

The significance of the surface film in salt marsh plankton metabolism¹

Abstract—Plankton communities associated with surface films and the remainder of the water column in a Georgia salt marsh were compared. The fluorescence of acetone extracts indicated that a film several orders of magnitude richer in plant pigments than the underlying water developed as the tide rose over the marsh surface. As the tide ebbed, the concentration of pigment in the film dropped to levels similar to those in the water below. About 37% of plankton net photosynthesis was concentrated in the surface film. Respiration of the film averaged 21% of the gross photosynthesis while PS:R ratios ranged from 10.9 to 2.5.

Films forming at the air-water interface of natural bodies of water have been sampled with ceramic-coated drums (Harvey 1966), screens (Garrett 1965; Sieburth 1965), and glass plates (Harvey and Burzell 1972). Comparisons of these surface films with the water beneath has usually demonstrated higher concentrations of organisms and detrital material in the films. Hardy (1973) showed that the productivity of the algae in the upper 4 mm of the water in a temperate lagoon averaged eight times more than the plankton community beneath. Since a thick film forms on the tidal water flooding marsh surfaces, this layer is a zone where algal cells and primary production might be concentrated. Ragotzkie's (1959) measurements of phytoplankton primary production in the estuarine waters of Georgia indicated that light was a major limiting factor, so the high light intensity at the surface would provide a more favorable condition for photosynthesis than in the highly turbid water column. The algae are likely benthic in origin (Williams 1962) and are not inhibited by light intensities that cause substantial reductions in photosynthesis in oceanic forms (Williams 1962; Gallagher and Daiber 1973).

The research described here was de-

signed to ascertain if algae were concentrated in the surface film of the water flowing over the marsh, measure the photosynthesis and respiration of the film community, and determine the contribution of the film algae to total phytoplankton photosynthesis.

Surface film samples for cell counts and pigment extraction were collected with a glass plate (Harvey and Burzell 1972). The film was about 55 μ thick at high tide. Portions of the water beneath were collected by turning test tubes upright after they had been submerged to a depth of 10 cm while inverted. Cells were counted in fresh samples under 300 and 1,000 \times magnification. Pigments were extracted with acetone from particulate matter collected on glass fiber filters and the fluorescence of the extract measured before and after acidification (Yentsch and Menzel 1963).

Quadruplicate surface film samples for metabolic rate measurements were collected on pieces of Nitex cloth with 103- μ openings. Each cloth with the adhering film was formed into a cylinder and placed in a 500-ml jar with the film facing outward. Coarser Nitex cloth (1-mm openings) was positioned behind the flaccid finer cloth to hold it securely against the side of the jar. Since the film faced the glass, its integrity was not destroyed when water was added to the center of the jar. The jars were filled with estuarine water, sealed with parafilm, and incubated in a water-filled glass battery jar placed on a stand in the marsh. Temperature was controlled by adding crushed ice to the battery jar when its temperature rose more than 1°C above that of the water in the marsh. Bottles without surface films served as controls. Incubations began several hours after daylight and lasted 4-6 hr. Respiration was measured by holding the same films used for photosynthesis measurements in the dark in a laboratory incubator at the mean temperature recorded during the light incubations. Metabolic rates were inferred from changes in dissolved oxygen levels

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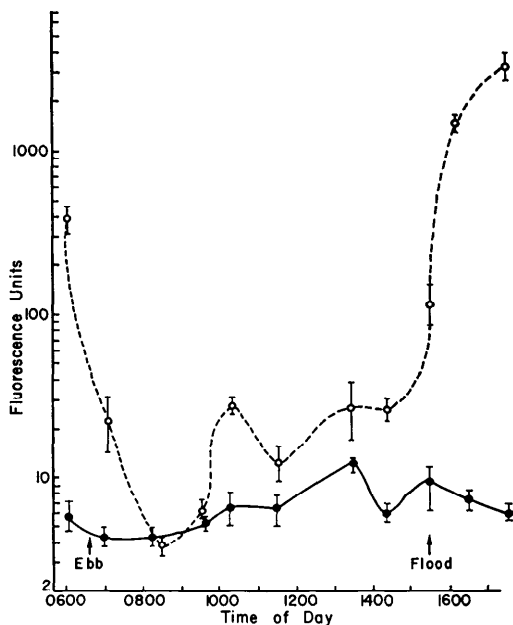


