Table 1. Wavelength of maximum absorption (λ_{max}) for the scotopic visual pigment of *Exoglossum maxillingua* compared to the λ_{p50} of the upwelling and downwelling light in Lake Cromwell

λ_{max} [nm] (S.E.)[a]	Depth [m]	λ_{p50} [nm] (S.E.)[a, b]	
		Up-welling	Down-welling
540.8 (0.7)	0	557.4 (1.2)[c]	531.2 (1.6)[c]
$n=36$	0.5	578.8 (1.2)[c]	539.7 (1.9)[d]
	1.0	587.9 (3.0)[c]	565.0 (1.0)[c]
	2.0	590.7 (1.2)[c]	592.0 (0.7)[c]

[a] Normality of data was verified using the Kolmogorov-Smirnov test (Lilliefors modification) [18]
[b] $n=4$ for all λ_{p50} means
[c] Significantly different from λ_{max}, $P<0.001$
[d] Not significantly different from λ_{max}, $P=0.623$

light at 0.5 m (Table 1, Fig. 3, *b*). Other observations that can be made are that the upwelling light was 'redder' than downwelling light and that light transmission is shifted to longer wavelengths as depth increases.

According to the various difference spectra presented, *E. maxillingua* possesses a single scotopic visual pigment based on vitamin A_2. This porphyropsin has a λ_{max} near 541 nm.

Among freshwater fishes this λ_{max} is one of the longest wavelengths reported for scotopic visual pigments (A_2). Other fish with porphyropsins absorbing maximally at long wavelengths are the lake trout (*Salvelinus namaycush*), $\lambda_{max}=540$ nm [15], the smelt (*Osmerus eperlans*), $\lambda_{max}=543$ nm [14], the brown bullhead (*Ictalurus nebulosus*), $\lambda_{max}=540$ nm and the knifefish (*Notopterus* sp.), $\lambda_{max}=548$ nm [16]. However, in all of these cases no spectroradiometric measurements of the photic environment were made.

To understand how a visual adaptation to the ambient downwelling light could be beneficial to the cutlips minnow one must look at its ecology and, more specifically, its feeding behavior. This cyprinid is primarily a benthic forager, feeding mainly on chironomid larvae [17]. It is a diurnal species with activity peaks occurring after dawn and near dusk. During a three year study on the cutlips minnow in Lake Cromwell it was found that this fish was relatively sedentary, remaining principally in the littoral zone (0.5–2.0 m) (A. Godin, Ph.D. thesis, University of Montreal). Captures in this study indicated that 80% of the fish were found at 0.5 m. One can see that much of the cutlips minnow's feeding would occur during periods of relatively low light intensity when the scotopic system would be operating. At such times location of prey could be aided by an adaptation to the ambient light. Items such as insect larvae would frequently be seen against the bottom itself and should often be darker than it. In this case matched pigments would function more efficiently. Also, if feeding occurred above the bottom this matching could optimize the contrast between dark silhouetted prey and the background spacelight.

After consideration of the cutlips minnow's feeding ecology in conjunction with the good correspondence between the visual pigment λ_{max} and the underwater λ_{p50} it appears that this cyprinid provides support for the sensitivity hypothesis in fresh water.

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Occurrence of Particle Tetrads in the Vacuole Membrane of the Marine Red Algae *Gigartina teedii* and *Ceramium rubrum*

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Freeze-fracture investigations of most biological membranes has revealed intramembranous particles which are unequally distributed between the protoplasmic (PF) and the external (EF) fracture faces. Some intramembranous particles are aggregated to form specific complexes [1–3]. In a few cases, such as, for example, in the particle rosettes in the PF of plasmalemma of growing plant cells, which participate in cellulose synthesis, the function of these particle arrays is known [1–5].

