MACROINVERTEBRATE DRIFT ASSOCIATED WITH *TRAPA NATANS*, AN INVASIVE MACROPHYTE: HUDSON RIVER, NY

RYDER DIAZ
Hunter College, New York, NY 10065 USA

MENTOR SCIENTIST: DR. STUART E. G. FINDLAY
Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. Greater densities of macroinvertebrates are found within beds of submerged aquatic vegetation (SAV) than in unvegetated areas in the Hudson River of New York State. Previous studies have attempted to identify the composition of macroinvertebrate communities within beds of water chestnut (*Trapa natans*), an invasive macrophyte, but none have attempted to identify the movement of macroinvertebrates associated with these beds. Due to the morphology of *Trapa*, floating leaves at the surface of the river create regions of low dissolved oxygen (DO) within these beds. Investigations have shown that many fish and invertebrates are sensitive to depletions of DO, therefore, I proposed the hypothesis that fluctuations in DO within the *Trapa* beds would affect the composition and distribution of invertebrates temporally, resulting in greater drift at lower concentrations of DO. In the Hudson River, periods of lowest DO for *Trapa* are directly related to tidal influence, with the lowest levels of DO coinciding with late ebb tide. Samples of invertebrates drifting from *Trapa* into surrounding open waters were collected by placing drift nets along the perimeter of the beds. For comparison, drift samples were also collected in the open water near these beds. As expected, lower levels of DO were found during ebb tide in beds with larger areas and more animals were found to be drifting at lower concentrations of DO. There was greater invertebrate drift observed from the beds into the surrounding waters than the drift recorded in the open water. The samples were dominated by chironomid midges, chydoridae, cyclopoid copepods, hydracarina, sididae, and naidide oligochaetes. A laboratory experiment was also used to mimic the variation in DO within the beds and observe the effects on the macroinvertebrate movement. Through this model, it was observed that levels of DO do not have a significant influence on macroinvertebrate drift.

INTRODUCTION

Submerged aquatic vegetation (SAV) is an extremely significant component of the Hudson River ecosystem. SAV beds have high primary productivity, are sites for nutrient cycling, enhance sediment dynamics and provide a habitat for fishes and invertebrates (Findlay et al. 2006). The importance of macrophyte habitats for invertebrates has been documented by Strayer and Malcom (2007) who demonstrated that macroinvertebrate densities were 4-5 times larger in submersed vegetation than in areas lacking vegetation. Additionally, densities of benthic macroinvertebrates are higher in vegetated habitats than in nearby unvegetated sediments (Strayer et al. 2006). Waters and San Giovanni (2002) also associate higher taxonomic richness and macroinvertebrate diversity with submerged aquatic vegetation. Such richness and density make vegetated areas a significant feeding habitat for juvenile fish (Yozzo and Diaz 1999, Findlay 2006) and sites of recent concern about protection and preservation. Previous work has shown that the introduction of the zebra mussel (*Dreissena polymorpha*) is correlated to an increase in SAV beds due to the enhanced clarity of the water (Skubinna et al.1995). *Dreissena* is directly responsible for a sharp decline in phytoplankton biomass since its invasion into the Hudson in 1991 (Caraco et al.1997) as well as shifts in the species composition of the phytoplankton (Smith et al. 1998). In the Hudson River, the invasive zebra mussel has dramatically reduced phytoplankton and zooplankton populations by 80-90% and consequently increased water clarity by 45% (Strayer 2006). Moreover, invertebrate density in the shallow vegetated habitats of the freshwater tidal Hudson River estuary has increased in the past decade while invertebrate density fell in unvegetated habitats (Findlay et al. 2006), possibly suggesting a link between decreased phytoplankton availability and the densities and distributions of invertebrates, many of whom depend on these organisms for food.

It is apparent that as SAV density in the Hudson River proliferated with the advent of the zebra mussel, it has become an ever more significant habitat for invertebrates. Several studies (Findlay et al. 1989, Yozzo and Diaz 1999, Feldman 2001, Strayer et al. 2003) have attempted to identify the invertebrate fauna associated with submerged aquatic vegetation as well as their locations within plant beds but none have measured the vectors of movement of macroinvertebrates associated with these habitats.

