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J. Aquat. Plant Manage. 30: 23-28

Factors Influencing Gas Evolution Beneath a Benthic Barrier[1]

DOUGLAS GUNNISON AND J. W. BARKO[2]

ABSTRACT

Laboratory studies were conducted to determine the influences of temperature, sediment type, and sediment organic matter on rates of gas evolution beneath a benthic barrier. Gas evolution was measured at two temperatures (15 and 30 C) from two compositionally distinct (sand and clay) sediments with and without additions of organic matter. Sediments amended by addition of coontail (*Ceratophyllum demersum*) produced gas at both 15 and 30 C. However, incubation temperature determined both the onset of gas formation and the maximum gas production rate achieved. Results demonstrate that gas evolution begins earlier and gas production rates are greater at warmer temperatures. Examination of the effect of organic matter level on gas evolution rates revealed pronounced increases in gas evolution rates from clay sediments amended by additions of 13 to 130 g of coontail at 30 C. Composition of the gases released proved similar for all of the treatment combinations (nitrogen – 47 to 55 percent; oxygen – 13 to 15 percent; methane – 3 to 4 percent; carbon dioxide – 28 to 36 percent). Based on findings of these studies, benthic barriers scheduled for deployment in areas sustaining high seasonal plant production rates should be emplaced during cooler periods of the year when the standing crop and decomposition rates are low.

Key words: Gas evolution, permeability, organic matter, sediment type, coontail.

INTRODUCTION

Benthic application of barrier fabrics provides a means to physically limit nuisance growth of aquatic plants (Mayer 1978, Perkins et al. 1979, Lewis 1983, Cooke 1986). Benthic barriers provide an attractive alternative to other types of control because they can be deployed and left in place for several growing seasons, thus eliminating the need for repetitive treatment efforts. Barriers can be easily installed with very limited training of personnel (Pullman 1990); however, benthic barriers cannot be recommended for widespread field use until their effectiveness has been firmly established.

A specific concern related to barrier use is the limitations on barrier performance resulting from sediment gas evolution following placement. Available barrier fabrics are reported to differ extensively in both their immediate and long-term permeabilities to gases (Pullman 1990). Permeability may be essential to prevent pockets of gas from buoying the barrier fabric up to the water surface, where wind and wave action can cause displacement.

An earlier study conducted at Eau Gallie Reservoir, Spring Valley, WI, was conducted to initially characterize

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[2] Research Microbiologist and Research Biologist, respectively, Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199.

the effects of gas evolution from sediment on barrier performance (Gunnison and Barko 1989, 1990). Benthic barrier mats (Dow Bottom Line™) equipped with gas collection systems were deployed in late summer of 1988 at both vegetated and unvegetated sites and were weighted down with bricks. Barrier placement at the vegetated site was followed almost immediately by release of large quantities of gases, causing the barriers to billow up noticeably (Gunnison and Barko 1989, 1990). In contrast, gas collection systems at the unvegetated sites contained no visible gas after 3 days of placement and only minor volumes when the barriers were finally removed at 8 weeks.

While results of the studies conducted at Eau Gallie Reservoir were useful, they did not enable us to evaluate the effects of factors specifically related to the presence vs. absence of vegetation on gas evolution rates. Subsequently, we conducted a series of controlled laboratory studies to examine effects of sediment organic matter, sediment textural composition, and water temperature on gas evolution rates. We report here the results of these investigations and their implications with respect to barrier performance in the field.

MATERIAL AND METHODS

An initial study was conducted to determine the extent to which sediment type alone, or in combination with added organic matter, at different temperatures might affect gas evolution rates beneath a benthic barrier. Plastic containers (3.8 liters) having a surface area of 540 cm^2 were filled with either fine-textured Brown's Lake sediment (BLS), consisting predominantly of clay, or a washed masonry sand intermixed with 25 percent (v/v) BLS (sand). Amended sediments were treated with an addition of 13 g freeze-dried coontail (*Ceratophyllum demersum*) intermixed with the upper 2 cm of sediment. This mass of addition mimicked complete incorporation of coontail standing crop at a level of approximately 240 g dry wt/m^2. Both amended and unamended sediments were then covered with 2 cm of washed masonry sand. The containers were covered with Botton Line™ Benthic Barrier Fabric (Dow Corning Corp., Midland, MI). A gas collection apparatus was placed under the barrier fabric to capture gases evolved from the sediments. The apparatus consisted of an inverted funnel that was held above the sediment surface on a tripod attached to the rim (Figure 1a).

