQ of 1.2 was used for the conversion of O_2-values into carbon).

C. glomerata showed a net primary production over 24 h that was similar in bottles and in plastic bags, while by *F. vesiculosus* the net primary production was higher in the bottles than in the plastic bags. This difference was also found when using the two methods (^{14}C and O_2) in the same plastic bag (Table 1). For comparison the results of an experiment with *F. vesiculosus* in the northern Baltic proper are given in Table 1.

A good correlation between fluctuations in light intensity during the day and the net primary production could be seen for both algae (Fig. 3). The production rate per g dry wt. and hour of *C. glomerata* was about 4 times higher than that for *F. vesiculosus*. Maximum net primary production was about 3 mg C g dry wt $^{-1}$ h^{-1} in *C. glomerata* and 0.8 in *F. vesiculosus*. The higher production per gram algae by *C. glomerata* can be explained by its filamentous structure which results in a relatively higher metabolism (ODUM et al., 1958). The thicker thallus of *F. vesiculosus* leaves many of the cells photosynthetically inactive. This could be seen in the distribution of assimilated carbon whithin the algae (Fig. 4). Most of the assimilated carbon (74 %) was found in the tips.

Using the plastic bag technique the exudation rate of *Fucus* could be measured and also the heterotrophic utilisation of the exudates by added natural bacterial population. At an in situ temperature of 17 °C in June the exudates (measured as ^{14}C) and the phytoplankton primary production each made up 3% of the C assimilated

Table 1

The net primary production of *C. glomerata* and *F. vesiculosus* comparing ^{14}C- and O_2-methods together with some environmental parameters

		Net primary production as mg C g dry wt $^{-1}$ exp. time $^{-1}$									
		C. glomerata			*F. vesiculosus*						
Locality	Exposure-time	O_2	^{14}C	$^{14}C/O_2$	O_2	^{14}C	$^{14}C/O_2$	Irradiance[1] kJ m^{-2} exp. $time^{-1}$	Temp. °C	Sal. ‰	Enclosure
Kämpinge, southern Baltic	750604 (00–24)	22,79		1,07	4,02 2,78		1,80 2,60	9541	12	9	plastic bags
	750604–05 (11–11)		24,45 (29,83)[2]			7,67 (9,39)[2]) 7,22[3])		7813	12	9	bottles
	760613 (12–19)				1,84	5,21	2,83	3659	17	10	plastic bag
Askö northern Baltic	730817 (00–24)				6,56	9,89 7,94[3])	1,18	9349	19	6	plastic bag (O_2), bottle (^{14}C).

[1]) PAR at surface
[2]) Sum of 4 hour-experiments
[3]) Recalculated for whole plants from experiments with apical parts only, with 1.3 times higher production. Used for comparisons of ^{14}C- and O_2-methods.

