Potential use of crab processing waste as a bait for whelks (*Buccinum undatum*) and European lobsters (*Homarus gammarus*)

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University Marine Biological Station Millport

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Introduction to the project

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.

Objectives

The objective of this project was to test the attractiveness of various formulations of bait derived from crab waste to whelks and other shellfish. This involved developing a laboratory testing system, test procedures and appropriate measures of whelk responses to the bait source. The parameters to be measured included the attractiveness and durability in different formulations of bait, the effective distance over which baits attract whelks, the relative responsiveness of whelks and other shellfish, and the effects of environmental factors such as time of day, light level, and substratum type. Facilities to perform these trials were available at the University of Glasgow and at the University Marine

Biological Station, Millport, and also if required at the premises of Burgon. The UMBSM was used to supply the test animals from its research vessels and Animal Supply Unit.

Expected Deliverables

- A review of the current scientific literature on shellfish attraction to baits
- A scoring index for measuring the attractiveness of baits to whelks and other shellfish that are caught by trapping
- A set of comparative results on the attractiveness of different bait formulations based on crab waste
- A recommendation of the most appropriate and cost-effective formulation for a marketable bait
- A report of the project methodology, results, conclusions and recommendations

Review on shellfish attraction to bait

The UK shellfish processing sector currently faces a major problem in the disposal of waste products. Production of waste from calcareous shellfish is in the region of 75,000 tonnes per year which costs between £30 and £60 per tonne to dispose of, primarily via landfill (Fitzgerald, 2008). This figure is on the increase with a landfill tax rise of 25% (£8) to £40 per tonne in April 2009 and a further rise of £8 per tonne per year set for the next 4 years (HM Treasury, 2009). 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 odor 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).

Another possibility for disposal of shellfish waste is its utilization as bait in the potting sector. The UK fisheries targeting whelk, crabs and lobsters require an estimated 6,000 to 7,000 tonnes of bait per year costing between £3 and £3.5 million. If waste from shellfish processing could be used effectively as bait for these fisheries it could offer a cheaper alternative to the currently used baits. This makes further investigation of this of interest to both the potting sector and the shellfish processing sector. Investment in a £35,000 waste processing facility could make an estimated yearly profit of £12,000 along with a saving of £15,000 on waste disposal for shellfish companies (Thefishsite, 2009). The viability of using processing waste for bait is dependant on the baits attractiveness to the organisms being targeted, the durability of the baits in water over the period of fishing and the cost of the processes involved in the formation of suitable bait.

Whelk biology and sensory abilities

An understanding of the biology of whelk is key when designing an experiment involving their feeding responses. *Buccinum undatum* is a commonly occurring coastal species around the British Isles and both sides of the North Atlantic. They inhabit a variety of substrata but typically sediment environments where they burrow a few centimeters down into the substratum while at rest (Scolding *et al* 2007 citing Nielson, 1975). A number of studies have been completed on their feeding activities and stomach analysis has found over 35 species of prey covering 8 animal phyla are ingested by whelk (Scolding *et al 2007* citing Taylor 1978). Gastropods locate food principally via chemoreception, the detection of water-borne chemical signals (Croll, 1988). Chemoreception allows for exact discrimination between substances and given a range of different food gastropods have been shown to actively select preferred items. This implies a strong selective advantage in the ability to discriminate between food items (Croll, 1988). Gastropods can be conditioned to certain food items; a study on *Urosalpinx* given an exclusive diet of one prey exhibits a stronger preference to that prey odor when exposed to a variety of different prey odors (Croll, 1988 citing Wood, 1968). It has also been shown to be able to negatively condition gastropods to food items, Gelperin (1975) (cited in Croll, 1988) demonstrated that *Limax* fed a previously novel food item paired with induced carbon dioxide poisoning caused selective avoidance of that food. A study on *Aplysia* fed on exclusive diets of different algae found a significant correlation between growth rates and food preferences indicating that *Aplysia* prefers foods that are nutritionally better. These findings together suggest that some gastropods are able to associate nutrition with diet and will continue to feed on feeds previously encountered that are able to sustain the animal health (Croll, 1988). Although experience might occupy a large part of the dietary preferences in gastropods there are other factors involved too. Innate preferences are believed to be important, it has been shown that juvenile *Achatina*, which had never previously consumed any vegetable matter, exhibited a preference towards the odor of carrots over cucumber. Innate olfactory preferences are believed to be modifiable with experience (Croll, 1988 citing Croll and Chase, 1980).Gastropods have been shown to use variety of methods often simultaneously to orientate food. Rheotaxis (movement against a current) may be used when detecting the lowest concentration thresholds since once a whelk detects the presence of a chemical it can locate it solely using the direction of the water should the odor cease (Croll, 1988). Fertilization in European *Buccinum undatum* occurs late autumn with spawning in November in (Jacklin, 1998). Examination of stomach content indicates that feeding activity sharply decreases during the reproductive season (Martel *et al*, 1986) although the authors mention that whelk can still be caught in this period reflecting their opportunistic nature. Feeding studies conducted during this period would need to take this into account.

