THE ANADROMOUS SEA LAMPREY IN PORTUGAL:

BIOLOGY AND CONSERVATION PERSPECTIVES

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Abstract

The sea lamprey is a species with high economic value in Portugal. During the spawning migration they are most active at night, and attain a ground speed that varies between 0.84 km h^{-1} and 1.5 km h^{-1}. The duration of the larval stage in Portuguese rivers is between four and nine years and metamorphosis occurs from autumn to winter, with a peak in October-November. Larval distribution is strongly dependent upon sediment, especially particle size composition. Smaller individuals (20 mm $<$ TL $\leq$ 60 mm) are commonly found on silty sand bottoms. Ammocoetes with a total length of 60 mm to 140 mm prefer a more heterogeneous substrate, where gravel and silt seem to make an identical contribution to sediment composition (gravel-silty-sand). The larger ammocoetes (140 mm $<$ TL $\leq$ 200 mm) clearly prefer more coarse sediments, substrates composed of sand or gravelly sand. The major constituents of the microphagous diet of the ammocoetes are microalgae belonging to the class Bacillariophyceae. Overfishing and habitat destruction are the two major threats to the conservation of the sea lamprey in Portugal.

Introduction

The sea lamprey (*Petromyzon marinus* L.) is an anadromous species, which supports commercial fisheries in most of the major Portuguese river systems, particularly in the central and northern regions of the country (Figure 1).

Sea lampreys are considered a delicacy in Portugal and, due to the high economic value of this fishery (one animal can cost as much as € 45), the main Portuguese estuaries and rivers are crowded with fishermen and poachers during the annual sea lamprey spawning migration. These intense fisheries along with the reduction of suitable habitat, due to the construction of impassable dams, are the major threats to the survival of this species in Portuguese river basins (Figure 1) (Almeida et al., 2002).

This paper is a synopsis of work on the general biology of the sea lamprey in Portuguese rivers. The information presented in this paper is mainly based on data obtained by the authors in recent research projects and summarizes previously published papers. The major threats to the survival of this species in Portuguese river basins are identified and discussed.

The spawning migration

Sea lampreys are usually captured when entering the estuaries to initiate their upstream reproductive migration, which, in Portuguese rivers, begins in December. Peak spawning migration occurs between February and April and spawning usually takes place between May and June, depending on the meteorological conditions (Guimarães, 1988; Machado-Cruz et al., 1990; Almeida et al., 2000; in press).

During this period, the lampreys exhibit a strong diel pattern of migratory activity. They are active during the hours of darkness and avoid light during the day, seeking out resting places on rocky substrates. Migratory activity begins at dusk and, under normal conditions, ends at dawn (Almeida et al., 2000; in press).

During periods of continuous movement, sea lampreys attain ground speeds (*GS*) of between 16.5 BL min^{-1} and 29.3 BL min^{-1} (0.84 km h^{-1} to 1.5 km h^{-1}, for an 85 cm sea lamprey) shortly after starting their movement (Almeida et al., 2000; in press) (Figure 2).

