

Estimation of the *Diopatra neapolitana* annual harvest resulting from digging activity in Canal de Mira, Ria de Aveiro

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Abstract

Bait digging for recreational and commercial fishing is widely practiced and economically significant. Since polychaetes often form part of the diets of several demersal species they are commonly used as fresh bait by sports and professional fishermen. The objectives of this paper are to quantify the annual bait digging of harvest *Diopatra neapolitana* in the intertidal mudflats of Canal de Mira, Ria de Aveiro, Portugal and comment briefly on its significance for management. Annual harvest, defined as *D. neapolitana* (kg) caught by collectors, was calculated as the product of independent estimates of harvesting effort using a progressive count and harvest rate through an access survey. Harvesting effort was higher during spring tides in all seasons except in winter and harvest rate lower during winter, regardless of tidal range, and higher during spring tides. Bait collection in the Canal de Mira is very intense with an annual harvest in excess of 45,000 kg per year valued at over € 325,000 per year.

Management of the remove needs to take account of both the ecosystem impacts of bait digging and the socio-economic importance of bait digging to the many families involved.

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1. Introduction

Diopatra neapolitana (Delle Chiaje, 1841) is a carnivorous, 15–50 cm long sedentary marine polychaete that lives inside a membranous tube buried in the sed-

iment (Fauvel, 1923; Leguerrier et al., 2004). This species inhabits the intertidal mudflats of estuaries and shallow water bodies in the Atlantic and Indian oceans (Fauvel, 1923; Paxton et al., 1995; Paxton and Chou, 2000). In Ria de Aveiro it is found buried on muddy sediment around 0–4 water depth. The tube consists of an inner lining secreted by its inhabitant, and an outer layer of foreign particles like sand grains, fragments of hard parts from other animals, or plants.

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Usually, it is longer than the animal (Paxton, 1986). The *Diopatra* genus comprises several species with very distinct reproductive patterns. The development of *D. neapolitana* includes a larval phase made up of lecithotrophic free-swimming larvae (Bhaud and Cazaux, 1987; Fadlaoui et al., 1995). Details of its breeding strategy are unknown, although a study carried in Canal de Mira suggests that they reproduce during summer and have separated sexes (R. Portela, pers. commun.).

D. neapolitana is commonly used as fresh bait by sport and professional fishers to catch several important demersal fishes like *Dicentrarchus labrax*, *Sparus aurata*, *Diplodus sargus*. Only the anterior part of the body (approximately 10 cm) is collected and utilised as bait. Digging activity to collect bait for recreational or professional purposes is widespread and has attained commercial significance in many parts of the world (Castro, 1991; Olive, 1993). In 1999 the European bait worm market was estimated to have a value of about € 200 million. More exact quantification is difficult because much of the trade in Europe is conducted through a “black economy” in which sales are not declared for VAT purposes (Olive, 1999).

The ecological impacts of this digging activity have concerned scientists for almost a quarter of a century. The impacts include the effect on bait species populations and their recovery dynamics (Blake, 1979; Cryer et al., 1987; Olive, 1993); the effect on the sediment texture and composition (Anderson and Meyer, 1986); the consequences for associated faunas including infauna and bird populations (McLusky et al., 1983; Van den Heiligenberg, 1987; Ambrose et al., 1998; Luís, 1998); and the effect on the bioavailability of heavy metals (Howell, 1985).

In Portugal *D. neapolitana* is collected in several estuaries (Sado, Ria Formosa and Ria de Aveiro), but the value of the total harvest is unknown or at best underestimated. The purpose of this paper is to quantify the annual harvest, harvesting effort and harvest rate of *D. neapolitana* resulting from the digging activity in the intertidal mud flats of Canal de Mira, and to make some observations concerning management. This kind of study is important because the lack of information on such more or less illegal use of natural resources in the coastal zone weakens the reliability of stock assessments and increases the risk of making inappropriate management decisions.