Containers, barrier fabric, and attached funnels (collectively termed "flats") were placed on the bottom of water-filled tanks (1200 L) maintained at either 15 or 30 C. Four replicates of each sediment-organic matter treatment were prepared for incubation at each temperature. The funnel from each flat was attached to tubing that ran up to an inverted graduate cylinder designed to collect gases through water displacement (Figure 1b). Graduate cylinder traps were suspended from the water surface on a raft (Figure 1c) and monitored for gas accumulation over an 8 week period.

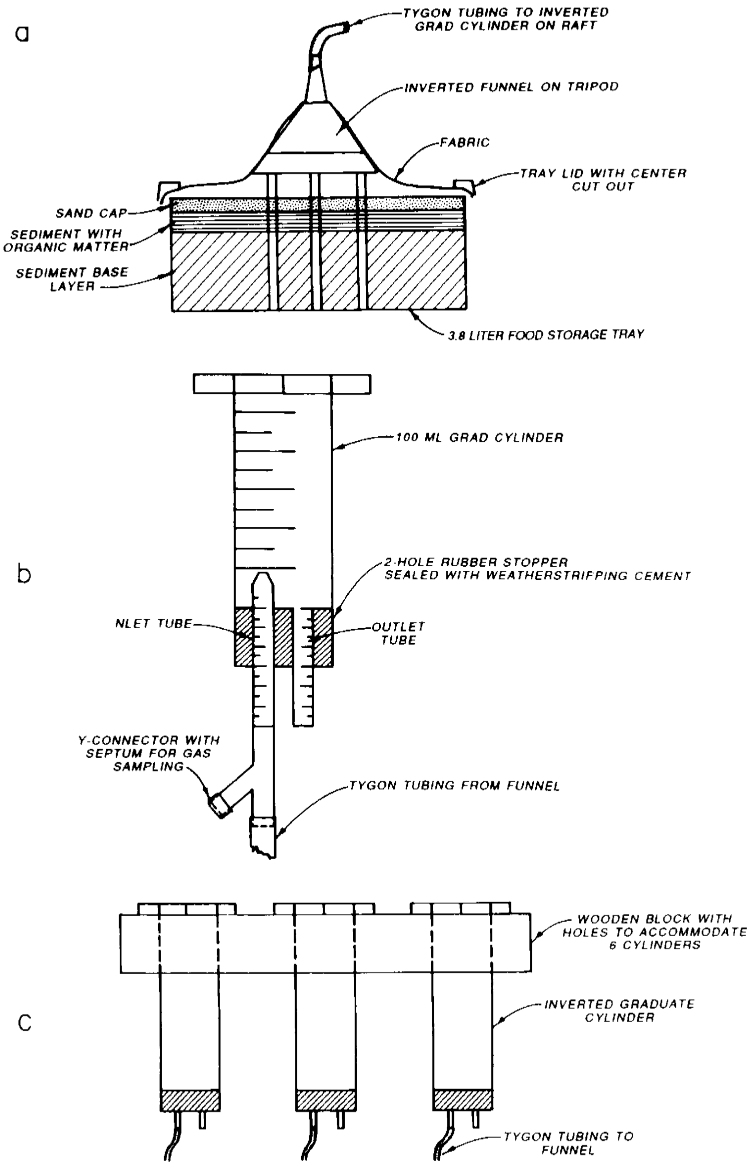

Figure 1. Diagrams depicting major components of the sediment tray and trap system: (a) sediment tray, funnel, and barrier fabric trap on tripod; (b) inverted graduate cylinder with inlet and outlet devices; and (c) support raft.

Gas evolution rates for individual treatments were determined by twice weekly monitoring the volume of gas trapped in cylinders. Once each week, gas samples were analyzed for composition on a Packard Model 419 Gas Chromatograph (Packard Instruments, Inc., Downers Grove, IL) equipped with an Alltech CRT-1 dual gas separation column (Alltech, Inc., Deerfield, IL) attached to a thermal conductivity detector. Helium was used as the carrier gas under ambient temperature conditions at a flow rate of 60 ml/min.