Fig. 1. Relative fluorescence of acetone extracts from components of surface film (open circles) and water column (closed circles) from the salt marsh plankton community on 1 January 1973. Bars indicate ± 1 SE.

determined by titrations (Strickland and Parsons 1968).

Water column photosynthesis and respiration rates were measured in situ (with water collected on the flooding tide near high water from about the 10-cm depth) according to the method for metabolic measurements using changes in dissolved oxygen (Strickland and Parsons 1968).

Microscopic examination of water column and surface film samples collected in October 1972 indicated that the algae present were primarily pennate diatoms. At high tide when film development appeared to be maximal, cells were about 15 times more abundant in the surface film than in the underlying water. As the tide ebbed, the surface film cell counts dropped rapidly to the level in the water column.

Although examination of the fresh samples enabled differentiation of living from dead organisms and actual numbers of cells, the procedure was too slow to be adequately replicated or to allow frequent

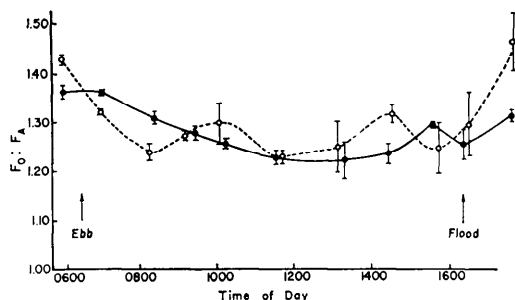


Fig. 2. Surface film (open circles) and water column (closed circles) acetone extract $F_0:F_A$ ratios over a tidal cycle on 1 January 1973.

sampling over the tidal cycle. Pigment extraction and measurement by the method of Yentsch and Menzel (1963) gave a rapid assessment of plant pigments. Single-filter methods of fluorometric analysis for chlorophyll *a* and phaeo-pigments are subject to variable errors depending on the ratio of various chlorophylls present (Loftus and Carpenter 1971). For this reason I have reported pigment concentration in fluorescence rather than in chlorophyll *a* or phaeo-pigment units.

Only small changes occurred in the wa-

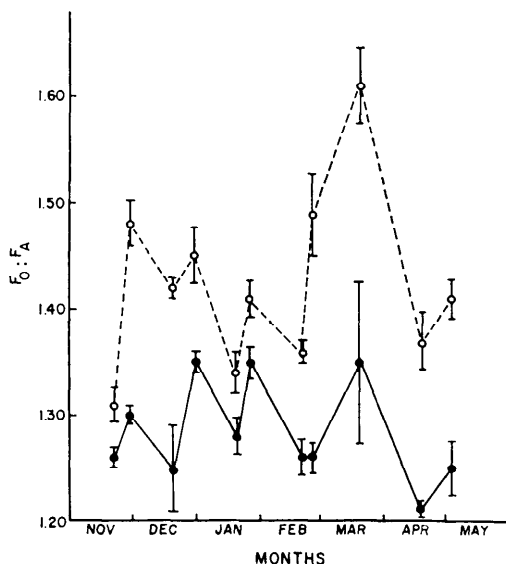


Fig. 3. Surface film (open circles) and water column (closed circles) acetone extract $F_0:F_A$ ratios at high tide at various sampling dates. Bars indicate ± 1 SE.

Table 1. Salt marsh plankton surface film and water column net photosynthesis (23-cm depth) measurements. Numbers in parentheses are coefficients of variation expressed in percent.