2. Materials and methods

2.1. Study area

The Ria de Aveiro (Fig. 1) is a complex shallow lagoon located on the northwest Portuguese coast, comprising an intricate system of bays and narrow channels, with a surface area of about 47 km². Today communication with the Atlantic Ocean is through an artificial canal. According to the classification of Pritchard (1967) it can be classified as a bar-built estuary. The Canal de Mira, where sampling took place, is the second largest channel in terms of average width and runs south–southwest from the mouth for 25 km, parallel to the coast. It receives a continuous freshwater supply through a small system of lagoons and streams. With a salinity range from full seawater salinity at the inlet to freshwater in the upper reaches, the Canal de Mira behaves like a tidally and seasonally poikilohaline estuary, where vertical physicochemical gradients appear to be negligible (Moreira et al., 1993; Abrantes et al., 1999).

After an initial pilot study covering the entire extent of the channel in April 2001, a 1.510 km² intertidal area was selected for more detailed analysis (Fig. 1C). Here, at periods of low tide, the numbers of *D. neapolitana* gatherers were visibly higher than on other mud flats. A rich macrozoobenthic community exploited by recreational and professional bait diggers, and dominated by *Nereis diversicolor*, *Scorbicularia plana*, *Cerastoderme edule* and *D. neapolitana* populates this area. According to Moreira et al. (1993) the sediment comprises sandy muds, medium sands and muddy sands. During low tide this area becomes naturally divided by small water courses into seven contiguous units identified as A–G (Fig. 1C).

2.2. General sampling procedures

Total harvest, here defined as *D. neapolitana* (kg) caught by collectors, was estimated as the product of independent estimates of harvesting effort and harvest rate (i.e., harvest per unit of effort). Therefore, we separated the sampling procedure into two components: a census of collectors to ascertain harvesting effort and interviews to determine the harvest rate.

The sampling programme was carried out over 12 months (May 2001–April 2002) during diurnal low tide

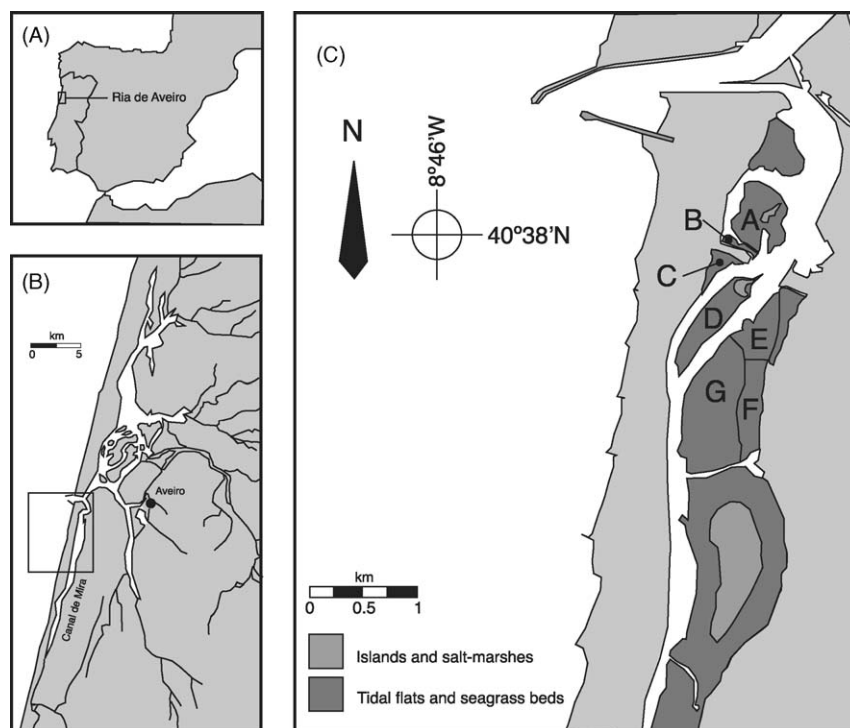


Fig. 1. Ria de Aveiro and Canal de Mira, Portugal, with location of the mudflats areas (A–G).

period (7 a.m.–7 p.m.), on weekdays, weekends and at holiday times. Within each month four to five sampling dates were randomly allocated, totalling 57 sampling dates during the whole year. The dates comprised both neap and spring tide situations. After a few nocturnal samplings it was concluded that the harvesting activity at night was sufficiently negligible to be discounted from the sampling programme.

