PRELIMINARY REPORT ON THE CHARACTERISATION OF BOTTOM SEDIMENT ON *NEPHROPS* GROUNDS OFF THE SOUTHWEST AND SOUTH-EASTERN COAST OF PORTUGAL

STUDY CARRIED OUT DURING THE JUNE 2004 CRUSTACEAN SURVEY

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Abstract

A study into the physical and biological characteristics of the sediment found on grounds of Norway lobster, *Nephrops norvegicus*, was carried out. Samples were collected during the "2004 Crustacean Survey", from designated locations off the southwest and south-eastern coast of Portugal at depths ranging from 250 to 650 m. All samples were collected with a (60x60x60) cm box-corer. Water content in all samples ranged between 36 and 59% in weight, with the muddy sediment attaining higher values than sandy-mud. Total organic matter content varied between 2.5 and 4.5% in weight, with the highest values found in the muddy sediment (i.e. sediment with more than 90% of the particles <63µm). Superimposition of sediment types at sampling positions onto maps showing *N. norvegicus* abundance and distribution, showed greater *N. norvegicus* occurrence in sandy-muddy grounds than muddy grounds. Such differential distribution was interpreted as preferential selection of feeding ground by *N. norvegicus*. The macrofaunal analysis has shown that polychaetes are the most abundant animal group on these grounds, yet present results did not provide enough data for an effective characterisation of the macro fauna related to *N. norvegicus* grounds. A detailed account of the various technical problems observed during the use of the coring equipment and respective solutions is provided.

Keywords: *Nephrops norvegicus*; bottom sediment; granulometry; S Portugal; box-corer; abundance

Introduction

The analysis of the data collected during crustacean surveys[1] has identified an area off the south-east coast of Portugal with high abundance of both adult and juvenile Norway lobsters (*Nephrops norvegicus*). In fact, the abundance of juvenile *Nephrops* at these grounds was found to be far greater than elsewhere along the Portuguese coast (Silva, 2002; Leotte, 2003). These grounds should therefore be considered of vital importance for the recruitment of Norway lobster into the fishery. In this particular area all fishing grounds have been heavily exploited over the last 20+ years and currently sustain a significant share of the commercial crustacean trawl fishery. In light of this, it becomes paramount to gain a better understanding into the recruitment controlling mechanisms which will ultimately reflect the status and capacity of the fishery itself. The more accurate the information used to devise the management plans, the more consistent and effective the management becomes.

[1] Surveys carried out on board IPIMAR's research vessels along the south and south-western coast of Portugal. These surveys have been carried out every year since 1999 generally during the month of June.

Sustainable management of the fisheries in general and of *N. norvegicus* in particular, can only be achieved with good knowledge of the species' life history.

In general, fisheries managers rely on assessment models which incorporate a wide range of information about the target species and, for *Nephrops* in particular, a critical input used in these models is the species' growth rate[2]. Nephrops growth rate is, nevertheless, likely to be influenced by differing habitat conditions; i.e. different habitats (different geographical locations) may well cause lobsters to grow differently. As such, it is crucial trying to assess whether there is a relationship between lobster growth and sediment type and if so, how clear is this relationship (note that a detailed answer to this particular question goes beyond the scope of the present study). This information will help fisheries scientists to better understand how differences in growth (if any) are reflected on the actual population over its entire geographical distribution. This information is of great value to fisheries scientists whose task is to incorporate these parameters into complex theoretical models to better understand the dynamics of the *Nephrops* population(s).

According to the latest ICES *Nephrops* Working Group Report (ICES, 2004) heavy fishing has lead to a worrying level of depletion of the Portuguese stocks of Norway lobster, i.e. an estimated total biomass significantly lower than the previous 20+ years and showing a decreasing trend (a decrease of ~ 45% in Total Stock Biomass (TSB) relative to 1984). Indeed, as a result of the low biomass estimates, the EU Fisheries Committee has promoted a series of meetings for devising a recovery plan for both *Nephrops* and hake stocks. Despite ongoing efforts to protect the fishery, through technical and short term fleet management measures, more information on how environmental conditions influence the species' life history is needed.

The present work seeks to provide additional information to help assess whether the characteristics of the sediment collected at known fishing grounds may, directly or indirectly, affect *Nephrops'* life cycle, with particular emphasis on recruitment and growth. To do so, sediment samples were collected in two distinct areas, one to the southwest, off the Sines coast (Alentejo) and the other in the southeast, off the south-east coast of Algarve. These two sampling areas were specifically chosen according to the characteristics of the individuals found at each of them, i.e. animals captured off the west coast of Sines are generally larger than those captured off the southeast coast (it is possible that these individuals attain larger sizes than those found off the south east coast) and conversely the abundance of juveniles is significantly lower than that found off the southeast coast (possibility of these being important *Nephrops* nursing grounds).

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[2] Information on the growth of *Nephrops* inhabiting the Portuguese shores has not been reviewed for the last 40 years; consequently existing information is likely to be outdated. It is possible that growth parameters might have suffered slight changes since they were firstly estimated at a period in time when the stocks were not under such an intense fishing pressure by the commercial trawl fleet, as they are today.

Methods

This work was carried out during the 2004 crustacean survey (June). Sediment samples were collected at depths ranging from 250 – 650 m using a (60x60x60) cm box-corer, as shown in Fig. 1, operated from the main winch using the steel trawl warp. Due to severe time shortage, the 12 initially programmed sampling stations had to be reduced down to 8 as a result of both equipment limitations and inadequacy of the hauling system. Yet, only 6 sites (Fig. 2) were successfully sampled. After starting the operations it soon became clear that the use of the 22 mm steel trawl warp was inappropriate as it prevented determining the precise moment when the corer reached the sea-floor, especially at depths greater than 300 m (an account of all problems encountered is detailed in the discussion section below).

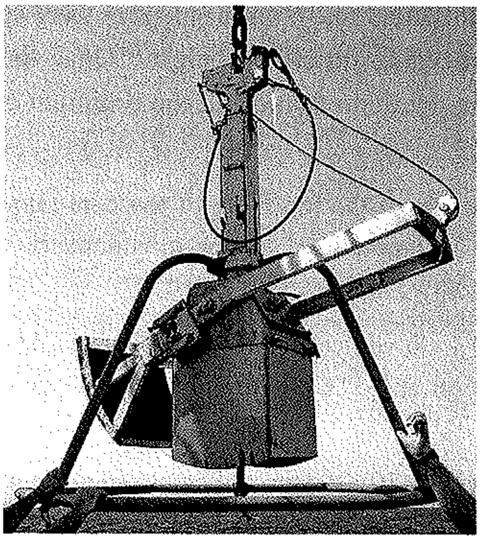


Figure 1 Box corer used to collect sediment samples; corer size (60x60x60) cm.