A second study was conducted to determine effects of organic matter type on rates of gas release from sediment beneath the benthic barrier. The same general procedures as in the previous study were utilized. However, only BLS at a temperature of 30 C was included in the design. Different types of dried and ground (40 μm mesh) plant materials were added to the sediment at a rate of 13.0 g for each flat to provide a variety of sources of organic matter for gas formation. Plant materials included oak leaves (*Quercus alba*), pine needles (*Pinus* spp.), cattail leaves

(*Typha latifolia*), coontail, or water hyacinth (*Eichornia crassipes*). Flats including controls (no organic matter addition) were prepared in quadruplicate. Flats were incubated for 10 weeks to allow for extensive decomposition of organic matter.

Another investigation was conducted to determine the effect of different levels of organic matter on gas evolution beneath the benthic barrier. The procedures used were identical to those in the second study, except that amendments consisted of a single plant species. Coontail was added to the BLS sediment in duplicate flats at each of the following levels: none (i.e., control), 0.13, 1.3, 13.0, and 130 g/flat. As in the second study (above), flats were incubated for 10 weeks.

Statistical analyses of gas evolution data and comparisons of treatment effects were conducted using the SAS system for data analysis (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

The release of gas from different sediment types at 15 and 30 C is presented in Figure 2. Unamended sediments maintained at 15 C produced no gas (Figure 2a), while release of gas from unamended sediment consisting of sand at 30 C was observed only at day 43 (Figure 2b). By contrast, unamended BLS held at 30 C produced gas, albeit very erratically and at a low rate, from day 20 until approximately day 47.

All sediments amended by addition of coontail produced gas, but production rates differed significantly with both temperature and sediment type. Amended sand incubated at 15 C had a very low gas production rate, with gas release first becoming apparent at day 20, and then reaching a maximum rate at day 27 (Figure 2c). Amended BLS at 15 C also showed a low gas production rate, with gas release first becoming apparent on day 15, and then reaching a peak on day 20 (Figure 2c). Amended sand held at 30 C exhibited an intermediate rate of gas production, with gas release beginning on the seventh day of incubation and then reaching a peak on the twelfth day (Figure 2d). Amended BLS at 30 C produced the highest rate of gas evolution, with releases first becoming apparent on day 3, and then reaching a peak of 123 ml/m^2/hr on day 7 (Figure 2d).

Nitrogen made up the bulk (47 to 55 percent) of the gases obtained, and oxygen comprised 13 to 15 percent of the total gas volume; its presence was confirmed by the formation of iron oxide coatings in the flats. Total gas contained 3 to 4 percent methane and 28 to 36 percent carbon dioxide. The ratio of carbon dioxide to methane was maintained at nearly 10:1 over the entire course of the incubation.

