DO FISH SLEEP AT NIGHT?

By Stephan Reebs, Ph.D. Queen's University,

Kingston, Ontario, Canada

The title question was once asked to me at a scientific meeting where I had presented data on the nocturnal behavior of parental three-spined sticklebacks, *Gasterosteus aculeatus*. The enquirer was a specialist in mammalian behavior. Although he had no problem with the concept of sleep in mammals -- indeed, he had experienced it firsthand --- he was curious about its existence in the mammals' distant ancestors.

Of course, one need not be a mammalian behaviorist to wonder about sleep in fish. Most aquarists have been similarly intrigued, maybe after coming late one night and glancing at the aquarium in their half-lit living room. Armed with a flashlight and a lot of curiosity, we all have, at one point or another, peeked inside our tanks at night to determine what our fish were up to in the dark.

What we saw (*Plecostomus* fanciers excluded) was certainly suggestive of sleep. Most fish in the aquarium trade are diurnal (to enjoy them, we want them to be up and about at the same time we are). They are therefore ill-adapted to life in the dark, and accordingly they are fairly inactive at night, tending to rest motionless near the bottom, behind plants, or in cavities between rocks. But is such inactivity equivalent to sleep as we usually imagine it?

Well, even the experts do not all agree. It depends on the criteria used to define "sleep." Most sleep researchers, being focused on mammals, have relied upon typical patterns in the electrical activity of the brain to recognize sleep. Another criterion, used mostly in the field, or in situations where electro-encephalograms are not available, is prolonged eye closure. But fish lack complex brain structures and eyelids and, therefore, the two above criteria cannot be used.

Fortunately, other criteria exist that can be expanded throughout a vast array of animal classes, including fish. These are (1) prolonged behavioral quiescence, (2) typical resting posture, (3) circadian organization, and (4) high arousal thresholds. Thus, most people would agree that an animal is, for all practical purposes, asleep when it remains almost completely immobile (criterion 1), in almost always the same posture and same location (criterion 2), at the same time every day (criterion 3), and in a state of decreased sensitivity to disturbances (criterion 4).

A few scientists have applied these criteria to fish and taken the question to the laboratory. Dr. Colin M. Shapiro, now at the University of Edinburgh, has reported that the Mozambique mouthbrooder *Tilapia mossambica* tends to rest on the bottom of the tank at night, with a lower respiratory rate and no detectable eye movement, and that it does not respond as readily as during the day to stimuli such as electrical current or the delivery of food (Shapiro and Hepburn 1976). Juveniles, however, do not show such a behavior; it takes them about 22 weeks to develop these sleep patterns, unless if adults are present with them in the tank (Shapiro et al., 1981).

At the Academy of Sciences of the USSR in Leningrad, I.G. Karmanova and his team have observed that the brown bullhead, *Ictalurus nebulosus*, displays a typical sleep posture. The tail fin lies flat on the ground, other fins are stretched out, and the body is inclined at an angle of 10-30° to the vertical. The cardiac and respiratory rhythms are much slower, and the fish is less sensitive to sound and tactile stimulation (Titkov 1976; Karmanova et al. 1981).

Other researches have shown that rest and activity periods continue to alternate with near 24 h periodicity even when the lighting conditions are kept constant (see Schwassman 1971). For example, Dr. Martin Kavaliers, now at the University of Western Ontario, has left killifish, Fundulus heteroclitus, in complete darkness for up to 20 days and recorded their activity with an ultrasonic system. He has found that the activity patterns remain rhythmic, sleep and activity alternating at a periodicity of about 26 h (Kavaliers 1980). Thus the fish would start being active later and later evey day by 2 h. Such "freerun" in the absence of time cues is similar to what has been observed in other animals, including birds and mammals, and it shows that an internal circadian clock is dictating when the fish go to sleep.

Aquarists can easily make similar observations on their own favorite species. provided they are willing to stay up late. However, a note of caution is necessary regarding the means of illumination. Some species are known to react in a special way to sudden bright light at night; they sink to the bottom where they remain motionless for several minutes (see Davis 1962). This "light shock" may give the impression of sleep in species that could be normally active at night. It is preferable to use very dim illumination constantly throughout the night, or to switch on a veiled flashlight in the middle of the night and rapidly make the observation

I was able to obtain infra-red goggles from an Army Surplus store, and combined with a powerful rescue flashlight on which I attached an infra-red filter (Kodak #87B), I used them to unobtrusively observe fish in complete darkness. The use of infra-red illumination ensured that the behavior I witnessed was not influenced by the presence of visible light, however dim. I concentrated on members of the family Cichlidae, as these are common in the pet trade and known to be insensitive to infra-red light (Schwanzara 1967). What I found was that these fish are indeed quiescent at night . . . most of the time.

