CATCH ESTIMATES AND BIOECOMOMIC ANALYSIS OF FISHING BAIT IN EUROPEAN COASTAL LAGOONS: THE CASE OF AVEIRO LAGOON IN PORTUGAL

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ABSTRACT

There has been an extensive review on the environmental and commercial significance of fishery species in European coastal lagoons in addition to a representative indexing of fishing fauna. However, the findings on the economic effects of fishery and particularly bait digging to the local economy are scarce while the impacts of the activity to the stock reserves of different species are poorly explored. To this end, the current study has estimated the digging effort and catch rate of the solitary tube worm *Diopatra neapolitana* species while different management scenarios were scrutinized through a bioeconomic analysis. The Ria de Aveiro coastal lagoon at northwest Atlantic coast of Portugal was adopted as a representative case study of extensive bait digging activity for commercial purposes.

Keywords: Lagoons, Catch Estimate, Bioeconomic Modeling, Management Scenarios, Diopatra neapolitana, Portugal

1. Introduction

In the shallow subtidal and intertidal flats of the Ria de Aveiro lagoon several digging activities take place every day, such as shellfish and bait catch (Cunha *et al*., 2005). The Ria de Aveiro is a shallow coastal lagoon located in the north-west coast of Portugal and is connected to the Atlantic Ocean through a single inlet. The lagoon forms a unique mesotidal wetland area, characterized by four main channels with several branches forming islands, inner basins and mudflats.

The solitary tube worm *Diopatra neapolitana* or *casulo* as it is mostly known in Aveiro lagoon has been traditionally harvested as a bait for recreational and professional fishing activities (Cunha *et al*., 2005).C*asulo* is a sedentary carnivorous polychaete species, 15–50 cm long, which lives inside a membranous tube buried in intertidal mudflats (Fauvel, 1923; Leguerrier *et al*., 2004). The *casulo* digging activity is conducted in the mudflats exposed during low tide periods. It is practiced by individuals as well as by groups of diggers that collect *casulo* together upon previous order by one or several local bait stores (Cunha *et al*., 2005; Freitas *et al*., 2011).

Because the Ria de Aveiro lies in a temperate zone, biological production and bait digging change seasonally. Furthermore, many of the shellfish digging activities in the Ria also depend on tides. The tides may allow or obstruct the accessibility to fishing grounds for benthic species, influence the operation of fishing gear and affect the behaviour of the target species (Pires *et al*., 2012). Of lately, more people practice *casulo* digging either as a supplementary or as a main source of income. However, the economic value of *casulo* digging and the consequences of potential over-harvesting are yet unknown. Two previous studies have dealt with fishing effort and catch estimates of the *casulo* digging (Cunha *et al*., 2005; Freitas *et al*., 2011). Still though there is a knowledge gap on the catch estimates and the economic sustainability of the digging activity in the area.

In this context, the present study initially assessed the annual catch and catch per unit effort (CPUE) of *casulo* while the possible effects of tidal trends and seasonal variations were investigated. Further, a static bioeconomic analysis provided some insights on the economic and environmental sustainability of digging activity. Two main canals of the Ria de Aveiro lagoon were adopted as case study areas where a survey took place for one year period (2012-2013).

2. Methodology

We initially estimated the catch or as better known in fisheries, the "fishing effort" (E) of *casulo* activity. However, for a better suitability of the fishing effort term to our analysis we have renamed it as "digging effort" so at to better represent the relevant activity. To estimate the digging effort we applied methods based on the progressive counting method of Hoenig *et al*. (1993). This method involves having survey agents repeatedly travelling a route encompassing the target area and counting all diggers throughout the day. In this context, we employed survey agents travelling a route around the study area and counting the number of diggers in each sampling mudflat every 45 minutes. The Effort (E) spent for the catch of the *casulo* was based on the distribution of diggers (counts) over time, and was algebraically expressed as:

$$E = D \times HRs \quad (1)$$

Where, D = Diggers, HRs= Hours

We also conducted on-site interviews to estimate catch per unit effort (CPUE), based on the method of Pollock *et al*. (1997), in which bait diggers were randomly selected and interviewed after the digging session has ended. The catch per unit effort (CPUE) counts the number of polychaetes caught per digger per min, based on the on-site interviews, and is algebraically expressed as below:

$$CPUE = C / D \times HRs \quad (2)$$

Where C = Catch, D = Diggers, HRs= Hours

It is noted that the CPUE is an indicator frequently used in bioeconomic modeling of fishery (Cochrane and Garcia (Eds), 2009). We also inspected the effects of seasonal and of tidal range on daily catch and on the CPUE of individual diggers by using 2-way orthogonal ANOVA.

