Neotropical Ichthyology, 5(1):81-83, 2007

Scientific Note

Schooling behavior of *Mugil curema* (Perciformes: Mugilidae) in an estuary in southeastern Brazil

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Schools of mullets, Mugilidae, are abundant in estuaries and shallow marine waters. We report on the schooling behavior of juvenile white mullet, *Mugil curema*, in the estuary of the Canto da Paciência stream, in Ubatuba, southeastern Brazil. Schools of small fish (15 to 35 mm TL) were composed of a larger number of individuals (up to a hundred individuals), and were found feeding mainly in shallow nearshore waters, whereas schools of larger fish (40 to 100 mm TL) were observed only in deeper waters. Three patterns of swimming were observed for the schools: stationary feeding, slow movement while searching for food, and rapid displacement. The variations observed in school structure and behavior seem to be related to the balance between predation risk and increasing food intake.

Cardumes de mugilídeos são abundantes em ambientes estuarinos e de águas marinhas rasas. No presente trabalho registramos o comportamento de formação de cardume por juvenis de parati, *Mugil curema*, no estuário do Riacho do Canto da Paciência, em Ubatuba, sudeste do Brasil. Cardumes de peixes pequenos (15 a 35 mm CT) eram compostos por maior número de indivíduos (até uma centena) e observados se alimentando em águas marginais rasas, enquanto peixes maiores (40 a 100 mm CT) foram observados somente em áreas de maior profundidade. Três padrões de movimentação do cardume foram observados: forrageando estacionário, deslocamento lento procurando alimento e deslocamento rápido. As variações observadas na estrutura e comportamento dos cardumes parecem estar relacionadas com um balanço entre o risco de predação e a otimização do forrageamento.

Key words: white mullet, juvenile fish, coastal river.

Polarized and synchronized groups of fish made up of three or more mutually attracted individuals are termed schools. Usually, school members have similar sizes, show polarized swimming, and constantly adjust their speed and direction to match those of other members within the school (Partridge, 1982; Helfman *et al.*, 1997). Partridge (1982) proposed that schooling can be considered an anti-predatory tactic, because a single fish may have a higher probability of being eaten or because of the confusion effect to the predator. Although Pitcher (1986) recognized the importance of the school in detecting predators, he believed that its main functions is to increase the probability of detecting food, achieve a maximum rate of energy intake, and escape a variety of predators.

Schools of mullets, Mugilidae, are abundant in estuaries and shallow waters (Menezes & Figueiredo, 1985). Estuarine nursery areas are important to many species, including mugilids, because they provide an abundant supply of food for young fish, and serve as a refuge from predators (Montaño, 1994). Menezes & Figueiredo (1985) also mentioned the occurrence of juvenile mullets along shores, in shallow waters, mainly near the mouths of rivers. Here we report on the behavior of schools of juvenile white mullet, *Mugil curema*, in an estuary in southeastern Brazil, and attempt to analyze this behavior.

Field work was done on the west end of the Praia da Fazenda, in the Canto da Paciência stream estuary (approx. 44º48´W, 23º22´S), within the Núcleo Picinguaba, Parque Estadual da Serra do Mar, municipality of Ubatuba, São Paulo

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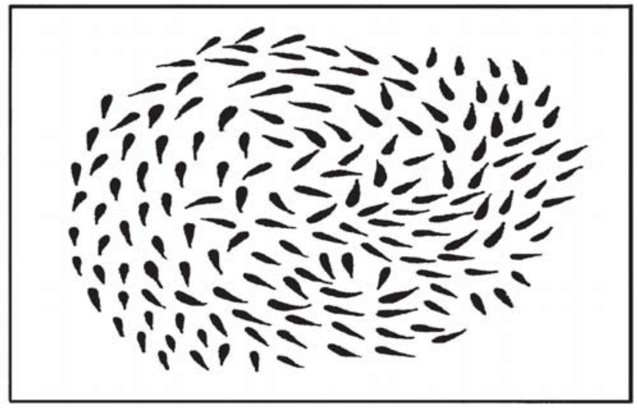

Fig. 1. A stationary school of *Mugil curema*, composed of small individuals in a shallow shoreline area (observed from the surface). In this situation, the fish are not polarized, and their arrangement resembles a chaotic image.

