# Utilization of shellfish processing waste as bait for whelk (*Buccinum undatum*) fishing

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## Preamble

Burgon (Eyemouth) Ltd. produces a full range of crab and crabmeat products for the caterer, for food-service, or for value-added processing. However, current costs of disposing of crab shell waste is proving to be a huge burden to the company and in the future may well become too great for the business to support. Their current route is to take the crushed waste to a land fill site, but with the recent increase in land fill tax by 23% this presents a real threat to the profitability of the company, which is facing ever declining markets in these difficult economic times.

One constructive use of this waste may be as bait in trap fishing for shellfish, such as whelk (*Buccinum undatum*), since the bait used in UK shellfish fisheries is worth up to £3.5 million per annum. This project will therefore evaluate the potential use of crab shell waste as bait attractants for creel-caught shellfish, particularly whelks.

Therefore, the objective of this project was to test the attractiveness of various formulations of bait derived from crab and other fishery wastes to whelks. Objectives and experimental trials from this project were based in the methodology and results obtained by a previous study performed by the University of Glasgow (Dr. Amaya Albalat and Prof. Douglas Neil) and the University Marine Biological Station Millport (UMBSM) (Mr Adam Goodlad and Dr Philip Smith). The UMBSM supplied the test animals and provided facilities for aquarium-based experiments and field trials.

## Introduction

The UK shellfish processing industry is worth £1,435.9 million, of which £672.3 million is brought in from Scotland. In the UK, the shellfish processing industry accounts for 0.16% of the total UK gross domestic product (GDP) revenue, employing in excess of 48,000 full time staff (Anderson and Curtis, 2008). A large proportion of UK shellfish processing is crab and lobster, with this proportion being even greater in Scotland, due to the high volume of crab and lobster caught by Scottish fishing vessels.

However, the UK shellfish processing sector currently faces a major problem in the disposal of waste products. For instance, a medium size processing company will process in the region of 760 – 800 tonnes of live crab annually, which equates to a minimum of just over 425 tonnes of marketable crabmeat and shell, and 335 tonnes of crab waste. The composition of crab waste comprises approximately, 55% crab gut, 21% crab leg waste, 15% crab purse waste and 9% crushed crab waste (figures provided by Burgon Ltd). Such a high quantity of waste poses a major problem to processing companies regarding the disposal. Currently the main form of crab waste disposal, and indeed all shellfish waste (equating to 75,000 tonnes annually in the UK), is burial in landfill sites (FitzGerald, 2008). The cost of waste disposal via landfill has been steadily increasing over the recent years, with a rise from £32 per tonne in April 2008 to £48 per tonne proposed by the HM Treasury in April 2010 (Timms, 2010). This is driving a search for alternative waste disposal options. The alternative options currently available include ocean dumping which requires special permitting, onshore handling and is overall an expensive operation as well as having a negative environmental stigma. Animal feeds offer another alternative to landfill although problems with odors and costs associated with the control of odors are an issue (Andree, 1988). Composting appears to offer a the most cost-effective solution to waste disposal, which if done properly can produce a product of value to the horticulture industry which is odour free, can utilize flexible technology ranging from the very sophisticated to the very simple to supply all forms of composting requirements and the final product can be stored for any duration without a degradation in quality (Mathies, 2002). New ideas are frequently emerging, one such idea being developed in China is the usage of shrimp shells as catalysts for the production of biofuel (Yang *et al*, 2009).

A more straightforward, alternative to landfill disposal is the use of shellfish waste as bait in the potting sector. In the UK 30,000–35,000 tonnes of crab, lobster and whelk are landed annually. The bait needed to catch this quantity of landings is estimated to be 6000–7000 tonnes per year with a total cost to the industry of £3–3.5 million per year (Seafish 2008) (Seafish, 2008). The use of seafood waste as bait is legally permitted and has been established for a long time, offering a profitable and efficient way of disposing of fish waste; however, the bait used is more commonly fresh waste rather than processed. This investigation focuses on determining whether the waste product from crab processing could be used as bait for fishing of the common whelk *Buccinum undatum* (Fig. 1).

*Whelk biology and sensory abilities*

*Buccinum undatum* is distributed in the coastal waters of the British Isles and both sides of the North Atlantic. They are most commonly found on subtidal soft sediments in which they may burrow a few centimetres below the surface, although they also occur on sand, gravel and rock down to depths of 1000 m (Scolding *et al*. 2007).

Until recently, fishing for *B. undatum* has been modest in the British Isles, with the majority of commercially fished *B. undatum* in the UK being sent to the Far East for human consumption (Fishonline, 2010). However due to a decline in yield from crab and lobster fishing, *B. undatum* fishing has increased over the past two decades, to provide continued income to the potting sector. Currently the main bait used by whelk fishermen for attracting *B. undatum* is herring or fresh crab; however, very little is known about the response of *B. undatum* to processed crab waste (Lawler and Vause, 2009).

**Figure 1**. Common whelk, *Buccinum undatum*, on gravel and rocks at a water depth of 4 m, Isle of Cumbrae (photo: I.P. Smith, 2009)

*B. undatum* are mainly scavengers, but have been shown to exhibit predatory behaviours to certain prey. Such predatory behaviour was investigated by Scolding, *et al.* (2007), demonstrating how *B. undatum* utilise their foot muscle to prise apart the shell of cockles. Their ability to predate and scavenge is evident from the gut contents of *B. undatum* collected around the British Isles (Taylor, 1978). Thirty-five species of different prey were identified, comprising eight different phyla, with the main component of the diet being polychaetes, followed by bivalves.

*B. undatum*, similar to other gastropods (marine, terrestrial and freshwater) are able to detect a food source by chemoreception. They have reportedly responded to chemical cues from food up to 30 m away (Himmelman, 1988), and this ability to detect food via chemical cues also allows the gastropod to discriminate between foods using taste and smell (Croll, 1983). A preference or avoidance of certain foods is thought to be largely related to previous experience of that food.

As well as chemoreception, gastropods are adept at using hydrodynamic cues to orientate to a food source. Positive rheotaxis, the action of turning into an oncoming current and moving against it, is widely used by *B. undatum* to detect low concentrations of chemicals and locate their source, using only the direction of the water, even after the odour has declined (Croll, 1988). Furthermore, Nickell and Moore (1991) found that faster currents increased the ability of *B. undatum* to locate food.

## Aims

The main aim of this investigation was to determine whether the waste product from processed shellfish elicits a feeding response in *B. undatum.* Should the response observed be similar to that seen with herring (the most common bait currently used to attract *B. undatum*), this would demonstrate a potential to market shellfish waste product as a commercial bait. Not only would this open an opportunity for increased income to Burgon Ltd., but it would also alleviate the financial pressure from the rising landfill tax, as well as reducing the quantity of shellfish waste entering landfill sites.