Further, the current study attempted to elaborate an economic assessment on the income generated by *casulo* and the management plans to be introduced under different regulatory frameworks. We implemented a static bioeconomic model for the bait digging activity conducted in the period of October 2012 - October 2013. Initially, we considered that the *casulo* activity takes place as an open-access digging activity without any particular property rights and regulatory policies. The open access equilibrium however may not ensure the sustainability of *casulo* reserves. Thus we tried to identify the Maximum Sustainable Yield (MSY) which should provide a sustainable income and also preserve the population of the species. It is noted though that the MSY point does not also foster the maximum economic benefits for the *casulo* diggers. To this end, the maximum economic yield (MEY) equilibrium was also sought, which could ensure the highest benefits for the diggers in relevance to the effort spent for this activity (Flaaten, 2010).

The costs were assumed to be homogenous and constant for each digger without presenting any significant variation. In other words, each digger was considered to be equipped with the same gearing while he/she was taking an equal time for reaching and leaving the digging mudflat. Also, the time spent for the digging activity was regarded to be similar for each digger. We also assumed that the price of *casulo* for the period examined was the same across time and quantity.

The two major *casulo* digging areas where the survey took place are located in the Canal de Mira, in the south of the lagoon, and in the Canal S. Jacinto-Ovar, in the north of the lagoon. Because of logistic constrains, a much smaller sampling was conducted in Canal de Ovar, which restricted the tidal and seasonal assessment as well as the bioeconomics analysis of *casulo* digging.

3. Results

The catch and the CPUE data of the survey along the period 2012-2013 shows some trends that may provide some inferences for the digging activity in Ria de Aveiro. As presented in Figure 1, the catch is plotted against the digging effort for all diggers along the observation days. A clear trend is presented among the digging activities, which foresees that the increase in digging effort in terms of hours will accordingly trigger an increase in the total catch of *casulo*. The findings are in full accordance with the theoretical background that indicates the catching trends of a fishing species in the short run (Flaaten, 2010).

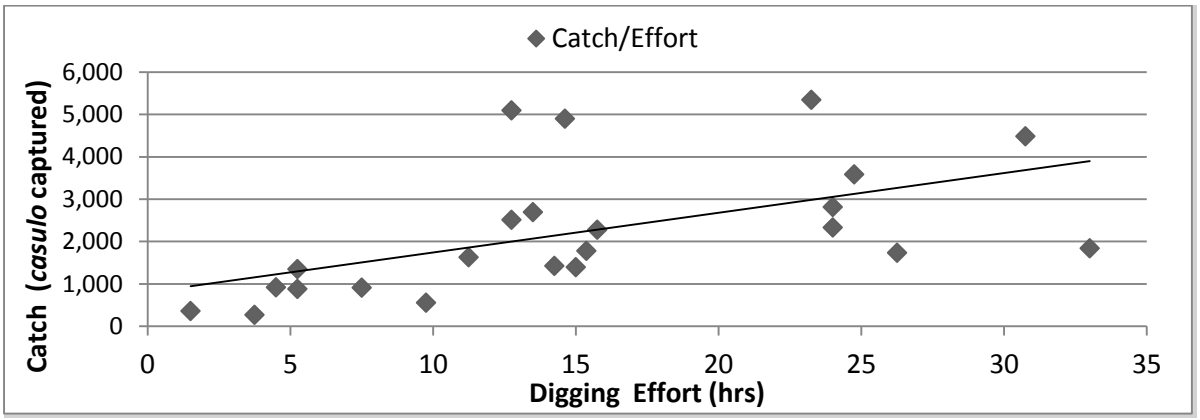

Figure 1: Catch of casulo as a function of effort.

The mean digging effort was found to be higher in spring tides in all the four seasons, except for autumn. Winter was the season in which the mean digging effort was higher and spring was the season that presented the lowest values. However, significant effects of season, tidal range and their interaction on effort were not detected ($p > 0.15$ in all cases). The mean daily catch was usually higher in spring tides, except in autumn season. Again however, no significant effects were detected from season, tide range and of the interaction on effort ($p > 0.20$ in all cases).

In turn, the CPUE as a function of the digging effort is exhibited in Figure 2. As presented, a moderate but distinctive downward slope of the CPUE is indicated for the period 2012-2013. This downward slope suggests that the higher digging effort may decrease the CPUE and hence the economic efficiency and stock reserves of *casulo* species.