Hydrodynamics play an important part in the feeding of whelk with the direction, stability and speed of currents all modifying detection of bait in whelk (Lapointe and Sainte-Marie, 1992). These authors found that whelk actively moved towards baits rather than simply against a current indicating that they orientate to some extent on chemotaxis not rheotaxis alone which is consistent with the findings of Brock (1933) (cited in Lapointe and Sainte-Marie, 1992), that whelk are able to locate bait in still water.

Currents influence the field of attraction and effective area of baited traps. Faster currents decrease the spread of an odor plume at any distance from the origin; odor gradients across the plume will also be steeper enabling animals to locate it more effectively (Lapointe and Sainte-Marie, 1992 citing Kleerekopper *et al*, 1975). Faster currents were also found to improve location of food by Nickell and Moore (1991) while decreasing the foraging abilities of other species which use different mechanisms to locate food (Ferner and Weissburg, 2004). These authors also found increased turbulence to aid the detection of prey odor and feeding success in the knobbed whelk *Busycon carica*. This was attributed to a gastropods potential to assimilate a temporal average of chemical concentrations facilitating finding dilute odors or the mean concentration of rapidly varying signals such as those generated by turbulent conditions. Ferner and Weissburg (2004) mention that knobbed whelk use their muscular foot to detect stimulatory chemicals within the sediment which are transferred across the sediment-water interface to a greater extent in turbulent conditions.

Feasibility of the utilization of shellfish waste for bait

It is necessary to develop a method for accessing the relative attractiveness of baits to whelk to aid the formation of the most effective bait derived from processing waste and assess the feasibility of the idea. In-situ experiments are subject to a range of influential hydrodynamic factors along with predator interactions (Powers and Kittinger, 2002) and competing food odors which confound analysis of the results. The simplest, cheapest and most accurate method for analysing the attractiveness of baits to whelk is most likely via laboratory study. The only previous study to date directly pertaining to the focus of this report was done by Fitzgerald (2008) testing the response of whelk, lobster and crabs to waste derived from scallop, brown crab and whelks. A static flow tank was used with test baits presented alongside ‘standard bait’ which was gurnard.

PRELIMINARY TRIALS

Materials and methods

<u>Collection and maintenance of whelks</u>

Four samples of *Buccinum undatum* were collected from the Firth of Clyde over a period of three weeks from the 19th of June 2009 from creel pots baited with salted herring. They were numerically identified with nail polish and their shell length recorded from the apex to the end of the siphonal canal (Mensink *et al* 2000). Animals were stored in holding tanks with an inflow of fresh seawater. Whelks were starved for at least 2 weeks before any experiments were run in agreement with the findings of Ferner and Weissburg (2004).