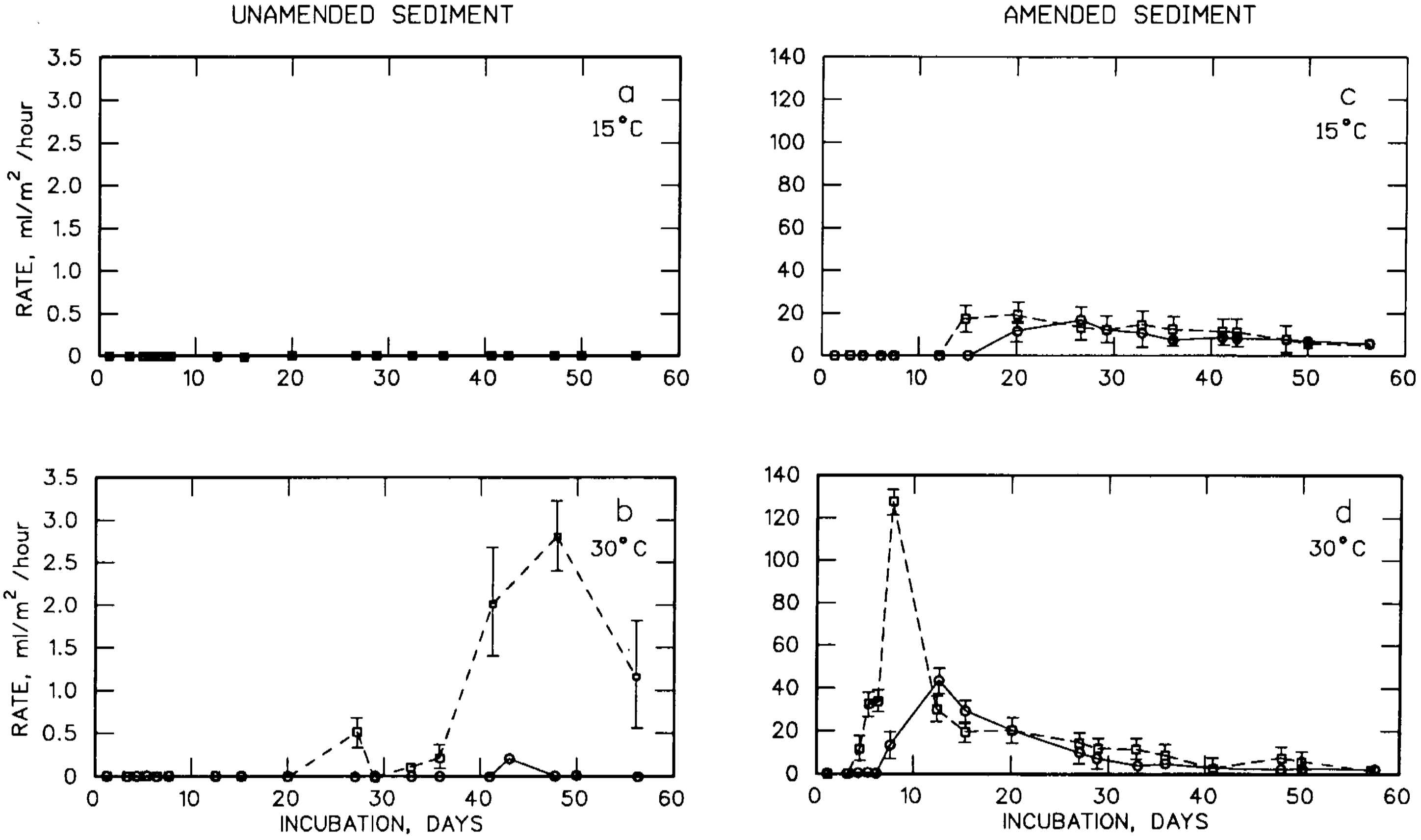

Figure 2. Gas evolution rates for BLS and sand sediments: (a) unamended sediment at 15 C, (b) unamended sediment at 30 C, (c) amended sediment at 15 C, and (d) amended sediment at 30 C. Values given are the means of 4 replicates with bars showing standard error for each mean. Solid lines are sand. Dashed lines are BLS only. Note differing scales.

In the study comparing organic matter types, gas release was first evident in the coontail-amended sediment (Figure 3). This sediment also exhibited the highest gas production rates, reaching levels in excess of 125 ml/m²/hr within the first two weeks (Figure 3a). The onset of gas release from coontail-amended sediment was closely followed by releases from all other amended sediments. Waterhyacinth was second only to coontail in gas production rate (Figure 3b). Cattail, among all treatments, provided the longest duration of gas release (about 65 days). Unamended sediment produced relatively insignificant quantities of gas releases.

The evaluation of the effects of sediment organic matter levels on gas production showed that unamended BLS provided low-level gas production after about 5 weeks of incubation. The maximum release rate achieved at 7 weeks was less than 4.0 ml/m²/hr (Figure 4a). Sediment amended with 0.13 g of coontail demonstrated a pattern of gas release nearly identical to that of control (unamended) sediment (Figure 4b); however, the peak release rate at 7 weeks of incubation was nearly double that of the control sediment. Sediment containing 1.3 g of coontail began releasing gas at the onset of incubation (Figure 4c). The initial peak at about 1 week was followed by a second peak at about 7 weeks. The maximum rate of gas release from sediment treated with 13.0 g addition of coontail occurred one week following initiation of incubation; release rates declined sharply thereafter (Figure 4d). This maximum was nearly identical to that (125 ml/m²/hr) observed for coontail in the earlier study (Figure 3a) at the same level of organic matter addition. The maximum rate of gas release from sediment amended with 130 g of coontail (790 ml/m²/hr) also occurred after only 1 week of incubation. The broad-shouldered release peak showed little decrease from the initial maximum value until about the third week of incubation (Figure 4e). Maximum rates of gas release from sediments amended by additions of coontail between 1.3 and 130 g increased in an approximately linear fashion with the mass of addition.