Adult oscars, Astronotus ocellatus, are sluggish and unresponsive at night. Typically they rest on the bottom with their eyes turned downwards. Severum cichlids, Cichlasoma severum, are also motionless although they can be near the bottom or up

Infra-red goggles and light used to observe fish in complete darkness.





in the water column. Rainbow cichlids, *Herotilapia multispinosa*, and convict cichlids, *C. nigrofasciatum*, are often immobile with their pelvic fins lowered all the way down, but occasionally they set off on slow promenades with their pelvic fins brushing against the gravelly bottom.

Things change when the fish are in breeding conditions. My observations here have focused on the convict cichlid. If a pair is showing signs of being ready to spawn just prior to the lights going off at dusk, it will carry on into the night. The fish will keep on digging pits and shoving gravel away; they will continue to nudge and skim the spawning substrate in apparent cleaning movements; they will even spawn! In my experience, the broods of such night-spawners tend to be more scattered on the spawning substrate than those of day-spawners. Yet they do not seem to compromise more unfertilized eggs. It is worth emphasizing that all of this takes place in complete darkness (even the pilot lights of the heaters were disabled), yet the convict cichlid is normally diurnal and

visually-oriented in its behavior.

Better still, both night and day-spawners will keep on fanning their eggs at night throughout the incubation period (about 3 days in my studies), and nocturnal fanning levels tend to be much higher than during the day. Whereas females will spend about 30% of their time fanning during the day, they will devote about 85% of their time to this parental activity at night (Reebs and Colgan 1991). The males usually do not fan, either day or night. In day fanning, the female is normally broadside to the eggs, 1-3 cm away from them, fanning mostly with the fins from one side; at night, she is much closer to her clutch, and her snout and fins come in frequent contact with the eggs. This suggests that she uses olfactory and/or tactile cues to locate her eggs in the dark. I am currently conducting night experiments with artificial odorless eggs and with real eggs in tea bags, and the results seem to indicate that olfaction is the fish's primary means of recognizing if and where eggs are present in the nest.

the parental behavior of other cichlids such as C. severum, C. spirulum, and H. multispinosa, and all showed intense fanning at night. The pattern may indeed be typical of the whole family. It makes sense: if fanning serves to bring new oxygenated water to the eggs, and the eggs keep on consuming oxygen at night (a safe assumption), then the parents should continue fanning at night. However, why they should do it at such high levels is still unclear. Maybe it is a hard-wired adaptation to lower oxygen availability caused by the absence of oxygen-producing photosynthesis by aquatic plants at night (this may happen in nature but not in the well-oxygenated home aquarium). Or maybe they simply do the only useful thing in the absence of other worries such as looking for food, threat, mate, etc.

Had I known all this a few years ago, I would have been able to give a more precise answer to that inquisitive mammalian ethologist. As it were, I just made a vague

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I have made preliminary observations on





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A Final Note:

For safety sake, do not take chances: always fit a humidity (residual) circuit breaker to the appropriate line that supplies the electric current to where you are using your appliances or installing your pumps and lights. Always ground the pump and lights. If in doubt, make an extra ground connection using a probe made from a four foot length of 1/2" copper piping driven into the ground besides the pool. A car battery terminal connector will be ideal to connect your ground wire. If in doubt, consult your local qualified electrician and, above all, if at any time you need to enter, or put your hands in the water while working on your installation or during periods of maintenance, make a habit of switching off the electrical supply beforehand. This might take up a little extra time but it stands to reason that electricity and water are deadly. Residual circuit breakers are cheap and easy to fit. They can be found in any good hardware, electrical supply, or boat store.

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statement about how inactive diurnal fish appear to be at night. Since then, I have learned that fish show many functional signs of sleep at night, but that these signs readily disappear during the parental cycle (human parents of newborn babies would no doubt wish it was that easy). So the answer is: it depends. It depends on the criteria used and on the reproductive state of the fish. By making and reporting their own observations, aquarists could help figure out how widely across fish species this answer applies.

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