Biological production in temperate areas is a seasonal phenomenon. Therefore, it is likely that both harvest effort and harvest rate change with the season of the year. Actually it became clear during fieldwork that larger numbers of collectors were present during summer months. Moreover, spring tides expose a wider area and the lower zones of the intertidal flats, where segments of the population that are unavailable for exploitation during neap tides exist.

2.3. Statistical methods

In order to test if tidal range (spring tides, neap tides) and season (spring, summer, autumn and win-

ter) had any influence on harvesting effort and harvest rate variables, we performed a two-way orthogonal ANOVA using tidal range and season as fixed factors. A Cochran's test (Sokal and Rohlf, 1981) indicated that variances were homogenous in both cases. Therefore, transformation of variables was not needed. Since the average tidal range at the Ria de Aveiro is 2 m, the distinction between spring and neap tides was set at this value. Since total harvest is calculated as the product of the two variables, we decided to calculate mean values of both variables for each combination of season and tidal range. The mean values were then used to calculate the total annual harvest.

We divided the total annual harvest by the mean bait weight, in order to estimate the number of polychaetes collected during the year. To calculate the mean bait weight we took 90 individuals obtained from the collector's baskets randomly chosen when they were leaving the areas and determined the weight in the laboratory. Although the animals were sampled from all seasons we were not able, because of logistic reasons,

to collect enough replicates to allow the analysis of seasonal differences in wet weight.

2.4. Harvesting effort

To estimate harvesting effort we adapted the progressive count method utilized to calculate sport-fishing effort, described by Hoening et al. (1993). This method involves having a survey agent travel a defined route covering the entire fishing area, and counting all anglers encountered throughout the day. The estimator is based on a sampling procedure analogous to a bus route with prolonged stops. In Canal de Mira bait digging takes place only when the mud flats are exposed and accessible, which corresponds approximately to a 3.5 h period around low water. Hence, the collector's entrance and departure hours are closely correlated to the tide. Bait diggers usually walk to their areas when the sediment is still inundated (water height around 20 cm) and start work immediately before the exposure of the mud flats or when they are able to distinguish *D. neapolitana* holes in the sediment. For this study we designed a circuit with stops at seven strategic watch-

ing points (A', B', C', D', E', F' and G') on the bank, from which it was possible to observe all the collectors in the seven mudflat areas (A, B, C, D, E, F and G). Identification of the species being harvested by each person was crucial, in order to insure that only *D. neapolitana* gatherers were counted. With the use of binoculars, this recognition was possible because collectors make use of specific gear to harvest different species. For *D. neapolitana* collectors use a shovel or hoe to dig the sediment. They locate the holes in the mud which indicate the presence of the buried *D. neapolitana* and dig 15–20 cm obliquely into the sediment thereby cutting the animal plus tube. Usually they collect only one animal on each trial, which is stored in a bucket. The areas are dug continuously day after day.

Hoening et al. (1993) suggested three requirements for proper use of the progressive counting method that were accomplished in this study: (1) a starting location along the survey route chosen randomly; (2) a direction of travel chosen randomly; (3) a travel speed that is greater than that of all the collectors while they are working (but not necessarily when they are traveling from one area to another). The circuit had 45 min