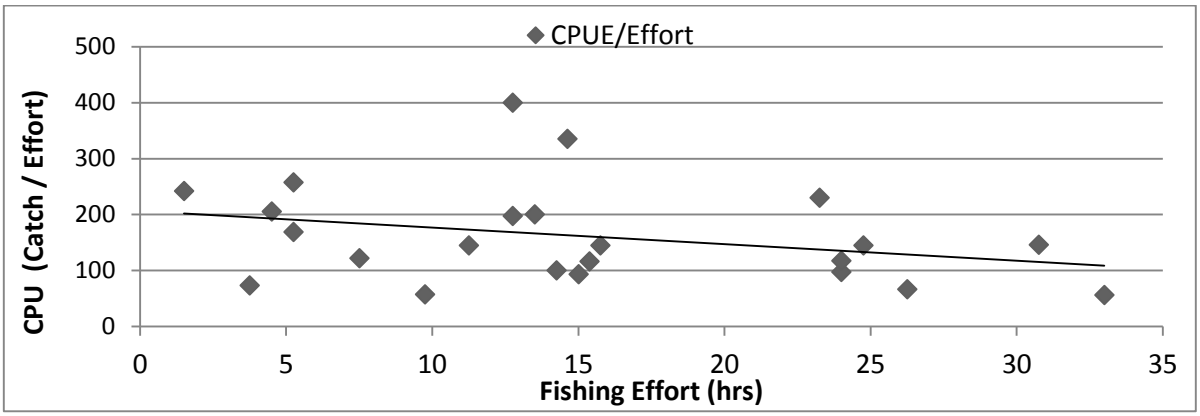

Figure 2: CPUE of casulo as a function of effort

The bioeconomic analysis for the open-access scenario identified when the total revenues will intersect the total costs and profits will be then eliminated. As estimated, the total revenues are about to intersect total costs at 38.08 hrs/day when all the diggers are counted for each day. The corresponding effort for each digger is counted at 8.92 hrs/day.

In turn, the Maximum Sustainable Yield (MSY) scenario identifies the point where the marginal revenues should be set to zero while at the same instance the total revenues should be maximized. The marginal revenues were ceased at the 22.27 hours/day for all diggers or otherwise at 5.22 hours/day per digger. At this point, the total revenues were maximized and appeared to largely overcome the total costs. In particular, the total revenues were identified on 239.68 EUR/day for all diggers or 56.16 EUR/day for each digger. Correspondingly, the total costs were mounted at 87.77 EUR/day for all diggers or 20.57 EUR/day for each digger. The difference between the total revenues and costs for each digger revealed a profit of 35.6 EUR/day or else 6.82 EUR/hour.

Finally, our data analysis has also captured the Maximum Economic Yield (MEY) scenario where the marginal revenues intersect with marginal costs while the total revenues should surpass the total costs with the highest possible difference. The marginal revenues intersected the marginal costs at 17.24 hrs/day for all diggers or else at 4.07 hours/day per digger. At this point, the total revenues were getting to 219.10 EUR/day for all diggers or 51.34 EUR/day for each digger. Correspondingly, the total were pointed at 68.43 EUR/day for all diggers or 16.03 EUR/day for each digger. The MEY scenario assumed a profit of 35.3 EUR/day or else 8.68 EUR/hour for each digger.

4. Diccussion and concluding remarks

The results obtained for Canal de Mira demonstrate that season, tidal range and their combination have a non-significant effect on digging effort. However, higher values of the fishing effort and daily catch were found in spring tides, in all seasons except autumn. This numerical difference shows that during this higher amplitude tides there are more diggers taking advantage of the exposed area of the mudflats, since they can explore a larger area in one tide. Additionally, spring tides enable access to the less frequently explored segment of the casulo population at lower tidal levels, which is exposed during these periods.

The bioeconomic analysis has indicated that in the open-access scenario, each bait digger could expand the digging activity until 8.92 hrs/day and eliminate the profits. The sampling survey has captured the daytime activities of each digger, which were limited to maximum of four (4) hours per day. In this case, the maximum effort described in the open-access scenario could be hardly attained. Based on previous surveys there are indications that bait diggers in some instances work in a second tide, during spring and summer when two high amplitude low tides occur during day-light hours (very early morning and early evening), or during low tides during the night, albeit with much less harvest (Cunha *et al*., 2005). The digging activity may therefore have been underestimated. It is highly unlikely, however, that this possible underestimation of effort would result into a pooled maximum effort of 8.92 hrs/day. However, no survey has been conducted during the present study to account for a second daily tide, and this should be explored in future studies.

In the case of the maximum sustainable yield (MSY) scenario, it reveals a 5.22 hours/day maximum effort per individual which still seems unattainable given the current tidal constraints. More closer to the current conditions appears to be the maximum economic yield (MEY) scenario of 4.07 hours/day effort which could be practiced by each digger on a daytime basis. Interesting is the case that in the MSY scenario the *casulo* diggers can earn more revenues per day if working the maximum daily effort (5.22 hours) than in the case of the MEY scenario. However, the hourly revenues are distinctively higher (8.68 EUR) in the case of MEY than in the MSY scenario (6.82 EUR). This difference indicates that the diggers may currently earn the highest possible income per day if working only on the daytime where the digging activity cannot exceed the 4 hours due to the tidal constraints.

However, it should be strongly mentioned that the results are based only on the time period 2012-2013 and monthly observations. A more detailed and longer time-series data is necessary to firmly conclude on the aforementioned findings.

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