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Scientific Editors

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Global Importance of Local Experience

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GLASS EEL MIGRATION AND FISHERIES IN THE MONDEGO ESTUARY – FUTURE PERSPECTIVES

Abstract

The fishery for glass eels (*Anguilla anguilla* L.) in the Mondego estuary started in the 1950's and its importance has increased since then, mainly due to a constant demand and the attractive price it has reached in the market. In 1990 the price was around 60 € per kilo and in 1999, during Christmas, it reached 300 €. The migration occurs all year round, the most intense period is from October to March - April, depending on the weather conditions, and the official fishing season, although variable, usually extends from November to February. This paper summarises the results of a study on glass eel migration, along the Mondego estuary, between 1988 and 1990, presents official data from captures (DGPA) and discusses the future of this fishery in Mondego, Portugal and in Europe. The probable causes for the decline in recruitment are analysed, and possible solutions are presented. The implications of the results with respect to the commercial fishery, population abundance in the watershed, and the contribution of Mondego eels to the European stock and recruitment are also discussed.

Introduction

Eel recruitment, eel stocks and eel fisheries have all declined since the 1970's and the future of the eel fisheries of Europe is an important matter that has seriously concerned fishery managers and scientists (Moriarty 1997). In fact, this concern expressed by so many people, led to the establishment of the working group EC Concerted Action AIR A94-1939, to pursue the project "*Enhancement of the European eel fishery and conservation of the species*" funded by the EU (Moriarty and Dekker 1997). The species Anguilla anguilla is classified as commercially threatened (CT) in Portugal (SNPRCN 1991).

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In Figueira da Foz the glass eel fishery started around 1950, when some representatives of a Spanish company visited the place with the intention of developing a system to capture glass eels and sell them to Spain. In the 1960's the glass eels were still very abundant and their fishery involved hundreds of fishermen, but in the 1970's, there was a decline in recruitment. It was then that the hand net was replaced by a type of fyke net, the portuguese botirão (Jorge and Sobral 1989).

The botirão (total length varying from 45 to 80 m) is a wing net consisting of two wings with a variable length (15 - 22.5 m) and height (2 - 4 m), attached to a conical net (length from 15 to 20 m) with a cod end in which the glass eels are trapped. The mouth of the net can measure 8 m. Although this net provides higher catches for fishermen, the considerable bycatch of postlarvae and juvenile of crustacean and other fish (unpublished data) does inevitably have an impact on the other fisheries both in the estuary and in the adjacent coastal area. The bycatch of this net can reach extremely high biomasses as happened in December 1987 (7.5 kg) and March 1988 (12.5 kg) in the Mondego estuary (Jorge and Sobral 1989).

Nowadays, the fishery for glass eels in the Mondego estuary is an activity that includes professional fishermen as well as many poachers using those wing nets which are illegal. Apart from the use of illegal nets, they also fish out of the official fishing season which, despite being variable, usually extends from November to February. All their catches are sold to brokers who afterwards transport them to Spain, the only European country where there is substantial human consumption of glass eels, considered a delicacy which can reach extremely high prices at the restaurants. Nevertheless, the business does not end in the restaurants. Most of the glass eels are exported to third parties, in other countries, for aquaculture purposes.

Glass eel migration

A study on the fluctuation of glass eel migration and its relation with some environmental parameters (lunar phase, salinity, temperature, rainfall and river flow) was done in the lower part of the Mondego estuary between 1988 and 1990 (Domingos 1991, 1992). Although glass eels are present in the Mondego estuary all year round (Fig. 1), according to these studies, there is a decrease in the amount captured out of the official fishing season, especially during summer months.

During winter, normally the most intense period of migration, temperature ranged from 9.7°C to 17.7°C at the surface and from 10.1°C to 18.3°C near the bottom. However, in July 1988, when there was an unexpected important yield, temperature ranged from 13.8°C to 20.2°C (Domingos 1991). Thus, the migratory activity does not seem to be related with water temperature. This conclusion is supported by Naismith and Knights (1986), and Tongiorgi et al. (1986), who state that the thermal preference of *A. anguilla* glass eel changes in relation to different environmental conditions.