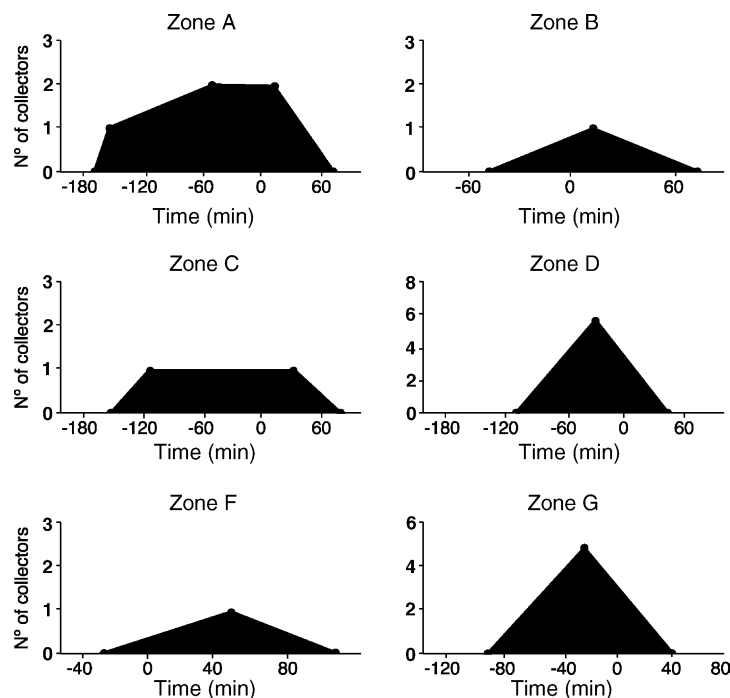


Fig. 2. Plot of Number of collectors against Time for the 23rd of September, for each of the zones. Zone E had no collectors on that day. Total estimated harvesting effort for this day was 1430 collector min.

duration; much less than the time spent harvesting (ca. 3.5 h). Hence, between two consecutive high water tides, the entire route was repeated three or four times, depending on tide amplitude. The trip began immediately before collectors started entering the areas and finished after they had all left. The exact clock time was registered in every count.

Daily harvesting effort (HE; collector min) in each survey day for each area (A–G) was calculated by plotting the number of diggers against time (see Fig. 2 for a representative example). Time was expressed in minutes relative to the moment of low water as estimated from the tide tables of the Hydrographical Institute calibrated specifically for the Canal de Mira. The area under the curve was calculated by planimetry. The daily harvesting effort for the whole area (HE_{daily}) is the sum of the harvesting effort (HE) recorded in each area (A–G) of the sampled day (Table 1).

We calculated the mean daily harvesting effort (\overline{HE}_{S-T}) for each season–tidal range combination by summing daily totals (HE_{daily}) and dividing by the number of days actually sampled within each season–tidal range combination (d_{S-T}) (see central tendency and standard error in Table 1).

2.5. Harvest rate

In order to estimate harvest rate, also called harvest per unit of effort, (HPUE; $\text{kg}(\text{collector min})^{-1}$), we adapted the survey design described by Pollock et al. (1997) for recreational fisheries. Generally, this kind of method involves on-site interviews that may either be based on access (complete trips) or roving (incomplete trips) interviews. In our study, records were based in complete trip interviews since collectors were interviewed as they exited the mud flat at each of seven areas (A–G). For each complete trip interview we recorded the wet weight (kg) of the total catch of *D. neapolitana* harvested (tube plus animal) as well as the length of the corresponding digging period (min). The number of persons that contributed to the weighted sample was also registered, sometimes more than one person being involved. The total weight (kg) of the creel was calculated using a spring balance. According to Jones et al. (1995) and Pollock et al. (1997) when the access method is used the appropriate rate estimator is the ratio of means estimator – also called “per day” estimator ($HPUE_{\text{per day}}$) – calculated by dividing the total

daily harvest (H ; kg) by the total daily effort (HE_i ; collector \times min) of all the interviews (Table 1).

The mean daily harvest rate (\overline{HPUE}_{S-T}) for each season–tide combination was calculated by dividing the “per day” estimator of harvest rate of each season–tidal range combination ($HPUE_{\text{per day}}$) by the number of sampled days in each season–tidal range combination (d_{S-T}) (see central tendency and standard error in Table 1).

2.6. Total harvest and total number of individuals

The mean daily harvest for each season–tidal range combination (\overline{HD}_{S-T} ; kg) was estimated as the product between the mean daily harvest effort (\overline{HE}_{S-T}) and the mean daily harvest rate (\overline{HPUE}_{S-T}) (Table 1). The corresponding standard error was calculated considering that the mean daily harvest effort, \overline{HE}_{S-T} , is independent of the mean daily harvest per unit of effort, \overline{HPUE}_{S-T} (see standard error in Table 1).

The total harvest for each season–tidal range combination (H_{S-T}) was estimated as the product between the mean daily harvest for each season–tidal range combination \overline{HD}_{S-T} by the total number of days within each season–tidal range combination – sampled and non-sampled – (D_{S-T}) (see central tendency and standard error in Table 1).

The total annual harvest (H_{total}) was calculated by summing the total harvest for each season–tidal range combination (H_{S-T}) (Table 1). To calculate the corresponding standard error we used parametric bootstrap methods (Efron, 1993) to estimate confidence intervals for H_{total} values at the 95% level (see standard error in Table 1).