## Conclusions from previous study

The previous study performed in 2009 jointly by the University of Glasgow and UMBSM investigated, through laboratory experiments, the response of *B. undatum* to the following components of crab waste that are currently generated by Burgon Ltd.:

- crab purse
- crab leg waste
- crab gut

The results obtained indicated that the most promising component of crab waste to be used as bait for *B. undatum* was crab gut (Fig. 2).


**Figure 2**. Percentage of whelks with 'very positive', 'positive' or 'negative' or nil responses to different bait types in the raceway tank

The study also established the optimum experimental conditions needed to study feeding responses of *B. undatum*. This comprised a raceway tank, which gave more reliable results than a choice chamber system. An appropriate scoring system was also developed to evaluate the responses of the whelks to the different baits. Both the experimental system and the scoring system have been used in the present study.

However, the previous study did not establish whether mixes of these crab waste components could elicit a feeding response in *B. undatum*, and it did not test the potential of other fishery wastes. Also, no field trials were performed to determine whether the responses observed in the laboratory studies corresponded with the degree of attraction of whelks into baited traps deployed in the sea. All these questions were addressed in the present study.

## Objectives of present study

*Phase 1*: To investigate, via laboratory experiments, the responses of *B. undatum* to '*Nephrops* heads' (the cephalothorax of Norway lobster, *Nephrops norvegicus*), scallop waste (*Pecten maximus* and *Aequipecten opercularis*) and mussel waste (*Mytilus edulis*). Thereby to understand the potential for these shellfish wastes to be used in a commercial bait, as an additional attractant.

*Phase 2*: To investigate, via laboratory experiments, the response of *B. undatum* to four different mixtures of bait incorporating crab processing waste, two of which included supplementary attractants selected from the results obtained in phase 1. Thereby to determine the viability of using these bait mixtures commercially.

*Phase 3*: To investigate, in field experiments with creels (baited traps), the responses of marine scavengers to the two bait mixtures that elicited the greatest positive responses in phase 2. This phase was intended as a preliminary investigation to inform a larger commercial field trial to ascertain the effectiveness of potential commercial baits for *B. undatum* based on shellfish waste.

## Materials and Methods

<u>Animal collection and maintenance</u>

Owing to this investigation being a continuation of a previous investigation conducted in 2009, there were already 68 *Buccinum undatum* available for testing. Whelks were maintained in two circular tanks of glass-reinforced plastic in the seawater aquarium at the University Marine Biological Station Millport. A continuous supply of unfiltered seawater at near-ambient temperature (15°C ± 1) was piped to the holding tanks and allowed to overflow to waste.

During the intervening period between the 2009 study and the present study the *B. undatum* were fed and regularly checked; they appeared healthy and active. On commencing this investigation both circular tanks were thoroughly cleaned removing any residue of food or faeces that had built up in the tank. The room in which the tanks were held had an air temperature of 17 °C (± 1 °C). Additional freshly-caught *B. undatum* that had not yet become accustomed to the artificial environment of the laboratory were also obtained. A fleet of eight soft-eye D-shaped creels (the entrance to the creel made entirely from netting) baited with herring was deployed from the UMBSM research vessel ‘Actinia’, in water depths of 6–10 m to the east of the Isle of Cumbrae, Firth of Clyde.

A total of 21 new *B. undatum* were thus obtained. Both groups of animals were used in the tests. Each whelk was marked with an individual code on the ventral side of the shell near the siphonal canal. These markings allowed the response of each whelk to be tracked throughout the varying experiments, and also ensured that no individual whelk was tested more than once with the same bait, thus reducing bias in the experimental procedure.

Raceway tank configuration

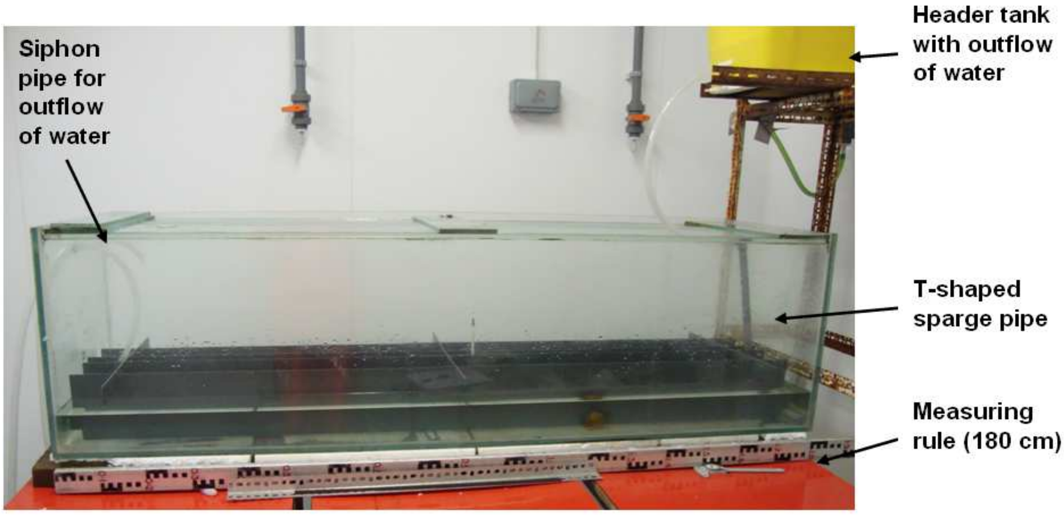


**Figure 3**. The set up of the raceway tank

The responses of whelks to different baits were tested in a glass tank measuring 181 × 48 × 48 cm which was located in a room next to the holding tank room (average temperature 17 °C, ± 1 °C). The tank was divided into four lanes along its length by vertical partitions of 2.5 mm thick plastic (polyvinyl chloride) sheets, creating four raceways in the tank, allowing for four whelks to be tested in one observation session. A 180 cm rule was placed along the length of the tank to measure distances moved by the whelks. Bait odour was administered from a header tank positioned on a shelf above the raceway tank. The header tank was a plastic container measuring 55 × 30 × 30 cm in which the bait to be tested was placed. The container had two outlet plastic tubes attached to it; one situated at the front approximately 5 cm from the bottom of the container, and a second situated at the back approximately 5 cm from the top. The front outlet tube was connected to a T-shaped plastic 'sparge' pipe, closed at both ends of the horizontal sections. This plastic pipe had eight identical holes in it, positioned equidistantly along the pipe, to create streams of water directed along the length of the glass tank.