For a particular non-native macrophyte, the water chestnut (*Trapa natans),* little is known about how composition and distribution of its associated invertebrates respond to variations in dissolved oxygen (DO). This invasive species has been responsible for the decline in many native species of submerged aquatic vegetation and lower DO levels within the beds due to the plant's morphology (Caraco et al. 2006, Findlay 2006). In contrast to native SAV, *Trapa* is composed of rosettes that float on the water's surface and vent oxygen into the atmosphere rather than into the water column, as most native SAV does. Caraco and Cole (2002) found that variation in DO levels associated with large beds of *Trapa* in the main channel occur on a 12.5 h tidal cycle. The correlation with DO levels is not diurnal as one might expect. This is most likely due to the tidal influence of the river. Consequently, at ebb tide, DO levels in *Trapa* beds were found to be the lowest and flood tides re-oxygenated the beds to their peak values, both at edge and inner sites (Caraco and Cole 2002). During ebb tides oxygen levels in *Trapa* are regularly hypoxic and can often reach levels of anoxia (Caraco et al. 2006).

A glaring lack of knowledge exists about how invertebrate communities respond to variations of oxygen within *Trapa*. As invertebrates are often indicators of water quality and ecosystem health, an important food source for fish, and engage in the breaking down organic material, it is important to understand the ways these organisms function and drift within submerged aquatic vegetation, an ecosystem where invertebrate densities are the highest in the river.

Drift gives organisms the ability to escape adverse conditions and colonize new habitats and this action may be passive or active (Brittain 1988). There are several factors that may influence possible movement and change in composition of macroinvertebrates: flow velocities, levels of dissolved oxygen (DO), tidal influence, sunlight, food availability, and plant biomass submerged versus exposed to the open air. For instance, large reductions in DO levels have been shown to have stressful (Giller and Malmqvist 1998) or even lethal effects for macroinvertebrates (Connolly 2004), suggesting that drift may occur at lower levels of DO.

This investigation had the following objectives: to examine the movement of macroinvertebrates between *Trapa* beds and open water in relation to a tidal cycle and to assess the effects of this cycle on rates of drift and composition of invertebrates. How do variations in concentrations of dissolved oxygen (DO) within *Trapa natans* affect the movement of macroinvertebrates?

The hypothesis was that within larger beds, dissolved oxygen would be the major factor affecting the movement of macroinvertebrates. During periods of low DO, I expected to observe macroinvertebrates that are oxygen sensitive move into open water to avoid low DO levels. I also expected to see an increase in drifting invertebrates as DO levels decrease. It was also hypothesized that macroinvertebrates in smaller beds will have negligible responses to tidal cycles and engage in less drifting.

METHODS AND MATERIALS

Study Site

The study took place in the freshwater, tidal Hudson River in eastern New York at 5 sites from Germantown, NY to Newburgh, NY. *Trapa* occupies approximately 2% (1,421 acres) of the Hudson River area from Hastings-on-Hudson to Troy, New York (Nieder 2004). The investigation focused only on large beds in this area, as size of beds has a direct effect on the magnitude of DO depletions. Small beds were omitted from the study due to the fact that severe reductions of DO are associated with large beds of *Trapa* while smaller beds have markedly less significant depletions of DO (Caraco 2002). These largest beds account for over half of the total coverage in the Hudson (Findlay, personal communication). Therefore, these sites are representative of areas where low oxygen conditions are frequent. The five beds that were sampled for drift included Norrie Point (110 000m^2), Dennings Point (260 000m^2), Fishkill (420 000m^2), Tivoli South Bay (860 000m^2), and Inbocht Bay (2 100 000m^2). Areas for these beds are based on 2002 aerial photographs compiled by Findlay, et al. Sites were sampled from 12 July 2007 to 3 August 2007. Densities of epiphytic invertebrates tend to be more abundant than benthic invertebrates from June until August (Findlay 1989) so this was an optimal time to look at movement and possible drift of epiphytic invertebrates.

Measuring Macroinvertebrate Drift in the Field

In the field, 5 beds of various sizes were examined for macroinvertebrate drift. Hummel and Findlay (2006) found that in the area of the Hudson River from the Tappan Zee to Troy, *Trapa* bed sizes range from 12 m^2 to 989 518 m^2 with a median of 1 571 m^2. Hummel and Findlay (2006) found that for small *Trapa* beds (<624m^2) the DO was never below 6.0 mg/L. This figure is significant as Frodge et al. (1990) have shown that DO below 5 mg/L has a negative effect on sensitive fish and invertebrates while DO below 2.5 mg/L negatively affects most fish and invertebrates. Since very small beds do not exhibit dramatic reductions in DO (Hummel and Findlay 2006) and therefore do not negatively affect even the most sensitive of organisms, they were omitted from this investigation. In this study the largest beds were separated into two categories, Large beds (L) and Extra-Large beds (XL). Large beds were defined as those being greater than 15 000m^2. While XL beds were defined as greater than 500 000 m^2. For XL beds, this is an area that is greater than that of approximately 95% of the other beds in the Hudson