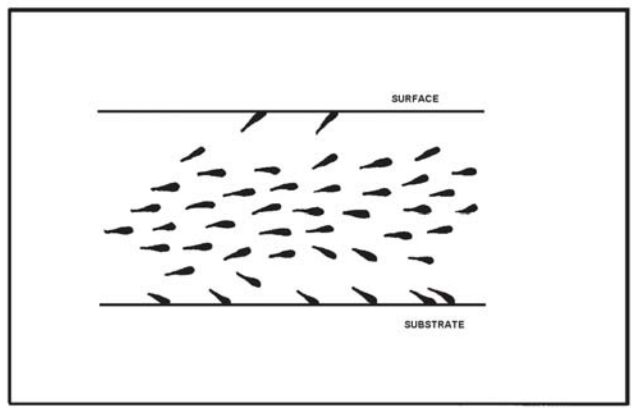

Fig. 2. The distribution of individuals of *Mugil curema* in the water column while feeding, in a slow-movement school pattern, with polarized individuals (viewed as a cross-section of the stream).

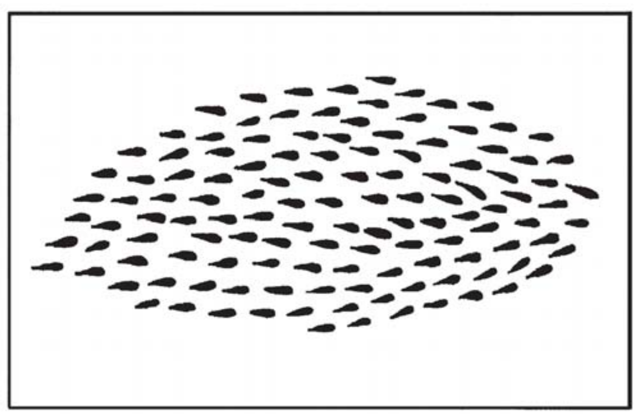

Fig. 3. A school of *Mugil curema*, in a fast movement pattern, with polarized individuals (observed from above).

State, Brazil. The estuary is 15 to 65 cm deep, with a sandy bottom. We observed 49 schools of *Mugil curema* during the day and at night, in June, September and November of 2002 and February and May of 2003, over nine, non-consecutive days. The schools were observed from the riverbank and by underwater observation, in 10-15 minute sampling sessions, using the *ad libitum* method, *sensu* Lehner (1979). Fish sizes were visually estimated, and the schools were analyzed in two categories: small fish (fish 15 to 35 mm in total length) and large fish (fish 40 to 100 mm in total length).

Schools composed of small fish usually had more than 100 individuals, and were observed either stationary or swimming, in shallow nearshore waters (up to 20 cm deep). Schools of large fish had mainly 15 to 80, and were observed swimming in deeper waters, near submerged or shoreline rocks and tree trunks (more than 50 cm deep). At night, individuals of *M. curema* were not observed forming schools, and often came to the surface and jumped repeatedly.

When in high-speed dislocation (fast movement pattern), the fish formed a school with individuals aligned and polarized, seldom feeding. When in slow dislocation (slow movement pattern), they formed a dispersed group with all the fish facing the same direction and often feeding. When stationary, they formed a non-polarized loose group, with its members feeding and facing in many directions.

Observed from the surface, stationary schools appeared circular, with individuals staying close to the bottom. Stationary schools observed in nearshore shallow water (up to 15 cm deep) had fish moving randomly (not polarized), constantly biting at the bottom (Fig. 1). Fish in slowly moving schools, displayed polarized swimming and were distributed along the entire water column, feeding on the bottom, in midwater, or at the surface (Fig. 2). Sometimes this type of school split into two or more groups that moved in different directions. Fish in schools with fast movement were observed swimming polarized and with synchronized movements, with the school in an elliptical shape (Fig. 3). Some individuals might be biting at the substrate and catch items on the water surface, but most of the time the fish were swimming in midwater. Sometimes, two schools in fast movement would merge.

