EFFECT OF ORGANIC POLLUTION LEVELS ON AQUATIC INSECT ABUNDANCE IN FIELD PILOT-SCALE ANAEROBIC ANIMAL WASTE LAGOONS[1]

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ABSTRACT. Insect diversity and abundance in the field pilot-scale swine and poultry waste lagoons were related to the organic pollution level of the lagoon water. Insect diversity was lowest in lagoons with high levels of organic pollution (ca. supernatant COD = 2000 mg/l, TOC = 1000 mg/l and TKN = 500 mg/l or higher). Shore flies, *Brachydeutera argentata* Walker, moth flies, *Psychoda alternata* Say and *P. cinerea* Banks, and rat-tailed maggots, *Eristalinus aeneus* (Scopoli) were the only insects found in these highly polluted lagoons. Mosquitoes, *Culex quinquefasciatus* Say, were not present in the lagoons with the highest levels of organic pollution but were the predominant insects in all other lagoons. *Cx. quinquefasciatus* were most abundant in lagoons with intermediate pollution levels (ca. supernatant COD = 600 mg/l, TOC = 250 mg/l and TKN = 175 mg/l for swine lagoons and COD = 650–950 mg/l, TOC = 250–450 mg/l and TKN = 165 mg/l for poultry lagoons). Midges, *Chironomus* sp., predaceous water beetles, *Tropisternus* sp., backswimmers and water boatmen, present in small numbers, appeared to be tolerant of only low to intermediate levels of organic pollution (ca. supernatant COD = 1000 mg/l, TOC = TOC = 500 mg/l and TKN = 400 mg/l or less). Insect control by manipulating the organic pollution level of the lagoon water is discussed.

INTRODUCTION

Anaerobic animal waste lagoons which are commonly used for disposal of manure from confined poultry and livestock often provide a favorable environment for insect production. Mosquitoes, primarily the southern house mosquito, *Culex quinquefasciatus* Say, in the southern United States, can be produced in large numbers in these lagoons (Axtell et al. 1975, Barr et al. 1969, Steelman and Colmer 1970) and insecticide treatment for control is sometimes necessary (Axtell et al. 1980, Barker and Booram 1979). Mosquito production from lagoons is closely related to the organic pollution level of the lagoon water and the abundance of vegetation and floating debris around the lagoon margins (Rutz and Axtell 1978). During the early stages of our investigation to determine the factors affecting mosquito production from lagoons, we observed that the organic pollution level not only appeared to affect mosquito abundance but also the diversity and abundance of several other aquatic insects. Therefore, we systematically monitored the insect populations in pilot-scale swine and poultry waste lagoons for 2 years to determine the correlations of insect diversity and abundance with the level of organic pollution.

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MATERIALS AND METHODS

The abundance of aquatic insects was determined in field pilot-scale (0.21m^3, 55 gal drums) swine and poultry waste lagoons having several different levels of organic pollution. These lagoons were located at swine and poultry research facilities at North Carolina State University Research Farm Unit 2, Raleigh, NC. Each pilot-scale lagoon was recessed into the ground and fitted with an overflow pipe (2.5 cm diam. × 20 cm) inserted through the side of the lagoon, 10 cm from the top. A 90° elbow (2.5 cm diam. × 4 cm) was placed at the end of the pipe on the inside of the lagoon and positioned with the open end toward the water surface. This allowed lagoon water to be drained from approximately 3–4 cm beneath the water surface instead of directly from the surface, preventing the loss of insects during heavy rains. The lagoons were filled with water to within 2–3 cm of the overflow pipe and loaded with either swine or poultry manure from April through November in 1974 and 1975. Detailed loading procedures are discussed in Rutz and Axtell (1978). The loading rates of the pilot-scale swine and poultry waste lagoons are presented in Table 1.

In the swine waste study, 14 pilot-scale lagoons were used in 1974 which included 3 replicates of 4 loading rates (0.45, 0.23, 0.12 and 0.055 kg COD/m³/wk) and 2 controls (clean water, no manure added). In 1975, 24 lagoons were used; these included 4 replicates of 6 loading rates (0.91, 0.45, 0.23, 0.12, 0.055 and 0.028 kg COD/m³/wk) and 2 controls. All the pilot-scale lagoons were cleaned (drained and filled with clean water) before loading in 1975. The common recommended loading rate for swine lagoons was 0.73 kg COD/m³/wk (Anon. 1977) with a recommended reduction to 0.24 kg COD/m³/wk for odor control purposes.