The results obtained in these studies suggest that large volumes of gas released from organically-enriched sediments can potentially accumulate beneath benthic barriers. Sediments amended by addition of coontail produced gas at both 15 and 30 C; however, incubation temperature determined both the onset of gas formation and the maximum gas production rate achieved. Our results demonstrate that gas evolution begins earlier and gas production rates are greater at warmer water temperatures. These results correspond with those of Pederson and Saylor (1981), who found that temperature in combination with organic matter content accounted for up to 43 percent of the total variability in methane formation in freshwater sediments. Gas formation is clearly a reflection of degradational activity, which is temperature-sensitive. For example, Best et al. (1990) demonstrated that degradation of coontail is stimulated by increasing temperatures, with degradation rates undergoing a 20 percent increase between 5 and 10 C and a 2 percent increase between 10 and 18 C. Use of ground plant material as a source of organic matter for this study enhanced degradation by maximizing contact with the sediment surface and microflora. Thus, the gas release rates observed in this study are probably higher than would be expected had intact plants been used.

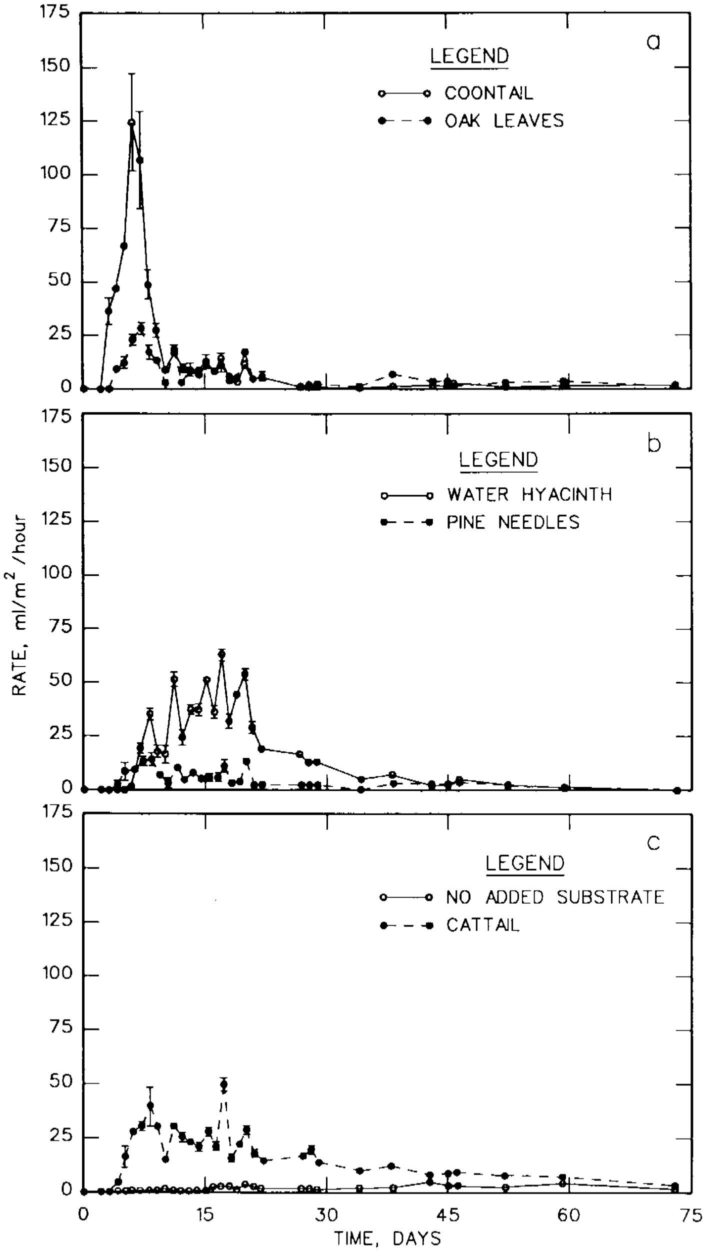

Figure 3. Gas evolution rates for BLS treated with various types of organic matter. Additions include: (a) coontail or oak leaves, (b) water hyacinth or pine needles, and (c) cattail or no amendment. Sediments were incubated for 70 days at 30 C under water. Values presented are the means of 4 replicates with bars showing standard error for each mean.

In our studies, the presence and type of degradable organic matter in sediment beneath the barrier were both very important factors determining the rate and duration of gas formation. The rates of gas evolution decreased in the order coontail > water hyacinth > cattail > oak leaves > pine needles > no added organic matter. Similar results were obtained by Barko and Smart (1983), who found that gas releases were generally greater from sediment amended with relatively labile mixed filamentous algae and watermilfoil (*Myriophyllum spicatum*) than from sedi-