All sites were sampled for drift as low tide approached, when DO levels are theoretically the lowest. Three nets were placed on the perimeter and down “flow” at each bed, mid depth in the water column. Nets were also placed in open water for comparison to the vegetated sites. Nets were held stationary by anchoring each net with a brick and kept afloat by using an empty 2 liter plastic bottle as a buoy. Nets were never clogged during their duration in the water. At all sites, dissolved oxygen, flow velocity, chlorophyll a, and water temperature were also measured. Due to the slow moving currents, an accurate measurement of drifting animals per unit water volume could not be established. Therefore, drift was measured per unit of time, in animals per hour. Contents of the nets were filtered in the field through a 308um mesh sieve and placed in a cooler. Upon return to the laboratory, samples were preserved in a 4% formaldehyde 60g/L sucrose 100mM $NaHCO_3$ solution

Samples were sorted under a dissecting microscope and identified to order and family, where possible. In order to account for the fragmentation of samples during handling, only heads of specimens were counted. Ecology and Classification of North American Freshwater Invertebrates, Freshwater Invertebrates of the United States, and Freshwater Macroinvertebrates of Northeastern North America were used as sources to aid in the identification of the specimens.

Measuring Macroinvertebrate Drift Using Model

An experiment was used to simulate the deoxygenation of *Trapa* rosettes as it occurs in the Hudson River and to observe the behavior of the macroinvertebrates associated with the *Trapa* rosette. A number of *Trapa natans* rosettes were removed from beds in the freshwater, tidal Hudson River at Norre Point in August when *Trapa* is at its peak biomass. A rosette was placed into a 3 L tub containing 2 L of Hudson River water. The tub was placed on a stirrer to maintain a steady current and kept close to atmosphere concentrations of DO for 3 hours. During this time, the tub was sampled twice for drifting invertebrates. Over the next 6 hours, nitrogen was bubbled through the water in order to deoxygenate the water in a manner that mimics the deoxygenation in the field. Temperature and DO concentrations were recorded hourly and samples of drifting invertebrates were taken at the same intervals. Samples were sieved and preserved using the same methods as samples gathered in the field. The experiment was repeated twice.

RESULTS

Measuring Macroinvertebrate Drift in the Field

The most abundant invertebrates drifting were chironomid midges, chydoridae, cyclopoid copepods, hydracarina, sididae, and naidide oligochaetes Figure #1 illustrates bed size has a significant impact on the amount of animals drifting in the field. The open water and large beds (L) have similar drift rates while a large increase in drift is observed in Extra-Large beds (XL). We would infer that the cause for this pattern in bed size is related to DO levels. As DO decreases we see an increase in animals drifting (figure #2). Although these field data are significant, the relationship only explains a small amount of variation. A model experiment was able to give more information about this relationship between DO and drift.

Measuring Macroinvertebrate Drift Under Controlled Conditions

The decrease in DO for both experiments was identical. It would be expected that more invertebrates would drift as the DO concentrations decreased. However, that is not what was observed. Figure #3illustrates that as DO decreased in the model, neither replicate showed a large increase in drifting invertebrates. These data then suggest that decreases in DO do not have a significant influence on the drifting of macroinvertebrates found on *Trapa* in the Hudson.

Through this experiment, it was also observed that many invertebrates remain on the plants during periods of low DO, perhaps being tolerant of the temporary decline in DO.

DISCUSSION

Levels of available oxygen can have an effect on the composition and distribution of organisms within freshwater rivers. Macroinvertebrate response to poor water quality is to increase drift rates (Brittain and Eikeland 1988). Therefore, one would expect to see an increase in drifting invertebrates with a decrease in the percent saturation of dissolved oxygen in *Trapa* beds. Larger drift densities would also be likely to be observed from larger *Trapa* beds in comparison to smaller beds.

Ultimately we saw greater drift out of the largest beds of *Trapa*. This suggests that the largest beds may not be the most hospitable for invertebrates. Moreover, fish may be using these beds as feeding grounds; assuming that they too can tolerate the low DO concentrations of the water emerging from the beds. A lot of effort has also been put into removing *Trapa* from the Hudson. From a macroinvertebrate perspective, *Trapa* removal efforts should concentrate on the largest of beds.