In the poultry waste study, 14 pilot-scale lagoons were used in both 1974 and 1975 with 3 replicates of 4 loading rates (1.0, 0.25, 0.063 and 0.016 kg/COD/m³/wk) and 2 controls. Since the loading rates of the lagoons remained the same in 1974 and 1975, it was not necessary to clean the pilot-scale lagoons (as in the swine lagoons) before loading in 1975. The common recommended loading rate for poultry lagoons was 0.46 kg COD/m³/wk (Anon. 1977) with a recommended reduction to 0.31 kg COD/m³/wk for odor control purposes.

Water samples for laboratory analysis were collected from each pilot-scale swine and poultry waste lagoon every 3 weeks in 1974. In 1975, water samples were taken every 2 weeks from each pilot-scale swine waste lagoon and every 3 weeks from each poultry waste lagoon. The samples were obtained by inserting a capped plastic bottle (180 ml) into the lagoon to a depth of ca. 5–10 cm, removing the cap to allow water entry, and recapping. Water samples were taken at this depth to prevent the entry of surface scum and other floating debris into the sample. Laboratory analysis of the water included chemical oxygen demand (COD), total organic carbon (TOC) and total Kjeldahl nitrogen (TKN) (conducted only in 1975) as described in Standard Methods (American Public Health Assoc. 1971) and sub-

Table 1. Anaerobic reactor loading rates of field pilot-scale swine and poultry waste lagoons (0.21 m³, 55 gal. drums).

Waste type	Waste Volume added per week (liters)	Metric system: Kg COD/m³/wk[1]	Metric system: m³ lagoon volume per 45 kg hog or 1.8 kg chicken	English system: lb COD per 1000 ft³ per wk[2]	English system: ft³ lagoon volume per 100 lb hog or 4 lb chicken
Swine	4.54	0.91	2.3	58	80
	2.27	0.45	4.6	29	160
	1.14	0.23	9.2	14.5	320
	0.57	0.12	18.4	7.2	640
	0.28	0.055	36.8	3.6	1280
	0.14	0.028	73.6	1.8	2560
Poultry	1.90	1.0	0.13	60.9	4.6
	0.47	0.25	0.50	15.9	17.6
	0.12	0.063	2.00	4.0	70.6
	0.03	0.016	7.87	1.0	277.9

[1] Based on 0.3 kg COD/day/45 kg hog and 0.018 kg/day/1.8 kg chicken.
[2] Based on 0.71 lb COD/day/100 lb hog and 0.04 lb/day/4 lb chicken.

sequent adaptations (Overcash et al. 1974).

The numbers of aquatic insects were determined weekly by a standard dipping method using a 10 cm diameter water dipper, 3 dips per pilot-scale lagoon. The swine waste lagoons were sampled for 20 weeks (June–October) and the poultry waste lagoons for 17 weeks (July–October) in 1974. Both the swine and poultry waste lagoons were sampled for 21 weeks (July–November) in 1975.

RESULTS

Representatives of 8 families of aquatic insects were collected from field pilot-scale swine and poultry waste lagoons. Mosquitoes (Culicidae) were the most abundant insects found in these lagoons with *Culex quinquefasciatus* Say being the dominant species. A few specimens of *Cx. restuans* Theobald and *Cx. salinarius* Coquillett were also collected. The majority of the other insects found in the lagoons belonged to the families Ephydridae (shore flies, *Brachydeutera argentata* Walker), Psychodidae (moth flies, *Psychoda alternata* Say and *P. cinera* Banks), Chironomidae (midges, *Chironomus* sp.) and Hydrophilidae (predaceous water beetles, *Tropisternus* sp.). Occasional specimens of the families Syrphidae (rat-tailed maggots, *Eristalinus aeneus* (Scopoli)), Notonectidae (backswimmers) and Corixidae (water boatmen) were also found. All of the insects collected were immatures except for an occasional adult hydrophilid, notonectid and corixid.

SWINE WASTE LAGOONS. The relationship between insect abundance and organic pollution levels in the swine waste lagoons is presented in Table 2. As the loading rate (kg COD/m^3/wk) of swine waste in the lagoons decreased, the resulting supernatant concentrations of COD, TOC and TKN (indicating organic pollution levels) decreased significantly in 1974 and 1975. These differences in lagoon water organic pollution level had a significant effect on insect abundance, particularly on mosquitoes (Culicidae), shore flies (Ephydridae) and moth flies (Psychodidae).