This construction allowed the baited water to run from the container (via gravity) into the raceway tank. Each lane was serviced by two holes in the tube, thus producing a good flow of baited water along the lanes. A steady flow of fresh seawater (200 ml $s^{-1}$) was piped into the header tank, producing a constant flow of water into the raceway tank. At the opposite end of the raceway tank was another plastic pipe, used as a siphon to draw water out through the lanes, thus maintaining a constant volume of water in the tank (Fig. 3).

### Bait experiments – Phase 1

The first phase of this investigation examined the responses of *B. undatum* to *Nephrops* heads, herring (*Clupea harengus*), scallop waste (*Pecten maximus* and *Aequipecten opercularis*), mussel waste (*Mytilus edulis*) and no bait. The scallop and mussel wastes were provided by Burgon Ltd of Eyemouth. The *Nephrops* heads were obtained from trawl samples taken in the Firth of Clyde from a UMBSM research vessel.

In order to reduce the amount of experimental error, taking into account any effect that time of day may have on the responses of whelks to bait, and to ensure that each bait was tested 32 times (for the purposes of statistical analyses) a Latin square design was used. Each bait was tested over a period of 12 hours, over 8 days from 16$^{th}$ – 25$^{th}$ June 2010. Using digital scales, 100g of each bait was weighed, placed into fine mesh bags and frozen for later use. Before testing, the baits were removed from the freezer and allowed to defrost for a minimum of 12 hours prior to being placed in the header tank.

For each experiment four whelks were chosen at random from the holding tanks and transported to the raceway tank, in a bucket containing seawater. The lane into which each whelk was placed was chosen at random and recorded, as was the orientation of each whelk to the sparge pipe, in order to avoid bias towards the bait. Each subject was placed in the middle of the lane, at a distance of 90 cm from either end of the tank. The whelks were then left to acclimate for 15 minutes, before starting the trial. Trials were allowed to run for 45 minutes, and scores were assigned to each of the four whelks tested, according to their responses (Table 1).

**Table 1.** Scoring system for *B. undatum* response to various baits

| **Score** | **Response description** |
|---|---|
| Very negative | Whelk moved away from sparge pipe and reached the end of the tank |
| Negative | Whelk moved away from sparge pipe, but did not reach the end of the tank |
| Closed | No response, whelk was withdrawn into shell |
| No response | No response, but siphon was extended |
| Positive | Whelk moved towards sparge pipe, but did not reach it |
| Very positive | Whelk reached sparge pipe |

The data collected were analysed and compared with the results obtained from the 2009 study to inform decisions on bait mixtures to be tested in phase 2.

<u>Composition Bait Experiments – Phase 2.</u>

After analysis of the results obtained from phase 1, the second phase focused on testing four baits, each of which consisted of particular compositions of crab processing waste and other wastes. The waste was provided by Burgon Ltd. in four categories: ‘crab gut’, ‘leg waste’, ‘purse (middle body of crab) waste’ and ‘crushed crab waste’ (pulverised shell). The percentage by weight of each crab waste component in the factory waste produced normally by the processing factory was calculated from figures provided by Burgon Ltd (Table 2).

**Table 2**. The quantity of each component and their corresponding percentages in the factory waste.

| Crab waste component | Quantity of waste (tonnes) | Percentage of total (%) |
|---|---|---|
| Crab gut | 185 | 55 |
| Crab leg waste | 70 | 21 |
| Purse waste | 50 | 15 |
| Crushed crab waste | 30 | 9 |
| Total | 335 | 100 |

The first bait mixture tested comprised all of the four crab waste components in their factory proportions (Table 2, hereafter referred to as ‘proportional crab waste’). On the basis of the data obtained from the 2009 study and from phase 1 of the present study on the attraction of *B. undatum* to each crab waste component, it was apparent that the crab gut waste elicited more positive responses than the other components. For this reason, the second bait was made up of 75% crab gut waste and 25% proportional crab waste (hereafter referred to as 75:25 crab waste bait) (Table 3). The third and fourth bait compositions were a mixture of the crab waste in factory proportions with an addition of mussel waste (Table 3). The mussel waste tested in phase 1 proved to be a good attractant for *B. undatum* and is more widely available as a waste product than are *Nephrops* heads. The third bait composition comprised 20% mussel waste and 80% proportional crab waste. The fourth bait composition comprised 40% mussel waste and 60% proportional crab waste (Table 3).

**Table 3**. Composition of the four different bait mixtures

| Bait tested | Bait constituents | Percentage by weight |
|---|---|---|
| Proportional crab waste | Crab gut | 55% |
| | Leg waste | 21% |
| | Purse waste | 15% |
| | Crushed crab waste | 9% |
| 75% crab gut waste, 25% proportional crab waste | Crab gut | 75% |
| | Leg waste | 12% |
| | Purse waste | 8% |
| | Crushed crab waste | 5% |
| 20% mussel waste, 80% proportional crab waste | Mussel | 20% |
| | Crab gut | 44% |
| | Leg waste | 17% |
| | Purse waste | 12% |
| | Crushed crab waste | 7% |
| 40% mussel waste, 60% proportional crab waste | Mussel | 40% |
| | Crab gut | 33% |
| | Leg waste | 13% |
| | Purse waste | 9% |
| | Crushed crab waste | 5% |

In order to maintain consistency with phase 1, all the baits were made up to the same weight (100 g), the procedures for selecting, transporting and acclimatising the whelks were the same, and the method of recording attraction towards a bait was identical. A total of 32 *B. undatum* were tested for each bait mixture.

Field Experiments – Phase 3.

On the basis of the results from phase 2, three baits were chosen for use in the field trial, namely 75:25 crab waste (as the bait mixture that elicited the most positive responses), crab waste in factory proportions (as the bait of moist most commercially interest), herring and, as a control no bait.

As in both phases 1 and 2 all baits were made up to 100 g (± 2 g) before being placed into fine mesh bags and frozen. All baits were removed from the freezer a minimum of 12 hours before testing. Two fleets of eight creels were used: one consisted of eight *Nephrops* creels (with hard eye openings) and the other consisted of eight soft eye creels (Fig. 4). By using these two types of creels there was a greater prospect of catching a wider variety of species, to investigate which  other species, apart from *B. undatum,* would be attracted to the bait.

**Figure 4**. A *Nephrops* creel, showing the hard eye opening.

The utilisation of eight creels in each fleet allowed for each of the three baits, and no bait, to be used in two creels each in one deployment. After baiting both fleets of creels as shown in Table 4, the fleets were deployed within 20 m of each other, in water depths of 6–10 m off the east coast of the Isle of Cumbrae between Lion rock and Clashfarland Point, and their positions recorded by global positioning system (Fig.5).

