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Nutrient excretion by the Asiatic clam *Corbicula fluminea*

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Abstract. The freshwater Asiatic clam, *Corbicula fluminea* (Müller), has become a prominent component of the benthic community in many lakes and rivers since its introduction to this continent some 50 years ago. Because of its abundance, this filter-feeding clam has the potential to influence nutrient cycling by excretion of metabolic wastes, including NH_3 and PO_4 . Excretion rates of ammonia and orthophosphate were estimated seasonally in *Corbicula* freshly collected from the Chowan River, a large coastal plain river in eastern Virginia–North Carolina. Excretion was expressed as a function of clam dry weight, and was highest in May and September for both nutrients. Using *Corbicula* population estimates from an earlier benthic survey of the Chowan to calculate excretion volumes per square meter suggests that the clams can have a substantial effect on nutrient cycling in summer in the upper Chowan River and a large tributary, the Blackwater River, with ammonia excretion ranging from 357 to 8642 $\mu\text{moles m}^{-2} \text{ d}^{-1}$, and orthophosphate excretion ranging from 161 to 3924 $\mu\text{moles m}^{-2} \text{ d}^{-1}$.

Key words: *Corbicula*, bivalve, excretion, ammonia, orthophosphate, Chowan River.

An increasing body of evidence indicates that benthic invertebrates can be important factors in nutrient cycling in aquatic habitats, both indirectly through burrowing and sediment reworking (e.g., Krantzberg 1985) and bacteria-invertebrate associations (Chatarpaul et al. 1980), and directly, through excretion of metabolites (Kuenzler 1961, Kautsky and Wallentinus 1980, Gardner et al. 1981, Jordan and Valiela 1982). Filter-feeding bivalve molluscs may be one of the most substantial sources of excreted nutrients in aquatic systems because of their abundance and relatively large biomass; ammonia (NH_3) is the principal nitrogenous waste product (Bayne and Scullard 1977) while phosphate (PO_4) is the primary form of phosphorus released (Kuenzler 1961). Both of these excreted nutrients are usually very reactive biologically, and can be rapidly absorbed by phytoplankton (e.g., Kautsky and Wallentinus 1980). This “fertilizing” effect due to excretion is balanced on the other hand by the fact that the bivalves are also removing suspended material (including algae) as they feed (e.g., Lauritsen 1986). Thus we can view these organisms in terms of enhancing or accelerating nutrient remineralization.

Most bivalve excretion studies to date have involved marine species that may be abundant in shallow waters and estuaries and may significantly augment nutrient remineralization (e.g., Lewin et al. 1979, Kautsky and Wallentinus 1980). An analog in freshwater may be the Asiatic clam, *Corbicula fluminea* (Müller), an exotic that has become abundant in many lakes and rivers in the southern United States (McMahon 1983).

A 1980 benthic survey of the Chowan, a large coastal plain river in Virginia and North Carolina, indicated that *Corbicula* had recently invaded that watershed (Lauritsen and Mozley 1983). Since the clams represent a large percentage of the benthic invertebrate biomass in the upper river, they are probably the most important recyclers of nutrients among the benthic invertebrates. In the present study, rates of excretion of ammonia and phosphate were estimated in clams freshly collected from the Chowan River. The relative magnitude of nutrient regeneration by clams was then determined by extrapolation to earlier clam biomass estimates, and compared with other nutrient sources in the river.

Study Area

The Chowan River is formed by the confluence of the Blackwater and Nottoway rivers near

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the Virginia–North Carolina border. Over 75% of the catchment (total area: 12,650 km²) lies in Virginia and drains mostly forests (76%) and agricultural land (22%). Point sources of nutrient input include a number of small municipal waste treatment facilities as well as several large industrial sources. Retention times for the river range from 15–30 d in winter up to 260 d in a dry summer. The river water is usually well-mixed, but transient thermal stratification has been observed in summer in the lower river (Paerl 1982).

In 1982, surface chlorophyll *a* concentrations (usually ranging from 2 to 8 µg/L in summer) peaked in May owing to the predominance of the flagellate *Eudorina elegans*. Other flagellated algae were abundant sporadically throughout the summer, whereas the filamentous diatom *Melosira* sp. dominated algal biomass in the winter (NCDEM 1984).