Mosquitoes, *Cx. quinquefasciatus,* were found at all organic pollution levels of the swine waste lagoons (Table 2). However, mosquitoes were significantly more abundant in lagoons with supernatant COD = 593 mg/l and TOC = 227 mg/l in 1974 and COD = 553 mg/l, TOC = 249 mg/l and TKN = 173 mg/l in 1975.

Shore flies, *B. argentata,* increased in abundance as the organic pollution level of the swine lagoon water increased with the highest numbers occurring in the most polluted lagoons (Table 2). Moth flies, *Psychoda* spp., were also generally more abundant in the more polluted swine lagoons (ca. supernatant COD = 550 mg/l, TOC = 250 mg/l and TKN = 175 mg/l or higher). In 1975, no moth flies were found in lagoons with low organic pollution levels (supernatant COD = 174 mg/l, TOC = 62 mg/l and TKN = 14 mg/l or less).

Midges, *Chironomus* sp., were found at all organic pollution levels of the swine waste lagoons (Table 2). However, differences in midge abundance with respect to changes in organic pollution level were evident only in 1975 when midge populations were highest in lagoons with supernatant COD = 625 mg/l, TOC = 241 mg/l and TKN = 69 mg/l. Small numbers of predaceous water beetles, *Tropisternus* sp., were also commonly observed with differences in organic pollution level having no significant effect on beetle abundance. Too few rat-tailed maggots, backswimmers and water boatmen were collected from the swine waste lagoons to justify any statement about the effect of organic pollution level on their abundance.

Larvae of the soldier fly, *Hermetia illucens* L. (Stratiomyidae), were occasionally found on the surface of the swine waste lagoons. These larvae were abundant in the swine manure which was held in pits located under the hog houses. When the lagoons were loaded with this manure, some soldier fly larvae were also added to

Table 2. Insect abundance in field pilot-scale swine waste lagoons (0.2m³, 55 gal drums) in relation to the degree of organic pollution expressed as supernatant COD, TOC and TKN.

Loading rate (kg COD/m³/wk	Supernatant concentration (mg/1)[1]			Average number/dip/week[1,2]				
	COD	TOC	TKN	*Culex quinquefasciatus* (Culicidae)	*Brachydeutera argentata* (Ephydridae)	*Psychoda* spp. (Psychodidae)	*Chironomus* sp. (Chironomidae)	*Tropisternus* sp. (Hydrophilidae)
1974								
0.45	893a	300a	[3]	283.8a	17.8a	3.1a	0.1a	0.1a
0.23	593b	227b		431.3b	2.9b	0.2a	0.1a	0.5a
0.12	500b	173b		217.4a	0.9b	0.1a	0.1a	0.1a
0.055	221c	87c		163.8a	0.6b	0.1a	0.2a	0.1a
1975								
0.91	912a	434a	332a	19.0a	17.1a	0.8a	0.1a	0.1a
0.45	553b	249b	173b	213.2b	13.8a	10.5b	0.2a	0.0a
0.23	625b	241b	69c	141.9c	1.4b	0.1a	1.0b	0.1a
0.12	336c	135c	32d	70.5a	0.6b	0.1a	0.6ab	0.1a
0.055	174d	62d	14	53.1a	0.4b	0.0a	0.2a	0.1a
0.028	132d	57d	12d	36.4a	0.1b	0.0a	0.1a	0.1a

[1] Within each year, means in the same column followed by the same letter are not significantly different from each other (5% level) (Duncan's multiple range test).

[2] Three replicates/loading rate sampled weekly for 20 weeks (June-October) in 1974; four replicate/loading rate sampled weekly for 21 weeks (July-November) in 1975.

[3] No TKN analysis in 1974.

the lagoons. However, this aqueous environment was not suitable for soldier fly development and the larvae died within a few days.

The unpolluted control lagoons (not loaded with manure) were apparently unattractive to most insects except anopheline mosquitoes which were infrequently collected. Because the control lagoons were essentially insectfree, they were not included in Table 2.