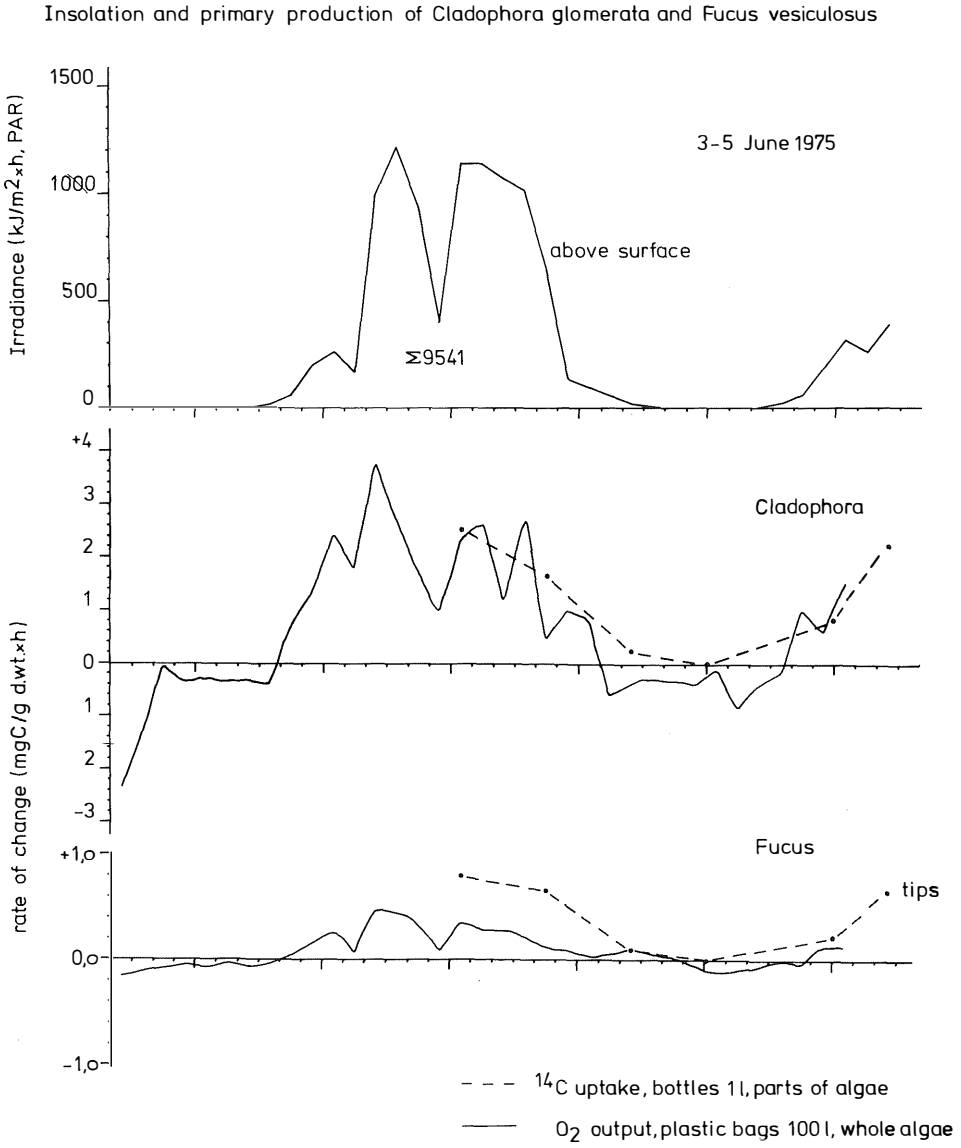

Figure 3

The daily fluctuations in light intensity (4–5th June 1975) and the rate of change in oxygen output (recalc. to carbon see text, plastic bags) and in carbon assimilation (^{14}C bottles) for *C. glomerata* and *F. vesiculosus*

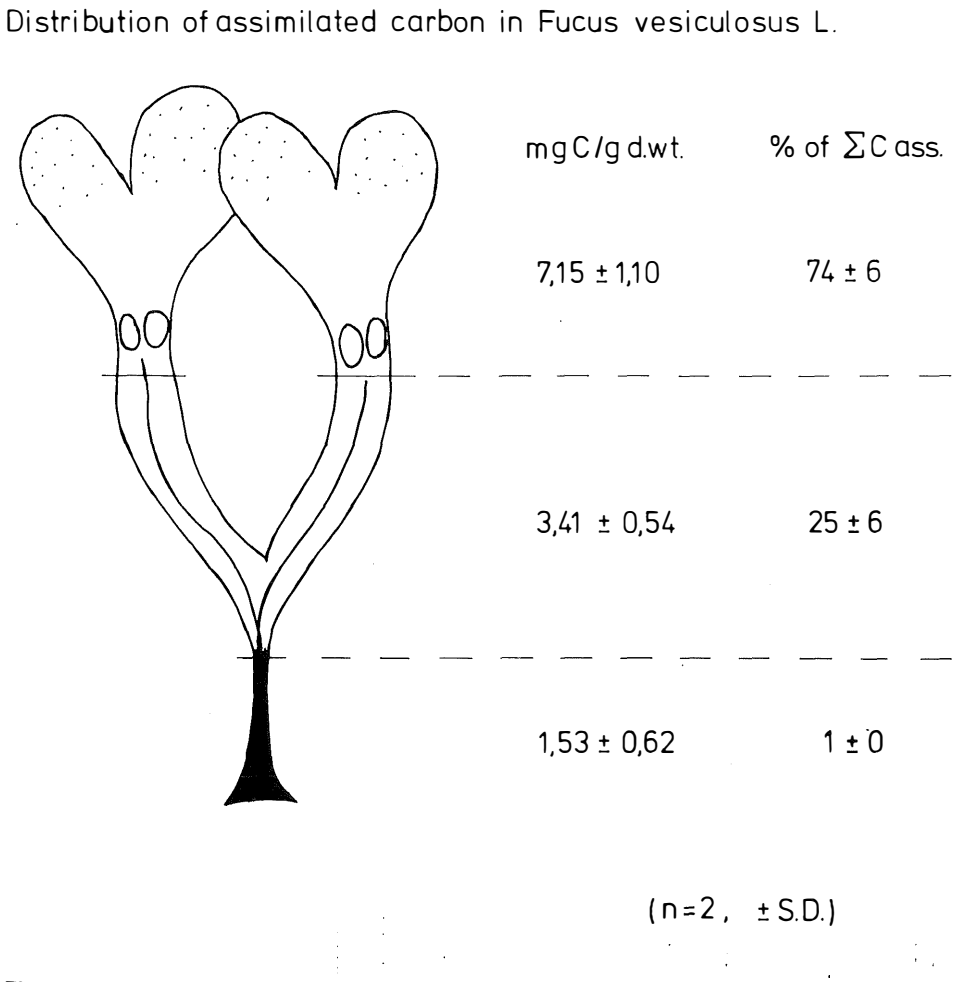

Figure 4

Distribution of assimilated carbon in *F. vesiculosus* (mean of the two plants used)

by *Fucus* when the heterotrophic activity in the water was 0.1% (Table 2). The turn-over time of exudates was calculated to be 208 h. The same water samples showed a heterotrophic uptake of glucose (Vmax, ITURRIAGA, 1977) of 0.0206 µg C l $^{-1}$ h $^{-1}$ with a turn-over time of 48 h.