Date (1973)	community net photosynthesis			water temperature (°C)
	surface film (mg O ₂ m ⁻² hr ⁻¹)	water column (mg O ₂ m ⁻² hr ⁻¹)	surface film % of total	
20 Mar	7.9 (25.7)	12.2 (12.7)	39	16
19 Apr	7.5 (23.8)	10.1 (8.0)	43	21
3 May	13.0 (15.2)	49.0 (1.6)	21	22
26 Jun	6.2 (29.0)	17.0 (14.2)	27	30

ter column over the tidal cycle, although the surface film pigments (as indicated by fluorescence) increased several orders of magnitude as the tide flooded the marsh (Fig. 1). The natural films appeared to lift off of the soil and plant (*Spartina alterniflora* Loisel.) surfaces as the soil-air interface became a soil-water interface. Films similar to those created on the rising tidal water could be produced by enclosing an area of marsh with a plastic cylinder and slowly adding estuarine water filtered through glass fiber filters. No diatoms were found in the filtered water, but they were present in the artificially produced films. This observation indicates that many of the diatoms in the natural film were probably of benthic origin. The film that naturally formed during the floodtide (Fig. 2) had $F_O:F_A$ ratios (unacidified fluorescence: acidified fluorescence) above 1.35, which

Table 2. Salt marsh plankton surface film respiration, surface film PS:R (gross photosynthesis: respiration) ratio, and water column respiration. Numbers in parentheses are coefficients of variation expressed in percent.

Date (1973)	surface film respiration (mg O ₂ m ⁻² hr ⁻¹)	surface film PS:R	water column respiration (mg O ₂ m ⁻² hr ⁻¹)
19 Apr	0.8 (31.6)	10.9	--
3 May	2.4 (18.0)	6.4	--
26 Jun	3.5 (5.3)	2.5	25.8 (7.6)

Lorenzen (1965) found to mean that about 50% or more of the pigment was active. During the drainage of water from the marsh surface, the $F_O:F_A$ ratio dropped below 1.35 in both the surface film and the water column. It is likely that at that time degraded pigments were mixed into the water from the soil by the scouring action of the ebbitide currents. The relatively small increase in water column pigments seen in Fig. 1 (log scale) may be evidence of this addition.

In addition to having an acetone extract fluorescence several orders of magnitude greater than an equal volume from the water column at high tide, the surface film (Fig. 2) had $F_O:F_A$ ratios generally above those of the water column (Fig. 3), indicating a higher proportion of photosynthetically active pigment. These observations on the pigments indicated that photosynthetically active film formed at the air-water interface in the marsh.

The comparison of the net photosynthesis of the surface film and the water column (Table 1) is based on an average high tide depth over the marsh surface of 23 cm. This weighted mean depth was calculated from the percentage of the marsh occupied by various stands of plants, determined from interpretations of aerial photographs (Reimold et al. 1973), and the elevation of the stands in relation to tide height as obtained by leveling. Mean low water elevation was obtained from R. J. Reimold

(personal communication). The contribution of the surface film to the total plankton community net photosynthesis averaged 32% and ranged from 21 to 43%. Since the films were collected just before high tide, they represent the most highly developed films in the tidal cycle, a fact which tended to maximize their contribution. On the other hand, their importance was minimized by using high tide water volume when making the calculations. At low tide water is present only in the bottom of the stream channels.

The respiration data (Table 2) indicates that the surface film community had a measurable heterotrophic component. Water column respiration was so slight that it could not be detected with the method used in two of the three experiments. Surface film community PS:R ratios showed the film to be more strongly autotrophic in early spring than in early summer. A similar pattern was observed by Ragotskic (1959) in measurements of the water column plankton community in a sound adjacent to this marsh.

Although the surface film is present only when water covers the marsh, its area is great when it exists; the marshland area is six times the permanent water area in the Duplin River watershed (Reimold et al. 1973). The data reported here, as well as those of Hardy (1973), suggest that the surface film is one of the centers of metabolic activity in such ecosystems and deserves further study.

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