Lastly, lower concentrations of DO may not have as large of an effect on invertebrate drift as predicted from field data. Under controlled conditions, I observed many macroinvertebrates remaining on the *Trapa* rosettes despite hypoxic conditions. This may suggest that the some invertebrates may be tolerant of this temporary cyclic decline in DO. One possible reason for more animals drifting from larger beds is there are simply more animals "upstream" of the nets. If it is simply a random falling loose process then in large beds you may have an area of $500m^2$ upstream where macroinvertebrates are present while possibly an area of only $50m^2$ where macroinvertebrates reside, for the smaller sites.

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LITERATURE CITED

Brittain, J. E., and T. J. Eikeland. 1988. Invertebrate drift—a review. Hydrobiologia. **166 (1)**: 77-93.

Caraco, N. F., J. J. Cole. 2002. Contrasting impacts of a native and alien macrophyte on dissolved oxygen in a large river. Ecological Applications. **12 (5)**: 1496-1509.

Caraco, N. F., J. J. Cole, P. A. Raymond, D. L. Strayer, M. L. Pace, S. E. G. Findlay, and D. T. Fischer. 1997. Zebra mussel invasion in a large, turbid river: Phytoplankton response to increased grazing. Ecology. **78 (2)**: 588-602.

Caraco, N. F., J. J. Cole, S. E. G. Findlay, and C. Wigand. 2006. Vascular plants as engineers of oxygen in aquatic systems. BioScience. **56 (3)**: 219-225.

Connolly, N. M., M. R. Crossland, and R. G. Pearson. 2004. Effect of low dissolved oxygen on survival, emergence, and drift of tropical stream macroinvertebrates. Journal of the North American Benthological Society. **23 (2)**: 251-270.

Feldman, R. S. 2001. Taxonomic and size structures of phytophilous macroinvertebrate communities in Vallisneria and Trapa beds of the Hudson River, New York. Hydrobiologia. **452 (1-3)**: 233-245.

Findlay, S. E. G., C. Wigand, and W. C. Nieder. 2006. Submerged macrophyte distribution and function in the tidal freshwater Hudson River. Pages 230-241 *in* J. S. Levinton and J. R. Waldman , editors. The Hudson River estuary. Cambridge University Press, New York, New York, USA.

Findlay, S. E. G., K. Schoeberl, and B. Wagner. 1989. Abundance, composition, and dynamics of the invertebrate fauna of a tidal fresh-water wetland. Journal of the North American Benthological Society. **8 (2)**: 140-148.

Frodge, J. D., G. L. Thomas, and G. B. Pauley. 1990. Effects of canopy formation by floating and submergent aquatic macrophytes on the water-quality of 2 shallow Pacific-Northwest lakes. Aquatic Botany. **38 (2-3)**: 231-248.

Giller, P. S., and B. Malmqvist. 1998. The biology of streams and rivers. Oxford University Press, Oxford, UK.

Hummel, M. and S. E. G. Findlay. 2006. Effects of water chestnut (*Trapa natans*) beds on water chemistry in the tidal freshwater Hudson River. Hydrobiologia. **559**: 169-181.

Nieder, W. C., E. Barnaba, S.E.G. Findlay, S. Hoskins, N. Holochuck, and E. A. Blair. 2004. Distribution and abundance of submerged aquatic vegetation and *Trapa natans* in the Hudson River estuary. Journal of Coastal Research. **45**: 150-161.

Peckarsky, B. L., P. R. Fraissinet, M. A. Penton, and D. J. Conklin, Jr. 1995. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, New York.

Pennack, R. W. 1978. Freshwater invertebrates of the United States (Second edition). John Wiley and Sons, New York.

Romaniszyn, E. D., J. J. Hutchens, and J. B. Wallace. 2007. Aqautic and terrestrial invertebrate drift in southern Appalachian Mountain streams: implications for trout food resources. Freshwater Biology. **52**: 1-11.

Shearer, K. A., J. W. Hayes, and J. D. Stark. 2002. Temporal and spatial quantification of aquatic invertebrate drift in the Maruia River, South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research. **36**: 529-536.

Skubinna, J. P., T. G. Coon, and T. R. Batterson. 1995. Increased abundance and depth of submersed macrophytes in response to decreased turbidity in Saginaw Bay, Lake Huron. Journal of Great Lakes Research. **21 (4)**: 476-488.