The steel cable's own weight (1.67 kg.m^{-1}) coupled with the weight of the sampling gear, kept the cable always taut even after the corer reaching the sea-floor, i.e. no difference in cable tension observed at the sea surface whether the equipment was suspended or already on the bottom; at 500 m the cable by itself weighed over 835 kg.

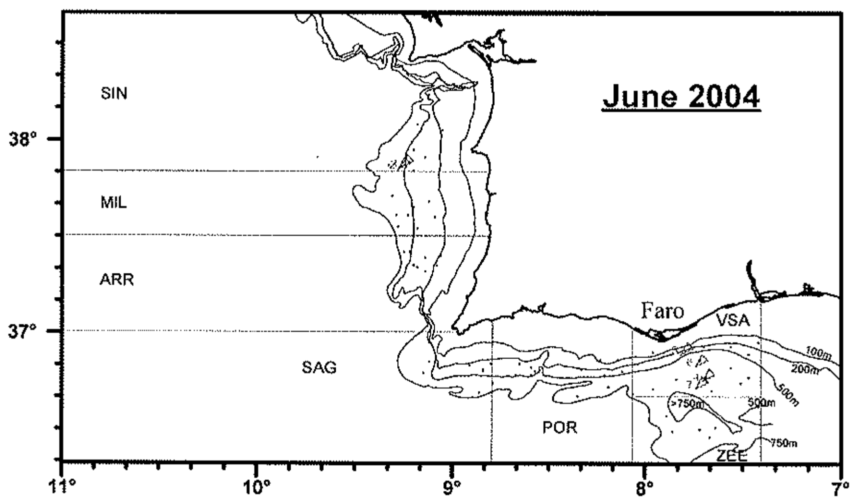


Figure 2 Sediment sample collection sites (▿); black dots show the position of each trawling station.

It is, therefore, likely that often more cable than necessary was released causing the corer to topple and thus preventing it from working properly. It is important to note that several attempts were needed for the collection of each sediment sample, only one was successfully collected at the first attempt.

Table 1 Position and depth of each sample collection site.

Position	Station #1	Station #2	Station #4	Station #5	Station #6	Station #7
Depth (m)	300	537	578	255	566	612
Longitude	09° 14.4'	09° 15.4'	07° 40.9'	07° 47.6'	07° 43.0'	07° 43.0'
Latitude	37° 53.0'	37° 52.2'	36° 46.5'	36° 54.7'	36° 51.1'	36° 44.1'

Despite several operational difficulties, 6 valid samples were successfully collected and treated according to the procedure described below. Once the corer was on deck, the core box was detached from the main frame and the sediment collected according to the following sequence:

a) **Sample Type I** – sample of the top 5 cm of the core (approx. 800 cc); stored in the refrigerator at (+5° C); sample used for the granulometric, total organic material and water content analyses; two replicates collected;

b) **Sample Type II** – ∅ 1 cm vertical sediment profile sample with minimum height of 10 cm; stored in the freezer at (–5° C); two replicates collected; **NOTE:** samples not used for this study;

c) **Sample Type III** – a (20x20x20) cm sediment sample kept in a plastic bag, preserved with formalin and stored in a drum protected from light exposure; samples used for the macrofaunal analysis.

Sediment Analysis

Granulometry

For the granulometric analysis, a sample of 500 g wet-weight was removed from sample Type I. The sediment was thoroughly washed with distilled water followed by chemical destruction of the organic matter with H_2O_2. It was then dried for approximately 24 h at 60° C until constant weight was obtained (in a sub-sample of 100 g). After the first drying procedure the sample was submitted to continual chemical particle dispersion for another 24 hours in tetra-sodium pyrophosphate (30 $g.l^{-1}$) and then sieved through a 63 µm mesh screen. After all fine particles (< 0.63 µm) were removed, the sample was again dried to constant weight. After acquiring a sample free of fine sediment, a grain size analysis was performed by dry mechanical sieving using sieves with mesh screens ranging from 63 µm to 8,000 µm (63, 80, 100, 125, 160, 200, 250, 315, 500, 800, 1000, 2000, 4000 and 8000 µm). The fractions retained in each sieve were weighed and their relative proportion determined (relative to the sub-sample's total weight i.e. including the weight of the fine sediment initially removed).

Organic Matter and Water

For determining the organic matter content, a quantity of 5 g of sediment (wet-weight) was removed from sample Type I. The sediment was dried according to the procedure described above (24 h at 60° C) and then ground. Total organic matter (TOM) by loss on ignition was determined as the weight difference between the dried sample at 60° C and the combusted sample at 450° C. For this purpose a 200 mg sub-sample of ground material was removed and incinerated in a muffle furnace at 450° C until constant weight was obtained, which occurred after a period of approximately 2 hours. Before weighing, the samples were left to cool in a desiccator for 30 minutes. In order to reduce sampling error, the waiting time was carefully monitored and was the same for all samples. Additional care was taken to ensure that the weight variation of the evaporation dishes was accounted for, thus ensuring that external error was minimized.

The water content of the samples was obtained by estimating the difference between wet and dry weight (100 g sample dried at 60° C until constant weight was obtained). The results presented here show proportions relative to the total wet weight of each sample. The sediments used for this analysis were acquired from the refrigerated sediment samples (Type I). All analyses were carried out in IPIMAR's laboratories.

Macrofaunal Analysis

For the macrofaunal analysis, each sediment sample (Type III) was sieved through a 1 mm mesh screen and the residues carefully scraped from the mesh and placed into small plastic containers for later observation. Fauna were preserved in containers with buffered 4% formaldehyde. For observation, the flask contents were poured onto white plastic trays containing enough water so that the residues were always fully emerged, facilitating the sorting procedure. Complete or parts of individual macrofauna present were taxonomically identified to the family level wherever possible and enumerated.