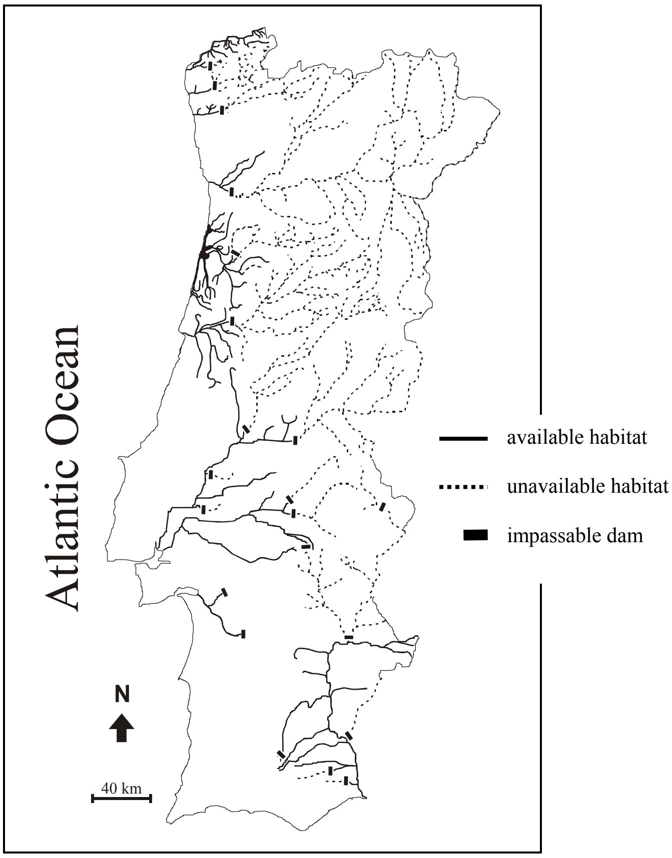

Figure 1. Habitat available to sea lamprey populations in Portuguese river basins where the species is known to occur.

The alternation between high and low flow regimes, resulting from the operation of dams, can act simultaneously as a stimulus and as a constraint to migration. When the discharge reached the sea lampreys it stimulated the animals to move, or to increase their swimming activity (Figure 2), however if the flow was too high (>72 m^3s^{-1}) it caused a delay in their upstream migration (Almeida et al., in press; Quintella et al., in press). Similar conclusions were made by Machado-Cruz et al. (1990) for the same species in River Tagus, in that the high flow released from dams can have a negative impact on sea lamprey migrations.

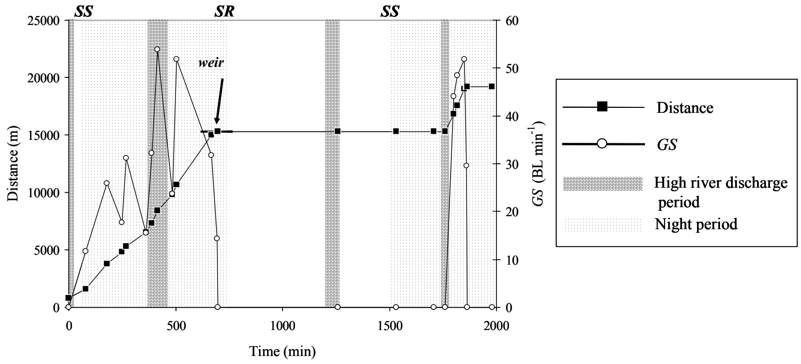

Figure 2. Distance moved by a sea lamprey during its upstream migration in a Portuguese river. The ground speed (*GS*) values were registered using radiotelemetry techniques. *SS* – sunset; *SR* – sunrise (adapted from Almeida et al., in press).

General ecology of larval sea lampreys in Portuguese rivers

Duration of the larval phase

Due to the absence of bony structures, such as otoliths, scales or spines, investigations on the larval growth of lampreys have usually relied on the analysis of length-frequency data (Hardisty and Potter, 1971). Recent studies provided reliable age estimates when comparing ages determined from statoliths and length-frequency distribution (Barker et al., 1997). Based on theoretical growth from length-frequency distribution analysis, Quintella et al. (in review) found that the sea lamprey larval stage in a Portuguese river (River Mondego) lasted four years. Sousa (1992) suggested that the ammocoetes from the River Lima (Northern Portugal) remained in the river for a period of 7 to 9 years before metamorphosing. Compared with colder, more northern rivers, the larval phase in River Mondego lasts a shorter duration. This is probably the result of higher productivity associated with the high water temperature, which may enhance ammocoete feeding efficiency and growth (Quintella et al., in review).

On average, the ammocoetes attained 31.4% of the total length (TL) in the first year (i.e. 72 mm) and 72.1% of the TL by the end of the second year (i.e. 165 mm). In the size class corresponding to the second year of life, in spite of reaching the minimum length to initiate metamorphosis, only 18.7% of the lampreys captured had already begun this process. In the third year the growth rate showed a slight reduction; the ammocoetes attained 88.6%

of the TL (i.e. 203 mm), and about 29% of the individuals belonging to this size class showed signs of having begun metamorphosis. In the fourth year of the larval phase the growth rate was also quite low, with ammocoetes attaining 95.2% of the TL (i.e. 218 mm), and all larvae having initiated metamorphosis. It is possible that a small number of ammocoetes could remain in the river for a few more months, until the onset of the feeding migration, at the beginning of the autumn, not completing five years in freshwater (Quintella et al., in review).

