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A NEW PEST OF RICE IN MISSOURI: RANGE EXPANSION OF *TRIOPS LONGICAUDATUS* (CRUSTACEA: NOTOSTRACA: TRIOPSIDAE) INTO THE NORTHERN MISSISSIPPI RIVER ALLUVIAL PLAINS

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Tadpole shrimp, *Triops longicaudatus* (LeConte) (Notostraca: Triopsidae), are pests in California rice production systems. Tadpole shrimp are an obligate species of ephemeral freshwater aquatic habitats and in North America were considered primarily a species of the western United State for many years. Taylor et al. (1987) reported an eastward range expansion into Oklahoma. Tadpole shrimp were not known to be in Missouri until 1979 when a report was filed with the Missouri Department of Conservation. There were 2 more records filed in 1983 and 2007. Early reports were along the Missouri River with the 1979 and 1983 reports being from Jackass Bend (Jackson County) and the 2007 record from Darst Bottoms (St. Charles County) (Dorothy Butler, personal communication). Additional populations of tadpole shrimp have been found in 2009 on the Arkansas/Missouri state line north of Gosnell, AR in Missouri (Dunklin County) and near Luxora, AR (Mississippi County).

How tadpole shrimp came to be in Missouri is unknown, but dispersal occurs via floodwaters (Taylor et al. 1987), wind (Cáceres & Soluk 2002; Nathan et al. 2005; Graham & Wirth 2008), birds (Green & Figuerola 2005), and via the pet trade (Halliday 2008).

On June 8, 2007, a single specimen of an unknown invertebrate was brought to the Delta Research Center in Portageville, Missouri (Pemiscot County) for identification. The specimen was collected from a drill-seeded rice field in Pemiscot County (near Bakerville). The specimen was determined to be a tadpole shrimp but the species was not determined. Growers were alerted of its presence in the state at winter meetings.

On May 20, 2008, a phone call was received about a 16-hectare field in Stoddard County (located north and west of Catron), of water-seeded hybrid rice that had not emerged. The water was drained from the field and thousands of tadpole shrimp were congregated in the remaining puddles. No viable seeds were present and the field was replanted (Ottis, personal observation). On June 2, 2008, another call was received about multiple fields in New Madrid County (near Lilbourn) that were infested. At least 1600 hectares had tadpole shrimp present and of those infested, nearly 800 hectares were economically impacted and approximately 40 hectares were replanted (Minson, personal observation).

Specimens collected from both locations in 2008 were yellow-brown in color and ≤5 cm in length. The carapace covered slightly less than the anterior half of the animal. Numerous appendages were present on the thorax and abdomen. Two close-together, sessile, compound eyes with a simple eye in between were located on the head. There were >35 body segments. Two tails extended from the telson. The taxonomic treatment of Longhurst (1955) recognizes *T. longicaudatus* as the only North American *Triops* species and on the basis of this treatment, specimens were identified as *T. longicaudatus*. However, this taxonomy may not be supported as new techniques reveal genetic differences due to reproductive isolation (Sassaman et al. 1997).

Tadpole shrimp females lay an average of 81 eggs in 24 h; however, 1 individual laid 198 eggs (594 eggs/ 3d) (Scott 1972). Eggs are laid on either decaying or living plant material, algae, or in the soil. Egg hatch is affected by pH (Scott 1972; Hamasaki & Ohbayashi 2000), soil type, age of egg (Su & Mulla 2002), temperature (Scott 1972), salinity (Horne 1967; Scott 1972) and depth of burial in the soil (Scott 1972). Eggs require a desiccation period prior to hatching (Fry & Mulla 1992). When a larva ecloses, it feeds on diatoms and protozoa in the mud (Longhurst 1955) during early instars. Then it acquires feeding behaviors similar to that of the adult, which consumes vegetative material and aquatic invertebrates (Walton et al. 1991) and is cannibalistic (Scott 1972). The foraging behavior (i.e., movement in the mud) of nearly mature and adult tadpole shrimp uproots small seedlings and muddies the water. Larval development is influenced by temperature; although individuals reared at 30°C were smaller than those reared at lower temperature, they reached sexual maturity at an earlier age (Fry-O'Brien & Mulla 1996).

Tadpole shrimp are problematic in California water-seeded rice production systems when larvae eclose after fields are flooded. Sexually ma-

ture tadpole shrimp are found as early as 9-12 days after floods are established (Scott 1972); therefore, rice plants have <9 days to break the surface of the flood (i.e., the time at which rice is no longer vulnerable), before tadpole shrimp are large enough to uproot seedling rice (Godfrey 2005). Rice planted by drill-seeded or dry-seeded methods has an adequate root system when fields are flooded, and tadpole shrimp are not pests in these systems. Once rice is no longer vulnerable to tadpole shrimp damage, tadpole shrimp may serve as a biological control agent for mosquitoes (Fry et al. 1994) and/or weeds (Takahashi 1977; Yonekura 1979).

Hybrid rice varieties are planted at a lower seeding rate (33-45 kg/ha) than conventional varieties (100-120 kg/ha), making them more susceptible to tadpole shrimp damage than higher seeding rates. For example, losing 10% of a stand planted at 33 kg/ha is more detrimental than losing 10% of a stand planted at 110 kg/ha.

Southeastern Missouri is part of the Mississippi Alluvial Plain (USGS 2003). Historically, the region was covered with swamp lands and heavy timber (Nolen 1912), but much of which is now croplands. These croplands include rice fields that mimic ephemeral ponds inhabited by tadpole shrimp. In 2008, <10% of the 80,000 hectares of rice production in Missouri was water seeded. Therefore, tadpole shrimp will impact only a small percentage of hectares in Missouri. However, rice production also occurs on almost 757,000 ha in the Mississippi Alluvial Plain states of Arkansas and Louisiana (NASS 2008), and the percentage of water-seeded rice varies each year, with many hectares of water-seeded rice in those states that could be impacted if there is further dispersal southward.

Summary

In North America, tadpole shrimp, *Triops longicaudatus,* are pests of water-seeded rice production in California. In 2008, tadpole shrimp were documented to be a pest of rice of water-seeded rice in Missouri for the first time. This occurrence represents a range expansion into a new physiographic region (Mississippi Alluvial Plain) and the Southern U.S. rice producing region. A brief review of the biology and implications of this pest are described.

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