Results and Discussion

Sediment Analysis

Granulometry

The granulometric analysis indicates that at the majority of the sampling sites the sediment is classified as sandy-mud with exception of stations #5 and #7 at which the sediment consisted mainly of mud i.e. more than 90% of sediment weight consisted of silt and clay particles. Table 2 shows a summary of the results of the various analyses.

A graphical summary of the granulometric analysis data is shown in Figures 3 to 8 through cumulative curve plots. These graphs are particularly useful for comparing different samples and help visualising the different types of sediment collected at each sampling station. Figures 6 and 8 clearly show the high silt and clay content of samples from stations #5 and #7 in which particle composition is clearly different from all other samples.

Table 2 Characterisation of the sediment collected during the June 2004 crustacean survey on board R/V "CAPRICÓRNIO", including total water content and organic matter of each sample.

St.	Granules (%) ≥ 2000 µm	Sand (%)				Silt + Clay (%) ≤ 63 µm	Sediment Classification	H_2O (%)	TOM (%)
		Coarse 2000-500 µm	Medium 500-250 µm	Fine 250-125 µm	Very Fine 125-63 µm				
# 1	0,00	0,06	0,36	6,50	13,89	79,19	Sandy mud	44	3,5
# 2	0,13	0,24	0,53	22,88	8,36	67,86	Sandy mud	47	4,5
# 4	0,13	0,23	0,95	12,69	9,63	76,37	Sandy mud	37	3,0
# 5	0,00	0,00	0,06	0,17	0,49	99,28	Mud	59	4,0
# 6	0,46	0,30	1,07	8,55	16,88	72,74	Sandy mud	36	2,5
# 7	0,00	0,09	0,27	3,06	2,86	93,72	Mud	45	4,5

Total Organic Matter (TOM) and Water

The TOM of all samples ranged between 2.5 and 4.5 %. Although there are no reference values for this parameter, (Bordovskiy, 1965) has reported values ranging from 5 to 10 % for the total amount of organic matter in marine sediments. Yet, subsequent investigations into the distribution of organic matter in the sediments of various marine basins have confirmed that its concentration is related to the granulometric composition of the sediments and of course, to the morphological features of the basin itself. The accumulation of organic matter in sediments is known to be affected by the size of the basin, width of the continental platform, bottom relief and other morphological features. In some basins organic concentration increases uniformly as the particle size of the sediments decreases, but in others concentration is reduced in finer sediments. Present results indicate that organic matter content in finer sediments is clearly higher than in coarser sediments, with exception of station #2 in which the organic content was similar to that found in finer sediments. Due to the reduced number of sampled stations, the present results only provide an indication of the range of values that can be found in the two types of sediment collected. A comprehensive study would have to be carried out in order to understand how *Nephrops* is distributed in relation to organic matter content in sediment and assess whether or not these parameters are correlated. Gomez-Parra and Frutos (1988) have emphasized that the TOM data should be considered as a relative measure useful to compare samples, but not an absolute value of the organic content of the sediment, they have added that several of the routine procedures to estimate TOM content may in fact be subject to considerable error if not fully checked and always replicated in the same way.

The water content in all samples ranged between 36 and 59 %. Sample #5 showed the highest value (59 %). Sediment granulometry plays an important role in the overall geochemical properties of the sediment, namely in the cohesion of the particles. The finer the sediment, the higher the water content (Lesueur, 1992), with this author reporting water content as inversely correlated to particle size (ibid).

It is possible that the sediment water content might be another factor actively determining the geographical distribution of *N. norvegicus*. Norway lobsters may choose suitable grounds according to the total water content in the sediment, yet additional work is needed to determine water content thresholds (min. and max.) and draw further conclusions into the general characteristics of the *Nephrops* grounds.

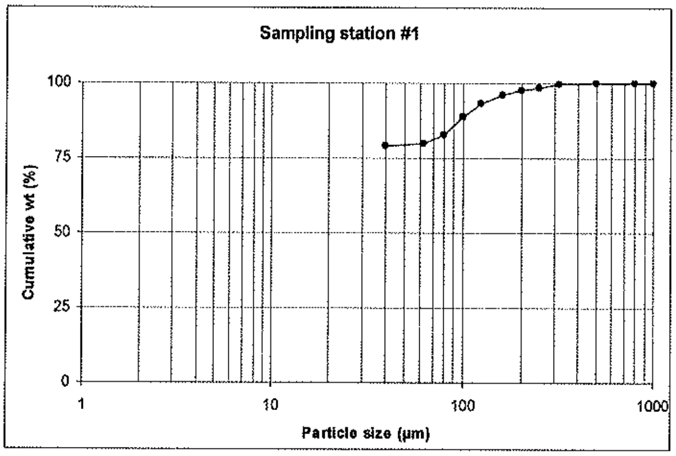


Figure 3 Cumulative curve of sediment weight by particle size for station #1. Fine particles (< 63 µm) consisted of 79.2 % of sample weight.

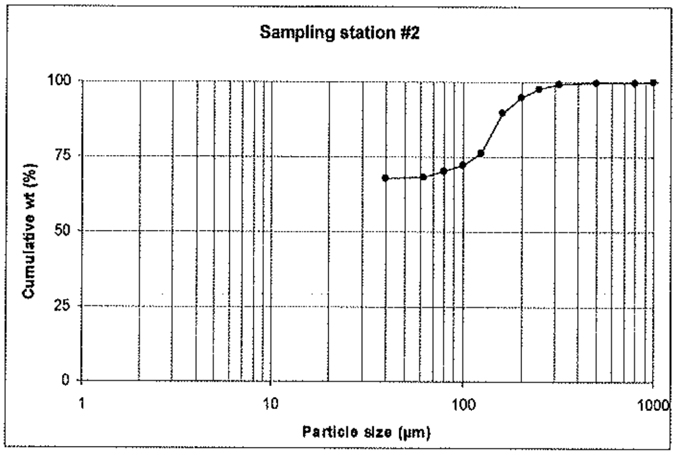


Figure 4 Cumulative curve of sediment weight by particle size for station #2. Fine particles (< 63 µm) consisted of 67.9 % of sample weight.