The use of the tide to progress upwards is confirmed by the amount of glass eels captured according to the phase of the moon. The greatest catches were registered during new moon and full moon when the tides have wider ranges (unpublished data).

A research on the relation between glass eels' abundance and tidal evolution was performed, in the Mondego estuary, during a spring tide (March 1989), and it was noted that, after the turning point of the tide, the abundance started to increase and was highest when the water column was vertically homogeneous (Domingos 1991). These results are supported by McCleave and Kleckner (1982) who believe that, in order to ensure rapid landward transport, glass eels adjust their behaviour according to hydrographic conditions, selecting the flood tide to leave their shelter at the bottom.

As Gascuel (1987) and Domingos (1991, 1992) concluded, it seems that the river flow is the most important factor ruling the glass eel migration. The more intense period of migration occurs during winter months which is coincident with the rainy season. However, it was also noticed that heavy rain during the summer months, which is not very common, can also promote a more intense migration, as happened on the 13th July 1988 (Fig. 1), supporting the idea of the importance of river flow in this process.

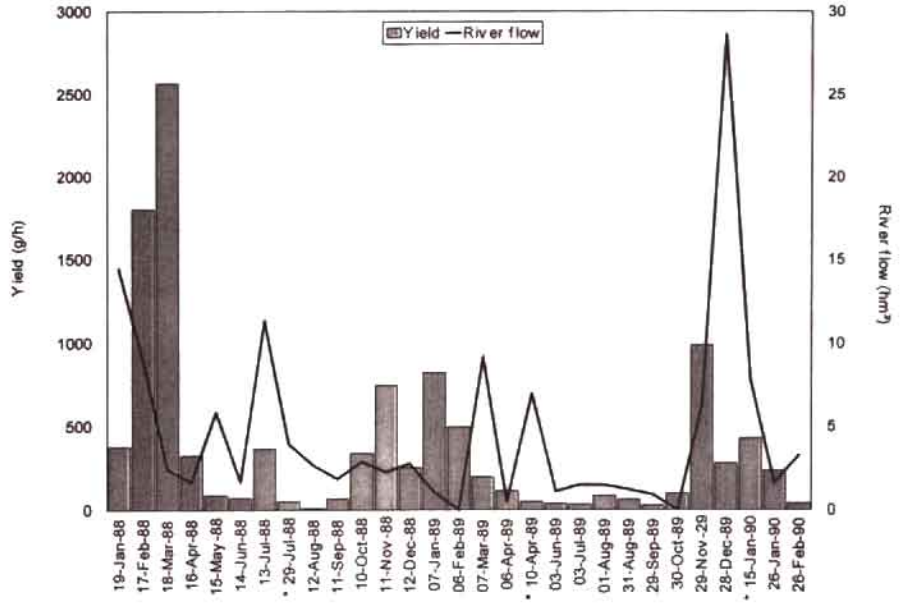

Figure 1. Relation between yield (g/h) resulting from passive fishing at new moon, and freshwater flow (hm3) from Raiva. (*) Fishing not performed at new moon.

The relation between river flow and glass eel migration has been indirectly confirmed by many authors (Deelder 1958, Creutzberg 1961, Crnjar et al. 1992, Tosi and Sola 1993, Sola 1995) who stated that glass eels and elver stages are, in general, attracted towards the freshwater odours.

Heavy rainfall and river flow can, however, have a negative effect on the success of migration, as happened in December 1989 and January 1990, suggesting that the river flow was too strong to enable glass eels to proceed with their migration using the flood tide (Domingos 1992).