**Table 4**. The sequence of baits placed along a fleet of creels (both soft and hard eye)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Proportional crab | No bait | 75:25 crab waste | Herring | Proportional crab | No bait | 75:25 crab waste | Herring |

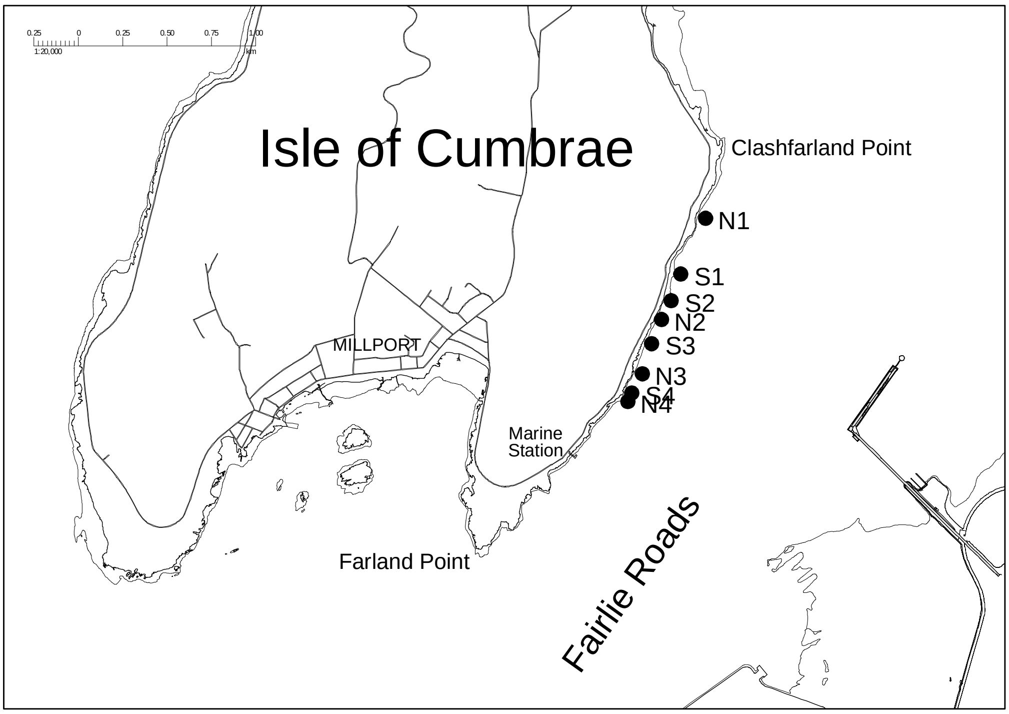


**Figure 5.** Map of the southern part of the Isle of Cumbrae showing the location of fleet deployments ('N1' first deployment of Nephrops creels, 'S4' fourth deployment of soft-eye creels). Coastline, roads and paths © Crown Copyright/database right 2010. An Ordnance Survey/ (Datacentre) supplied Service

In each deployment, after a period of approximately 24 hours (±1.5 hours), both fleets of creels were recovered onto the research vessel. The number of species caught in a creel as well as the abundance of each species in that creel were recorded for each bait type, with each animal being released after the data had been collected. Having removed the caught animals each creel was re-baited using the same bait type as was previously present (to avoid cross-contamination of creels with odours of different baits), and the fleets were deployed again, in a different location. A total of four deployments were conducted over a period of five days (2$^{nd}$ – 6$^{th}$ August, 2010) allowing for each bait to be tested eight times in both types of creels, with the exception of the factory proportion crab bait, which was tested only 7 times in the *Nephrops* creels due to the loss of one *Nephrops* creel on the final day.

The data from all phases were compiled using Microsoft Excel. Statistical tests were carried out to check whether differences in whelk responses were indicative of real differences between bait types, or could simply be due to chance variations.

## Results

<u>Phase 1</u>

*Nephrops* heads elicited the largest percentage of *B. undatum* exhibiting a 'very positive' response (53%), closely followed by herring (50%). However the *Nephrops* heads bait also yielded the highest percentage of 'very negative' responses (16%). Of all the baits tested scallop elicited the fewest 'positive' responses. As expected, the control of 'no bait' received the fewest 'very positive' responses, with the majority of the *B. undatum* remaining stationary with extended siphons (Fig. 6).

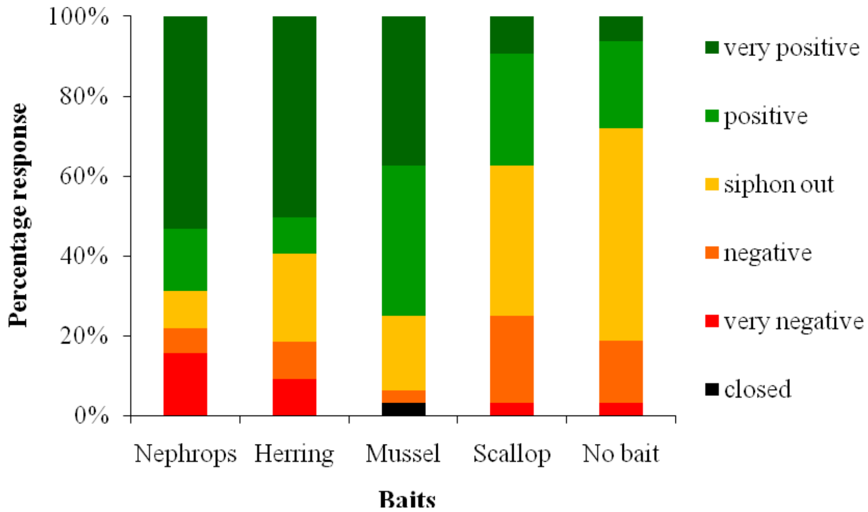


**Figure 6**. The percentage of *B. undatum* responding to the baits tested in phase 1.

When combining 'very positive' and 'positive' responses, mussels gave the highest 'total positive' responses (75%), followed closely by *Nephrops* heads (69%). Both elicited a greater percentage of 'total positive' responses than did herring, the bait commonly used for attracting *B. undatum* (Fig. 7).