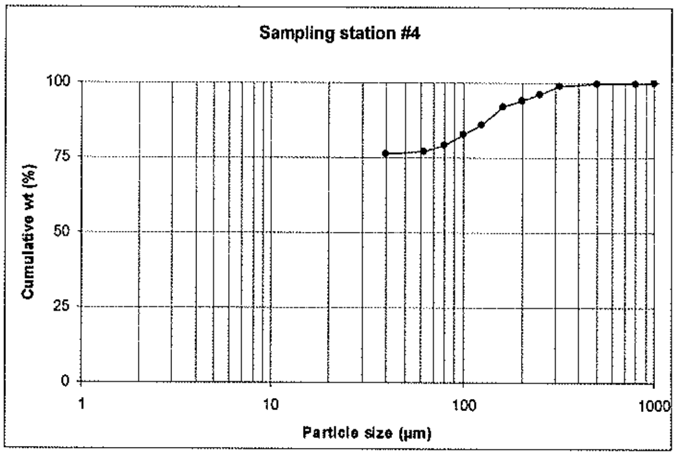


Figure 5 Cumulative curve of sediment weight by particle size for station # 4. Fine particles (< 63 µm) consisted of 76.4 % of sample weight.

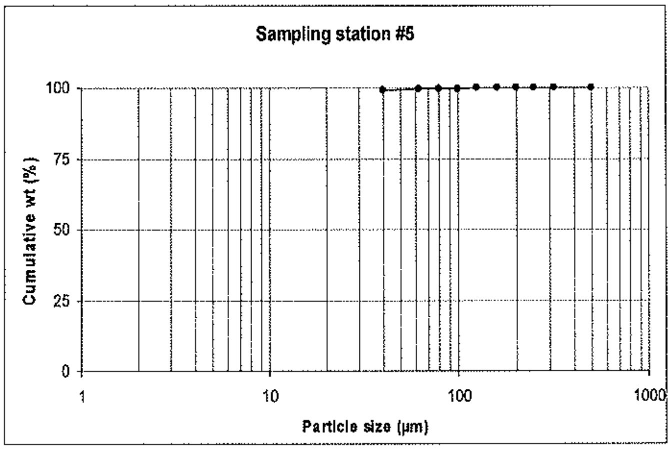


Figure 6 Cumulative curve of sediment weight by particle size for station # 5. Fine particles (< 63 µm) consisted of 99.3 % of sample weight.

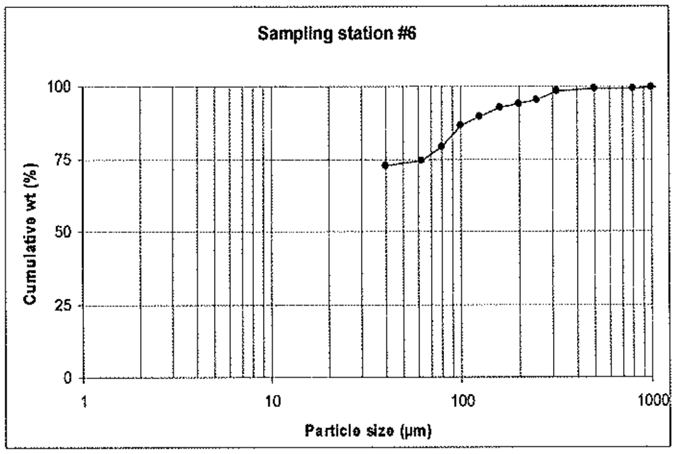


Figure 7 Cumulative curve of sediment weight by particle size for station # 6. Fine particles (< 63 µm) consisted of 72.7 % of sample weight.

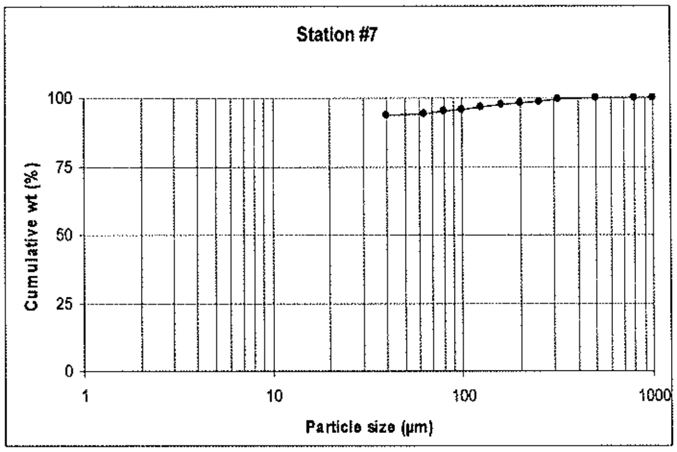


Figure 8 Cumulative curve of sediment weight by particle size for station # 7. Fine particles (< 63 µm) consisted of 93.7 % of sample weight.

Figure 9 shows the *Nephrops* distribution estimated using data from the 2003 crustacean survey. Despite the map only showing 2003 data, it has been observed that the general distribution of *N. norvegicus* has not changed throughout the years, and hence Fig. 9 can be taken to represent the actual geographical spread of the *N. norvegicus* populations. Observing the position of the sediment collection stations on the map it seems that the lobsters occur with greater frequency on sandy mud as opposed to mud grounds, given that all the sandy mud samples were collected in stations well within the lobsters' distribution area.

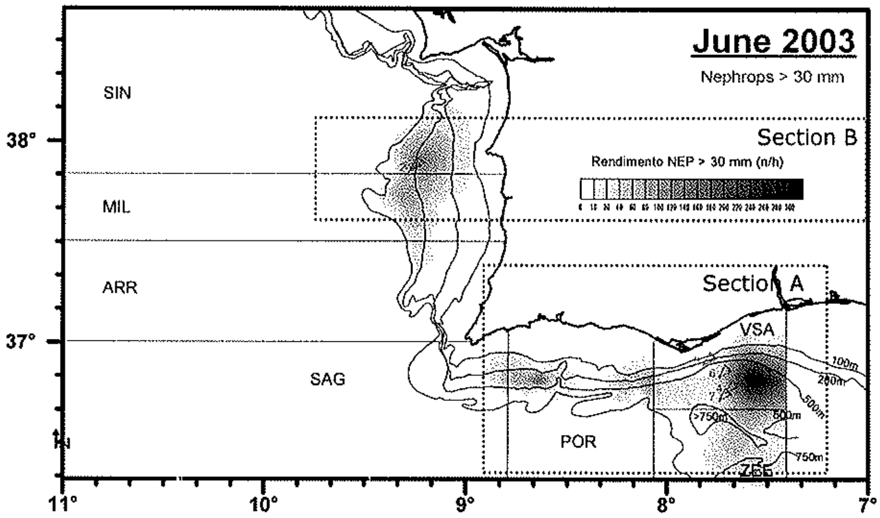


Figure 9 Abundance of *Nephrops norvegicus* off the southwest and southern coast of Portugal (Leotte, 2003).