The three patterns described for schools of *M. curema* (stationary, slow and fast movements) differed in feeding behavior. Milinski (1986) suggested that a more profitable strategy to improve the probability of detecting a predator consists in enlarging the number of eyes looking around, so that predators approaching from different directions can be perceived. This type of social behavior facilitates escaping reactions, so that the fish can evaluate the actual risk of predation and continue feeding longer, increasing the rate of food intake. Large schools of *Phoxinus phoxinus* (Cyprinidae), in the presence of a predator, reduce their foraging rate but remain feeding longer in an area (Milinski, 1986). Slow movements of the schools probably are utilized mainly when searching for food, whereas high-speed displacement is employed when moving between feeding grounds. At this time they are also susceptible to a predator attack, and may react with defeating synchronized movements (Partridge, 1982; Milinski, 1986; Pitcher, 1986; Helfman *et al.,* 1997).

The schools of small mullets, composed of many individuals, can be easily detected by aerial predators in the shallow nearshore areas, where, on the other hand, they can be protected against aquatic predators. Schools of large mullets have fewer individuals and are found foraging in deeper waters, where they can take advantage of this social behavior as they may have less food competition among school members and a large volume in which to maneuver and escape rapidly into deeper areas, where there is a supposedly higher potential risk of encounter with aquatic predators. This behavior can be explained as well by the balance between food availability and the risk of predation (Power, 1984; Pitcher, 1986).

The relation between the predation risk and optimal foraging was evident at night when mullets are dispersed, feeding continuously on polychaetes at the water surface, as also observed by Rowinski (2005) in the same area. Amaral & Nonato (1996) mentioned the occurrence of this annelid in large numbers at night on the water surface, because of the reproductive phenomenon of epitoky. At this time, the mullets have a plentiful protein resource available, but a high potential risk of predation by fishing bats. In fact, Bordignon (2001), in analyzing the feeding habits of the fishing bat *Noctilio leporinus* (Noctilidae) in Guaratuba Bay, Paraná, Brazil, found a high frequency of juvenile white mullets in the stomach contents of these bats. Therefore, despite the high potential risk of predation, the mullets keep foraging on the plentiful, protein rich resource available at the water surface, which seems to represent an optimal foraging strategy.

Acknowledgments

Thanks to Hamilton A. Rodrigues for the help in field work, to Cristina Sazima for critical reading of the manuscript, to Instituto Florestal – Núcleo Picinguaba for local support and research permit, and to Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP for the financial support.

Literature Cited

Amaral, A. C. Z. & E. F. Nonato. 1996. Annelida Polychaeta: características, glossário e chaves para famílias e gêneros da costa brasileira. Campinas, Editora da Unicamp, 124p.

Bordignon, M. O. 2001. Padrão de atividade, comportamento de forrageio, dieta, reprodução e coloração da pelagem em *Noctilio leporinus* (Chiroptera, Noctilionidae) na Baía de Guaratuba, Paraná. Unpublished Ph.D. Dissertation, Universidade Federal do Paraná, Paraná. 90p.

Helfman, G. S., B. B. Collette & D. E. Facey. 1997. The diversity of fishes. Massachusetts, Blackwell Science, 528p.

Lehner, P. N. 1979. Handbook of Ethological Methods. New York & London, Garland STPM Press, 403p.

Menezes, N. A. & J. L. Figueiredo. 1985. Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4). São Paulo, Museu de Zoologia da USP, 105p.

Milinski, M. 1986. Constraints placed by predators on feeding behaviour. Pp. 236-252. *In*: Pitcher, T. J. (Ed.). The Behaviour of Teleost Fishes. Australia, Croom Helm.

Montaño, O. J. F. 1994. Recruitment of white mullet in Lake Maracaibo, Venezuela. North American Journal of Fisheries Management, 14: 516-521.

Partridge, B. L. 1982. The structure and function of fish schools. Scientific American, 246 (6): 90-99.

Pitcher, T. J. 1986. Functions of shoaling behaviour in teleosts. Pp. 294-337. *In*: Pitcher, T. J. (Ed.). The Behaviour of Teleost Fishes. Australia, Croom Helm.

Power, M. 1984. Depth distributions of armored catfish: predator-induced resource avoidance? Ecology, 65: 523-528.

Rowinski, M. 2005. História natural de uma comunidade de peixes de um riacho costeiro. Unpublished MSc. Thesis, Universidade Estadual Paulista, Botucatu. 72p.

Received October 2006
Accepted February 2007