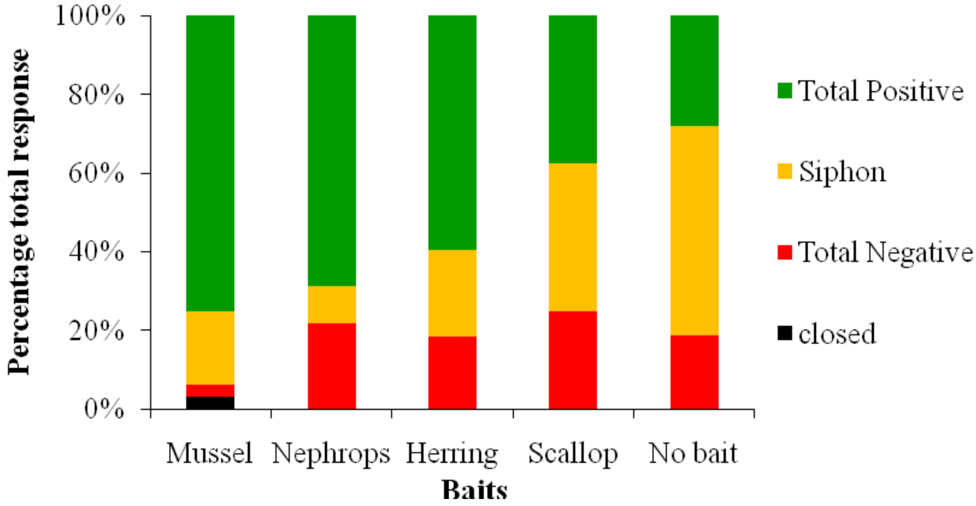


**Figure 7**. The percentage of *B. undatum* responding to the baits tested in phase 1 when combining 'positive' and 'very positive' responses together as well as 'negative' and 'very negative' responses.

On average, *B. undatum* moved significantly faster when presented with odours from *Nephrops* heads or herring, compared to scallop waste and no bait. In fact, scallop waste elicited the slowest response of all the baits, similar to the response seen when no bait was present. On the other hand, no significant difference was observed between mussel waste and the remaining 4 baits tested (Fig. 8).

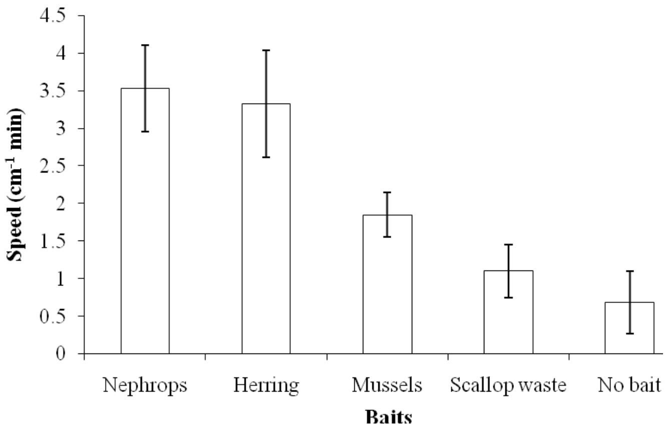


**Figure 8**. The speed of *B. undatum* exhibiting a positive or negative response. NB, direction of movement was disregarded in the calculation of speed.

Phase 2

Bait made up of 75:25 crab waste elicited the highest percentage of ‘very positive’ responses from whelks, whereas bait made from proportional crab waste elicited the lowest percentage of ‘very positive’ responses (Fig. 9).

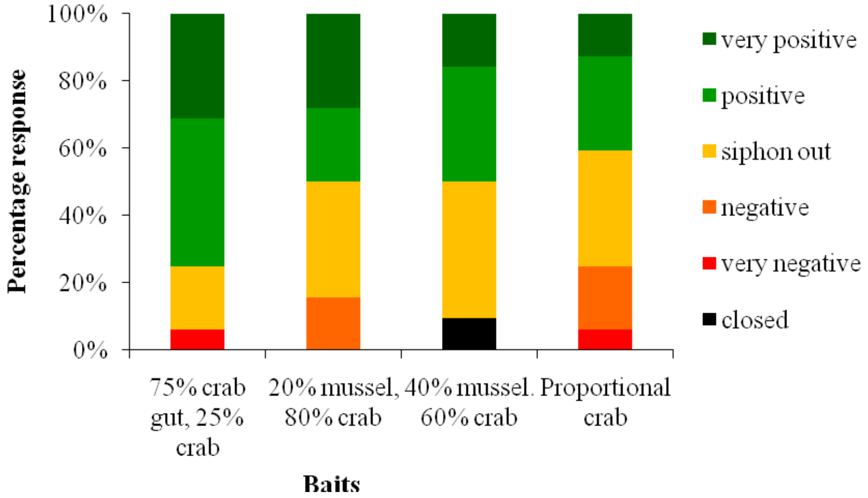


**Figure 9**. The percentage of *B. undatum* responding to the baits tested in phase 2 (ranked in order of ‘Very positive’ responses).

*B. undatum* exhibited ‘positive’ or ‘very positive’ responses most frequently when the 75:25 crab waste was placed in the bait container. Both the bait containing 20% mussel, 80% factory proportional crab and that containing 40% mussel, 60% factory proportional crab elicited the same percentage of these ‘total positive, responses by *B. undatum* (50%), suggesting that an increase of mussel in the bait mixture has no effect on the attractiveness of the bait. The bait made up of factory proportional crab waste elicited the lowest percentage of ‘total positive’ responses (Fig. 10).

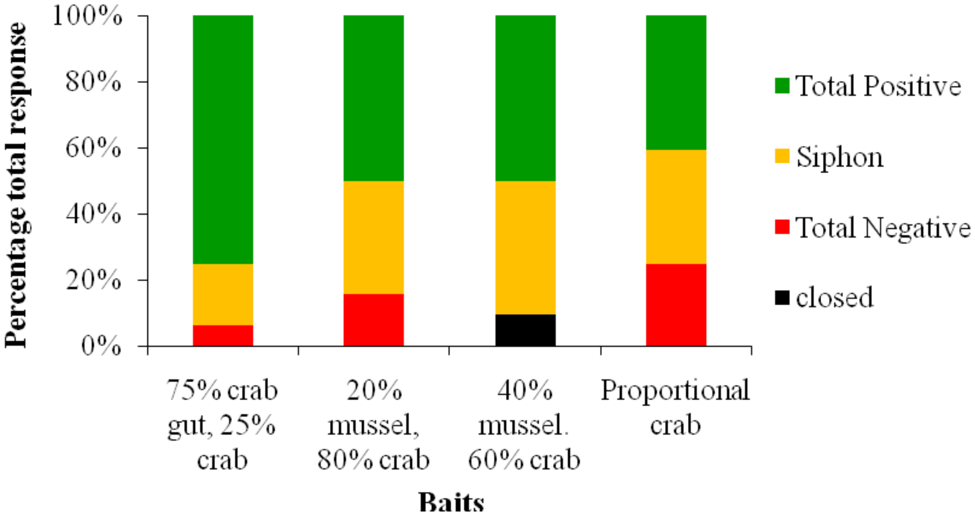


**Figure 10**. The percentage of *B. undatum* responding to the baits tested in phase 2 when combining 'positive' and 'very positive' responses together as well as 'negative' and 'very negative' responses, (ranked in order of 'Total positive').