Figure 1 shows the river and the collection site near Winton, North Carolina. In 1980, a benthic survey was conducted in which the river and its tributaries were divided into a series of 17 regions; two transects, randomly located, were sampled in each region (Lauritsen and Mozley 1983). The mean density of *Corbicula* in the lower half of the Chowan was <10 clams/m², while in the upper river and its tributaries the mean density was 205 clams/m² (the highest densities were about 400 clams/m²). *Corbicula* densities were generally higher at depths >2 m (Lauritsen and Mozley 1983).

Methods

Collections of *Corbicula* (taken with a Ponar grab sampler) and river water were made in May, September, and December 1982 near Winton, North Carolina (Fig. 1). Upon collection, clams were placed in large buckets containing sediments and river water, in an effort to minimize stress on route to the laboratory (3 hr travel time). In the lab, clam shells were scrubbed, and individuals were sorted into size classes based on shell length. Nine treatments, consisting of five clams of the same size (<1-mm range in shell length) each, were set up for each sample date. Clams were placed in acid-washed 1-L beakers containing 750 ml of filtered (Whatman GF/C) river water, which were sealed with aluminum foil to prevent contamination from the air. Two beakers containing

only filtered river water were used as controls for each excretion experiment. The rate of excretion for each treatment was determined as the difference in nutrient (NH₃ and PO₄) concentration over time between beakers with clams and the controls without clams. The May and September experiments were conducted at room temperature (about 23°C) whereas the December experiment was run at 6°C. Water samples (50 ml) were taken from each beaker after 14 hr and placed in acid-washed polyethylene bottles. These samples were refrigerated and nutrient analysis was completed within 24 hr of collection. Ammonia concentrations were determined by the phenol-hypochlorite method of Solorzano (1969), and the molybdate blue method (Murphy and Riley 1962) was used for orthophosphate (soluble reactive phosphorus) analysis.

Clams removed from the beakers were frozen and later dried in an oven at 60–70°C for 7 d. Shell length (longest dimension) and dry flesh weight were then determined for each clam.

Results

Excretion rates of ammonium and orthophosphate averaged over 14 hr were fitted to power functions of dry flesh weight (DFW; weights were pooled for the 5 clams in each beaker) according to the following equation: $V = aW^b$, where V is in µmoles/hr, W is in mg of clam dry flesh weight, and a and b are regression constants. An orthogonal contrast (ANOVA) of May and September NH₃ excretion rates was not significant ($F = 3.8$, $p > 0.05$) so data from both experiments were pooled and a single regression line for summer data was fitted. However, summer and winter regressions showed a highly significant difference, even between means adjusted by analysis of covariance with DFW as the covariate ($F = 145.2$, $p < 0.001$). The slopes of the winter and pooled summer regression lines were not significantly different ($F = 2.01$, $p > 0.15$; Fig. 2) showing the relationship between excretion rate and DFW was the same but winter rates were significantly lower. Using the power functions, an average size clam of 20-mg DFW would excrete 2.06 µmol/hr NH₃ in summer and 0.95 µmol/hr NH₃ in winter.

Orthophosphate excretion rates between May and September were also not significantly dif-

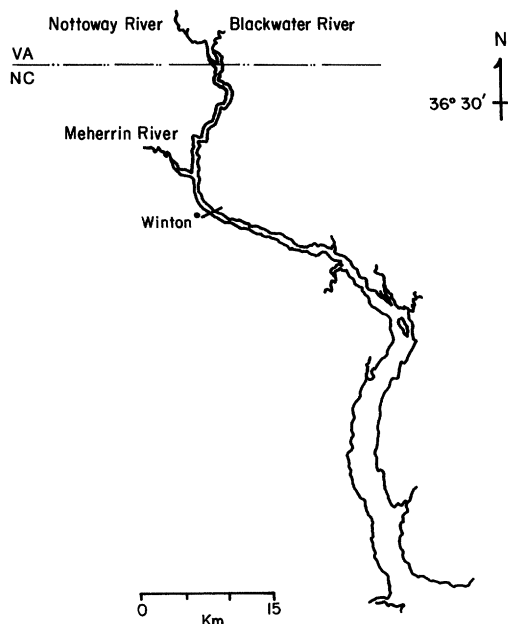


FIG. 1. Map of the Chowan River, Virginia-North Carolina. Clams for excretion experiments were collected from the Chowan near Winton.