<u>Tank configuration and experimental protocol</u>

Raceway tank

A raceway tank was set up in a 181.5 x 48 x 48 cm glass tank (filled 20 cm deep) with a unidirectional flow of water achieved via an inflow through a hose connected to a vertical section of plastic pipe with a T shaped horizontal section of pipe at the end with 8 holes drilled equidistant along its length. This ‘sparge pipe’ was designed to generate currents of water along the whole width of the tank rather than just along a central path which would facilitate the possibility for whelks to move outside the current of bait odour. An outflow at the opposite end of the tank was achieved using a siphon (Figure 1.1).

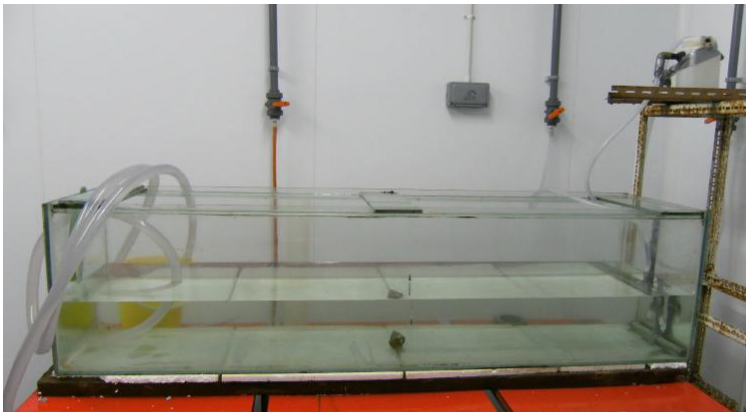

Figure 1.1 Picture of the raceway tank used in the preliminary trials

The inflow was set to a constant 200 ml per second using a measuring cylinder and stopwatch. Test baits were placed in a plastic pot on a shelf above the tank with a flow of water running through it and into the tank via a 'y-connector' meeting the current emerging from the sparge pipe and being carried along the length of the tank (Figure 1.2). Dye tests showed that the water flow was moderately turbulent with a slight eddy being formed in between the two innermost holes in the sparge pipe and then a degree of mixing between this turbulent water and the more uniform water flow originating from the sparge pipe.

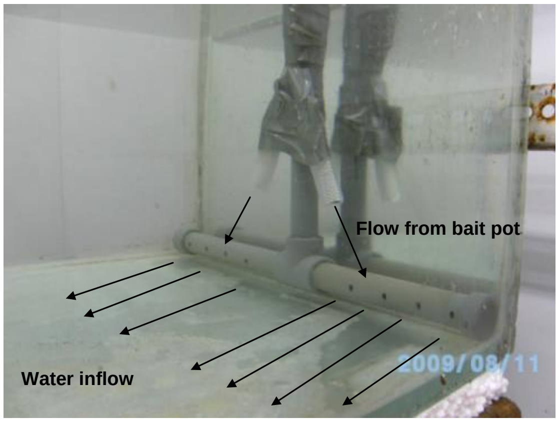

Figure 1.2 Close up of the sparge pipe and y-connector which transferred the bait odors from the bait pot used in the preliminary trials

Tests were performed on individual whelks to prevent any communication between them and therefore preventing any aggregatory / reproductive behaviour which may influence the results. Whelks were transferred from the holding tank submerged in plastic containers to preventing aerial exposure and additional handling stress. Whelks were placed along the centre line of the tank facing in a random direction and were restricted from moving by placing a section of narrow drain pipe on top of them. The light was switched off and a hand held red light (undetectable by whelk) was used for vision. After a 30 minute acclimation period the drain pipe was removed, the test bait was introduced to the bait pot, the temperature was recorded and the timer started. Whelks were checked every ten minutes for 60 minutes using the red light and the time of any positive responses noted. A positive response was judged to be when a whelk made contact with the sparge pipe from which the bait odours originated. After each experiment the whelk was placed back in the holding tank, the water was drained from the tank using a siphon and the bait pot and tank were thoroughly washed using a cloth then rinsed out.