Smith, T. E., R. J. Stevenson, N. F. Caraco, and J. J. Cole. 1998. Changes in phytoplankton community structure during the zebra mussel (*Dreissena polymorpha*) invasion of the Hudson River (NewYork). Journal of Plankton Research. **20 (8)**: 1567-1579.

Strayer, D. L. 2006. The benthic animal communities of the tidal-freshwater Hudson River estuary. Pages 266-278 *in* J. S. Levinton and J. R. Waldman , editors. The Hudson River estuary. Cambridge University Press, New York, New York, USA.

Strayer, D. L. and H. M. Malcom. 2007. Submersed vegetation as habitat for invertebrates in the Hudson River estuary. Estuaries and Coasts. **30 (2)**: 253-264.

Strayer, D. L., C. Lutz, H. M. Malcom, K. M. Munger, and W. H. Shaw. 2003. Invertebrate communities associated with a native (*Vallisneria americana*) and an alien (*Trapa natans*) macrophyte in a large river. Freshwater Biology. **11**: 1938-1949.

Thorp, J. H. and A. P. Covich. 2001 Ecology and Classification of North American Freshwater Invertebrates (Second edition). Academic Press.

Waters, N. M. and C. R. San Giovanni. 2002. Distribution and diversity of benthic macroinvertebrates associated with aquatic macrophytes. Journal of Freshwater Ecology. **17 (2)**: 223-232.

Yozzo, D. and R. Diaz. 1999. Tidal Freshwater Wetlands: Invertebrate Diversity, Ecology, and Functional Significance. Pages 889-918 *in* D. P. Batzer, R. B. Rader, and S. A. Wissinger, editors. Invertebrates in freshwater wetlands of North America: ecology and management. Wiley, New York, New York, USA.

APPENDIX

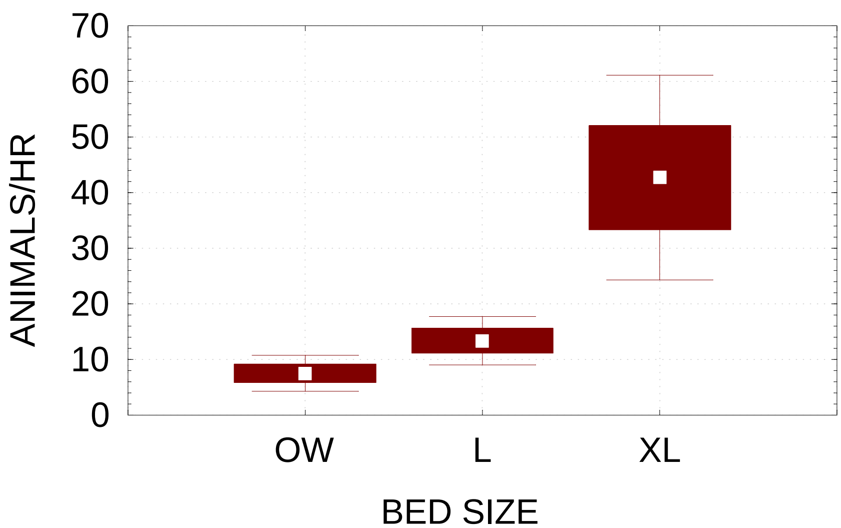

FIGURE 1. Effect of bed size on invertebrate drift.