Figure 10 shows in more detail that in stations #5 and #7, at which the sediment consisted of mud, the abundance of Norway lobster was lower than in adjacent stations #6 and #4 at which the sediment had a higher sand content (sandy mud).

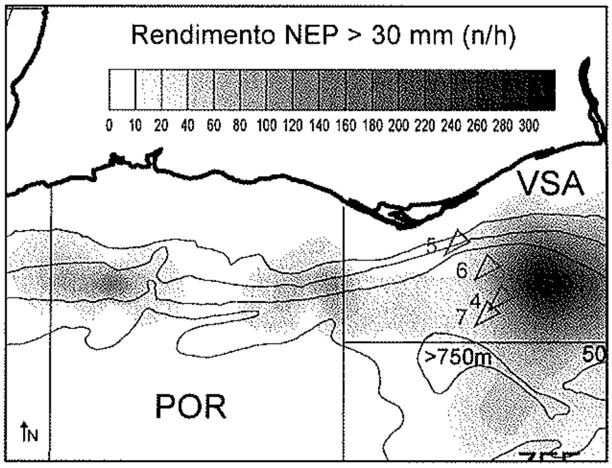


Figure 10 Detail of section A referred to in Figure 2 (south coast).

Figure 11 shows that the abundance of *Nephrops* in sandy mud sediment was in fact high. This type of substrate may, therefore, provide the best habitat conditions, especially for burrowing species such as the Norway lobster.

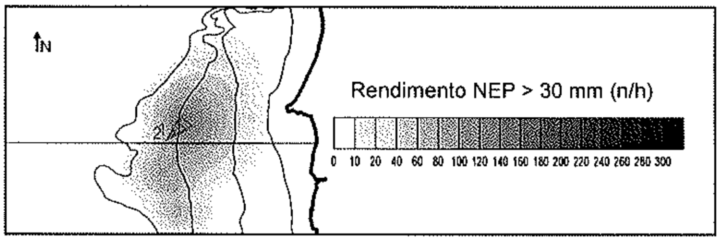


Figure 11 Detail of section B referred to in figure 2 (west coast).

Growth and Recruitment

Figures 12 and 13 show the size frequency distribution of the lobsters captured in trawling stations # 1 and # 2 (west coast). The estimated mean size (CL) of the captured animals at these stations, sex and station combined, is 46.2 mm. On stations # 4 and # 6 the estimated combined mean size was 38.8 mm (Fig. 14 and 15). These results suggest that the animals captured off the south coast are smaller than those captured off the west coast. Further work is, therefore, needed to assess whether the small sized animals captured in the south are a result of the heavy exploitation pattern (old aged individuals removed from the population) or the individuals found off the south shore are effectively smaller (slower growth) than those found off the west coast. To both successfully identifying existing differences in lobster growth rate between two distinct geographical locations, and to determine whether fishing selectively removes older individuals from the population, there is a need for information on the age structure of each population. However, obtaining age data for crustacean species under natural conditions has proven to be virtually impossible, especially for deep water species such as *Nephrops*. New approaches and methodologies are therefore needed to help resolve this issue.

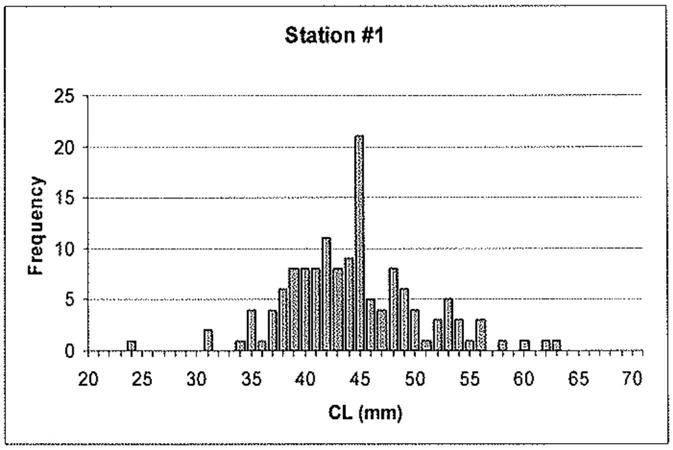


Figure 12 Size frequency distribution of *Nephrops norvegicus* captured at station # 1. Carapace Length (CL).

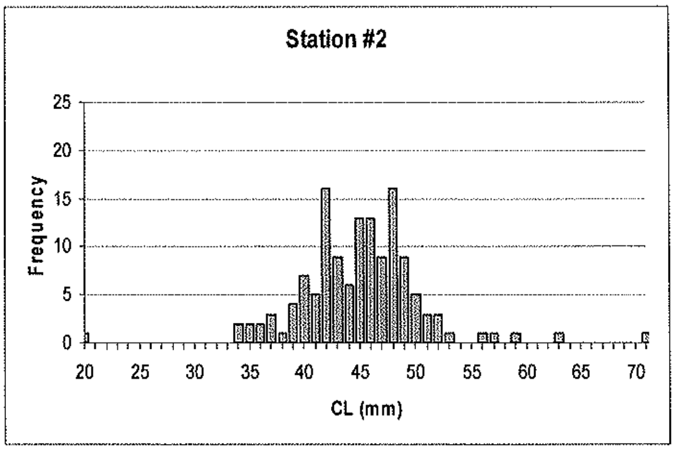


Figure 13 Size frequency distribution of *Nephrops norvegicus* captured at station # 2. Carapace Length (CL).

Difficulties experienced determining the lobsters' age, and the subsequent lack of data, have significantly hampered further advances into this area of research, i.e. crustacean resource management, particularly into the management of *Nephrops* fisheries.