The mean bait weight (\overline{W}) was calculated by dividing the total weight of the sampled polychaetes (W_{total}) by the number of individuals (n) (see central tendency and standard error in Table 1).

The total number of collected polychaetes (N_{total}) was calculated by dividing the total annual harvest (H_{total}) by the mean bait weight (\overline{W}) (Table 1). The standard error completely depends on the distribution type selected to modulate the mean weights. For instance, if we choose the Normal distribution (based on the Central Limit Theorem) the standard error for N_{total} even becomes ∞ . Like before, we used the bootstrap methodology to obtain confidence intervals for N_{total} values at the 95% level.

Table 1
Formulas of the statistics used in the study

Statistics	Central tendency	Standard error
Daily harvesting effort for the whole area	$HE_{\text{daily}} = \sum_A^G HE$	–
Mean daily harvesting effort for each season–tide combination	$\overline{HE}_{S-T} = (\sum HE_{\text{daily}}) / d_{S-T}$	$S_{\overline{HE}_{S-T}} = S_{HE_{S-T}} / \sqrt{d_{S-T}}$
“Per day” estimator of harvest rate	$HUPE_{\text{per day}} = \sum H / \sum HE_i$	–
Mean daily harvest rate for each season–tide combination	$\overline{HPUE}_{S-T} = (\sum HUPE_{\text{per day}}) / d_{S-T}$	$S_{\overline{HPUE}_{S-T}} = S_{HUPE_{S-T}} / \sqrt{d_{S-T}}$
Mean daily harvest for each season–tide combination	$\overline{HD}_{S-T} = \overline{HE}_{S-T} \overline{HPUE}_{S-T}$	$S_{\overline{HD}_{S-T}} = \sqrt{\left(S_{\overline{HE}_{S-T}}^2 + \overline{HE}_{S-T}^2\right) \left(S_{\overline{HPUE}_{S-T}}^2 + \overline{HPUE}_{S-T}^2\right) - \overline{HE}_{S-T}^2 \overline{HPUE}_{S-T}^2}$
Total harvest for each season–tide combination	$H_{S-T} = \overline{HD}_{S-T} D_{S-T}$	$S_{H_{S-T}} = S_{\overline{HD}_{S-T}} D_{S-T}$
Total annual harvest	$H_{\text{total}} = \sum H_{S-T}$	$S_{H_{\text{total}}} = \sqrt{\sum S_{H_{S-T}}^2}$
Mean bait weight	$\overline{W} = W_{\text{total}} / n$	$S_{\overline{W}} = S_W / \sqrt{n}$
Total number of polychaetes	$N_{\text{total}} = H_{\text{total}} / \overline{W}$	

HE: daily harvesting effort recorded for each area (A–G); HE_{daily} : daily harvesting effort for the whole studied area; S–T: season–tidal range combination; \overline{HE}_{S-T} : mean daily harvesting effort for each season–tidal range combination; d_{S-T} : number of days sampled within each season–tidal range combination; $S_{\overline{HE}_{S-T}}$: standard error of mean daily harvesting effort for each season–tide combination; $S_{HE_{S-T}}$: standard deviation of daily harvesting effort; $HPUE_{\text{per day}}$: “per day” estimator of harvest rate; H : total daily harvest; HE_i : total daily effort of all interviews; \overline{HPUE}_{S-T} : mean daily harvest rate for each season–tidal range combination; $S_{\overline{HPUE}_{S-T}}$: standard error of mean daily harvest rate for each season–tidal range combination; $S_{HPUE_{S-T}}$: standard deviation of the “per day” estimator of harvest rate; \overline{HD}_{S-T} : mean daily harvest for each season–tide combination; $S_{\overline{HD}_{S-T}}$: standard error of mean daily harvest for each season–tide combination; H_{S-T} : total harvest for each season–tidal range combination; D_{S-T} : total number of days (sampled and non-sampled) for each season–tidal range combination; $S_{H_{S-T}}$: standard error of total harvest for each season–tide combination; H_{total} : total annual harvest; $S_{H_{\text{total}}}$: total annual harvest; \overline{W} : mean bait weight; W_{total} : total weight of the sampled polychaetes; $S_{\overline{W}}$: standard error of mean bait weight; S_W : standard deviation of the sampled weights; n : number of individuals; N_{total} : total number of polychaetes.

