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Organic matter dynamics in Keppel Creek, southeastern Australia

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Keppel Creek is a 4th-order stream draining 1428 ha of mixed eucalypt forest in the Victorian central highlands in southeastern Australia (Table 1). Elevation ranges from 400 m to 1200 m. Geology is a mix of ignimbritic rhyodocite and granodiorite (VandenBerg 1977) and soils are deep, friable mountain loams. Annual precipitation averages 125 cm, some falling as snow, during winter, above 1000 m. Vegetation within the catchment is dominated by mountain ash (*Eucalyptus regnans*), one of the tallest hardwood trees in the world. Riparian vegetation comprises manna gum (*E. viminalis*) and messmate stringy bark (*E. oblique*) with an understorey of blackwood (*Acacia melanoxylon*), hazel pomaderris (*Pomaderris aspera*), blanket leaf (*Bedfordia arborescens*), fishbone water fern (*Blechnum nudum*), and soft tree fern (*Dicksonia antarctica*) (Land Conservation Council 1991).

The gradient of Keppel Creek at the field station is 0.027 m/m with a pool–riffle structure and a mean bankfull width of 3.5 m. The stream bed substrate consists of small to large cobbles with some coarse sand deposits, and regularly spaced debris dams. Discharge ranges from 66 to 800 L/s with an annual average of 171 L/s. Snow melt contributes to increased discharge in late spring and intense summer thunder storms can cause rapid increases in discharge. Annual stream temperature averages 10.3°C.

Phosphorus and ammonium concentrations in Keppel Creek are generally low with soluble reactive phosphorus of 2–10 μg P/L and NH_4–N of 2–5 μg N/L. However, NO_2+NO_3–N is considerably elevated at 68–142 μg N/L, perhaps a result of recent logging within the catchment upstream from the sampling site (Treadwell 1995). Logging has been shown to result in an increase in the export of nitrogen from the terrestrial ecosystem into streams both in Australia (Campbell and Doeg 1989), and in North America (Likens et al. 1970, Golladay et al. 1992).

Inputs

Benthic community metabolism was measured in 1993 using clear perspex chambers clamped to 15-cm-deep trays buried in the stream bed (Treadwell 1995). Buried trays were bottomless to allow for hyporheic respiration and to provide a more heterogeneous substrate than can be achieved with shallow colonised trays. Measurements were made for 24–48 h twice per season throughout the year using dissolved oxygen as a measure of productivity. Annual GPP was 1172 g O_2 m^{-2} y^{-1}, which was converted to carbon units using a photosynthetic quotient of 1.2 (Bott et al. 1985) and assuming 1 mg O_2 = 0.375 mg C. A factor of 2 was used to convert from grams of carbon to AFDM, assuming AFDM is 50% carbon, resulting in a final GPP of 1055 g AFDM m^{-2} y^{-1}.

Annual litterfall was measured as 744 g AFDM m^{-2} y^{-1} (Campbell et al. 1992). Leaf litterfall was collected approximately once a month from June 1987 to June 1989. Litterfall was measured over a 100-m stream reach using five 1-m^2 traps suspended 0.5 m above the water. Samples were air dried, weighed, and sorted into 5 components: leaves, bark, reproductive structures, wood, and other. Leaves accounted for the largest litter component (57%), followed by wood (16%) and bark (11%). The 2 most

TABLE 1. Physical characteristics and organic matter parameters for Keppel Creek. All organic matter parameters are in AFDM.

Variable	Value	References and notes
Physical characteristics		
Latitude	37°S	
Order	4	
Catchment area (ha)	1428	
Streambed area (m^2)	16,450	Calculated as bankfull width multiplied by main channel length
Gradient (m/m)	0.027	
Mean annual water temperature (°C)	10.3	Edwards, unpublished data
Mean annual discharge (L/s)	171	Edwards, unpublished data
Mean annual precipitation (cm)	125	Land Conservation Council (1991)
Inputs ($g\ m^{-2}\ y^{-1}$)		
Gross primary production	1055	Treadwell (1995)
Litterfall	676.6	Campbell et al. (1992)
Lateral movement	67.7	Campbell et al. (1992)
Groundwater DOM	5507	Campbell and Treadwell, unpublished data
Standing crops (g/m^2)		
CBOM > 1 mm (not including wood)	105	Campbell and Treadwell, unpublished data
FBOM < 1 mm	26	Campbell and Treadwell, unpublished data
Wood > 1 mm	3916	Campbell and Treadwell, unpublished data
Outputs		
Autotrophic respiration ($g\ m^{-2}\ y^{-1}$)	528	50% GPP
Heterotrophic respiration ($g\ m^{-2}\ y^{-1}$)	738	Treadwell (1995)
Particulate transport (kg/y)	31.8×10^3	Edwards, unpublished data
Dissolved transport (kg/y)	27.8×10^3	Edwards, unpublished data

abundant taxa in leaf litter were *Pomaderris aspera* (41%) and *Eucalyptus* spp. (38%). Litterfall varied seasonally with 40% of total litter and 50% of leaves entering the stream during summer. Lateral inputs were not measured at this site; however, lateral input at a similar site contributed 10% of total litter input (Campbell et al. 1992).

