FOR: DNREC DIVISION OF SOIL AND WATER

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END OF YEAR REPORT ON MOSQUITO PRODUCTION POTENTIAL OF BIOSWALES IN DELAWARE

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Introduction

In previous years, we have conducted studies on the mosquito breeding potential of various types of stormwater ponds (BMP's). We have studied retention steep and shallow ponds, constructed wetlands, CREP ponds, detention ponds, extended detention ponds, sand filters, and bioretention ponds. All of these groups breed mosquitoes in some numbers, depending on the condition and design of the BMP. Of the above BMP's, bioretention ponds most closely resemble bioswales, the current BMP of interest. In both bioswales and bioretention ponds, water is supposed to drain within a day or two, so mosquitoes should not be able to complete their development in that time. However, in last year's study, we found that about 60 percent of bioretention sites had a significant amount of mosquito breeding for most of the summer season.

Materials and Methods

Bioswales were selected with the assistance of BMP inspectors at the county level and DNREC Soil and Water senior staff, who helped us coordinate the site selection. There were four bioswales from Sussex County, six from Kent County, and seven from New Castle County. Most of these sites had rip-rap associated with either an inlet or part of the swale proper. The studies were begun during the first week in June, and continued through the end of September, 2005. All sites were studied every two weeks. The following data were taken at each of the bioswales during each visit:

1) Collection of 20 standard mosquito dips (350 ml) for larval mosquitoes per subsite at 1-6 subsites, depending on the overall size and surface area of water available.
2) Measurement of water temperature, pH, and conductivity at each subsite.
3) Measurement of chlorophyll A and turbidity, using a fluorometer.
4) Measurement of orthophosphates (by taking returning samples to the lab) using a colorimeter-based test kit
5) Identification and counting of all larval mosquitoes collected and returned to the lab.

All data were recorded first on paper, then returned to the lab and entered into an Access database. Data was then compiled for all bioswales, and individual queries and reports were made from the database. At this point, we have only run tables and charts, and not statistically validated analyses. However, in many cases, we observe that the charts and tables present clear trends that can give us information worthy of analysis and interpretation until further work can be completed.

Results

Ten of 17 bioswales allowed mosquitoes to breed through to 4th instars or beyond, meaning that they almost certainly yielded adult mosquitoes. Of these ten, seven yielded substantial numbers of mosquitoes (0.60 mosquitoes per dip or more) on average throughout the season. In one pond, the average mosquito larvae per dip was actually over 11. This is higher than virtually any other pond or BMP we have seen in three years of study except sand filters. Table 1 shows the names, locations, and mosquito abundance of the 17 bioswales.

TABLE 1. BIOSWALES AND MOSQUIITOES PER DIP BY SITE, 2005

Type	Slope	AvgOfSpeciesPerDip	SiteCode
Swale	Gradual (<=30 deg)	2.627083333	Village of Savannah
Swale	Gradual (<=30 deg)	0	Rustic Lane
Swale	Gradual (<=30 deg)	0	Kimburton Academy
Swale	Gradual (<=30 deg)	0	Happy Harry's Bethany
Swale	Gradual (<=30 deg)	0	Corbitt Estates 2
Swale	Gradual (<=30 deg)	0	Corbitt Estates 1
Swale	Gradual (<=30 deg)	0.1	Greenwood
Swale	Gradual (<=30 deg)	0.15	Destiny Church
Swale	Gradual (<=30 deg)	0.286538462	Deerborne
Swale	Gradual (<=30 deg)	0.603125	Twelve Oaks 2
Swale	Gradual (<=30 deg)	1.115789474	Tidewater
Swale	Gradual (<=30 deg)	1.341891892	Corbitt Estates 3
Swale	Gradual (<=30 deg)	1.708928571	Lighthouse View
Swale	Gradual (<=30 deg)	1.845238095	Twelve Oaks
Swale	Gradual (<=30 deg)	11.4625	Bunting Mills
Swale	Gradual (<=30 deg)	0	Northstar
Swale	Gradual (<=30 deg)	0	Farifield Marriott Dover