3. Results

Significant effects of season, tidal range and their interaction on harvesting effort were not detected (Fig. 3, Table 2). Regarding harvest rate (Fig. 4, Table 3), significant effects of season ($p < 0.05$) and tidal range ($p < 0.05$) were detected, but the interaction

was not significant ($p > 0.30$). Post hoc comparisons (Table 4) showed that harvest rate is typically lower during winter, regardless of tidal range, and higher during spring tides.

Mean daily harvest is calculated as the product of mean daily harvest effort and mean daily harvest rate. Therefore, differences in this variable depend on the

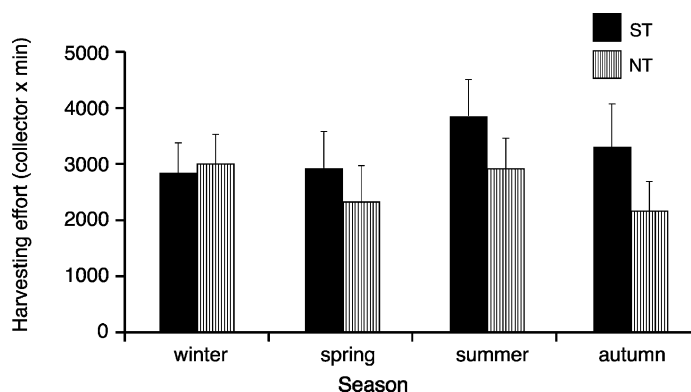


Fig. 3. Mean daily values of harvesting effort according to Season and Tidal range. Wiskers show +1 S.E. ST = spring tide; NT = neap tide.

Table 2

Results of the two-way ANOVA of the effect of season and tidal range on harvesting effort

Source of variation	df	MS	F	p
Tide	1	5151180	2.082255	>0.10
Season	3	1430122	0.578096	>0.50
Tide × season	3	1108744	0.448186	>0.50
Error	45	2473847		

df = degrees of freedom; MS = mean square; F = F -test values; p = probability values.

Table 3

Results of the two-way ANOVA of the effect of season and tidal range on harvest rate

Source of variation	df	MS	F	p
Tide	1	0.001403	5.187127	<0.05
Season	3	0.000995	3.676001	<0.05
Tide × season	3	0.000290	1.071593	>0.30
Error	21	0.000271		

df = degrees of freedom; MS = mean square; F = F -test values; p = probability values.

differences described above. The results (Fig. 5) show that this variable is usually higher in spring tides, except in winter. Summer is the season with the highest daily production (ranging from ca. 250 to 120 kg d⁻¹, in spring and neap tides, respectively). Daily production in spring and autumn reached intermediate values (ca.

180–70 kg d⁻¹). The lower values were recorded in winter (ca. 70 kg d⁻¹ in both spring and neap tides).

The total harvest estimated for the annual period was 45,174 kg (with a standard error of 4955 and a confidence interval between 36,578 kg and 55,229 kg) or 0.03 kg m⁻² as our study area had a surface of

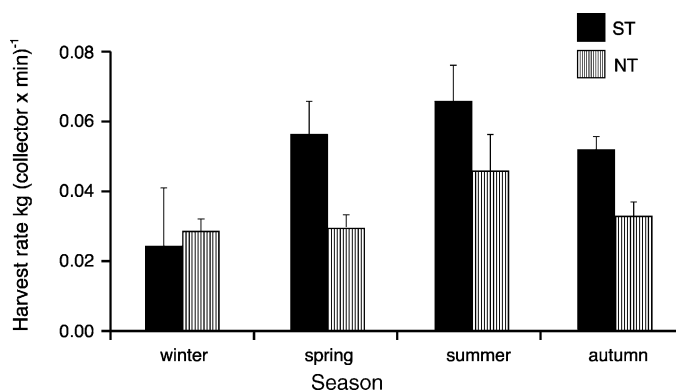


Fig. 4. Mean daily values of harvest rate according to season and tidal range. Wiskers show +1 S.E. ST = spring tide; NT = seap tide.

