THE EFFECT OF CULTURAL PRACTICES ON MOSQUITO ABUNDANCE AND DISTRIBUTION IN THE LOUISIANA RICELAND ECOSYSTEM[1]

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ABSTRACT. The effects of cultural practices on mosquitoes breeding in the rice fields of 3 agroecosystems in north, central and south Louisiana were determined. Larvae of *Anopheles crucians* Wiedemann, *An. quadrimaculatus* Say, *Culex erraticus* (Dyar and Knab), *Cx. salinarius* Coquillett, *Psorophora columbiae* (Dyar and Knab), and *Uranotaenia sapphirina* (Osten-Sacken) were collected from producing rice fields.

Mosquito breeding occurred in the rice fields from the end of May through September although rice planting and initial irrigation occurred approximately 1 month earlier in the southern and middle rice-growing regions than in the northern region of the state. Mosquito breeding increased substantially in the field that was reflooded with irrigation water to produce a second crop of rice.

Molinate applied to 2 fields at the registered rate of 6.72 kg AI/ha, 4.42 ppm in 15.24 cm of rice field floodwater, to control aquatic weeds completely eliminated mosquito breeding for 2–3 weeks. Laboratory data indicated that the LD_{50} of molinate to 4th instar *Cx. pipiens quinquefasciatus* Say larvae was 1.0 ppm and the LD_{90} was 2.4 ppm. For *Ps. columbiae*, the LD_{50} was 1.2 ppm and the LD_{90} was 3.8 ppm.

Early season applications of carbofuran to control the rice water weevil, *Lissorhoptrus oryzophilus* Kushel, in 3 rice fields aided in preventing mosquito breeding, while late season application of methyl parathion to control the rice stink bug aided in preventing the reestablishment of permanent water species in the field. Late season application of insecticides to crops in adjacent fields could have had a detrimental effect on adult female mosquitoes attempting to utilize the rice field as breeding habitat.

The population density of *PS. columbiae* increased with the introduction of cattle into the harvested fields, which provided both host animals and hoofprint oviposition sites. Harvest equipment tracks partially filled with rice plant debris provided additional ovipositional sites for *Ps. columbiae* and *Cx. salinarius.*

The riceland agroecosystem, and productive rice fields in particular, has been identified by a number of authors as sites of mosquito breeding. However, the relative abundance of mosquitoes breeding in these rice fields varies extensively from year to year and field to field. This variation has been attributed to the different rice cultural practices of various farmers.

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Cultural practices that have been shown to be important in determining mosquito populations are land rotation (Horsfall 1942 and Gerhardt 1959), water management (Gerhardt 1955, Rourke 1964, USDA/ARS 1967, and Bohart and Mitchell 1976), the application of chemicals to control insect pests of rice (Lancaster and Tugwell 1969 and Gifford et al. 1969, 1970), and the application of chemicals to control plant pests in rice fields (Smith and Isom 1967).

This study reports the effects of cultural practices on mosquitoes breeding in rice fields of 3 different rice agroecosystems in Louisiana.

MATERIALS AND METHODS

FIELD LOCATIONS AND CULTURAL PRACTICES. In this study, 6 producing rice fields, 2 in each of 3 different agroecosystems were studied throughout the 1977 rice growing season. The exact locations of the 6 fields sampled were previously described by Chambers, et al. (1979). The specific dates on which rice cultural practices occurred and when the fields were sampled to determine mosquito abundance in the 6 fields are shown in Figures 1–6. In the southern rice growing region of Louisiana, field S1 was in a relatively high, dry, and permanent rice ecosystem which was under a yearly rotation system with adjacent fallow fields that serves as pastureland for cattle. LaBelle variety rice was water-planted by airplane after the field had been initially flooded. The field received 2 applications of 112.03 kg/ha of 6–24–24 fertilizer followed by an application of 19.04 kg/ha of carbofuran (Furadan®) used to control the rice water weevil (*Lissorhoptrus oryzophilus* Kuschel). The herbicide, molinate (Ordram®), was applied to the rice field at 33.61 kg/ha to control weeds. After the 1st crop of rice had been harvested the field was spot fertilized with 84.03 kg/ha of 6–24–24.