Groundwater DOC was sampled from a well approximately 1 m deep and 1 m from the stream edge. Samples were filtered through preashed GF/C Whatman filter paper (0.45-μm pore size), and DOC was determined on a Shimadzu Organic Carbon Analyser. Groundwater DOC input was 8.4 mg C/L. Multiplying DOC by annual discharge, dividing by total streambed area, and assuming that DOC represents 50% of DOM, gives an annual DOM input of 5507 g AFDM $m^{-2}\ y^{-1}$. This estimate assumes all stream flow originates as groundwater. Streambed area was calculated by multiplying mean bankfull width by main upstream channel length.

Standing crops

Benthic organic matter was measured twice a season in 1993 (Treadwell 1995). On each occasion 3 samples were collected using a 0.051-m^2 Surber sampler (mesh size 0.3-mm). Material was separated into 2 fractions: >10 mm and <10 mm. Samples were dried at 60°C, weighed, ashed at 500°C, and reweighed to determine AFDM.

In Autumn 1994 FBOM 0.3–1 mm, CBOM >1 mm, and wood >1 mm were measured (Campbell and Treadwell, unpublished). Fine BOM was collected in 40 Surber samples and the contents passed through a 1-mm sieve. All wood and CBOM was collected in five 1-m long transects across the full width of the stream. Each piece of wood was assumed to be either a rectangle or a truncated cone. A subsample of wood from each transect was dried at 60°C and weighed, and its density was determined by water displacement. A further subsample was ashed at 500°C for AFDM determination. Total

wood standing crop was determined by calculating total stream wood volume, converting volume to dry mass using wood density, and converting dry mass to AFDM from percentage ash of the subsample. Data from the seasonal and autumn samplings were combined to determine BOM in Keppel Creek. Total BOM was 4047 g AFDM m^{-2} of which 97% was wood.

Outputs

Benthic community respiration was measured at night in clear perspex chambers and during the day in blacked out chambers. Hourly respiration rate did not differ between night and day so night time respiration was extrapolated to 24-h community respiration (R_E) (Treadwell 1995). Hyporheic respiration was accounted for in the measurement of R_E because trays buried in the stream bed were 15 cm deep and open at the bottom. Annual R_E was 1985 g O_2 m^{-2} y^{-1} or 1266 g AFDM m^{-2} y^{-1}, assuming 1 mg O_2 = 0.375 mg C, AFDM is 50% C, and using a respiratory quotient of 0.85 (Bott et al. 1985). Community respiration was separated into autotrophic (R_A) and heterotrophic (R_H) components assuming R_A was ½ GPP (528 g AFDM m^{-2} y^{-1}) and $R_H = R_E - R_A$ (738 g AFDM m^{-2} y^{-1}).

Particulate organic matter in transport was measured in Keppel Creek during base flow and storms from 1988 to 1993 (Edwards, unpublished). Coarse POM was collected using a 1-mm mesh net that slotted into the opening of a small sandbag-and-timber weir such that the whole stream flow could be sampled. Five samples, taken at 0.5–10 min intervals depending on discharge, were taken weekly. Ash free dry mass was calculated as for BOM. Fine POM was collected at the same time by taking 1-L water samples through the 1-mm mesh. Samples were filtered through pre-ashed GF/C filter paper and AFDM was determined. Particulate organic matter was also measured during floods using an automatic water sampler (ISCO 3700). Samples were taken at various intervals depending on flood intensity. These samples were treated in the same way as the routine FPOM samples. Fine POM contributed 96% of total POM with up to 80% of total POM transported during floods. Annual POM export was 31.8 × 10^3 kg AFDM y^{-1}.

Dissolved organic carbon was determined on samples taken at the same time as POM samples by filtering them through pre-ashed GF/C filter paper and analysing the filtrate. Dissolved organic matter export was 27.8 × 10^3 kg AFDM y^{-1}.

Conclusions

The annual ratio of GPP to R_E in Keppel Creek was 0.83, indicating that on an annual basis heterotrophic conditions predominate. However, when litter and DOM inputs, and POM and DOM outputs are incorporated into the energy budget, Keppel Creek is accumulating organic matter at 2417 g AFDM m^{-2} y^{-1}. At the calculated aggradation rate it would require only 20 d to accumulate the observed storage, excluding wood. This estimate is similar to that in a nearby stream, where Doeg et al. (1989) found that following the removal of 70% of BOM, a return to control levels was reached in 21 d in winter and 8 d in summer.

We anticipate that future work at Keppel Creek will be directed at groundwater carbon inputs and use of this carbon source by the in-stream community.

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