On average *B. undatum* moved significantly faster when exposed to 20% mussel and 80% crab waste, compared to proportional crab waste and the bait made up of 40% mussel, 60% crab waste (Fig. 11).

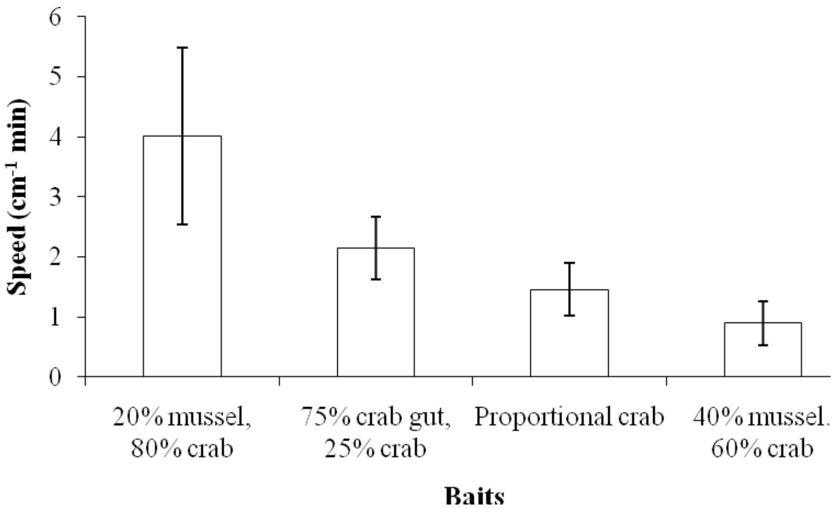


**Figure 11**. Speed of *B. undatum* moving towards the sparge pipe. Of note, direction of distance travelled was removed as a factor in the calculation of speed.

Phase 3

From four deployments each of eight *Nephrops* creels and eight soft-eye creels no *B. undatum* were caught by any creel type or with any bait in any of the deployments. Investigations conducted by Martel *et al.* (1986) on the reproductive cycle and seasonal feeding activity of *B. undatum* show that feeding is significantly decreased during the breeding season, i.e. from late May to late August. This may explain the lack of whelks caught with herring, the common bait for catching *B. undatum*, since the field trials were carried out in early August.

There was not a large difference between the number of species caught in the *Nephrops* creels and those caught in the soft eye creels (Fig. 12). Overall, the bait that attracted the greatest number of species was herring followed by the bait composition of 75:25 crab waste, although differences were not statistically significant. The creels with no bait in them attracted, overall, as many species as those with the factory proportional crab waste and one less than those with the bait composition of 75:25 crab waste, thus highlighting the risk of ghost fishing (Fig. 12).

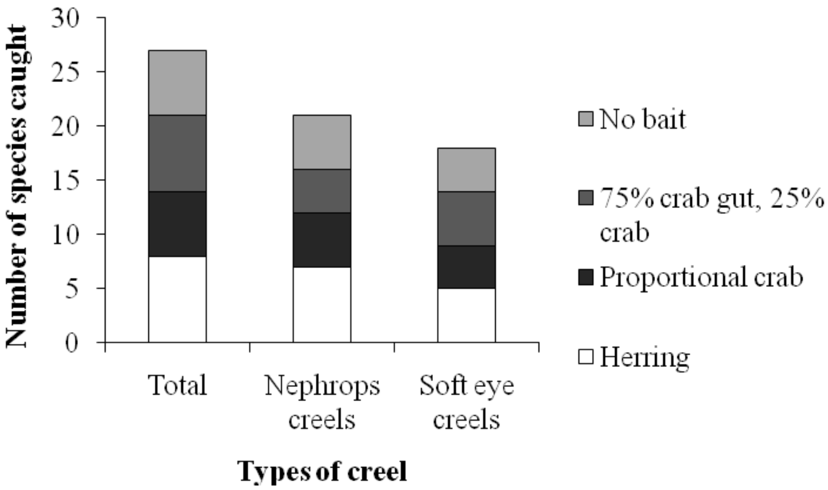


**Figure 12**. Number of species caught using the different baits, for each creel type and both creel types combined.

In order to have a sufficient sample size for statistical analysis, comparisons were conducted on the total number of individuals caught with each bait in both creel types combined. Herring attracted the greatest number of individuals (46 individuals caught), with proportional crab waste attracting 29 and the bait composed of 75:25 crab waste attracting 31 (Fig. 13). However, given the variability in catches per creel, statistical analysis indicated that these differences could have arisen by chance and therefore could not be attributed conclusively to the different baits. Further field trials, however, may provide stronger evidence of real differences between bait types.