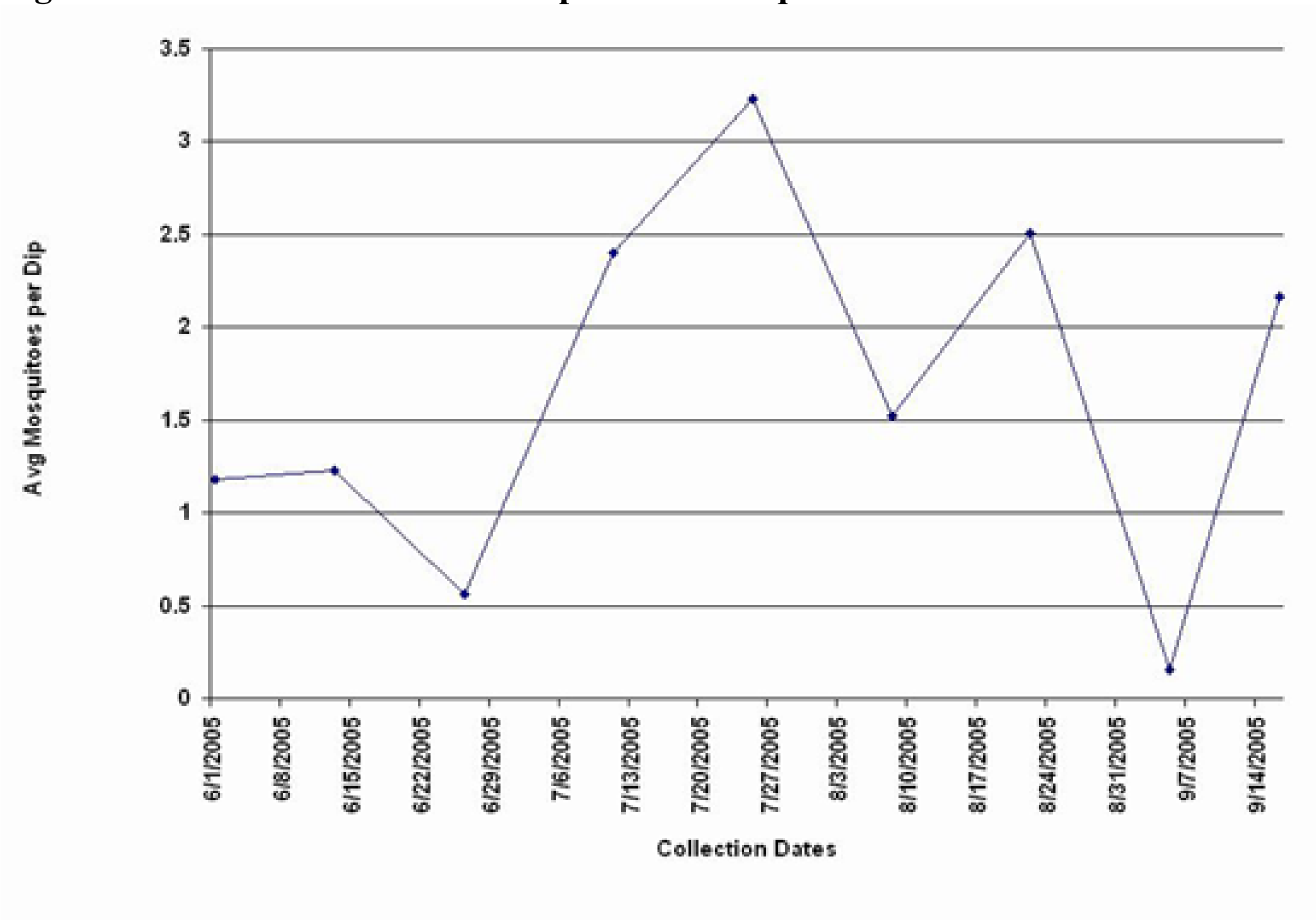
We had a total of 15 mosquito species found in bioswales (not counting genus only groups), with 9 species having 10 individuals or fewer in total number (Table 2). Of these, *Aedes vexans* and *Culex pipiens* were most abundant, both of which are vectors of West Nile virus. *Aedes vexans* is also a nuisance biter of humans. *Culex* was by far the dominant genus, and these are, for the most part, breeders in pools with high organic content, and often polluted. No other species of *Aedes* were common, and only one anopheline, *An. punctipennis*, was occasionally abundant. *Uranotaenia sapphirina* was the most common mosquito that is neither a vector nor a nuisance biter, since it feeds mainly on amphibians and reptiles.