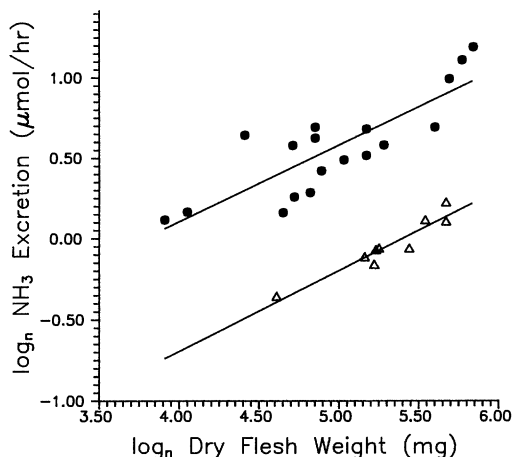


FIG. 2. Relationship between ammonia excretion (V , in $\mu\text{mol/hr}$) and *Corbicula* dry flesh weight (W , in mg) for clams collected from the Chowan in May, September, and December 1982. Excretion rates are expressed as the power function $V = aW^b$. Closed circles show summer rates (no significant difference between May and September rates [$a = 0.167$, $b = 0.476$, and $r = 0.834$]); open triangles show winter rates ($a = 0.068$, $b = 0.497$, and $r = 0.947$).

ferent ($F = 0.46$, $p > 0.50$) so the data were pooled to give a summer regression. A clam of 20-mg DFW would excrete $0.36 \mu\text{mol/hr PO}_4$ using this summer regression equation (Fig. 3). Winter excretion rates were much lower, and the slopes of the two regressions were not parallel ($F = 17.4$, $p < 0.001$), showing that the size-rate relationship did not hold between seasons. There was little difference between weight-specific excretion rates of large and small clams in summer (Fig. 3). Using the same example of a 20-mg DFW clam, the winter regression yields a PO_4 excretion rate of $0.02 \mu\text{mol/hr}$.

Summer ammonia and orthophosphate fluxes due to *Corbicula* excretion were calculated for the upper Chowan River and tributaries using the pooled summer excretion rates and biomass estimates from the 1980 benthic survey. Ammonia excretion rates ranged from 357 to $8642 \mu\text{moles m}^{-2} \text{d}^{-1}$, while orthophosphate rates ranged from 161 to $3924 \mu\text{moles m}^{-2} \text{d}^{-1}$. The highest excretion rates were roughly correlated with regions of highest *Corbicula* density, although clam biomass did not always parallel densities (some areas had larger numbers of smaller clams, which contributed less biomass [Lauritsen and Mozley 1983]).

Dry flesh weight-shell length relationships

of clams collected from the Chowan showed substantial seasonal differences, with clams in September having much reduced dry flesh weights for a given shell length. Slopes of the regression lines were significantly different between seasons (F -test for common slope = 11.21 , $p = 0.005$; Fig. 4).

Discussion

Corbicula fluminea has been characterized as a lotic species that is most successful in flowing, well-oxygenated waters (McMahon 1983). In the Chowan, densities of clams drop off sharply downstream from Region 7, where the river broadens and current velocity decreases (Lauritsen and Mozley 1983). The mean density of clams in the upper river is representative of average numbers of clams found in other rivers in the Southeastern United States, although densities can vary widely both spatially and temporally (e.g., Sickel 1979). In other locations, such as Texas reservoirs, *Corbicula* densities are generally much higher (McMahon 1983).

