ABSTRACT: The locomotor activity cycle of the American eel (*Anguilla rostrata*) was studied in a light-proof shelter. Measurements of activity were registered by a mechanical assembly triggered by the eel's movements. The results demonstrate that the eel possesses a locomotor cycle with greater activity in dark than in light and activity peaks in response to light changes at dawn and dusk. The latter is significantly higher than any of the peaks during the night or the one at dawn. The one at dawn is frequently not any higher than some peaks of activity occurring throughout the night. The presence of peaks at dawn and dusk appears to be a more generalized condition than the period of maximum activity. Both frequency and phase of the eel's cycle were shown to vary directly with the light conditions, and the cycle was totally obliterated under constant conditions of either light or dark. It is concluded that this locomotor activity cycle is essentially exogenous, under the control of the environmental light cycle, with the preference for dark activity being the only endogenous component.

Introduction

The specific aims of this study are to determine the presence of a locomotor cycle of the American eel (*Anguilla rostrata*); to describe this cycle; to investigate the effects of controlled environmental light cycles on it; and to discuss the applicability of current theories of circadian rhythms and biological clocks to the results.

Biological rhythms are a fundamental property of life and are present in all living organisms. Considerable attention has been focused on constructing a general theoretical framework concerning these rhythms, i.e., Welsh (1938), Park (1940, 1941), Kleitman (1949), Stephens (1957), Brown (1957), Bruce and Pittendrigh (1957), Harker (1958), Cloudsley-Thompson (1961), Aschoff (1960), Pittendrigh (1960), Bruce (1960), and Sollberger (1962).

An exogenous biological rhythm is one which responds directly to physical changes in the environment and does not persist when conditions are kept constant. A rhythm that is not directly responsive to the environment and persists, at least for a time, under constant conditions is assumed to be endogenous (Park, 1940).

According to Aschoff (1960), the rhythm of an organism with a day-night periodicity can be purely exogenous with the environment being the real and only cause of the rhythm, or the organism can have a circadian rhythm which is a free running biological rhythm whose period is an approximation to that of the earth's rotation. Pittendrigh (1960) defines circadian rhythms as being ubiquitous, endogenous, existing in both single and multicellular systems, self-sustaining, and always innate. To establish a periodicity as circadian, Aschoff (1960) says it is necessary to exclude all possible zeitgebers (exogenous factors which might entrain the rhythm). However, as Brown (1962) indicates, one can
never exclude the possibility that some factor in the geophysical environment provides essential timing signals to the organism. On the other hand, to prove a rhythm to be exogenous one need only find the environmental factor responsible.

The inhibiting effect of light on eels is commonly known to fishermen. Bertin (1956) recounts that fishermen in Comacchio, Italy, light huge fires at night to calm the masses of swarming eels caught in the traps in order to prevent damage to the fish. He also cites an early experimental study made by Peterson in 1906. Peterson netted a shallow river used by migrating eels. On a very dark night, 50 pounds of eels were taken between 9:00 and 9:15 p.m. He then projected a beam of bright light on the water for the next 15 minutes and during this time netted only one pound of eels. The light was removed, and in the next quarter of an hour 50 pounds of eels were again taken. He concluded that migration of eels is inhibited by light. Creutzberg (1961) demonstrated that eels move inward on flood tide during day and night.

Various methods are known for measuring fish activity: direct observation (Shaw et al, 1938), indirect observation by measuring oxygen consumption (Claussen, 1936), by attaching the fish directly to the recorder as the "Icthyometer" (Spencer, 1939), by having various mechanical devices between the fish and recorder (Spoor, 1941; Jones, 1956; Roberts, 1963; Davis and Bardach, 1965) or by using an electric eye beam (Hasler and Bardach, 1949; Roberts, 1963). In this study a mechanical device was used.

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Materials and Methods

A total of 145 American eels was used in this experiment. These eels were all from the Chesapeake Bay area and their length varied from about 8 to 12 inches total length. None had enlarged gonads nor were they anywhere near adult sizes. They were stored in 50-gallon tanks at the Behavior Laboratory of the University of Maryland, Zoology Department, and were fed twice a week during the day with red manure worms. No feeding took place during the experiments. Experimentation began on 29 September 1963, and was continued through 25 March 1964.

All tests took place within a light-proof shelter constructed of several layers of opaque black plastic enclosing a wooden tank stand and access space for the experimenter. This shelter was divided into two parts by a partition of the same plastic, each part housing 9 tanks. These tanks were of 15-gallon capacity each (30 x 30 x 60 cm). They contained sand and gravel simulating to some extent the shelter available to the eel in its natural habitat. Experiments were run with one eel per tank. A constant water level of 12.5 cm was maintained throughout each experiment.

An attempt was made to keep the water temperature constant at 21°C by use of a thermostat-controlled electric room heater. Water temperature readings were taken by a telethermometer throughout the duration of the experiments. The mean temperatures of all experiments ranged from 19.5°-24°C. The temperature variation seemed to have no effect on the activity of the eels, as patterns of activity on the days in which the temperature remained constant did not differ from the pattern on the days that the temperature varied. In addition, a control was run with each experiment except Test 6 and no significant differences were revealed among activity patterns of the controls.

The apparatus for measuring the locomotor activity consisted of an armature and a set of four movable rods extending into the water. The armature was a 26" x 2" x 1" wooden beam having two parallel wires supported 1/2 inch apart and a 1/2 inch below it. The rods were four stiff wires freely suspended from eyehooks between the two armature wires (Fig. 1a). The lower part of the rods, which extended to within one inch of the bottom of the tank, was covered with plastic to prevent