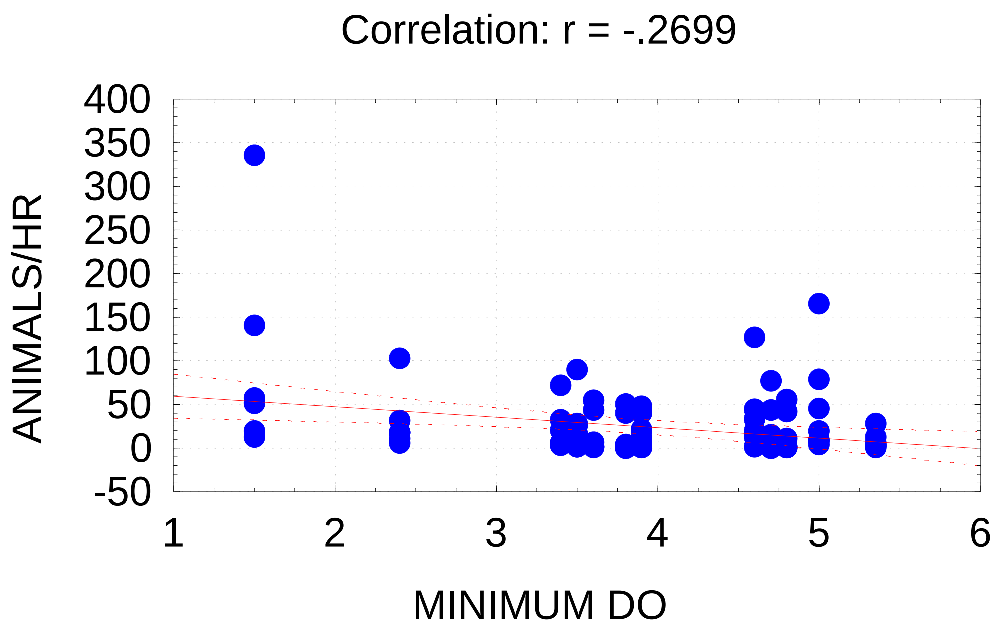

FIGURE 2. Relationship of controlled DO on macroinvertebrate drift.

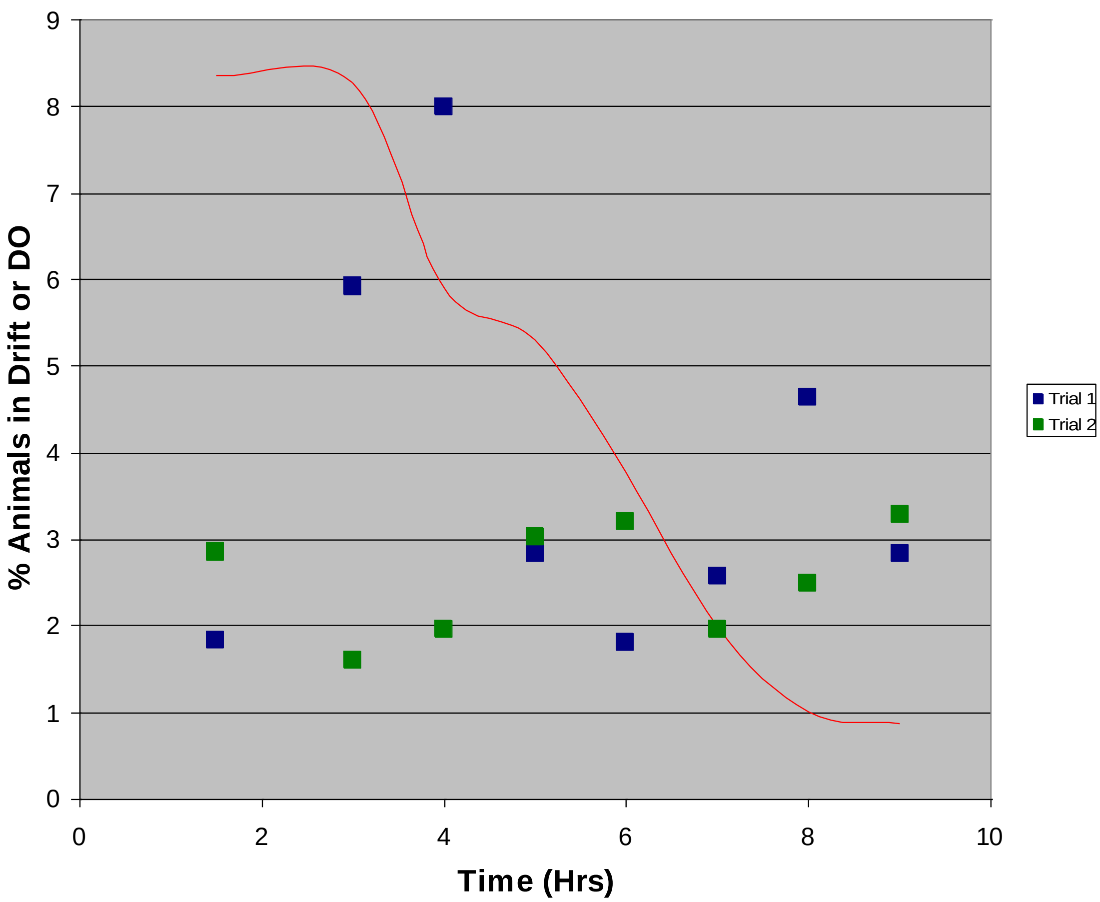

FIGURE 3. Model for controlled experiment.