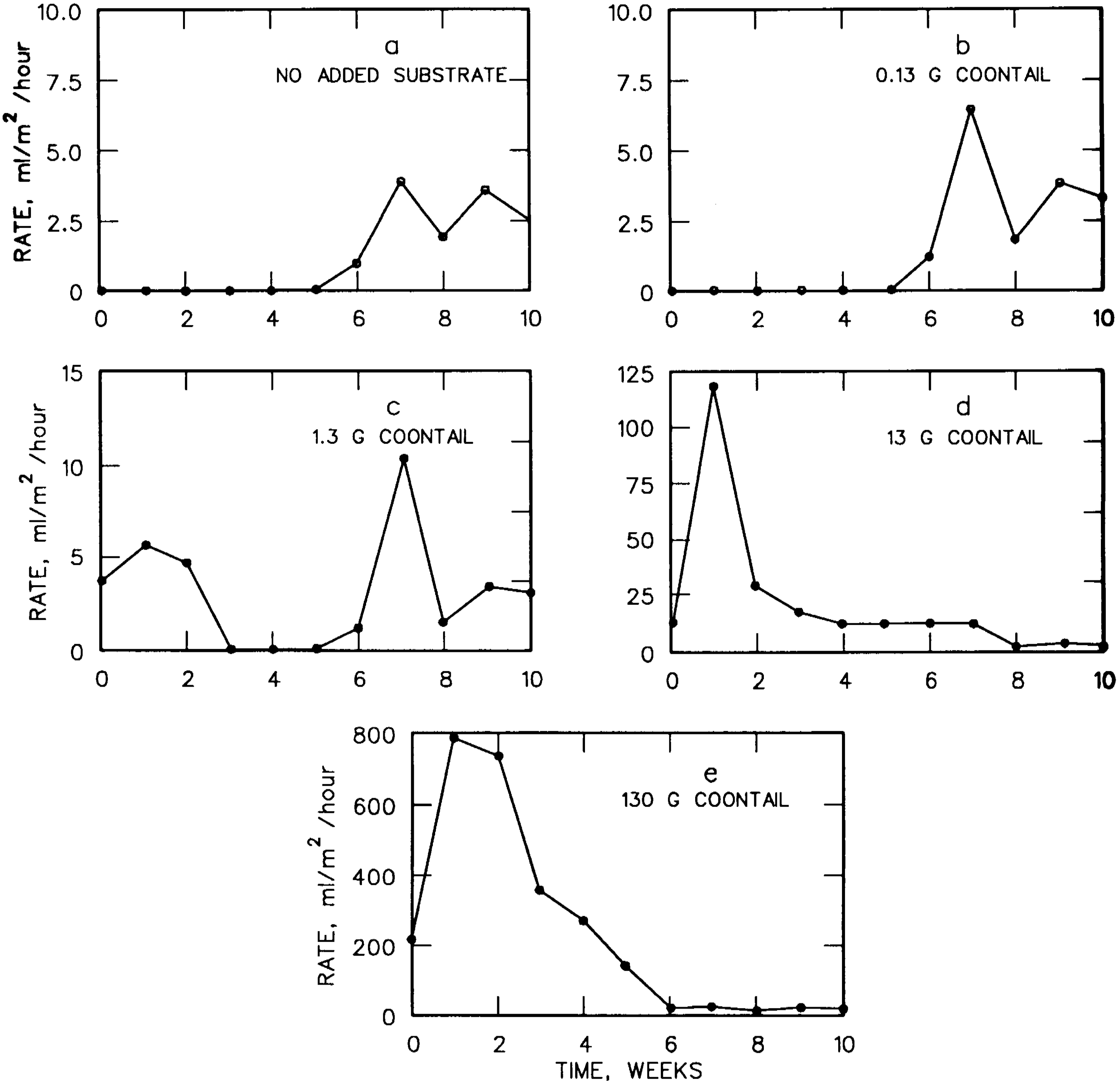

Figure 4. Gas evolution rates from BLS amended with varying levels of coontail. Additions were (a) none, (b) 0.13 g, (c) 1.3 g, (d) 13 g, and (e) 130 g. Sediments were incubated for 10 weeks at 30 C under water. Data points represent averaged values for 2 replicates over weekly intervals, with multiple determinations during each week. Note differing scales.

ment amended by addition of more refractory organic materials (cattail leaves, oak leaves, pine needles). In addition, the amount of degradable organic matter in sediment is important to the gas evolution process. Our results, based on use of coontail, suggest a linear relationship between gas evolution rate and organic mass over a broad range (1.3 to 130 g) in sediment.

Problems with barrier performance related to gas evolution are likely to be greatest in areas of high plant biomass, particularly among species having tissues that are readily decomposed. In areas sustaining high seasonal plant production rates, we recommend that barrier deployment be restricted to periods of the year during which the standing crop is low. With perennial plant populations, the second most important factor to consider is water temperature. Barriers should be placed during cooler months of the year when microbial decomposition rates are at a low point, thus decreasing the rate of release of barrier-buoying gases. When large areas are to be covered with benthic barriers and substantial gas evolution cannot be avoided, benthic barriers should be mechanically affixed to the sediment surface.

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Establishment and Impact of Redbelly Tilapia in a Vegetated Cooling Reservoir

JOHN U. CRUTCHFIELD, JR., D. H. SCHILLER, D. D. HERLONG,[1]
AND M. A. MALLIN[2]

ABSTRACT