POULTRY WASTE LAGOONS. Insect abundance in the pilot-scale poultry waste lagoons in relation to organic pollution level is summarized in Table 3. The supernatant concentrations of COD, TOC and TKN decreased significantly as the loading rate (kg. COD/m^3/wk) decreased in the poultry lagoons in 1974 and 1975. Similar to the swine waste lagoon study, the organic pollution level of the poultry lagoon water had a significant effect on insect abundance. In 1974, mosquitoes, *Cx. quinquefasciatus,* were significantly more abundant in lagoons with supernatant COD = 668 mg/1 and TOC = 242 mg/1. These COD and TOC concentrations are similar to those at which mosquitoes were found to be most abundant in the swine waste lagoons in 1974 and 1975. In 1975, mosquitoes were significantly more abundant in poultry waste lagoons with supernatant COD = 948 mg/1, TOC = 469 mg/1 and TKN = 165 mg/1. No mosquitoes were found in the highly polluted poultry waste lagoons (supernatant COD = 2528 mg/1 and TOC = 669 mg/1 in 1974 and COD = 2390 mg/1, TOC = 1436 mg/1 and TKN = 728 mg/1 in 1975).

Shore fly and moth fly abundance in the poultry waste lagoons increased significantly as the organic pollution level of the lagoon water increased with the highest numbers occurring in the most polluted lagoons in both 1974 and 1975 (Table 3). Rat-tailed maggots which appeared to prefer high levels of organic pollution were the only other insects prevalent in these highly polluted lagoons (supernatant COD = 2528 mg/1 and TOC = 669 mg/1 in 1974 and COD = 2390 mg/1, TOC = 1436 mg/1 and TKN = 728 mg/1 in 1975).

Small numbers of midges and predaceous water beetles were occasionally collected from poultry waste lagoons but only from those lagoons with supernatant COD = 1000 mg/1, TOC = 500 mg/1 and TKN = 200 mg/1 or less. Backswimmers and water boatmen were infrequently found in the poultry lagoons.

The unpolluted control lagoons produced only an occasional anopheline mosquito. Therefore, these lagoons were not included in Table 3.

DISCUSSION

Insect diversity and abundance in field pilot-scale swine and poultry waste lagoons were related to the organic pollution level of the lagoon water. Insect diversity was lowest in those lagoons with high levels of organic pollution (ca. supernatant COD = 2000 mg/1, TOC = 1000 mg/1 and TKN = 500 mg/1 or higher). Similar results were reported by Steelman and Colmer (1970) who observed that decreases in aquatic insect fauna in swine lagoons paralleled increases in organic pollution levels until only those insects which respired through specialized organs directly from the atmosphere remained.

Shore flies, *B. argentata,* moth flies, *Psychoda* spp., and rat-tailed maggots, *E. aeneus,* were the only insects found to be tolerant of highly polluted lagoon water (supernatant concentrations greater than COD = 2000 mg/1, TOC = 1000 mg/1 and TKN = 500 mg/1). Furthermore, these insects which were generally present at all pollution levels were most abundant in the highly polluted lagoons.

Mosquitoes, *Cx. quinquefasciatus,* were not collected from highly polluted lagoons (ca. supernatant COD = 2000 mg/1, TOC = 1000 mg/1 and TKN = 500 mg/1). Smith and Enns (1967), Steelman and Colmer (1970) and Sinha (1976) reported that *Cx. quinquefasciatus* larval and pupal abundance in polluted water increased in proportion to the amount of

Table 3. Insect abundance in field pilot-scale swine waste lagoons (0.2m³, 55 gal drums) in relation to the degree of organic pollution expressed as supernatant COD, TOC and TKN.

Loading rate (kg COD/m³/wk	Supernatant concentration (mg/1)[1]			Average number/dip/week[1,2]				
	COD	TOC	TKN	*Culex quinquefasciatus* (Culicidae)	*Brachydeutera argentata* (Ephydridae)	*Psychoda* spp. (Psychodidae)	*Chironomus* sp. (Chironomidae)	*Tropisternus* sp. (Hydrophilidae)
1974								
1.0	2528a	669a	[3]	0.0a	50.9a	6.6a	0.0a	0.0a
0.25	668b	242b		540.0b	6.6b	0.1a	0.1a	0.1a
0.063	328c	122c		91.2c	0.4b	0.0a	0.1a	0.1a
0.016	180c	75c		50.7c	0.3b	0.0a	0.3a	0.1a
1975								
1.0	2390a	1436a	728a	0.0a	100.0a	100.0a	0.0a	0.0a
0.25	948b	469b	165b	303.0b	7.4b	1.6b	0.0a	0.1a
0.063	462c	171c	38c	86.1a	1.4c	0.2c	0.2b	0.2b
0.016	145c	75c	10c	66.6a	0.2c	0.0c	0.0a	0.1a

[1] Within each year, means in the same column followed by the same letter are not significantly different from each other (5% level) (Duncan's multiple range test).