Commercial fishery

The first document regulating the glass eel fishery, in national rivers, started to be applied since the 1st December 1985, until a law was published on the 17th of July (Decreto Regulamentar nº 43/87, 17th July). This legislation establishes the rules for this activity restricting it exclusively to inland waters within the maritime jurisdiction area, by means of a hand net either along the bankside or by boat, and obliges fishermen to report their catches. Another regulation (Portaria nº 564/90, 19th July) adds that the permission to fish for glass eels will only be granted to professional fishermen.

The official fishing period, as well as the maximum number of licences to be issued, are established each year by specific regulation, and the fishermen are obliged to return monthly reports on catches.

Official data on catches before 1985 are unknown because the previous legislation did not oblige fishermen to apply for fishing licences or report their catches. Table 1 contains data from those reports between 85/86 - 90/91 and 96/97 - 99/00 periods. It must be noted that until 1990 the number of established licences was rather large. More recently, an effort has been made to restrict the fishery by reducing the number of licences and, despite some extension of the fishing period in 97/98 and 98/99 (Tab. 1), in the last fishing season more strict measures were undertaken resulting in a reduction to only three months of fishing and 34 issued licences.

Table 1. Catch statistics for glass eels, licences and fishing period for each fishing season in Figueira da Foz.

Fishing season	Fishing period	Established licences	Issued licences	Total catches (kg)
	1 Dec - 28 Feb	(?)	94	383.7
1986/1987	1 Nov - 28 Feb	350	179	225.1
1987/1988	1 Nov - 28 Feb	350	29	345.5
1988/1989	1 Nov - 28 Feb	350	151	337.7
1989/1990	1 Nov - 28 Feb	350	260	761.8
1990/1991	1 Nov - 28 Feb	350	67	128.0
1991-1996	(?)	(?)	(?)	(?)
1996/1997	1 Nov - 28 Feb	150	(?)	(?)
1997/1998	1 Nov - 31 Mar	150	72	262.8
1998/1999	15 Nov - 15 Mar	80	52	264.0
1999/2000	15 Dec - 15 Mar	35	35	385.5

Source (DGPA)
(?) Data not available

Figure 2 illustrates the official catches. Despite being clear that total catch has sharply decreased in 1990/1991, it is obvious that there is a fluctuation which does not show any clear trend in glass eel abundance. The variation in the number of fishermen as well as differences in fishing effort, which are unknown, make the analysis more

difficult. Nevertheless the catch per fisherman has been higher during the last two seasons than during the period from 88/89 to 90/91, but it looks as if it is almost independent from the total catch.

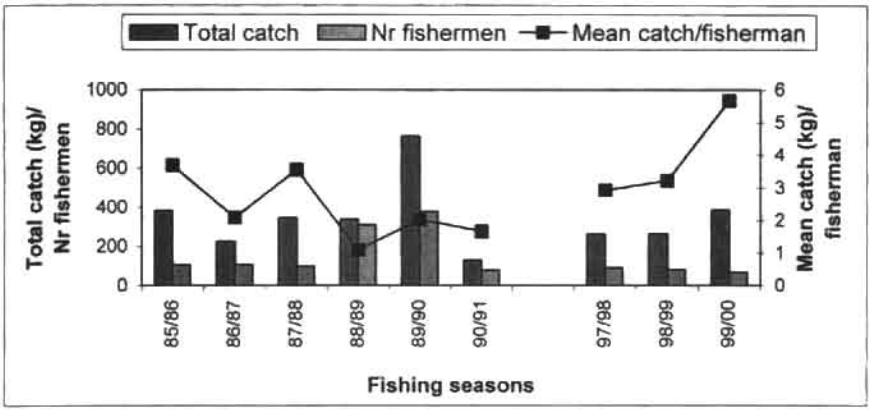

Figure 2. Catch statistics for glass eels, number of fishermen and mean catch per fisherman for the official fishing seasons from 85/86 to 90/91 and 97//98 to 99/00 periods in Figueira da Foz.

