Abstract

The downstream migration of silver eels is the last continental phase of their life cycle. During their migration, individuals of this species, which is now considered as threatened, will be confronted to obstacles implanted on the waterway. The danger represented by possible entrainment in the turbines of hydroelectric power plants leads us to consider ways of developing indices to evaluate quantitatively the fraction of migrants, to predict migration runs in relation to environmental parameters, and to study solutions for the avoidance and safe passage of downstream migrating eels.

A physio-anatomical and morphological characterization of the transitional stages between the yellow and silver phases was achieved: this description was performed on a sample of more than a thousand male and female eels, captured at eight sites distributed on several watersheds in France. Data analysis methods were carried out to define five successive stages for female eels and three for males. These are based on the development of gonads, regression of the digestive tract and increase of pituitary gonadotropin hormone (GTH II). Fundamental knowledge obtained on the eco-physiology of silver eels mainly concerns the definition of each silvering stage up until the typical migrating stage for male and female eels as well as their sequence in time. In terms of application, these results allowed us to build indices based on biometrical measurements, for the identification of the silvering stages. A standard method was then suggested to measure the morphological parameters on the eel and to assign a stage. These results are directly applicable to the quantitative estimation of the fraction of migrants through the surveys, which are routinely done on the French territory (Hydro-biological and Fish Network) as well as through fisheries data.

Downstream migration was studied at different scales in space and time, through the analysis of twelve years of data from a silver eel fishery on the Loire river and through experiments which took place during three years in the vicinity of a hydroelectric power plant on the Nive River: daily trapping of migrating eels, radiotracking of migrants, and measurement of eel activity in closed tanks. Downstream runs occur in autumn, when photoperiod reduces and temperature decreases the most. Results led us to the notion of “environmental migration windows”: eels will migrate when there is a fall in conductivity, an increase in turbidity generally associated to a rise in water flow; this parameter operates as a migration vector. Darkness is the necessary condition to the start and persistence of downstream migration. Daylight will induce the eels to stop; these halts can last several days if light conditions are too strong, even during the night. Thus, migration is achieved through several runs. The prediction of downstream runs can be done based on water flow, on small rivers and upstream of large catchments.

The behavior of eels is rather flexible as it was observed throughout the behavioral study of eels confronted to an obstacle: they are capable of swimming back against the flow of water and to find alternative ways of passage. The trashrack located in front of the water intakes of the power plant has a repulsive effect on the eels, regardless of the physical possibility for them to pass through it. However, a reduction of the bar spacing from 3 to 2 cm, is recommended for smaller eels (less than 55 cm). Turbine avoidance devices must nevertheless be associated to fish bypasses which can be located either at the surface or bottom of the water column, such as it was observed through efficiency tests performed in this study.

Keywords: Downstream migration, silvering, typology, *Anguilla anguilla*, obstacle, behavior, environmental factors