Table 4
Results of post hoc LSD test for the harvest rate variable

ST/W	NT/W	NT/SP	NT/A	NT/SU	ST/A	ST/SP	ST/SU
0.0234	0.0276	0.0277	0.0340	0.0461	0.0506	0.0563	0.0647

The means of the season–tide combinations are ranked in order of magnitude. The lines join homogeneous groups of means. ST: spring tide; NT: neap tide; Sp: spring; Su: summer; A: autumn; W: winter.

1.510 km². The mean wet weight of each collected polychaete, independent of season and tidal amplitude, was 0.010 kg. Therefore, the estimate of the total number of individuals collected is 4,364,620 (with a confidence interval between 3,413,878 and 5,369,160 ind) which is equivalent to 2.88 ind m⁻².

4. Discussion

The results demonstrate that season and tidal range exert a non-significant effect on the mean daily harvesting effort (Fig. 3, Table 2). Nevertheless, they show that in spring, summer and autumn the effort is numerically higher during spring tides than in neap tides. This is probably related to higher biomasses of the less exploited segments of the population at the lower levels of the flats, which become accessible only during high amplitude tides. The highest value of this vari-

able corresponds to the summer. In fact during summer Canal de Mira mudflats are very crowded due to its pleasant natural characteristics and so many tourists and holidaymakers take part of the digging activity, thereby increasing the number of collectors and the effort.

Concerning mean daily harvest rate, the results demonstrate the existence of a significant effect of season and tidal range (Fig. 4, Table 3) and the post hoc comparisons (Table 4) show that harvest rate was usually higher during spring tides. This finding is consistent with higher biomass in the lower parts of the flats. The higher standing crop may be a consequence of greater densities in the less exploited areas, and/or larger weights of individuals less exposed during low tide and, consequently, with better feeding conditions. The lower harvest rates detected in winter (Fig. 4, Tables 3 and 4) are also probably related to lower biomasses during this season, which is less favourable to individual and population growth. In addition we noticed that during summer the few polychaetes that we were able to sample were heavier.

The investigation confirmed that bait collection in Canal de Mira is very intense and the mudflat area supports an important biological production with a total harvest of approximately 45,173 kg yr⁻¹, or 0.03 kg m⁻². This corresponds to 4,364,620 individuals caught yr⁻¹, or 2.88 ind m⁻² yr⁻¹. We estimate that the global economic income resulting from sales of *D. neapolitana* is over € 327,346 yr⁻¹ since each caught animal has

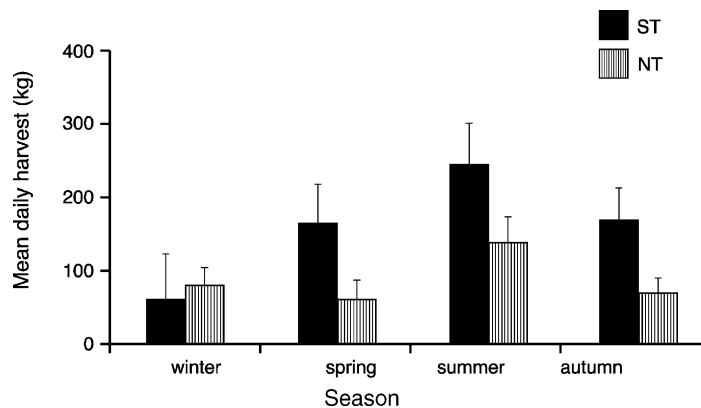


Fig. 5. Mean daily values of harvest according to season and tidal range. Wiskers show +1 S.E. ST = spring tide; NT = neap tide.

a first selling price of € 0.075. If we considered only this species, the studied mud flats have a potential economic value of € 0.022 m⁻² yr⁻¹. However, the actual amount is considerably higher since a suite of other species is regularly collected in the area although records concerning the exploitation of those species are inexistent. These include the polychaetes *Nereis diversicolor* and *Nephtys hombergii*, collected for bait, and bivalves *Cardium edule*, *Solen marginatus* and *Scrobicularia plana*, are sold for human consumption.

