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Estimates of Energy Budgets for a Typha (Cattail) Marsh

Abstract. Yearly utilization of total solar radiation by a *Typha* marsh shows approximately equal allotment to reflection (albedo), evapotranspiration, and conduction-convection. Reflection during the growing season is proportionally lower because of greater light absorption by the vegetation. Photosynthesis is a negligible quantity, although in relation to visible radiation during the growing season it nearly equals reflection.

Measurements of production of above-ground organic matter, reflection of visible light, and evapotranspiration have been made for a *Typha* (cattail) marsh at Cedar Creek Natural History Laboratory, Bethel, Minnesota (*1*). These measurements, together with solar radiation data from the nearby weather station at St. Cloud, Minnesota, provide material for estimating the total energy budget of the marsh.

Mean total solar radiation measured by an Eppley pyrheliometer at the St. Cloud station from 1950–1959 is given in Table 1 for the growing season, May through September, and for the entire year (*2*). Visible radiation (390 to 760 mμ) was calculated as 50.4 percent of total radiation for the growing season on the basis of data in Tables 137, 148, and 170 of List's report (*3*) by the method outlined by Bray (*4*).

The mean net above-ground production of oven-dry organic matter of *Typha* over a 3-year period was 1360 g/m^2 per year. The energy content of this matter was 4340 g cal per gram, as measured by a Parr oxygen bomb calorimeter, for a net production of 590 g cal/cm^2 per year (*5*). Underground production could not be measured. The weight of underground material in 1957 was 2960 g/m^2 (*6*). Underground production of *Zizania aquatica*, a marsh annual, was 10 percent of above-ground matter. Underground production for *Typha*, which has a large and thick root and rhizome system, is estimated to be at least 20 percent of above-ground matter. Respiration is estimated to be about 15 percent of gross production, a value which represents the median respiration estimate from a wide survey of the literature. Consumption by animals is estimated to be about 1.0 percent of gross production, a value similar to that measured for tree leaves of an angiosperm forest by Bray. (*7*). When these estimates of underground production, respiration and consumption are used in the calculation, the gross photosynthetic production is approximately 842 g cal/cm^2 per year.

Table 1. Estimated energy budgets for a *Typha* marsh.

Form	Growing season				Year	
	Visible radiation		Total radiation		Total radiation	
	100 g cal/cm^2	Percent	100 g cal/cm^2	Percent	100 g cal/cm^2	Percent
Solar radiation	379	100	760	100	1292	100
Photosynthesis	8.4	2.2	8.4	1.1	8.4	0.6
Reflection	11.4	3.0	167	22.0	439	34.0
Evapotranspiration and conduction-convection	359	94.8				
Evapotranspiration			292	38.4	413	32.0
Conduction-convection			293	38.5	431	33.4

The reflection of visible radiation toward the zenith (visible albedo) in 1960 was 3.0 percent under a clear sky, with an incoming visible radiation of 110,870 lux. Total albedo for *Typha* was estimated by including measurements of reflection of infrared (760 to 5000 + mμ) from leaf and plant surfaces (*8–11*). These estimates were averaged for each interval of 200 mμ and weighted by the mean energy content of each interval as listed in Table 130 of List (*3*). The mean of these weighted values was 42 percent. This value, when averaged on a total energy basis with the measured reflection of 3 percent of the visible radiation, gave an estimate of total albedo for the *Typha* marsh of about 22 percent. No measurements of total albedo for a *Typha* marsh are available in the literature, but estimates of 26 percent for high fresh grass and 22 percent for wet grass by List (*3*) indicate that the estimate of 22 percent is within a reasonable magnitude.

Total albedo for the year was calculated to be 34 percent, an integration of the above value of 22 percent on a total energy basis with an estimate of winter albedo of around 50 percent, a median value for total reflection from old snow (*3*).

Evapotranspiration was measured in 1958 by Lawrence, Pearson, Rogosin, and Bray in a circular steel watertight tank 1.14 m in diameter which was located in a nearby and similar *Typha* marsh. This tank lost 49.3 g of water per square centimeter by transpiration and evaporation during the growing season. Taking the estimate of Transeau (*12*) that 593 g cal is required to evaporate 1 g of H_2O at the mean temperature of a Midwestern growing season, the energy expended in evapotranspiration was 29,235 cal/cm^2.

For the entire year, it is reasonable to assume that the evapotranspiration of the *Typha* marsh was very similar to the annual precipitation of 96.6 cm, since the level of water in the marsh was at the stable water table and while it overflowed slightly in the spring, it also received some runoff water from higher ground. Energy expended in evapotranspiration throughout the year was, therefore, about 41,300 g cal/cm^2.

The above measurements and estimates are incorporated in Table 1 which shows energy budgets for both visible and total radiation during the growing season (May through September) and for total radiation for the entire year. Energy incorporated in photosynthesis, an almost insignificant factor, is eventually changed to heat in a stable plant community. The decreased importance of total and visible albedo in summer is due to the greater absorption of light by chlorophyll. The similarity of values for reflection, evapotranspiration, and conduction-convection for the year is notable.

An estimate of an energy budget for "green vegetation" for total radiation during the growing season months May–September 1949 by Penman (*13*) in England gave 1 percent for photosynthesis, 20 percent for reflection, 39 percent for transpiration, and 40 percent for conduction-convection. These predicted values are very similar to those of my study.

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References and Notes

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