The variability found in *Corbicula* NH_3 excretion rates between summer and winter was probably a function both of the seasonal ga-

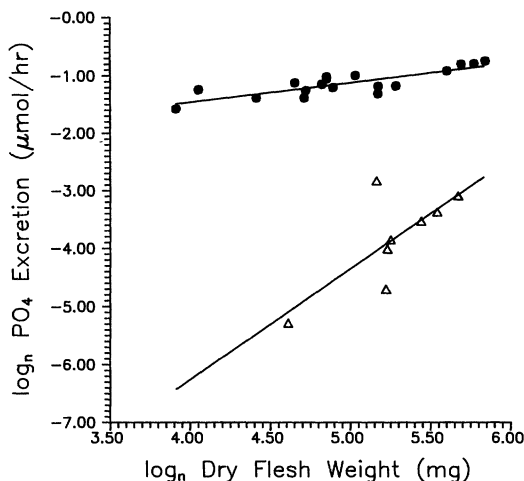


FIG. 3. Relationship between phosphate excretion (V , in $\mu\text{mol/hr}$) and *Corbicula* dry flesh weight (W , in mg). Closed circles show summer rates (no significant difference between May and September rates [$a = 0.060$, $b = 0.337$, and $r = 0.825$]); open triangles show winter rates ($a = 9.48 \times 10^{-7}$, $b = 1.904$, and $r = 0.772$).

metogenic cycle and of the metabolic effects of seasonal changes in ration (seston quality and quantity) and temperature. Reports of reproductive behavior in *Corbicula* in the U.S. indicate that there are two peaks in spawning, in spring and fall, separated by a reduction or cessation of activity during midsummer and winter periods (McMahon 1983). Working the salt-water mussel *Mytilus edulis*, Gabbot and Bayne (1973) found maximal NH_3 excretion rates in late spring and summer, before spawning. These authors concluded that during periods of glycogen use for gametogenesis, active protein catabolism resulted in high rates of NH_3 excretion, but in winter, when glycogen was available for energy metabolism, protein catabolism (and therefore NH_3 excretion) was reduced. Williams and McMahon (1985) observed a 20- to 40-fold increase in ammonia excretion rates of *Corbicula* with the onset of spawning in spring, and summer O:N ratios (a molar ratio of oxygen consumed to ammonia excreted) suggested that spawning individuals were catabolizing proteins. Water temperatures may also affect excretion rates; Bayne and Scullard (1977) noted significant increases in excretion rates with increasing temperature (over the range 11–21°C) in *M. edulis*.

Excretion experiments are generally conducted by isolating organisms from sediments

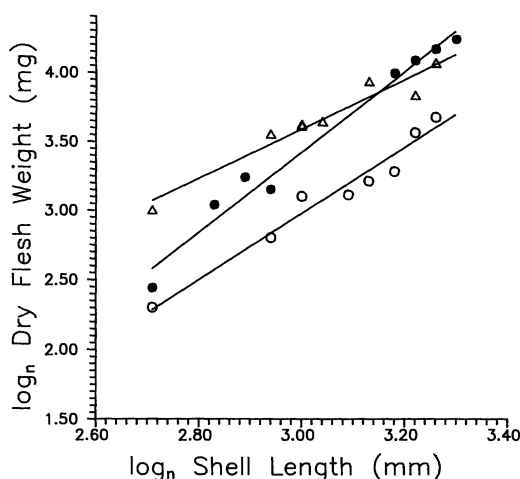


FIG. 4. Regressions of dry flesh weight (mg) and shell length (mm) for *Corbicula* collected from the Chowan River at Winton, at different seasons in 1982. Each data point is an average shell length and weight of five clams. ANCOVA (with shell length as the covariate) was highly significant ($p = 0.0001$). Closed circles show May data ($r = 0.988$); open circles show September data ($r = 0.978$); open triangles show December data ($r = 0.991$).

and a food supply (water is filtered to remove seston because of the confounding variable of algal uptake of excreted nutrients); these conditions probably influence excretion rates. The *Corbicula* excretion experiments described here were set up as soon as possible after collection of clams so that rates measured would reflect in situ conditions and diet. Controlled feeding experiments with *Corbicula* indicate that ammonia excretion rates peak about 2 hr after cessation of feeding and decline after that point (Lauritsen, unpublished data). Since clams in the present study were not fed over the course of the 14-hr incubation, rates measured were probably conservative.