[2] Three replicates/loading rate sampled weekly for 17 weeks (July-October) in 1974; and for 21 weeks (July-November) in 1975.

[3] No TKN analysis in 1974.

organic waste in the water. We found similar results as the organic pollution level increased up to certain intermediate levels (ca. supernatant COD = 600 mg/1, TOC = 250 mg/1 and TKN = 175 mg/1 for swine lagoons and COD = 650–950 mg/1, TOC = 250–450 mg/1 and TKN = 165 mg/1 for poultry lagoons). A decline in mosquito abundance occurred at pollution levels above these levels, indicating that the water was becoming too polluted for *Cx. quinquefasciatus* oviposition and development. A detailed discussion of the factors affecting mosquito production from animal waste lagoons has recently been published by Rutz and Axtell (1978).

Midges, *Chironomus* sp., predaceous water beetles, *Tropisternus* sp., backswimmers and water boatmen appeared to be tolerant of only low to intermediate levels of organic pollution (ca. supernatant COD = 1000 mg/1, TOC = 500 mg/1 and TKN = 400 mg/1 or less). However, even at these pollution levels, only small numbers were observed.

The data obtained from this investigation indicate that production of pestiferous insects from animal waste lagoons could be greatly reduced or possibly eliminated by manipulating the organic pollution level of the lagoon water. With mosquitoes, for example, this could be achieved by designing lagoons or regulating manure addition to existing lagoons to maintain organic pollution levels less than COD = 400 mg/1, TOC = 100 mg/1 and TKN = 50 mg/1 or greater than COD = 2000 mg/1, TOC = 1000 mg/1 and TKN = 500 mg/1.

Literature Cited

American Public Health Association. 1971. Standard methods for the examination of water and waste water. 13th edition, Washington, D. C.

Anonymous. 1977. Tentative guidelines for the design, installation and operation of animal waste treatment lagoons in North Carolina. North Carolina Agr. Ext. Ser. Publ. AG-18. 4 pp.

Axtell, R. C., D. A. Rutz and T. D. Edwards. 1980. Field tests of chemicals for the control of *Culex quinquefasciatus* in anaerobic animal waste lagoons. Mosquito News 40:36–42.

Axtell, R. C., D. A. Rutz, M. R. Overcash and F. J. Humenik. 1975. Mosquito production and control in animal waste lagoons, pp. 15–18, 21. *In* Managing Livestock Wastes, Proc. 3rd Int. Symp. on Livestock Wastes, Amer. Soc. Agr. Engrs., St. Joseph, Michigan, Publ. PROC-275. 631 pp.

Barker, R. W. and C. V. Booram. 1979. Mosquito control: Efficacy of diflubenzuron, CGA–19255 and Sumithion in swine waste lagoons. J. Georgia Entomol. Soc. 14:238–44.

Barr, H. T., B. A. Tower, C. D. Steelman and L. J. Cabes, Jr. 1969. Farm lagoons in Louisiana. Louisiana State Univ. Agr. Exp. Sta. Bull. 638:3–19.

Overcash, M. R., D. L. Reddell and D. L. Day. 1974. Chemical analysis. ASAE Paper No. 74–4546 Amer. Soc. Agr. Engrs. St. Joseph, MI.

Rutz, D. A. and R. C. Axtell. 1978. Factors affecting production of the mosquito, *Culex quinquefasciatus (=fatigans)* from anaerobic animal waste lagoons. North Carolina Agr. Expt. Sta. Tech. Bull. 256:1–32.

Sinha, V. P. 1976. Further observations on the physio-chemical factors of the breeding places of *Culex quinquefasciatus* Say = *fatigans* Wied. Mosquito News 36:358–60.

Smith, L. W., Jr. and W. R. Enns. 1967. Laboratory and field investigations of mosquito populations associated with oxidation lagoons in Missouri. Mosquito News 27:462–6.

Steelman, C. D. and A. R. Colmer. 1970. Some effects of organic waste on aquatic insects in impounded habitats. Ann. Entomol. Soc. Amer. 63:397–400.