Table 2. Total of mosquito larvae collected in bioswales.

Aedes spp.	82	*Culex salinarius*	141
Aedes vexans	2251	*Culex* spp.	7
Anopheles bradleyi	1	*Culex territans*	46
Anopheles crucians	2	Culicine spp.	15
Anopheles punctipennis	101	*Aedes canadensis*	6
Anopheles quadrimaculatus	39	*Aedes japonicus*	10
Anopheles spp.	1	*Aedes sollictans*	120
Culex pipiens	4544	*Psorophora columbiae*	333
Culex restuans	201	*Psorophora ferox*	5
Psorophora ciliata	5	*Uranotaenia sapphirina*	7
Psorophora spp.	10		

The seasonal distribution, counting all species, was typical in that there were three distinct peaks of abundance observed (Fig. 1). There was essentially one peak in each month except June, which was unusually cool.

Fig. 1. Seasonal distribution of all species of mosquitoes combined.



Bioswales had very low biodiversity compared to other BMP's we have studied, with the exception of sand filters. This is most notably observed by seeing the small variety of vegetation types, with very low quantities except for grasses, smartweed, algae, and trees (Fig. 2). Of these four, trees are actually overhanging shade, and not directly in the water or on the banks of the bioswales. Also, approximately 50 percent of the bioswales with standing water for most of the season displayed few or no mosquito predators. Those bioswales with few predators had far greater mean numbers of larvae per dip (Fig. 3). The most abundant predators were actually mosquitoes belonging to the genus *Psorophora* (Table 1). It is also interesting that when predators are most abundant, mosquito numbers actually increase slightly (Fig. 3). This has been seen in previous research in 2003 and 2004 (Gingrich et al. 2006), so it is not unexpected.

Fig. 2. Dominant vegetation types and associated mosquitoes.