Another possible confounding variable in this excretion experiment is the contribution of the microbial fauna associated with the clams to nutrient regeneration (by metabolizing any unassimilated N and P). In laboratory feeding experiments using ^{14}C labeled algae, some of the dissolved organic carbon released (excreted) by *Corbicula* in the first 24 hr after feeding was due to "leaching" of feces (Lauritsen 1985). It would be difficult to directly compare C, N, and P excretion, however, and a comparison between excretion rates measured with and without an-

tibiotics would be needed to assess the magnitude of any bacterial component. None of the studies we have cited in this paper have used antibiotics in the water.

Although excretion rate-dry flesh weight relationships were not different in May and September for both NH_3 and PO_4 , shell length-dry flesh weight relationships changed considerably between these periods, so that clams of a given size had a much reduced dry flesh weight in September compared with May. In summer, *Corbicula* puts most of its energy into shell growth and reproduction (Williams and McMahon 1985) and may experience some soft-tissue weight loss as a result of protein catabolism, so that dry flesh weight-shell length ratios may be significantly lower at this time.

Excretion rates of both ammonia and orthophosphate based on clam dry flesh weight were similar to rates for other freshwater benthic invertebrates such as chironomid larvae and oligochaetes (Gardner et al. 1981, 1983), but since the biomass per square meter of *Corbicula* is usually much greater, the overall volume of nutrients excreted can be quite substantial.

Blue-green algal blooms have been a problem in the Chowan River in recent years, resulting in an attempt to identify and quantify nutrient sources for the river. Allochthonous (non-point) loading in the Chowan is usually highest in spring, when precipitation levels are relatively high (Kuenzler et al. 1982). Other significant autochthonous sources of nutrients in the Chowan include sediment fluxes (a 1980 study using benthic chambers found mean fluxes from the sediment to the overlying water of $1220 \mu\text{moles m}^{-2} \text{d}^{-1}$ for NH_3 and $95 \mu\text{moles m}^{-2} \text{d}^{-1}$ for PO_4 at stations about 8.5 km downstream of Winton [Albert 1980]).

Particulate N concentrations in the Chowan usually reflect the distribution of phytoplankton; in summer 1981, for example, concentrations at Winton ranged from 5 to $20 \mu\text{moles/L}$ (Kuenzler et al. 1982). Summer particulate P concentrations, not always indicative of algal P because of the tendency for adsorption onto clays and other particles, ranged from 0.5 to $1.0 \mu\text{moles/L}$ at Winton in 1981 (Kuenzler et al. 1982). Phytoplankton uptake rates of NH_3 show significant annual variation; summer (May-September) mean gross NH_3 uptake rates near Winton were $1095 \mu\text{moles m}^{-2} \text{hr}^{-1}$ in 1980 (an algal bloom year) and $779 \mu\text{moles m}^{-2} \text{hr}^{-1}$ in

1981 (considered a non-bloom year [Kuenzler et al. 1982]). There was little seasonal variability in gross PO_4 uptake rates near Winton, with an average of about $500 \mu\text{moles m}^{-2} \text{hr}^{-1}$ (Kuenzler et al. 1982). *Corbicula* excretion rates, by comparison, could be $>30\%$ of phytoplankton uptake rates of these nutrients in the upper Chowan. It is clear that these clams can be a significant source of remineralized nutrients in this and other aquatic habitats where they are abundant.

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Literature Cited

- ALBERT, D. B. 1980. *In situ* measurements of sediment-water nutrient exchange rates in the Chowan River. M.S. Thesis, University of North Carolina, Chapel Hill.
- BAYNE, B. D., AND C. SCULLARD. 1977. Rates of nitrogen excretion by species of *Mytilus* (Bivalvia: Mollusca). Journal of the Marine Biological Association of the United Kingdom 57:355-369.
- CHATARPAUL, L., J. B. ROBINSON, AND N. K. KAUSHIK. 1980. Effects of tubificid worms on denitrification and nitrification in stream sediment. Canadian Journal of Fisheries and Aquatic Sciences 37:656-663.
- GABBOT, P. A., AND B. L. BAYNE. 1973. Biochemical effects of temperature and nutritive stress on *Mytilus edulis* L. Journal of the Marine Biological Association of the United Kingdom 53:269-286.
- GARDNER, W. S., T. F. NALEPA, M. A. QUIGLEY, AND J. M. MALCZYK. 1981. Release of phosphorus by certain benthic invertebrates. Canadian Journal of Fisheries and Aquatic Sciences 38:978-981.
- GARDNER, W. S., T. F. NALEPA, D. R. SLAVENS, AND G. A. LAIRD. 1983. Patterns and rates of nitrogen release by benthic Chironomidae and Oligo-