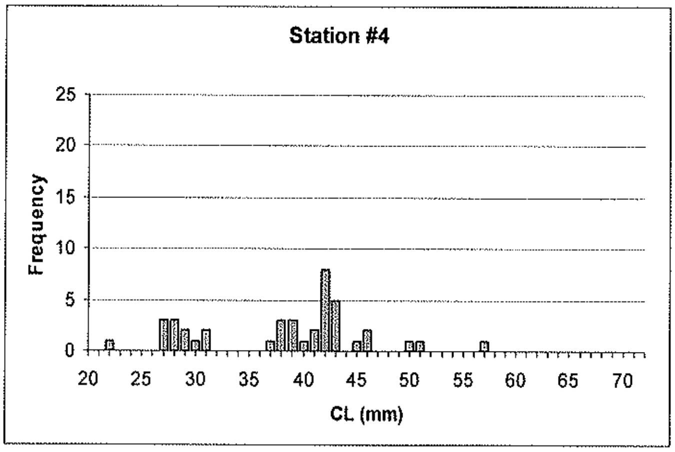


Figure 14 Size frequency distribution of *Nephrops norvegicus* captured at station # 4. Carapace Length (CL).

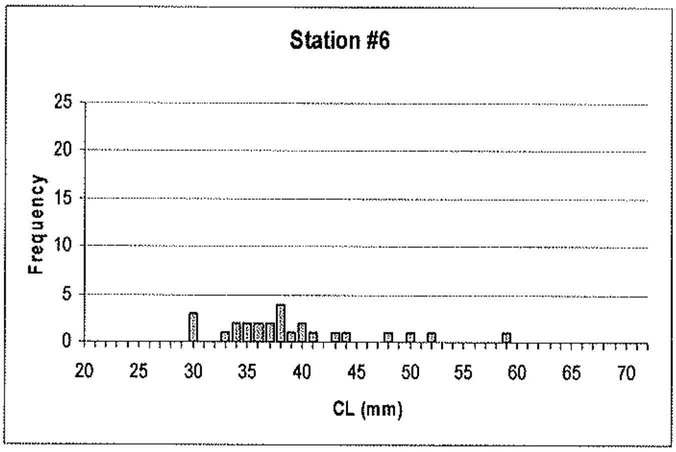


Figure 15 Size frequency distribution of *Nephrops norvegicus* captured at station # 6. Carapace Length (CL).

In light of this, a study into the size of first maturity (SOM) for both males and females is presently being carried out. The results of this study will provide some indication as to how the animals develop until reaching sexual maturity; with the hypothesis tested being that *N. norvegicus* found off the Algarve coast reach maturity at smaller sizes than those found off the west coast of Portugal. Should this be the case, there are two possible interpretations: a) they either reach maturity at younger ages, thus at smaller sizes (similar growth rate at both locations) or b) they reach maturity at the same age but the animals are effectively smaller sized (slower growth). It is however, important to emphasise that this hypothesis is being tested initially under the assumption that animals have similar growth rates. Should significant differences in the SOM be found it will then be crucial to identify which of the interpretations referred to above is the most appropriate or better justifies the results. To do so, a morphometric study will be carried out to verify whether age-related morphometric differences can be identified. If differences are in fact found and the relative age of the individuals determined it will then be possible to know whether they have similar growth rates but mature at different ages or smaller individuals actually grow slower (same age). Note that the age mentioned above refers to relative age as opposed to absolute age, which has proven to be technically very difficult to assess. From this stage onwards it will be possible to use size frequency distribution data, obtained during scientific cruises, to establish age cohorts, and rectify the SOM value used in the VPA (**V**irtual **P**opulation **A**nalysis).

With respect to station # 5 and # 7, only 5 animals were captured in the sample taken at station # 5 and none at # 7. Both stations seem to be outside the limit of *Nephrops* distribution. This observation further emphasises the lobsters' differential abundance on sandy-mud as opposed to mud grounds.

Despite the greater number of specimens smaller than 30 mm (CL) at stations # 4 and # 6 than at stations # 1 and # 2, no suggestion regarding the relationship between sediment type and recruitment can be made as there are not enough data to support the hypothesis that sandy-mud bottoms in the south are better nursing grounds than those off the west coast. However, it is a fact that the abundance of juvenile *N. norvegicus* is higher in southern fishing grounds, yet no conclusions as to a possible interaction between sediment type and juvenile abundance or as to any recruitment regulating mechanisms can be drawn from this study.

Macrofaunal analysis

Figure 16 indicates that polychaetes are the most abundant animals found in sandy-mud sediments (Table 3). Additional samples have, however, to be collected for a more detailed study into the meiobenthic community associated with *Nephrops* grounds. For future studies, the preservation of sediment samples has to be more carefully planned in order to obtain better quality data on animal diversity down to species level. Should specimens resist the preservation technique, remaining undamaged and easily identifiable, it will also be possible to estimate the total weight of the meiobenthic biomass.

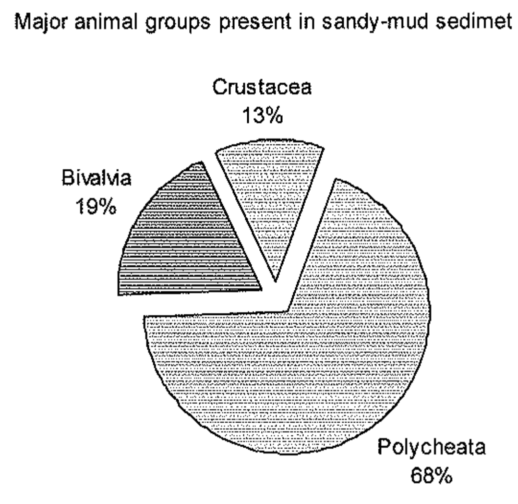


Figure 16 Relative abundance of major animal classes found in the samples. Data refers only to samples collected in sandy-mud grounds, i.e. stations # 1, # 2, # 4 and # 6 (*Nephrops* grounds). Polychaetes remained the most abundant group even after pooling data from all the collected samples (70% of all observed abundance).

Table 3 Classification and abundance (n.m^{-2}) of the animals found in the sediment samples.

Phylum	Class	Order	Station #1	Station #2	Station #4	Station #5	Station #6	Station #7
Hemichordata	Enteropneusta	Unidentified				**10**		
Mollusca	Bivalvia	Veneroida	**5**	**5**				
		Nuculoida		**5**				
Arthropoda	Crustacea	Amphipoda		**5**				
		Tanaidacea		**5**				
Annelida	Polychaeta	Unidentified					**5**	
		Spionida	**10**	**5**	**10**	**20**		
		Terebellida	**10**		**5**			
		Capitellida						**5**
		Eunicida		**5**				
		Phyllodocida		**5**				**5**
		Orbiniidae		**15**				

The following figures further emphasise that polychaetes were indeed the most commonly found animal group in sandy-mud sediment. Yet, present data does not provide an indication as to which particular group of animals is primarily associated with *Nephrops* grounds. As Fig. 17 indicates, all samples are significantly different from one another, with the sample from station # 2 having the greatest diversity as opposed to the sample from station # 6, which had only 1 non-identifiable polychaete specimen.