The 2nd field in the southern region (field S2) was in a low, marshy, marginal rice ecosystem. This field was rotated yearly with adjacent fallow fields which served as pastureland for cattle. Saturn variety rice was water-planted by airplane. The herbicide, propanil (Stam®) was applied to the field at 3.51 l/ha for weed control.

Field M1, in the middle region, was a relatively high, dry, and permanent rice ecosystem which was rotated yearly with adjacent fallow fields that served as pastureland for cattle. Nato variety rice was water-planted by airplane. Two herbicides (molinate at 30.61 kg/ha, and propanil at 4.48 kg/ha) were applied for weed control. The field received 2 applications of 90.72 kg of 18–18–12 fertilizer. After harvest cattle were placed in the rice field to graze, but were removed within a few days due to the moist condition of the field.

A 2nd field in the middle region (field M2) consisted of a high, and dry rice ecosystem that was in a 2-year rotation with adjacent fallow fields which served as pastureland for cattle. This was the 1st year of rice production and the field was dry-planted with Brazos variety rice by airplane. The rice seed was later harrowed into the soil. Propanil was applied to the field at 4.48 kg/ha for weed control. Carbofuran was applied to the field at a rate of 19.05 kg/ha along with 319.31 kg/ha of 14–14–14 fertilizer. After harvest, cattle were placed in the field and remained there until the end of the study. Due to heavy rains, the field stayed in a moist condition (water collected in the hoofprints) until the last day of the study (September 30) when soil samples for egg presence determination were removed from the dry field.

A field study site in the northern rice growing region of Louisiana (field N1) was a part of a permanent rice ecosystem and was on a yearly rotation with soybeans. In field N1, Starbonnet variety rice was dry-planted by airplane. The field received 2 applications of propanil applied at 9.35 l/ha and 1 application of milinate at 6.72 kg/ha for weed control. The rice was fertilized with urea on 2 separate dates (the 1st at a rate of 224.07 kg/ha and the 2nd at 112.04 kg/ha). An application of #4 methyl parathion at a rate of 2.34 kg/ha was used to control the rice stink bug, *Oebalus pugnaz* (Fabricius).

A 2nd field in the northern region (field N2) was in a rice ecosystem with no other crop grown on adjacent land. If the land was fallowed during any year, no cattle were pastured on it. Starbonnet variety rice was dry-planted by airplane. The field received 2 applications of propanil at a rate of 4.48 kg/ha and 1 application of molinate at 6.72 kg/ha for weed control. Carbofuran at a rate of 19.05 kg/ha was applied to control the rice water weevil. The field was fertilized 3 times with urea (the 1st application was at a rate of 90.72 kg/ha and the 2nd and 3rd at 112.04 kg/ha).

SAMPLING PROCEDURE. Larval sampling, as described by Chambers et al.

(1979) was conducted on a biweekly basis in each field using a standard metal dipper. There were 18 collection dates in 3 regions with 2 fields in each region, 2 replicates in each field, 3 sites in each replicate and 5 samples taken from each site (approximately 3200 samples).

On those sample dates when the rice fields were dry and mositure conditions of the soil permitted, soil samples were taken from the rice field as described by Chambers et al (1979) and analyzed for floodwater mosquito eggs. The procedures used in removing the 15 cm × 15 cm × 2.54 cm soil sample, initially separating the eggs from the soil, and salt water flotation separation of the eggs were as described by Horsfall (1956).

On those post-harvest sample dates when water had accumulated in hoofprints or harvest equipment tracks, usually after rains, larval samples were collected, transported to the laboratory for identification, and identified using the taxonomic keys developed by Carpenter and LaCasse (1955).

The susceptibility of 4th instar *Culex quinquefasciatus* Say and *Psorophora columbiae* Dyar and Knab larvae to molinate was determined in the laboratory using the standard World Health Organization procedure (WHO 1963).

RESULTS AND DISCUSSION

The effects of cultural practices on rice field mosquito abundance for each of the 6 fields studied are shown graphically in Figures 1–6. By carefully observing the overall effects of the rice cultural practices of each field studied on mosquito production, a number of important observations can be made.