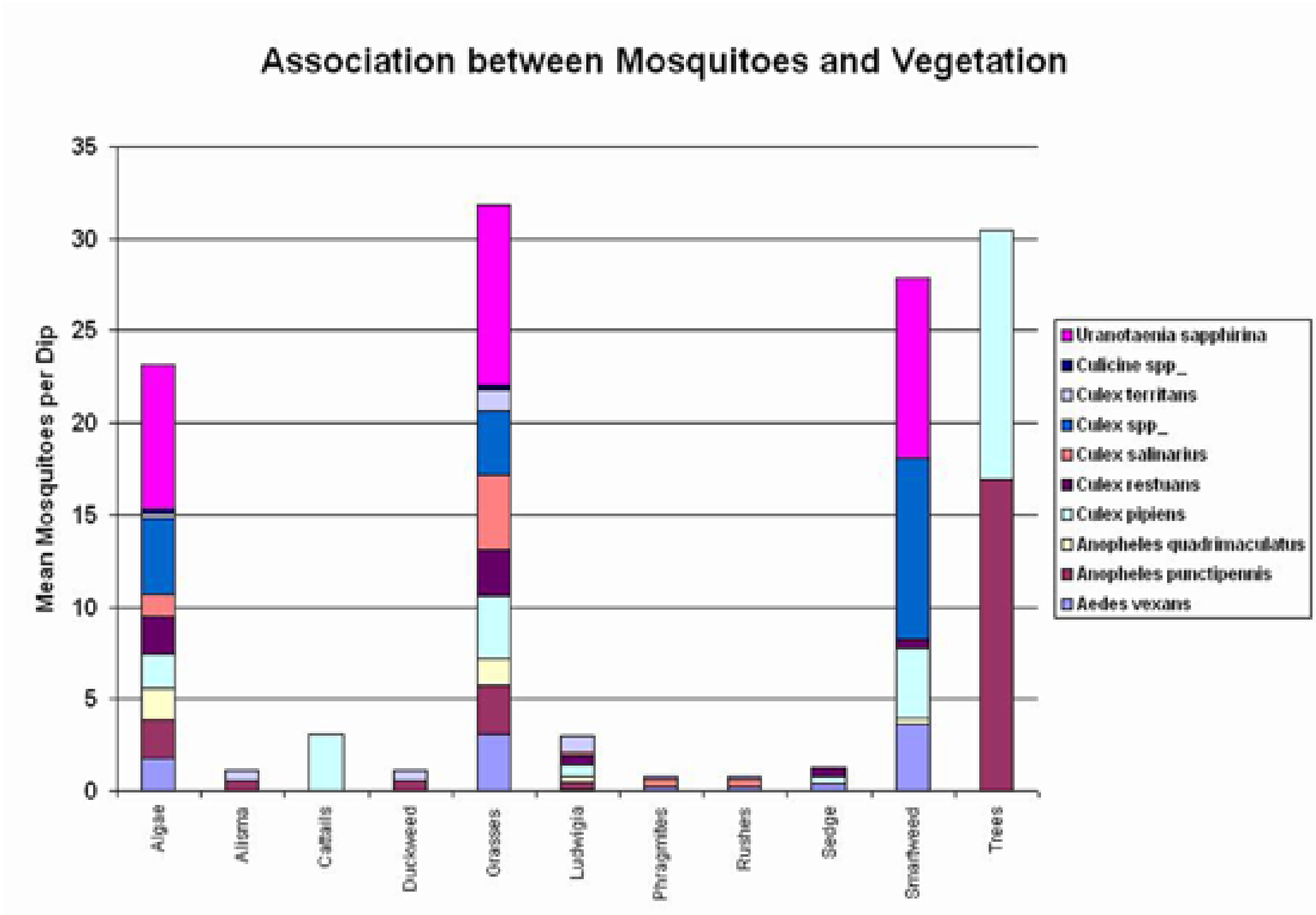
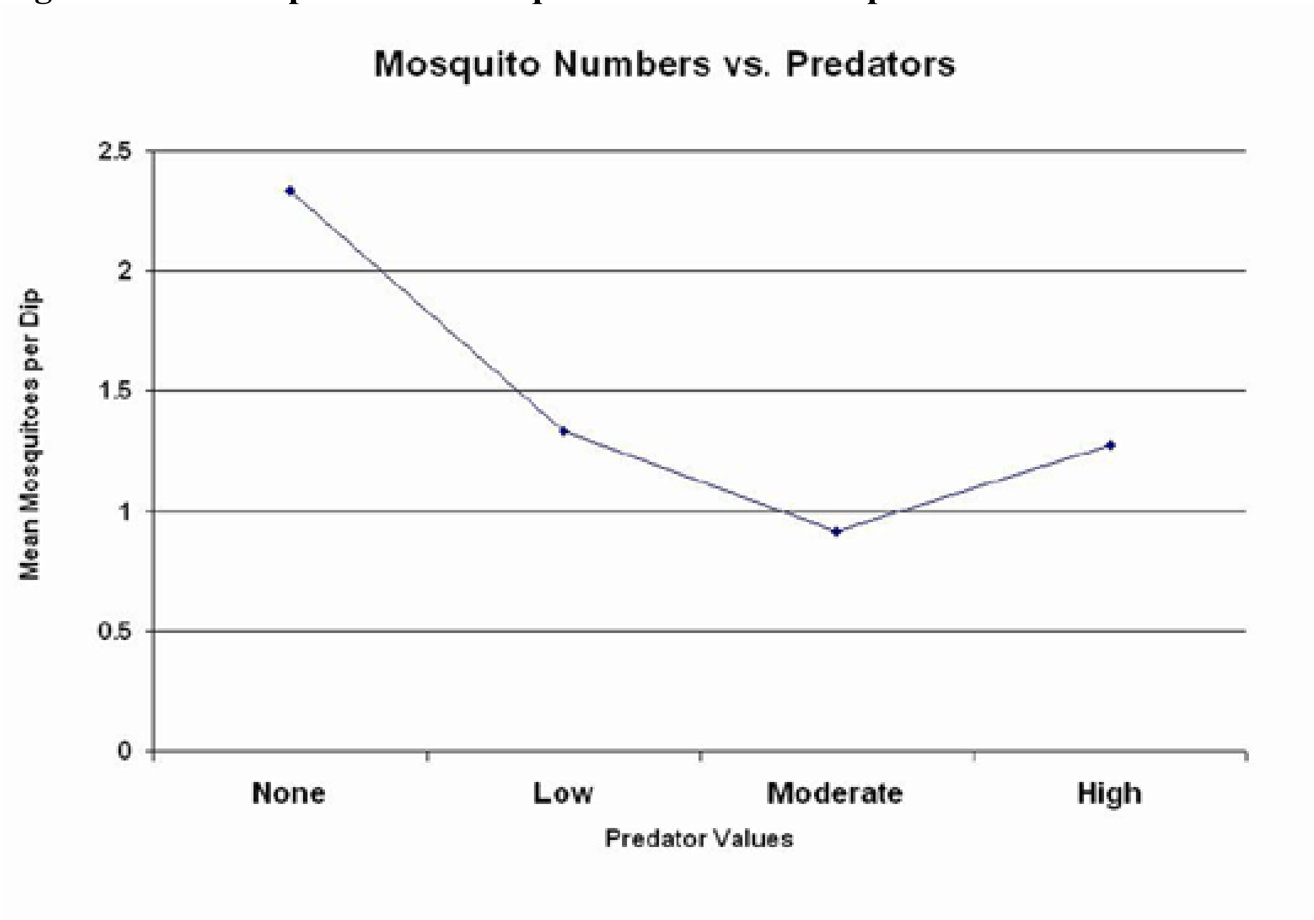