Choice chamber tank

The experiments for the choice chamber tank were performed in a tank (118 x 57 x 57 cm) with static water and a bait pot at either end of the tank enabling it to act as a choice chamber. Temperature varied from 14 to 15 degrees from the start to the end of the experiment.

Figure 1.3 Picture of the choice chamber tank used in the preliminary trials

Test baits were presented along with salted herring and any positive responses to bait were recorded along with the time taken. Baits were placed in plastic pots with mesh allowing the odor to leach while maintaining the position of the bait and preventing the whelk from feeding. The walls of the tank were divided into 8 sections and a positive response was recorded when a whelk entered one of the two sections with baits (Figure 1.3**)**.

Bait preparation

Salted herring was provided by the crew of the Research vessel 'Aora' from the University Marine Biological Station Millport and brown crab *Cancer pagurus* processing waste was provided by Burgon (Eyemouth) Ltd..

Bait descriptions:

Crab claw waste: Mostly claw and shell fragments with very low meat content

Crab offal waste: A mixture of internal organs

Crab brown meat waste

Baits were made up to 140-160g, packed in tights to contain them, then frozen to -20 degrees C. Baits were allowed to thaw for 45 minutes at room temperature prior to use in experiments.

Execution of experiments

The order of each treatment performed on each whelk was randomised to prevent any effects of repeated treatments on whelks from biasing the results.

Whelks were sexed after all the experiments were ran by removing them from the shell after 5 minutes immersion in boiling water and examining for the presence of a penis (Fretter and Graham, 1994).

Statistical tests employed

Chi-squared analysis was performed to test the response rates between treatments for both the raceway and choice chamber experiments. Further chi-squared analysis was also performed on the response rates of baited treatments (not including controls) with expected values of 25 % response and 75 % no response for both sets of whelk (raceway and choice chamber). A cumulative binomial distribution table was also used on response rates of both sets of whelks in baited treatments with a P value of 0.25. One-way ANOVA was performed on the response time amongst treatments in the raceway tank. The activity and speed of movement of whelks with different lengths were simply examined via graphs (for both tanks). The two starvation periods for whelks (in both tanks) were examined for significant deviations in the activity of the whelks and their speed of movement via Kruskal-Wallis test,s as were the activity and speed of movement of whelks with sex.

Results

Raceway tank experiments

It can be observed from Figure 1.4 that the treatment with the highest rate of positive responses was salted herring, followed by crab wastes consisting of claws and offal. The bait with the lowest percentage of positive responses was brown meat. Using a cumulative binomial probability distribution table (P=0.25) it can be seen that T4 (salted herring) is the only treatment with response rates significantly different from the predicted value (P=0.0197) with 6 positive responses. Also it is important to note that a 30 % positive response was obtained when no bait was present in the bait pot, suggesting that whelks have a tendency to respond with rheotaxis and go against the current.