First, there was approximately one month between the planting dates in the northern and the other 2 rice growing regions of the state, and a 2 month difference in flooding dates. Chambers et al (1979) previously observed that the presence of *Ps. columbiae* and *Anopheles crucians* Wiedemann larvae in rice fields was significantly correlated ($P < 0.005$) and highly significantly correlated ($P < 0.01$),

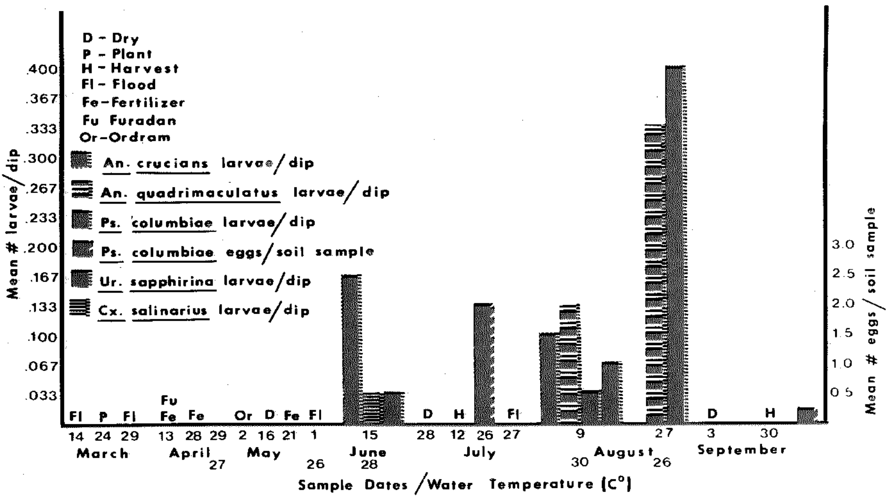

Fig. 1. Mean number of mosquito larvae collected/dip and eggs/sample/collection date, water temperature and the cultural practices used in field S1 from March 14 to October 1, 1977.

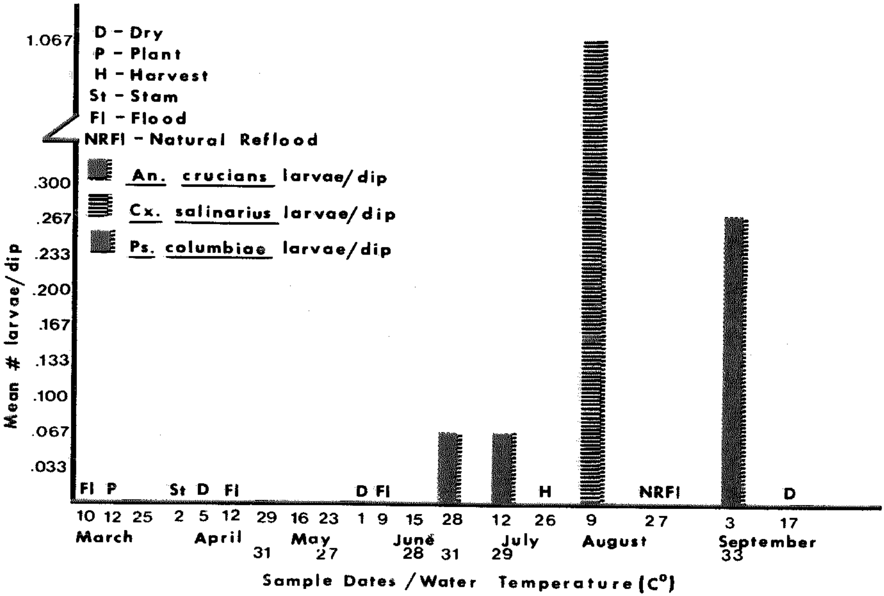

Fig. 2. Mean number of mosquito larvae collected/dip/collection date, water temperature and the cultural practices used in field S2 from March 10 to October 1, 1977.

respectively, to both soil and water temperature. During the longer dry period experienced in the north, the seasonal increase in soil and particularly water temperature (to above 28°C) occurred which caused the hatch of floodwater mosquito eggs on the initial flood date (shown graphically in Figures 5 and 6). In comparison, Figures 1–4 showed that in the southern and middle rice fields studied, there was a lag in mosquito occurrence of from 50 to 110 days from the date of initial flood. Mosquito larvae were observed in rice fields only after the water temperature reached 28°C or above. Therefore, the presence or absence of mosquitoes on the initial flood date was determined in large measure by water temperature.