The metamorphosis season for *P. marinus* in Portuguese rivers extends from autumn to winter, with a peak in October-November. Even though the ammocoetes from Portuguese rivers initiate metamorphosis at earlier ages than in most other studies, the total length required to initiate metamorphosis coincides with the average length presented by other authors (i.e. approximately 140 mm) (Quintella et al., in review).

Habitat selection

Although the location of larval lamprey populations within a river system can usually be predicted with some accuracy by an experienced observer, it is more difficult to specify in precise physico-chemical terms the essential characteristics of ammocoete habitat (Hardisty and Potter, 1971).

It is widely recognized that the availability of optimal river substrate particle size is one of the most important factors limiting the distribution of ammocoetes. Almeida and Quintella's (2002) work confirmed this observation and showed that distinct ammocoete length-classes prefer sediments with different particle size composition (Figure 3).

According to Almeida and Quintella (2002), ammocoetes with a total length between 20 and 60 mm prefer silty-sand substrates, i.e. sediments with a comparatively high percentage of sand, but also with a relatively large portion of silt (Figure 3). Considering the larval burrowing habit, it is understandable that smaller ammocoetes are usually associated with fine-grained sediments. Soft sediments allow younger larvae with a reduced swimming capacity to propel the head and branchial region below the surface.

A gravel-silty-sand substrate was the selection of the 60-140 mm ammocoete length-class (Figure 3). In this substrate gravel and silt seem to have an identical contribution to the composition of this more heterogeneous sediment. The larger body of the ammocoetes in this class gives them the opportunity to colonize a wider range of sediment types (Almeida and Quintella, 2002).

The larger ammocoetes (140 mm < TL ≤ 200 mm) sampled by Almeida and Quintella (2002) preferred coarse-grained sediments (gravely sand and sand) (Figure 3).

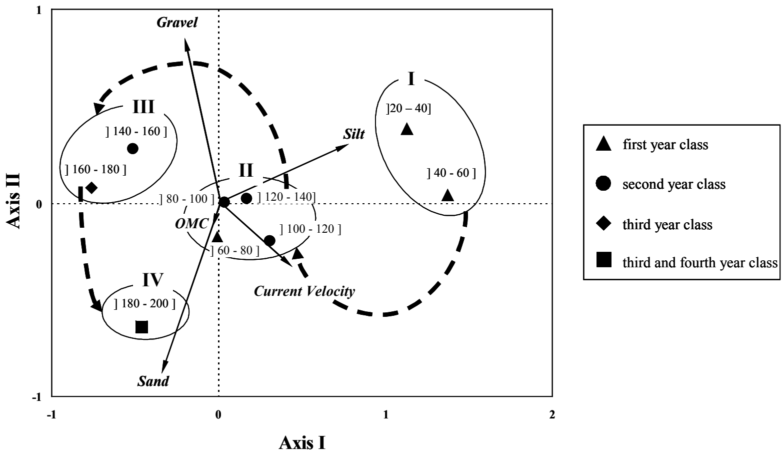

Figure 3. Sea lamprey ammocoete length-class distribution according to the sediment particle size, organic matter content (OMC) and current velocity. Detrended canonical correspondence analysis ordination diagram, with symbols corresponding to the nine length-classes, and arrows representing the environmental variables. The Roman numerals identify length classes with similar preferences and correspond to theoretical age classes. The dashed arrows represent the colonization sequence of the different sediment types (adapted from Almeida and Quintella, 2002).

Since the selection of the burrowing sediment is size-dependent, the differences observed in the preferences for distinct sediment types within the same age group probably resulted from a reorganization of the ammocoete distribution at the end of each annual growing season. This behavior could be a strategy developed by this species to avoid high densities in areas colonized by younger individuals, thereby reducing intraspecific competition for space and food (Almeida and Quintella, 2002).

Diet

Based on an analysis of the gut contents of sea lamprey larvae, Quintella (2000) found that microalgae belonging to the class Bacillariophyceae were the major constituents of the diet of the ammocoetes.