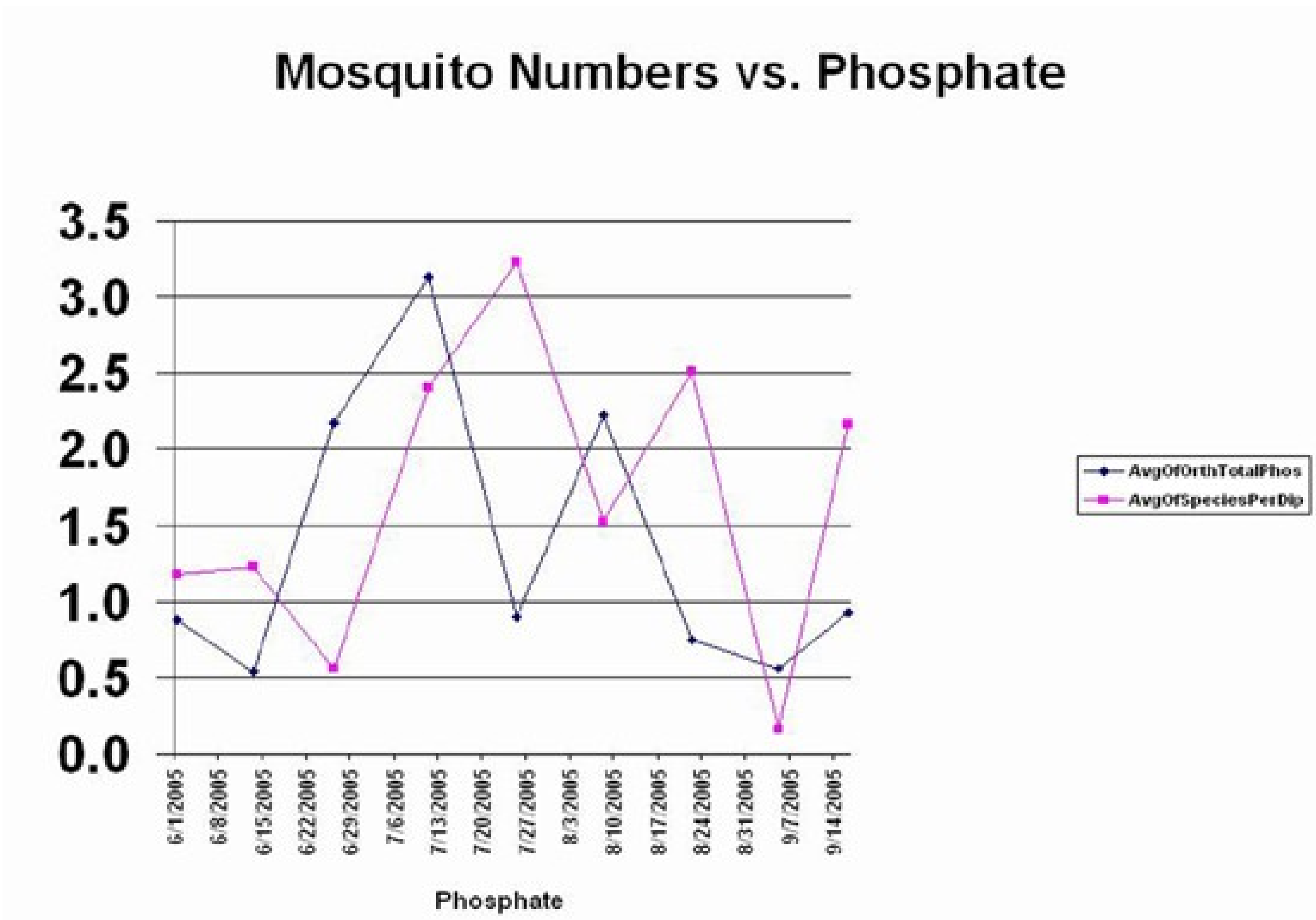