Large discrepancies occur between real catches and the amounts reported by the fishermen. As a matter of fact, I had the opportunity to be a witness of that situation, since I was informed by the buyers that, in February 1989, between the 19th and the 24th, 418 kg of glass eels were caught, while the official data, for the whole month, was 171 kg. This way it is clear that the statistics based on official data lead to false conclusions as catches are obviously underestimated.

Although neither table 1 nor fig. 2 suggest a decrease in catch per fisherman, maybe due to a bigger effort in fishing activity, the fishermen state that it is indeed decreasing which is supported by Moriarty (1992) and Castonguay et al. (1994) who state that American eel as well as European eel recruitment have declined dramatically since the 1980's.

Factors affecting the fishery

The fisheries have suffered severe losses from overfishing, mostly with illegal nets, physical modifications of the river, pollution, and parasites.

Overfishing

An effort to control the fishery has been done not only by introducing changes in the legislation, but also through the confiscation of illegal nets. This task has been

executed, either by the maritime police, who confiscated 281 "botirões" between 1998 and 9th March 2000 (Harbour Master Office from Figueira da Foz), or by the forest authorities (DGF), who confiscated 83 "botirões" between 1998 and 1999 (Eng. António Grácio, pers. comm.).

According to the same source (DGF), the confiscation of nets has mostly occurred between Ponte de Lares and Quinta do Canal, but some have also been confiscated between Ereira bridge and Quinta do Canal (Fig. 3). The location of the nets in these areas indicate that the tidal influence is noticed far beyond the limit of the maritime jurisdiction area since these nets are set across the river facing the incoming tide. According to the information given by the maritime police from Figueira da Foz, the nets are mostly found near the Cinco Irmãos, very close to the freshwater jurisdiction area.

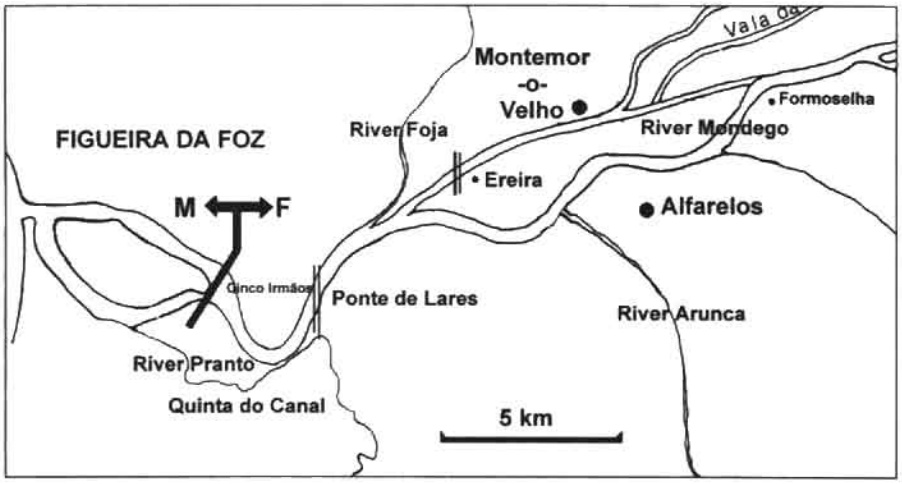

Figure 3. Limits of the maritime and freshwater jurisdiction areas and location of places where the wing nets (botirões) were apprehended. The line close to Cinco Irmãos is the limit of those areas. The arrows indicate the freshwater jurisdiction area (F) and the maritime jurisdiction area (M). The lines in the middle of the river are the bridges of Lares and Ereira.

Overfishing glass eels does most probably contribute to a low recruitment in the watershed, with inevitable implications in the subadult population (yellow eels and silver eels). The capture of yellow and silver eels is regulated in both freshwater and brackish water with definition of minimum size of capture (22 cm), and regulated fishing gear. Longline, fishing rod, "sertela" and "enguieira" are allowed in the Mondego freshwater area (Portarias nº 643/96, November 8th and nº 164/99, March 10th), and longline and fishing rod are the permitted gear for fishing eels in the maritime jurisdiction area (Portaria nº 564/90, July 19th). Apart from this, there is no closed season, and data from those captures are underestimated, or mostly unknown. An evaluation of the stock based on catch statistics is therefore almost impossible.