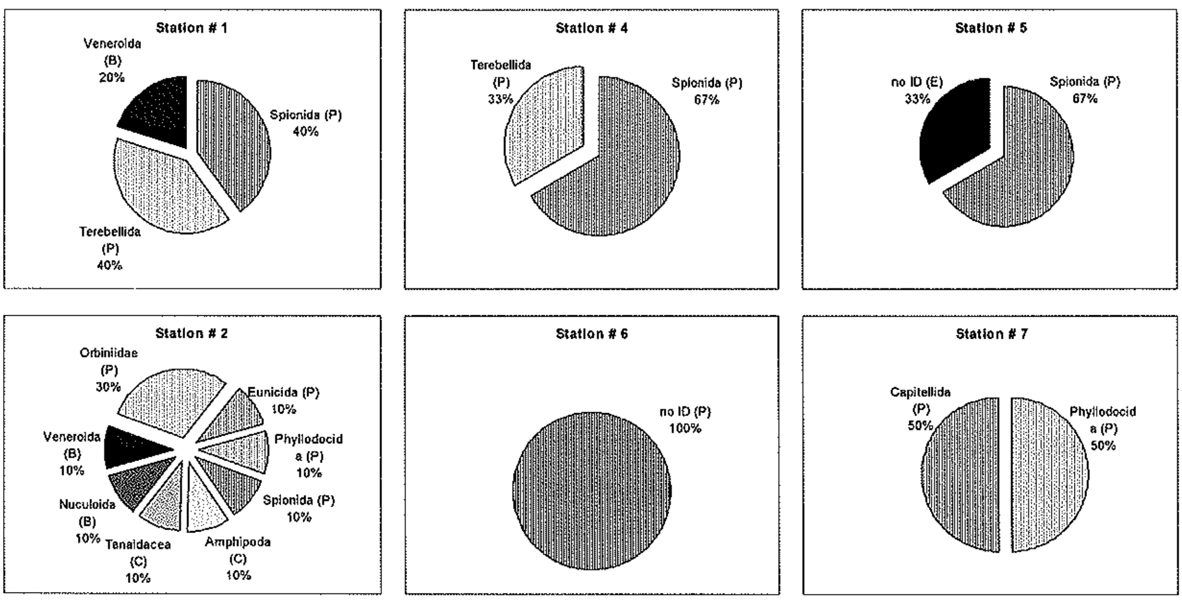


Figure 17 Relative abundance of each animal order found in sediment samples.

Conclusion and recommendations for future use of the box-corer

As suggested above, several changes should be adopted to the sampling procedures and equipment used, to improve the sampling efficiency and reliability. Such changes would help to ensure more data are collected to allow a fuller analysis to aid our understanding of the attributes of the Southern Portuguese *Nephrops* fishing grounds.

The number of sampled stations is clearly too few to provide complete answers to most of the questions initially posed at the outset of this study. More and better quality data are needed to obtain conclusive evidence on the characteristics and the assessed parameters of *Nephrops* grounds. Nevertheless, the results obtained provide an indication as to which sediment type *Nephrops* seem to prefer (sandy-mud). For future studies, collection of more samples on known *Nephrops* grounds on a wider scale has to be contemplated.

With respect to the operation of the corer equipment, it is also advisable to:

- make changes to the trigger system;
- align the core box with the sliding lid;
- use polyethylene cable for operating the corer for shallow water operations or a cable tensometer for deep water operations;
- develop a more effective method to prevent top lids from opening during the gear's ascent.

Problems encountered during the collection of the sediment samples

As previously mentioned, the material and techniques used for the collection of the sediment samples seem not to have been the most appropriate. Several problems prevented the collection of a greater number of samples. These problems related to inadequacies in both the hauling system employed and in the design of the box-corer itself. With respect to the design of the corer, the main problems were as described below.

Firstly, the rim of the stainless steel box did not close properly, i.e. it did not form a water-tight seal together with the sliding lid. The absence of a tight seal allowed sediment and mud to pass through the gap out into the sea. This was particularly noted when the collected sample was relatively small. The sediment left that remained inside the box after hauling was not collected as a sample because the majority of the fine particle fraction (if existing) had already spilled over into the water. The gap was often, in certain parts of the box, wider them 4 cm (see Fig. 18). There are two apparent reasons for the existence of this gap; (a) the stainless steel box was not well aligned with the sliding lid and (b) the design of the frame of the corer did not allow the sliding lid to close tighter, situation which was later aggravated due to the bending of the bar (Fig. 19) which supports the wheel through which the cable that activates the closing mechanism passes.

In addition to the fact that the bottom of the core box was not closed tightly, the top lids seemed to open quite easily during the corer's ascent. These openings effectively allowed water to flow through the box, entering at the top (Fig.20) and flowing out through the lower gap (Fig. 18). This flow effectively flushed the collected sediment out into the water again, particularly when the sample was reduced. Conversely, this did not occur with large samples (i.e. >15 cm vertical height of sediment) as the sediment prevented the referred flow.