Table 2

The distribution of photoassimilated carbon measured as ^{14}C (*F. vesiculosus* in plastic bags, 13th June 1976, after 7 h incubation in situ at 1 m depth)

	Fucus (11,45 g dry wt)			*Fucus* + antibiotics (9,67 g dry wt)		
	mg C	g dry wt^{-1}	%	mg C	g dry wt^{-1}	%
Fucus	59,67	5,21	100	54,23	5,61	100
Exudation	1,75	0,15	3	1,23	0,13	2
Phytoplankton	1,76	—	3	1,40	—	3
Bacteria[1])	0,06	—	0,1	—	—	—

[1]) assimilation of exudates measured after 7 h incubation. This value is calculated from a brutto uptake rate of 0,48% h^{-1}

Discussion and Conclusions

The net primary production of *C. glomerata* was similar to the values found by WALLENTINUS (1976a) in the northern Baltic (2.4–13.7 mg C g dry wt $^{-1}$ h^{-1}). The large variation reflects the different ages and conditions in the population of this seasonally (summer) occurring algae. *F. vesiculosus* also showed similar values to those found by GUTERSTAM (in prep.) using plastic bags and the O_2-method in the northern Baltic proper (average 0.72 mg C g dry wt^{-1} h^{-1} Feb.-Sept. at maximum daily insolation). Laboratory experiments with *F. vesiculosus* from the western Baltic showed higher values (about 2 mg C g dry wt^{-1} h^{-1}, recalc. from KING and SCHRAMM, 1976).

The results on relative assimilation rate in different parts of the *Fucus* plants (tips: middle:base in ratio 5:2:1) were similar to those of WALLENTINUS (unpubl.) using ^{14}C in plastic bags in the northern Baltic proper, although the total assimilation was slightly lower (0.67 mg C g dry wt.$^{-1}$ h^{-1}). She also found that if the productivity was calculated per unit of chlorophyll the differences in metabolic activity between the different parts were still more emphasized (14:2:1). Also if the different parts of the plants were separated before the experiments, about the same relations of carbon assimilation to weight (6:2:1) were found in glassbottle experiments in July in the northern Baltic proper, and with the assimilation of the whole plants (small specimens) about the same, too (ca. 3.5 times that of the basal parts, or 0.76 mg C g dry wt $^{-1}$ h^{-1}, ca. 60% of the values for the tips only, calculated per weight unit). If the middle parts were heavily covered with epiphytes, *Elachista fucicola*, the productivity of those parts expressed per dry weight was almost doubled, even if the epiphytes did not comprise a major part of the weight (WALLENTINUS, unpubl.).

The low exudation rate compared to those measured in laboratory experiments by SIEBURTH (1969) and KHAILOV and BURLAKOVA (1969), who measured an

exudation rate of about 40% of the net primary production by *F. vesiculosus*, is explained by the fact that they measured total dissolved organic carbon (DOC) released from the algae. In view of these results we could conclude that our values for exudation of newly assimilated carbon (^{14}C method) underestimate the total exudation. On the other hand, MOEBUS and JOHNSON (1974) found no exudation (DOC) by *F. vesiculosus* under laboratory conditions.

The heterotrophic activity measured in the surrounding water of *Fucus* is only a part of the total bacterial activity in a *Fucus* community. A higher total bacterial activity in our experiments where only *Fucus* was used, without the natural substrate was indicated by the difference in O_2-output between the two plastic bags with and without antibiotics (0.36 and 0.26 mg C g dry wt $^{-1}$ h^{-1}). For comparison the heterotrophic uptake of phytoplankton exudates in summer in the western Baltic was 8–17% per hour. These differences between the plastic bags reflect the importance of the bacteria even for the transfer of energy and recycling of nutrients in phytobenthic communities.

The discrepancy between the two methods used for primary production measurements (especially by *Fucus*), considering both (O_2 and ^{14}C) measure net primary production (JOHNSTON and COOK, 1968), may be a result of a high O_2-consumption by the heterotrophic organisms during the summer and even if the ^{14}C-values here are not corrected for dark fixation, this cannot account for more than a very low part of the higher figures for the ^{14}C-method. Other experiments have shown (WALLENTINUS, unpubl.) that even if the dark fixation by *Fucus vesiculosus* is higher than by the filamentous algae, it amounts only to about 2–6% of the light fixation during daytime; the highest figures for the basal parts and the lowest for the not separated tips. Higher percentage values are, of course, found during dawn and dusk.

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