Water demands and dams

During the last 20 years several human actions have severely changed the River Mondego watershed. The river bed regulation and embanking to prevent the floods, the channelisation of the river and finally hydroelectric schemes have contributed to completely change the river morphology and hydrology. The natural flow regime was also affected by the regulation of the water flow.

The population of *A. anguilla* has suffered severe losses due to anthropogenic factors. Water demands for agriculture, industry, human consumption and hydroelectric power are detrimental for fisheries if not properly managed. Studies to define ecological flows are extremely important in this watershed.

Dams, such as Aguieira and Raiva, have become major obstacles to upstream and downstream migration, and severe regulation of water levels, mainly by these power stations, has almost dried certain parts of the river and decreased the flow needed to attract the glass eels to the estuary. There are no fish passages in these dams and although eels are capable of finding their way up through humid soil during rainy periods, obstacles with a height of 80 metres, as in Aguieira dam, are inevitably discouraging, even for animals with a strong rheotropic behaviour. Upstream these areas fishermen claim that eels have become rare shortly after the dams were built.

Apart from hydroelectric power plants there is another relatively high obstacle downstream from that area, the Açude-Ponte dam, at Coimbra, which has a fish passage that is ineffective. Although some eels manage to pass this obstacle with a height of 4 m, the free colonising area is restricted to the last 35 km of the river.

Size is an important factor in the eels' ability to climb weirs since the climbing of smooth vertical surfaces is restricted to elvers and very small juveniles (Naismith and Knights 1993). As the Açude-Ponte dam is still relatively close to the river mouth, it is possible to find small eels which weight enables them to climb and overcome the obstacle. The probabilities of this happening in dams such as Raiva and Aguieira, further upriver, is much lower.

Another impact of dams on the species is related to the downstream migration of silver eels. Not only they constitute important obstacles, but the passage through turbines of hydropower stations usually provokes a considerable mortality in this migrant population, a problem well known in European rivers (Berg 1986, Hadderingh et al. 1992). Furthermore, loss of available habitat for growth, has reduced the number of females since the distribution of males and females differs from estuary to freshwater with more females in the upper reaches, an observation that is supported by Costa et al. (1993) and Naismith and Knights (1993). The number of females reaching the Sargasso sea is vital for the success of reproduction.

Pollution

The plan for developing agriculture in the Lower Mondego has contributed to poor water quality with eutrophication problems in certain areas. Modern agriculture with its emphasis on the use of chemical fertilisers, herbicides and pesticides which, in

the case of rice production are distributed from the air, has lead to an increase in water pollution. This is considered one of the most polluted areas in Portugal (INAG 1995). Industry and domestic sewage can also be a problem in certain points. Textile industry, located in some areas upstream, is another problematic source of pollution (INAG 1995).

Although eels are one of the species least affected by eutrophication and pollution (Dill 1990), human consumption of these animals may become dangerous in terms of public health. In the Thames River commercial fishing effort in the estuary was extremely reduced following the discovery of high levels of pesticide residues in the eels (Naismith and Knights 1993).

Parasites

The nematode *Anguillicola crassus*, a swimbladder parasite originally hosted by *Anguilla japonica*, was brought into Europe in the early 1980's. Although apparently harmless to the native host it appears to be pathogenic in the European eel only (Székely 1996). It causes an impairment of the swimbladder function, which may hamper the success of the spawning migration, as it increases the energy expenditure necessary for the eel to remain at a certain water depth (Würtz et al. 1996). Eels highly infected with this parasite loose their appetite and vitality and become emaciated (Egusa 1979). Although this study was done on cultured eels, it would be important to verify whether the same happens in natural conditions. If that is the case, a new mortality factor may have to be taken into consideration.