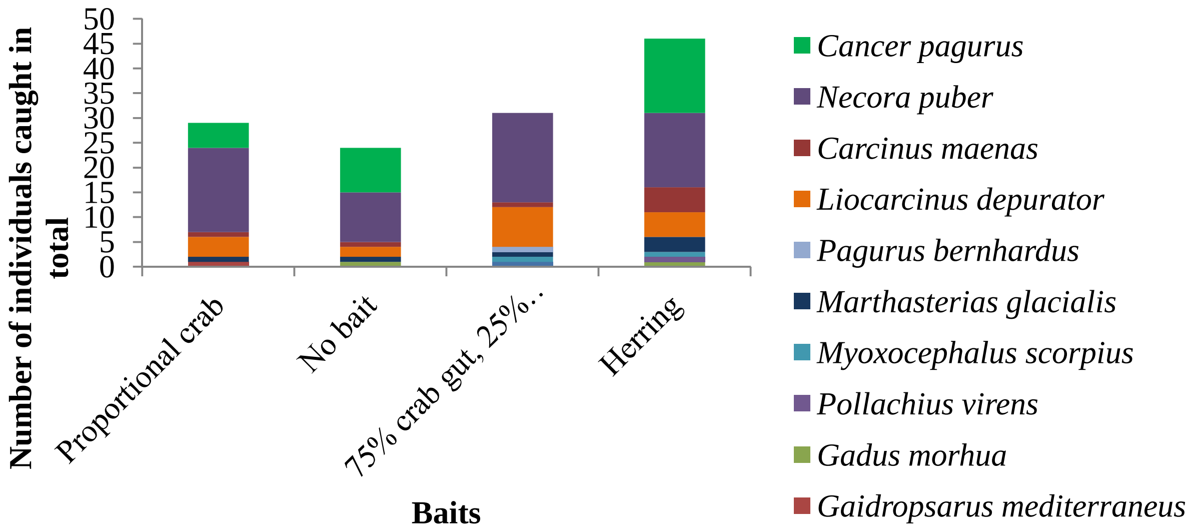


**Figure 13**. The number of individuals caught, in total, by species

The species caught in greatest numbers was the velvet swimming crab, *Necora puber*, with the bait composed of 75:25 crab waste attracting the greatest number (18), and the factory proportional crab waste attracting 17. Though the bait composed of 75:25 crab waste attracted the second greatest number of individuals, it was the only bait not to attract brown crab, *Cancer pagurus*, the species from which the crab waste was derived. The factory proportional crab bait attracted the second lowest number of *C. pagurus*. Several studies have investigated the avoidance of certain crustaceans to dead individuals of the same species. Chapman and Smith (1978) studied the creel catches of edible crab using different baits, and observed that an addition of dead crab to fish bait reduced the catch of live *C. pagurus* by

54%, suggesting that *C. pagurus* have chemically-induced intraspecific avoidance responses. The results obtained from phase 3 of this investigation are in accordance with this finding, suggesting that the *C. pagurus* may have specifically avoided both of the crab waste baits.

The results from this phase show that a greater number of individuals were caught using the *Nephrops* creels (78) than the soft eye creels (52), although there was virtually no difference in the number of species caught. In comparison, the 75:25 crab waste bait caught slightly more species in the soft eye creels than in the *Nephrops* creels, although the other baits tested (including no bait) all caught more species in the *Nephrops* creels than in the soft eye creels.

## Conclusions & Recommendations

*From Phase 1*:

1. Mussel waste elicited the greatest overall positive responses and achieved the lowest total negative responses of all the baits.

2. *Nephrops* heads elicited a greater number of 'very positive' responses than did herring and the other baits, although they also elicited the greatest 'very negative' of all the baits tested.

3. Whelk responses to scallop waste were similar to those seen when no bait was present. Scallop waste was therefore a less effective attractant than herring.

***Therefore, the results from phase 1 demonstrate a definite potential for the use of mussel waste and* Nephrops *heads as potential bait for* B. undatum.**

*From Phase 2*:

The '75:25' bait comprising a mixture of 75% crab gut and 25% crab waste in factory proportions elicited the greatest 'very positive' and overall total positive responses of all the baits, and also the lowest total negative response. This is in keeping with the results from testing all the crab waste components individually, which showed that *B. undatum* had the strongest preference for crab gut waste.

***Therefore, the results from phase 2 indicate the potential of the '75:25' mixture, comprising a mixture of 75% crab gut and 25% crab waste in factory proportions, as a bait for* B. undatum.**

*From Phase 3:*

1. Differences in the number of species and the total number of individuals caught in creels could not be conclusively attributed to the different bait types tested, probably because of the limited number of deployments possible.

2. No whelks were caught during this phase with any of the baits or creel types used. This suggests that further field trials focussing specifically on whelks should not be conducted at the same time of the year (at least in the location used in this investigation).

***Therefore, a full set of field trials is required to ascertain whether the different attractiveness of bait types indicated by laboratory experiments is evident in the field. It would be most appropriate for further field trials to be carried out in a realistic commercial manner.***

**Overall, results from this investigation suggest that processed crab waste could be utilised as bait for *B. undatum*. The bait composition that elicited feeding responses most similar to those elicited by herring was the mixture of 75% crab gut and 25% crab waste in factory proportions.**

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## References


Anderson, J. and Curtis, H. (2008) The economic impacts of the UK sea fishing and fish processing sectors: An input-output analysis. Report to Sea Fish Industry Authority

Andree, S. (1988) Alternatives for Wakulla County Management of blue crab processing solid waste. Florida Sea Grant Technical Paper, No. 53, 17pp.

Chapman, C.J. and Smith, G.L. (1978) Creel catches of crab, *Cancer pagurus* L. using different baits. *ICES Journal of Marine Science*, Vol. 38, No. 2, pp 226–229.

Croll, R.P. (1983) Gastropod chemoreception. *Biological Review*, Vol. 58, pp 293–319.

Fishonline. [*Buccinum undatum* species information] Available at: http://www.fishonline.org/search/advanced/?fish_id=120 (Accessed on: 14th August 2010)

FitzGerald, A. (2008) Shellfish flesh waste in bait. Report to Sea Fish Industry Authority, Ref. SR 603

Himmelman, J.H. (1988) Movement of whelks (*Buccinum undatum*) towards a baited trap. *Marine Biology*, Vol. 97, pp 521–531.

Lawler, A. and Vause, B. (2009) Whelk Biology. *Fisheries Science Partnership Report, CEFAS, Lowestoft and Sussex SFC*

Martel, A., Larrivée, D.H., Klein, K.R. and Himmelman, J.H. (1986) Reproductive cycle and seasonal feeding activity of the neogastropod *Buccinum undatum*. *Marine Biology*, Vol. 92, No. 2, pp 211–221.

Mathies, M. (2002) Disposal of seafood processing waste in Maine, USA. Report on the BIM Technology Transfer Trip, 26 January – 1 February 2002, Bord Iascaigh Mhara, Dublin. 11pp.

Nickell, T.D. and Moore, P.G. (1992) The behavioural ecology of epibenthic scavenging invertebrates in the Clyde Sea Area: laboratory experiments on attractions to bait in moving water, underwater TV observation *in situ* and general conclusions. *Journal of Experminental Marine Biology and Ecology*, Vol. 159, pp 15–35.

Scolding, J.W., Richardson, C.A. and Luckenbach, M.J. (2007) Predation of cockles (*Cerastoderma edule*) by the whelk (*Buccinum undatum*) under laboratory conditions. *Journal of Molluscan Studies*, Vol. 73, pp 333–337.

Seafish (2008) Use of shellfish by-products in bait. Sea Fish Industry Authority, Hull.

Taylor, J.D. (1978) The diet of *Buccinum undatum* and *Neptunea antique* (Gastropoda: Buccinidae). *Journal of Conchology*, Vol. 89, pp 309–318.