Redbelly tilapia (*Tilapia zilli* Gervais) rapidly established a reproducing population in a North Carolina power plant cooling reservoir after inadvertent introduction in 1984. It eliminated the submersed macrophyte community, including a 57-ha infestation of *Egeria densa* (Planch.) by late 1985. In August 1985, just prior to macrophyte disappearance from the reservoir, the mean estimates of redbelly tilapia density and standing crop were 1,080 fish/ha and 16.6 kg/ha, respectively. When macrophytes were scarce or absent, redbelly tilapia shifted to a diet dominated by detritus. The ability of redbelly tilapia to switch to alternate food sources permitted its population to continue expanding in the absence of macrophytes, the preferred food. Changes in water quality were minimal after macrophyte removal with no increased nutrient enrichment. Factors leading to the establishment of redbelly tilapia were an overwintering refuge provided by continuous thermal discharge > 10 C from the power plant, a paucity of predators largemouth bass (*Micropterus salmoides* Lacepéde) and bluegill (*Lepomis macrochirus* Rafinesque), and the species' ability to utilize alternate food sources following macrophyte removal.

Key words: Egeria densa, macrophyte control, biological control, herbivorous fish, *Tilapia zilli*

INTRODUCTION

Redbelly tilapia (*Tilapia zilli* Gervais), a cichlid native to Africa and the Middle East, has been introduced in the United States for aquatic macrophyte control (Shireman 1984). Because of its inability to survive at water temperatures < 10 C, redbelly tilapia must usually be restocked

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[1] Carolina Power & Light Company, Harris Energy & Environmental Center, Rt. 1, Box 327, New Hill, NC 27562.

[2] Institute of Marine Sciences, University of North Carolina, Morehead City, NC 28557.