Fig. 3. Relationship between mosquito abundance and predator indices.



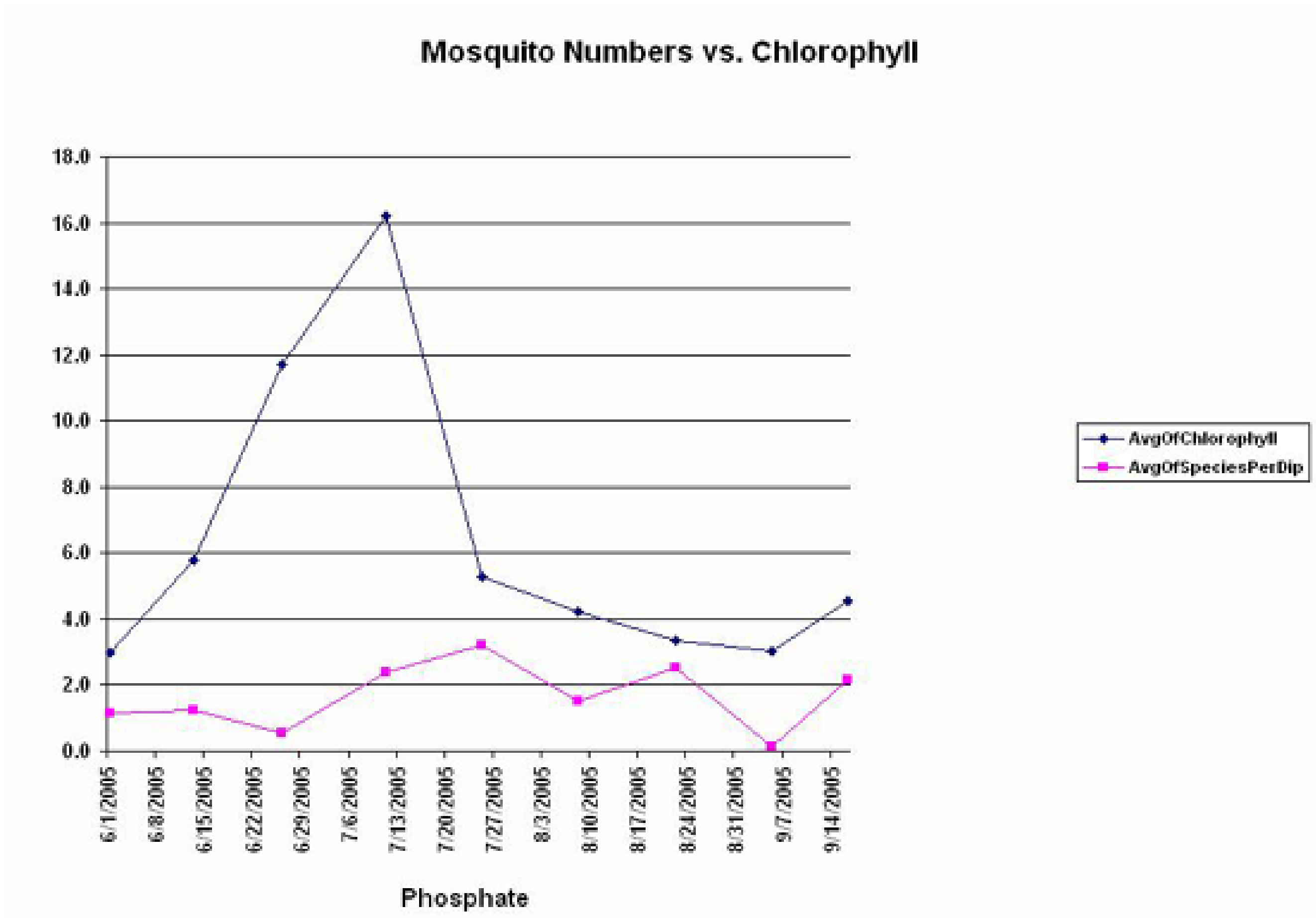
Because bioswales are very simple ecosystems, they presented a good opportunity to examine some key points of research interest, i.e. the relationship of orthophosphate concentrations and chlorophyll A levels to abundance of mosquito larvae. Most bioswales we studied were part of or adjacent to relatively new housing developments or new commercial use areas. The lawns were intensively maintained, and appeared to be principally maintained by lawn service companies. Phosphate levels were relatively high in such sites, and we could see a clear relationship between phosphate levels and mosquito abundance. There was a two-week lag between peak phosphate levels and peak abundance of mosquitoes, especially during June through mid-August (Fig. 4). By mid-August, both phosphate levels and mosquito abundance began to fall as rainfall all but ceased and runoff into bioswales was also greatly diminished. In September, rains resumed, but were not heavy until after the study officially stopped at the end of September. Nevertheless, there was a slight rebound in mosquito abundance at the end of September, as is usually the case in the mid-Atlantic region.