- chaeta. Canadian Journal of Fisheries and Aquatic Sciences 40:259–266.
- JORDAN, T. E., AND I. VALIELA. 1982. A nitrogen budget of the ribbed mussel, *Geukensia demissa*, and its significance in nitrogen flow in a New England salt marsh. Limnology and Oceanography 27:75–90.
- KAUTSKY, N., AND I. WALLENTINUS. 1980. Nutrient release from a Baltic *Mytilus*-red algal community and its role in benthic and pelagic productivity. Ophelia, Supplement 1:17–30.
- KRANTZBERG, G. 1985. The influence of bioturbation on physical, chemical and biological parameters in aquatic environments: a review. Environmental Pollution (Series A) 39:99–122.
- KUENZLER, E. J. 1961. Phosphorus budget of a mussel population. Limnology and Oceanography 6:400–415.
- KUENZLER, E. J., K. L. STONE, AND D. B. ALBERT. 1982. Phytoplankton uptake and sediment release of nitrogen and phosphorus in the Chowan River, North Carolina. Water Resources Research Institute Report #186, University of North Carolina, Raleigh.
- LAURITSEN, D. D. 1985. Filter-feeding, food utilization, and nutrient remineralization by *Corbicula fluminea* (Bivalvia) and its contribution to nutrient cycling in a North Carolina River. Ph.D. Thesis, North Carolina State University, Raleigh.
- LAURITSEN, D. D. 1986. Filter-feeding in *Corbicula fluminea* and its effect on seston removal. Journal of the North American Benthological Society 5: 165–172.
- LAURITSEN, D. D., AND S. C. MOZLEY. 1983. The freshwater Asian clam *Corbicula fluminea* as a factor affecting nutrient cycling in the Chowan River, N.C. Water Resources Research Institute Report #192, University of North Carolina, Raleigh.
- LEWIN, J., J. E. ECKMAN, AND G. N. WARE. 1979. Blooms of surf-zone diatoms along the coast of the Olympic Peninsula, Washington. XI. Regeneration of ammonium in the surf environment by the Pacific Razor Clam *Siliqua patula*. Marine Biology 52: 1–9.
- MCMAHON, R. F. 1983. Ecology of an invasive pest bivalve, *Corbicula*. Pages 505–561 in W. D. Russell-Hunter (editor). The Mollusca, Volume 6: Ecology. Academic Press, New York.
- MURPHY, J., AND J. P. RILEY. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27:31–36.
- NORTH CAROLINA DIVISION OF ENVIRONMENTAL MANAGEMENT. 1984. Summary of phytoplankton and related water quality parameters in the Chowan River 1982–83. North Carolina Department of Natural Resources and Community Development.
- PAERL, H. W. 1982. Environmental factors promoting and regulating N₂-fixing blue-green algal blooms in the Chowan River, NC. Water Resources Research Institute Report #176, University of North Carolina, Raleigh.
- SICKEL, J. B. 1979. Population dynamics of *Corbicula* in the Altamaha River, Georgia. Pages 69–80 in J. Britton (editor). Proceedings of the First International *Corbicula* Symposium, Texas Christian University.
- SOLORZANO, L. 1969. Determination of ammonia in natural waters by the phenylhypochlorite method. Limnology and Oceanography 21:357–364.
- WILLIAMS, C. J., AND R. F. MCMAHON. 1985. Seasonal variation in oxygen consumption rates, nitrogen excretion rates and tissue organic carbon:nitrogen ratios in the introduced Asian freshwater bivalve, *Corbicula fluminea* (Müller) (Lamellibranchia:Corbiculacea). American Malacological Bulletin 3:267–268 (abstract).

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