It is difficult to estimate the real impact of this activity on the *D. neapolitana* population due to insufficient data concerning its breeding period, age at maturity and longevity. In an attempt to estimate the proportion of the harvested population we carried out an assessment of the density of *D. neapolitana* in the area, by counting the number of tubes in 70 1 m² quadrates randomly allocated to the areas A–G. This assessment took place between 28 and 31 January 2005, before the arrival of the collectors. The results of this assessment must be interpreted with caution because it was made in winter and almost 3 years after the study on harvesting. Moreover, this estimate is based on the non-demonstrated assumptions that the tubes of all extant individuals are visible at the surface and that all visible tubes are occupied (Reys and Salvat, 1971). The estimated density of 2.87 ind m⁻² is similar to the estimated harvest of 2.88 ind m⁻². This would indicate that virtually all the detectable animals are caught in just a few days, because the search method used by the collectors and by the assessment of density is identical. This could be explained by (1) an extraordinarily high productivity of the population, (2) a large proportion of the population with undetectable tubes at the surface, and/or (3) a density during the density assessment period lower than the average density during the period of the harvesting assessment 3 years before. These aspects obviously need further investigation.

Another aspect in need of further research in this species is the contention that many tubicolous worms can regenerate the anterior part of the body (George and Hartmann-Schröder, 1985). In fact, during this study, several individuals were detected with signs of regeneration, which was indicated by a thinner anterior part of the body separated by a scar from the posterior portion. This is important because it indicates that fishing mortality may well be lower than would be estimated from the catches alone.

Along with the direct impacts on the target species, several studies show that digging activity has a wider influence on the ecosystem, as birds feeding on the Ria de Aveiro mudflats during low tide can be affected by disturbance caused by the collectors (Luís, 1998). Moreover, the digging for clams (*Mya arenaria*) in the State of Maine (USA) causes the surface sediment to become sandier with a lower organic content and the relative percentage of bioaggregated sediments to decrease after digging probably reflecting the biological inactivity caused by disturbance and burial (Anderson and Meyer, 1986). Ambrose et al. (1998) suggest that digging for bloodworm, *Glycera dibranchiate*, negatively affects the survival of *M. arenaria* by directly damaging shells and by exposing clams to increased risk of predation. After *Arenicola marina* digging the surrounding macrobenthic fauna suffered a significant reduction in number and biomass probably due to the death of the organisms, either as a direct consequence of the digging or indirectly through increased vulnerability to predators, but also by dispersal of the populations from the area dug over (Van den Heiligenberg, 1987). Concerning ecotoxicological effects, Howell (1985) encountered large increases in bio-available lead and cadmium in the surface layers of sediment and net uptake of these metals by the benthic nematode *Enoplus brevis* caused by *A. marina* collection.

In Portugal, according to national legislation, bait exploitation is allowed with hand gathering or with restricted gear used by licensed persons, but in reality there are large numbers of non-authorised persons that collect bait, as there are no landings or check points where the product of this activity can be assessed. In the Canal de Mira we can distinguish three types of bait diggers: (1) professional or full time bait diggers distributing the materials to retailers inside and outside the area of collection, often to the Spanish market; (2) semi-professional part-time diggers supplying a variety of local retail outlets; (3) occasional local inhabitants, mostly retired, and tourists that collect bait for their own use. A qualitative assessment of the total catch of each category indicates that occasional diggers have a negligible impact on the population. In addition, this activity co-exists with other anthropogenic pressures like pollution stress due to domestic and industrial sources (Moreira et al., 1993) and urban development, which together represent a conflict of interests.

5. Conclusions

In order to ensure the sustainable exploitation of this resource it is important to monitor its biological state. In addition we would recommend that, in any future management plan, economic and social issues ought to be considered, especially the impact on the domestic micro-economy of the many local families that may depend heavily on this activity for income. Through our fieldwork experience we estimate that at least 150 collectors are involved in this activity. Moreover, harvesting of *D. neapolitana* can be considered as an activity that, besides providing immediate income to collectors, also sustains several installations dedicated to the selling and commercialization of live bait, including the export to other areas.

Concern over the ecological impact of bait digging in areas like Ria de Aveiro also gives added significance to the development of rearing techniques which would allow the intensive culture of polychaetes like *D. neapolitana* (Conti and Massa, 1998), *Nereis virens* (Olive, 1999) and *Nereis diversicolor* (Fidalgo e Costa and Cancela da Fonseca, 2000).

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