Among them, the genera *Melosira* and *Navicula* are the two most important food items, occurring in more than 95% of the observed gut contents, and corresponding to 86% of the total identified food items. The genera *Cyclotella*, *Cymbella*, *Nytzchia*, *Cocconeis*, *Bacillaria*, *Synedra* and *Rhizosolenia* were also classified as preferred food items (Figure 4).

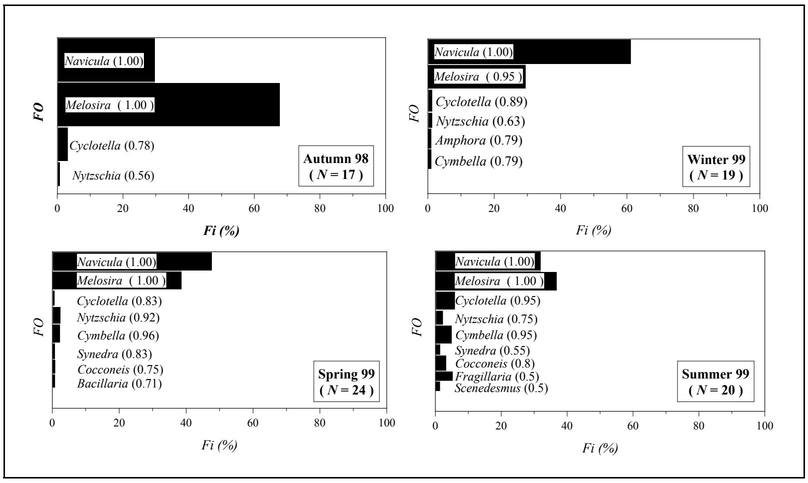

Figure 4. Ammocoete nutrition during the four seasons of the year. Numerical frequency (F_i) is given for each of the food organisms and the width of the bars is proportional to the frequency of occurrence (*FO*), which is indicated between brackets (adapted from Quintella, 2000).

During the spring and summer periods, as expected, the diversity of food items present in the analyzed gut contents was much higher than during autumn and winter (Figure 4). The diversity of food items was low throughout the year mainly due to the almost absolute dominance of the genera *Melosira* and *Navicula* (Quintella, 2000).

Quintella (2000) did not find any food items in the gut contents of the macrophtalmic lampreys.

Species conservation

In the last decades several authors have pointed out a reduction in sea lamprey population abundance in Portuguese rivers (Guimarães, 1988; Almaça, 1990; Assis, 1990; Assis et al., 1992; Ferreira and Oliveira, 1996; Almeida et al., 2000; Almeida et al., 2002). According to the Portuguese Red Book of endangered species, the Portuguese sea lamprey populations are considered “Vulnerable” (Vários, 1991). Habitat destruction resulting from dam construction, dredging, gravel extraction, channelization and pollution have contributed decisively to the decline of the sea lamprey populations in Portugal.

Freshwater use for agricultural, industrial and domestic purposes is also responsible for a considerable reduction in the river flow. As a consequence, migratory clues have been eliminated, resulting in a decrease in the number of adult sea lampreys that enter the rivers to spawn (Almeida et al., 2000).

As stated before, intense fishing pressure is one of the major threats to the conservation of this species in Portuguese river basins (Almeida et al., 2002). Professional fisheries regulations define the fishing season between December and April, and capture is allowed in both estuarine and freshwater environments.

Conservation measures can be divided into those concerning the habitat rehabilitation and those promoting the management of the commercial exploitation of sea lamprey populations in Portuguese rivers.

The rehabilitation of Portuguese river systems for sea lampreys should guarantee: (i) access of the adults to upstream spawning grounds by installing adequate and effective fish passages at impassable dams; (ii) the use of a flow regime in regulated river basins that would minimize the negative impacts resulting from high fluctuations in river discharge; (iii) limitations on dredging in river stretches considered irreplaceable for this species, namely spawning grounds and ammocoetes beds; and (iv) maintenance of water and sediment quality that are compatible with the ecological needs of sea lamprey.

Finally, the sustainable commercial exploitation of sea lampreys should be managed to ensure the existence of professional fishing areas, a five to eight day hiatus in fishing activity during the peak of spawning migrations, a reduction in the fishing effort and/or the establishment of annual quotas for each river basin, and eradication of poaching.

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