This parasite has been recorded in the eels from Mondego basin captured from 1988 to 1990 mostly inside the swimbladder, but they were also found in the mesenteric fat inside the abdominal cavity (unpublished data).

Management proposals

Moriarty and Dekker (1997), in a Concerted Action funded by The EU, have considered three management options for fishery managers: i) Control of fisheries including restrictions on fishing areas, periods or methods, to prevent or reduce exploitation; ii) Stocking strategies, which are vital in catchments with obstacles and in isolated waters suitable for eel, and increase in escapement of silver eels, especially large females in order to enhance the reproductive stock; iii) Use of passes to enhance recruitment into freshwater catchments.

In the River Mondego several threats to the stock have been previously identified. A solution to enhance the stock should include: i) the construction of efficient eel passage devices, which are not necessarily expensive, in all dams up to Aguieira (including this one), allowing the habitat available for the species to increase and return to its original size before the construction of dams; ii) the construction of parallel channels running for some kilometres upstream the dams to prevent migrant silver eels from being sliced in turbines; iii) to increase the river flow, at least during peak migration

season, so that glass eels can continue to be attracted to the Mondego estuary; iv) to Improve water quality, especially in the lower Mondego, which hopefully will be achieved with the implementation of the Council Directive for Water Quality and the Waterbasin Management Plan; v) to control and extinguish the black market for glass eels, which promotes illegal fisheries and overfishing contributing to the decline of recruitment; vi) to promote monitoring programmes for recruitment and downstream migration of silver eels, aiming at the evaluation of the stock; vii) to determine the carrying capacity of the watershed in order to develop a model to predict yield, and be able to advise fishery managers on the most efficient management of the eel fishery aiming at a sustainable exploitation of this resource; viii) to promote toxicity and bioaccumulation studies to check whether there is no problem for public health as happened in the Thames, and finally ix) to analyse the level of contamination by *A. crassus*.

All these proposals can be applied, with the necessary adjustments, to most of our watersheds. However, management measures for each watershed or country, despite being a valuable management action in helping to support the European stock, will not solve the problem if there is no international involvement and cooperation.

Eel fisheries have, for many decades, been managed on a local or national basis as if they were represented by independent local stocks. Recently, the question on whether management at a national level can sustain the stock throughout the distribution area has arised because the European eel is a shared marine resource since it reproduces in a common breeding area in the open ocean, and should be treated as such (Moriarty and Dekker 1997).

The EU Concerted Action is of vital importance since the European stock is under severe stress especially with the increasing demands of glass eels for aquaculture from East Asian countries, mainly China, which is competing with Japan in the production of eels. Either severe restrictions in European policy towards glass eels exports are established and exclude countries outside Europe, or the European eel will follow the same steps as *A. japonica* glass eels which recruitment has definitely declined since the 1980's (Gousset 1992), maybe because of overfishing for aquaculture purposes. Another way to solve the question would be to include the species in the CITES Convention. This way, exportation of glass eels to Asia would have to end, and the management of the stock would become less difficult.

In a near future, the European Concerted Action should be enlarged to include countries outside Europe, namely the United States of America, as there is also a decline in recruitment of the American eel *(A. rostrata)*, a species which has not been overexploited. This fact points out that climatic changes may be responsible for some of the decline in recruitment due to their implications on oceanic currents. According to Moriarty and Dekker (1997), further knowledge on the silver eel migration, reproduction, and leptocephalus biology could clarify the oceanic causes for the decline in recruitment.

Finally, a strong financial support to the development of studies on artificial reproduction, larval development and growth could be, in the long run, the solution for both aquaculture demands and conservation of the species in nature. Maybe this way

there is hope for the leptocephali to continue travelling along with the oceanic currents.

"The eel as a species may not be threatened, but many of the fisheries have an uncertain future until a European management plan is put into operation. At this stage we leave the contribution that may be done by the scientists and hand the matter over to the economists and politicians." (Moriarty 1997).

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