Secondly, the dates on which the fields were drained was important relative to the number of species and to the population density of mosquitoes breeding in the rice fields. As shown in Fields S1, S2, M1 and M2 (Figures 1, 2, 3, and 4, respectively) draining the fields during July and August caused these fields to become important sources of floodwater mosquito breeding. This is particularly important in areas where 2 crops of rice are grown on the same field during one season. As shown in Figure 1 (field S1), an average of 2.0 *Ps. columbiae* eggs/soil sample were obtained from soil samples collected on July 26 when the field was dry, thus explaining the 2nd brood of *Ps. columbiae* observed later after this field was reflooded.

In comparison, the post-harvest soil sample data collected from the late season drain date fields, fields N1 and N2 (Figures 5 and 6) showed a lack of floodwater mosquito oviposition. These data closely paralleled the observations of Horsfall (1942) who reported that rice fields that were drained early in the season provided

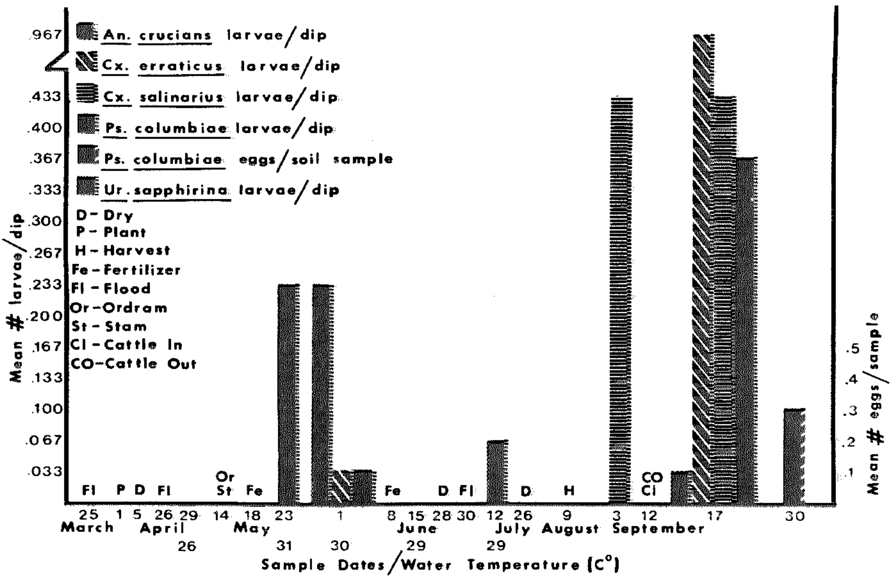

Fig. 3. Mean number of mosquito larvae collected/dip and eggs/sample/collection date, water temperature and the cultural practices used in Field M1 from March 25 to October 1, 1977.

oviposition sites for floodwater mosquito species, while fields that were drained late in the season did not.

Thirdly, the applications of pesticides to control insects other than mosquitoes or as herbicides also had an adverse effect on mosquito populations in the fields studied. Carbofuran applied to control the rice water weevil has been shown previously to provide excellent control of rice field mosquitoes (Gifford et al. 1969 and 1970, Lancaster and Tugwell 1969). In the present study, early season applications of this insecticide in 3 of the fields studied (fields S1, M2 and N2) probably aided in preventing or at least delaying mosquito breeding.