Timms, S. (2010) Economic and fiscal strategy report and financial statement and budget report. *HM Treasury*

# Appendix

*Phase 1 data*

Table 1. Average response times and standard error

| Bait | Average Time (mins) | Standard error |
|---|---|---|
| Mussel | 37.19 | 2.07 |
| Herring | 31.63 | 2.53 |
| Nephrops heads | 31.22 | 2.55 |
| No bait | 43.47 | 1.16 |
| Scallop | 42.03 | 1.66 |

Table 3. Average Speed and standard error

| Bait | Average Speed (cm $min^{-1}$) | Standard error |
|---|---|---|
| Mussel | 1.85 | 0.29 |
| Herring | 3.32 | 0.71 |
| Nephrops heads | 3.53 | 0.58 |
| No bait | 0.69 | 0.42 |
| Scallop | 1.10 | 0.35 |

Table 4. Percentage of *Buccinum undatum* exhibiting a response

| Bait | closed | very negative | negative | siphon out | positive | very positive |
|---|---|---|---|---|---|---|
| Nephrops | 0% | 16% | 6% | 9% | 16% | 53% |
| Herring | 0% | 9% | 9% | 22% | 9% | 50% |
| Mussel | 3% | 0% | 3% | 19% | 38% | 38% |
| Scallop | 0% | 3% | 22% | 38% | 28% | 9% |
| No bait | 0% | 3% | 16% | 53% | 22% | 6% |

*Phase 2 data*

Table 5. Average response times and standard errors

| Bait | Average time (mins) | Standard error |
|---|---|---|
| 20% mussel, 80% crab | 36.06 | 2.74 |
| 75% crab gut, 25% crab | 36.88 | 2.38 |
| Proportional crab | 40.88 | 1.96 |
| 40% mussel. 60% crab | 41.00 | 1.72 |

Table 6. Average distances

| Bait | Average distance (cm) |
|---|---|
| 20% mussel, 80% crab | 32.03 |
| 75% crab gut, 25% crab | 42.97 |

| | |
|---|---|
| Proportional crab | 8.28 |
| 40% mussel. 60% crab | 17.66 |

Table 7. Average speeds and error

| Bait | Average speed (cm $mins^{-1}$) | Standard error |
|---|---|---|
| 20% mussel, 80% crab | 4.01 | 1.48 |
| 75% crab gut, 25% crab | 2.14 | 0.52 |
| Proportional crab | 1.46 | 0.44 |
| 40% mussel. 60% crab | 0.89 | 0.36 |

Table 8. Percentage of *Buccinum undatum* exhibiting a response

| Bait | closed | very negative | negative | siphon out | positive | very positive |
|---|---|---|---|---|---|---|
| 75% crab gut, 25% crab | 0% | 6% | 0% | 19% | 44% | 31% |
| 20% mussel, 80% crab | 0% | 0% | 16% | 34% | 22% | 28% |
| 40% mussel. 60% crab | 9% | 0% | 0% | 41% | 34% | 16% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Proportional crab | 0% | 6% | 19% | 34% | 28% | 13% |

*Phase 3 data*

Table 9. Number of individuals caught by creel and bait

| | Total | *Nephrops* creels | Soft eye creels |
|---|---|---|---|
| Herring | 46 | 32 | 14 |
| Proportional crab | 29 | 20 | 9 |
| 75% crab gut, 25% crab | 31 | 17 | 14 |
| No bait | 24 | 9 | 15 |

Table 10. Total number of individuals caught in each species

| | Proportional crab | No bait | 75% crab gut, 25% crab | Herring |
|---|---|---|---|---|
| *Pleuronectes platessa* | 0 | 0 | 1 | 0 |
| *Gaidropsarus vulgaris* | 1 | 0 | 0 | 0 |
| *Gadus morhua* | 0 | 1 | 0 | 1 |
| *Pollachius virens* | 0 | 0 | 0 | 1 |
| *Myoxocephalus scorpius* | 0 | 0 | 1 | 1 |
| *Marthasterias glacialis* | 1 | 1 | 1 | 3 |
| *Pagurus bernhardus* | 0 | 0 | 1 | 0 |
| *Liocarcinus depurator* | 4 | 2 | 8 | 5 |
| *Carcinus maenus* | 1 | 1 | 1 | 5 |
| *Necora puber* | 17 | 10 | 18 | 15 |
| *Cancer pagurus* | 5 | 9 | 0 | 15 |

Table 11. Number of individuals caught in each species, in soft eye creels

| | Proportional crab | No bait | 75% crab gut, 25% crab | Herring |
|---|---|---|---|---|
| *Pleuronectes platessa* | 0 | 0 | 0 | 0 |
| *Gaidropsarus vulgaris* | 0 | 0 | 0 | 0 |
| *Gadus morhua* | 0 | 1 | 0 | 1 |
| *Pollachius virens* | 0 | 0 | 0 | 0 |
| *Myoxocephalus scorpius* | 0 | 0 | 0 | 0 |
| *Marthasterias glacialis* | 1 | 0 | 1 | 1 |
| *Pagurus bernhardus* | 0 | 0 | 1 | 0 |
| *Liocarcinus depurator* | 2 | 1 | 5 | 2 |
| *Carcinus maenus* | 0 | 0 | 1 | 0 |
| *Necora puber* | 3 | 5 | 6 | 2 |
| *Cancer pagurus* | 3 | 8 | 0 | 8 |

Table 12. Number of individuals caught in each species, in *Nephrops* creels

| | Proportional crab | No bait | 75% crab gut, 25% crab | Herring |
|---|---|---|---|---|
| *Pleuronectes platessa* | 0 | 0 | 1 | 0 |
| *Gaidropsarus vulgaris* | 1 | 0 | 0 | 0 |
| *Gadus morhua* | 0 | 0 | 0 | 0 |
| *Pollachius virens* | 0 | 0 | 0 | 1 |
| *Myoxocephalus scorpius* | 0 | 0 | 1 | 1 |
| *Marthasterias glacialis* | 0 | 1 | | 2 |
| *Pagurus bernhardus* | 0 | 0 | 0 | 0 |
| *Liocarcinus depurator* | 2 | 1 | 3 | 3 |
| *Carcinus maenus* | 1 | 1 | 0 | 5 |
| *Necora puber* | 14 | 5 | 12 | 13 |
| *Cancer pagurus* | 2 | 1 | 0 | 7 |

Table 13. Total number of species caught by creel and bait

| | Total | *Nephrops* creels | Soft eye creels |
|---|---|---|---|
| Herring | 8 | 7 | 5 |
| Proportional crab | 6 | 5 | 4 |
| 75% crab gut, 25% crab | 7 | 4 | 5 |
| No bait | 6 | 5 | 4 |
| Total | 27 | 21 | 18 |