Fig. 4. Seasonal relationship between mosquito abundance and phosphate concentration (ppm).



The relationship between chlorophyll A and mosquito abundance was unclear. We expected that chlorophyll A would increase prior to mosquito abundance, similarly to what happened with phosphates. This is because phytoplankton are considered important food sources for mosquito larvae. However, in recent years, Merritt et al. (1992) suggested that phytoplankton often went through the mosquito midgut without being digested, and suggested other sources of food, depending on species. Our study, presented inconsistent data in comparing larval abundance and chlorophyll A, to the point that we could not discern a relationship (Fig. 5).

Fig. 5. Seasonal relationship between mosquito abundance and chlorophyll A levels (fluorescence units).



Bioswales that have consistent mosquito problems tended to be in sites that had poor drainage and/or riprap that appeared to hold small pockets of water. In one bioswale, the Village of Savannah, *Ae. japonicus*, the invasive rock pool mosquito, appeared to take advantage of the riprap habitat (Fig. 6).

Fig. 6. Bioswale at the Village of Savannah, showing riprap habitat for mosquitoes.

Discussion

We have good evidence that bioswales as they are currently designed are greater producers of mosquitoes than we had foreseen. This finding was especially surprising in that we had a drought year in which only about half of the basins held water for sufficient time to allow mosquitoes to complete their larval and pupal stage (normally about 10 days). Those that did hold water frequently produced high levels of mosquitoes, often of very undesirable West Nile virus vectors such as *Cx. pipiens* and *Ae. vexans*. Poor drainage and riprap created ideal conditions for breeding mosquitoes in many sites. Part of the problem with riprap is that it enables mosquitoes to breed without interference by predators, because pockets of water are small and probably not able to sustain good predators.

Another possible issue with bioswales is the high level of phosphates that they capture from lawn runoff. There was a good correlation between mosquito abundance and phosphate concentration, with about a two-week lag between peaks of phosphate levels and mosquito peaks. We expected to see a similar relationship between chlorophyll A and mosquito abundance, since phytoplankton are reportedly an important food source of mosquitoes, but this was not apparent from our data. It is possible that other mosquito food sources that are still influenced by phosphate concentrations, such as bacteria or protests, may be involved. It is also possible that these groups have high importance for selected mosquito species, with emphasis on the two dominant species that wed observed, *Cx. pipiens* and *Ae. vexans*. Even though we can't completely explain the relationship between phosphates and mosquito abundance, we may be able to take advantage of this relationship by finding ways to limit phosphates.

References

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