The observed effects of the herbicide molinate applied to field N1 (Figure 5) on mosquito larvae was not expected. After molinate was applied to this field for aquatic weed control, no mosquito larvae were collected. Laboratory dosage mortality data confirmed our suspicions that this herbicide also had mosquito larvicidal properties. According to these laboratory tests 1.0 ppm of molinate caused 50% (LD_{50}) mortality of 4th instar larvae of *Cx. quinquefasciatus*, and 2.4 ppm caused mortality of 90% (LD_{90}); while 1.2 ppm of molinate caused 50% mortality in 4th instar larvae of *Ps. columbiae* and 3.8 ppm caused mortality of 90%. In the field, molinate applied to the rice field at the labeled rate of 6.72 kg AI/ha flooded with water at a depth of 15.24 cm would be 4.42 ppm. Thus, the field application provided 1.84 times and 1.16 times more molinate than was required to kill 90% of the 4th instar *Cx. quinquefasciatus* and *Ps. columbiae* larvae, respectively, in the laboratory tests. These data indicated that the larvicidal effect of this compound could be utilized as an efficient control strategy for mosquitoes breeding in rice fields. If the application of molinate was properly

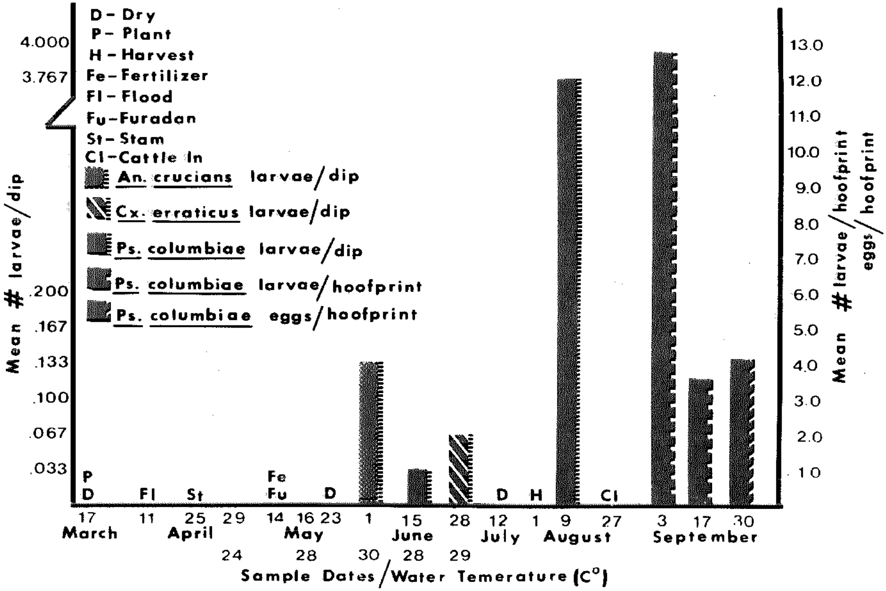

Fig. 4. Mean number of mosquito larvae collected/dip and eggs/sample/collection date, water temperature and the cultural practices used in Field M2 from March 17 to October 1, 1977.

timed, both vegetative and insect pest populations could be effectively controlled.

In addition, any other late-season insecticidal applications to the rice field or the surrounding areas could have had a detrimental effect on adult female mosquitoes attempting to utilize the rice field as an ovipositional site. In this study, the application of methyl parathion to field N1 (see Figure 5) to control the rice stink bug, probably prevented mosquito breeding in this field. After this application, even previously abundant nontarget aquatic species were difficult to observe. In addition, mosquito breeding in field N1 could have been further suppressed as a result of insecticidal drift of chemicals applied to an adjacent soybean field. As shown in Figure 5, 2 insecticides, *Bacillus thuringiensis* (Thuricide®) and methomyl (Lannate®) were applied to the soybean field.

And lastly, physical practices such as the introduction of cattle into harvested rice fields and the abundance of tire tracks from harvest equipment operations seemed to increase mosquito production in these fields. The effects on mosquito breeding from the introduction of cattle into the harvested rice fields are shown graphically in Figures 3 and 4 (fields M1 and M2). After the introduction of cattle into these 2 fields the mosquito populations increased drastically. This large influx of mosquitoes into the rice field supports the observations of Horsfall (1942) and Meek and Olson (1977), who showed the importance of the immediate presence of cattle for blood meals on the ovipositional behavior of *Ps. columbiae*. The observed effect of cattle on mosquito populations may provide an important consideration in the development of broad-based strategies to control rice field mosquitoes. Cattle could