In the EF of the vacuole membrane of

a
b
c

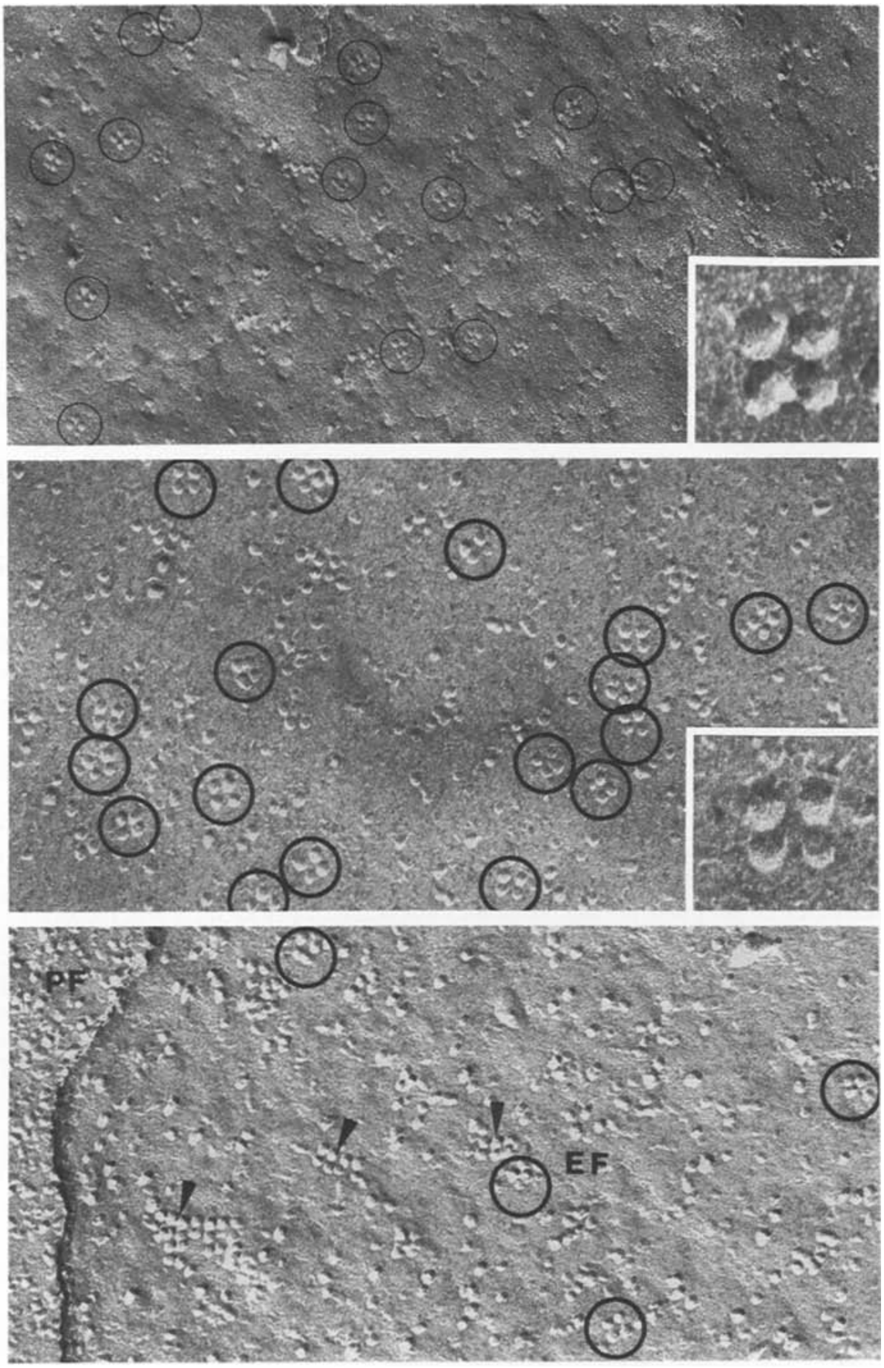

Fig. 1. Freeze-fracture. a) *Gigartina teedii,* cell of the cortical pericarp; EF of the vacuole membrane, high frequency of particle tetrads (*circles*), ×90000, b) *Ceramium rubrum,* cortical cell, ×130000. *Inserts* tetrad at high magnification (×500000). c) *Ceramium rubrum.* Freeze-fracture of a very young axial cell, EF of the vacuole membrane and PF of the plasma membrane, tetrads in clusters (*arrowheads*); single tetrads (*circles*), ×125000

cells of cystocarpic plants of the red algae *Gigartina teedii* (Roth) Lamour. and *Ceramium rubrum* (Huds.) J. Ag., we detected new forms of intramembrane particle complexes. The thalli were cut into small pieces, and immediately after sectioning were frozen in nitrogen slush (for details of the method see [6]).

After freeze fracture, particle complexes consisting of four subunits (tetrads) are visible on the (concave) EF of the vacuole membrane in all cell types of both red algae (Fig. 1a, b). The subunits of the tetrads have a center-to-center spacing of about 14 nm. The tetrad frequency varies between 4 and 17 μm^{-2} in *Gigartina teedii* and 10 and 25 μm^{-2} in *Ceramium rubrum.* In addition, the EF of the vacuole membrane contains single particles. They have the same size (diameter about 13.5 nm) as the subunits of the tetrads (Fig. 1c), while the plasma membrane particles are smaller (about 11.5 nm in diameter). Sometimes the tetrads are arranged in clusters (Fig. 1c).

We also found the same tetrads on convex membrane faces of unidentified origin. It is not possible to determine whether these faces are P fracture faces of a vacuole membrane or E fracture faces of cisternae of the endoplasmic reticulum, because the vacuole membrane of red algal cells is frequently closely associated by one or more ER cisternae [7]. It is, however, improbable that the same particles occur in both membrane halves.

The tetrads can be assumed to represent a vacuole-membrane-bound multienzyme complex. Considering that the vacuoles in red algae produce mucilage, it is tempting to assume that they are involved in polysaccharide synthesis, though evidence is lacking. To our knowledge, particle aggregates of this kind have been never found before.

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