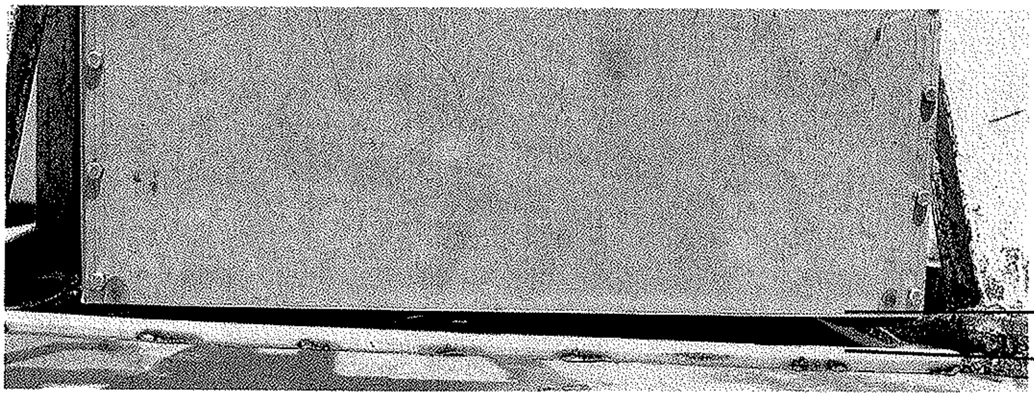
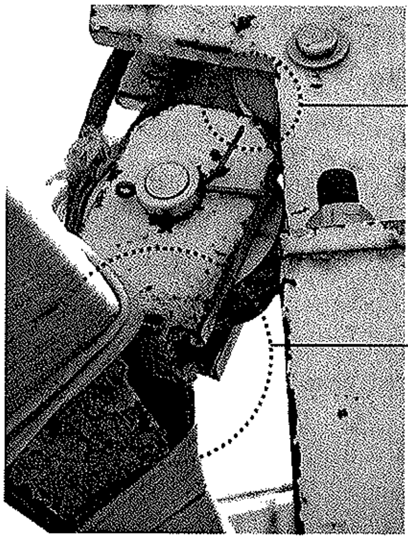


Figure 18 The gap between the rim of the box and the sliding lid. Care was taken to ensure that when the photograph was taken when all mechanical parts were tight or in tension (i.e. the corer was pulled up as if it was being hauled immediately after sediment collection).

In order to correct this problem, rubber bands were attached to the inner part of the lids to prevent them from opening, yet this seemed not to have solved the problem. Although several attempts were made to correct this situation by tightening the elastic bands (forcing the lids to close), they proved not to be able to hold up the pressure of the water passing through these apertures. As a result, both lids were always forced open during the gear's ascent. This is the main reason why only 6 samples were considered valid, i.e. all those with a reduced amount of sediment were rejected due to the possibility that they might have been heavily flushed and thus having lost all the fine sediment.



The entire swinging arm could not have moved further up because the two wheels touched one another. This problem was aggravated with usage as the wheel support bar bent and nearly broke.

Bar onto which the wheel was welded bent during sampling operations.

Figure 19 Detail of the wheel support bar that was bent due to strong tension during the hauling operation.

It is important to note that care was taken to ensure that the hauling speed did not exceed 1.5 $m.s^{-1}$ and that the initial speed, immediately after the collection of the sample, was significantly slower than this. Under ideal conditions of operation, a slow initial hauling speed would have allowed the gear to close properly, allowing all moving parts to tighten, and therefore ensuring minimal sediment loss from the sample.

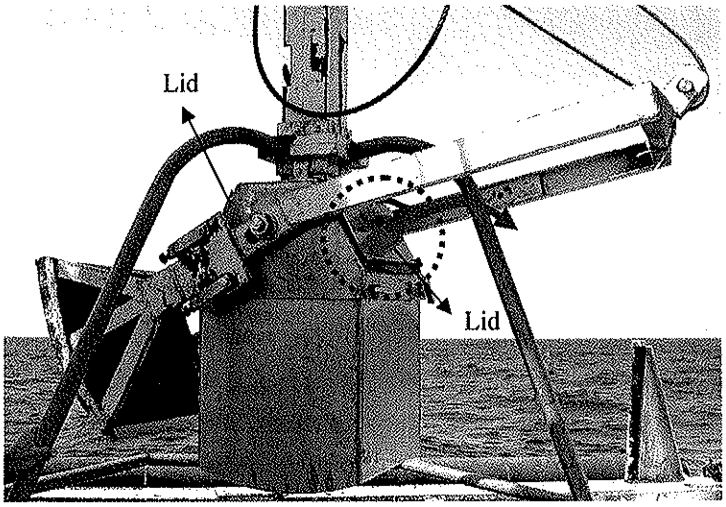


Figure 20 Location of the lids in the corer; the red arrow denotes the opening movement of the lid.

As mentioned above, another problem observed during the survey was the fact that the steel warp cable was too thick and heavy to be used for this type of work. For future studies a polyethylene rather than steel cable should instead be used with this gear. It would allow knowing the exact moment when the gear reaches the sea-floor and thus having a better control over the equipment during its operation. The cable also caused the trigger system not to properly operate. The connection between the corer and the cable was done by means of a heavy duty shackle (Fig. 21). This link has proven to be bulky and ineffective as it forced the trigger shaft against the side of the shaft chamber preventing it to slide back freely once the corer frame hit the bottom. It is therefore, advisable that changes be made to the trigger system before the next use of the equipment. Modifications should include changing the trigger shaft from quadrangular to round section and changing the trigger tension system, i.e. the trigger should be activated by means a metal spring, forcing the shaft out of the chamber, rather than making it slide by means of an elastic band (Fig. 21).

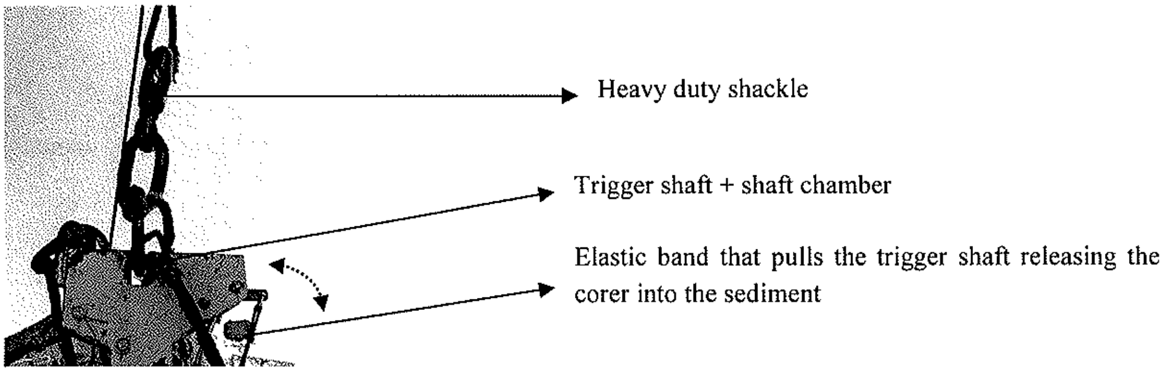


Figure 21 Detail of the trigger system and the link between warp cable and corer frame.

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