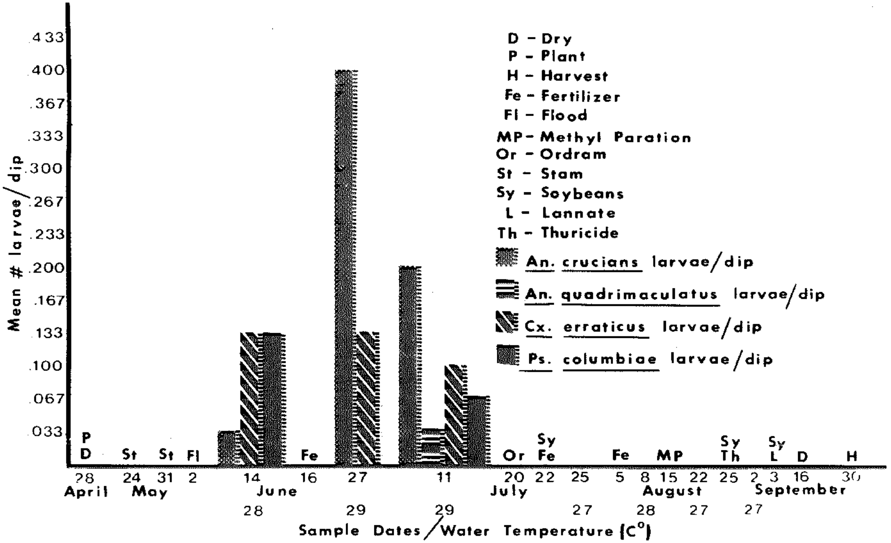

Fig. 5. Mean number of mosquito larvae collected/dip/collection date, water temperature and the cultural practices used in field N1 from April 28 to October 1, 1977.

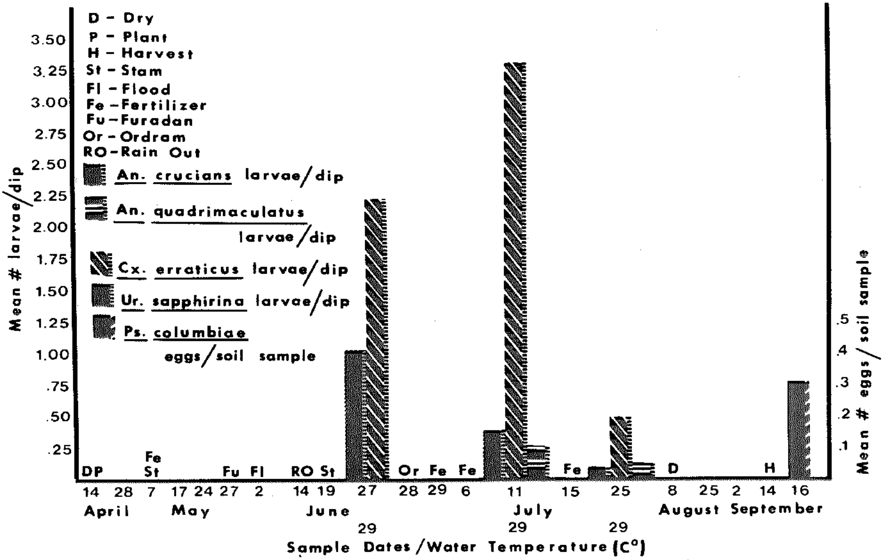

Fig. 6. Mean number of mosquito larvae collected/dip/and eggs/sample/collection date, water temperature and the cultural practices used in field N2 from April 14 to October 1, 1977.

be used as a trap to concentrate the mosquitoes and either the cattle could be treated with a residual insecticide to kill adult mosquitoes during feeding, or the breeding sites treated to kill the larvae.

The effects of harvest equipment tracks holding water on mosquito oviposition (particularly on *Cx. salinarius* and *Ps. columbiae*) are shown graphically in Figures 2, 3, and 4 (fields S2, M1, and M2 respectively). As shown in these figures, all the mosquitoes collected on August 9 (field S2 and M2) and September 3 (field M1) were collected from this particular habitat, which proved to be a substantial source of mosquito breeding in these rice fields after harvest. The mechanical destruction of these tracks after harvest could cause significant reductions in mosquito breeding in post harvest rice fields, and could be used as an important pest control strategy.

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