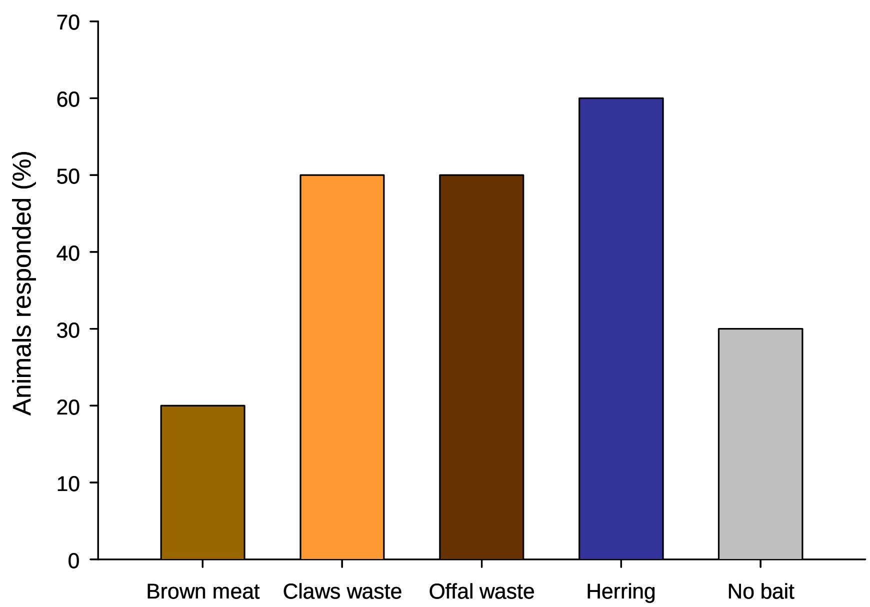

Figure 1.4 Percentage of animals that responded positively in the raceway tank preliminary trials.

The activity rates (%) of the whelks ranged from 0 to 100 % with a mean of 45 % (comparable to the findings of Fitzgerald, 2008 which were in a range of 0-100% with a mean of 59 %). There was no significant relationship between length of whelk and speed of movement, or between length and activity rate. There was also no significant relationship between sex and activity rate (Kruskal-Wallis test H = 0.05, P = 0.824, df = 1).

Table 1.1 Length, sex and activity rates of the whelk used in the raceway tank experiments in the preliminary trials

Whelk ID	Length (cm)	Sex	Activity rate (%)
2	7.91	F	50
4	6.31	F	50
5	7.65	F	50
19	8.19	F	0
8	6.86	F	25
18	7.45	M	50
17	7.14	F	100
21	6.75	M	100
14	11.48	M	25
15	6.99	M	0

Choice chamber tank experiments

There was a significant difference in response (to either bait) between treatments (4 cells with expected counts less than 5.0). There was no significant difference amongst treatments excluding T2 and if T1, T3 and T4 were aggregated and compared with T2 there was a significant difference between the responses (incorporating Yates correction, 1 cell with expected counts less than 5.0) implying that T2 is the source of the significant difference between the treatments. There was a significant departure from a 25 % response: 75 % no response distribution (3 cells with expected values less than 5.0). Using a cumulative binomial probability distribution table (P=0.125) the only significant deviation to the predicted values of response to a bait was salted herring in T2 (P=0.0183) with 4 positive responses.

Table 1.2 Responses to whelks in the choice chamber experiments from the preliminary work. Number of test was 10 and test baits where offered against salted herring (control bait)

		Test bait taken first			
Bait Type	No. of test	YES	NO	No response	% Bait preference
Brown meat	10	0	1	9	0
Claw waste	9	1	4	4	20
Offal waste	10	0	2	8	0
No bait	10	0	0	10	0

As summarised in Table 2.2 the number of no responses increased in the choice chamber system compared to the raceway system. In the choice chamber experiments the activity of whelks ranged from 0 to 67 % with a mean of 29.5% which is a greatly reduced figure to that seen in the raceway tank.

Table 1.3 Length, sex and activity rates of the whelks used in the choice chamber tank experiments in the preliminary trials

Whelk ID	Length (cm)	Sex	Activity rate (%)
1	6.68	M	0
16	9.08	F	33
3	7.72	F	33
20	7.05	M	33
6	7.54	F	0
9	6.94	F	67
10	7.33	M	67
11	11.19	M	33
12	8.03	M	0

From the preliminary trials it was observed that the following points should be addressed before final trials were conducted.

- Whelks are very susceptible to changes in the conditions in the experimental room (particularly light conditions) and are also susceptible to handling stress.
- Whelks had a higher activity rate in the raceway system compared to the choice chamber system, indicating that the raceway system is more suitable to study responses of whelks to different baits
- However, raceway tank experiments were not time-effective since it took approximately 2 h to assess the response of a single whelk to a single bait type

- The scoring system had to be improved since when for instance a whelk did not respond it was not possible distinguish if the animal was closed or if the animal had detected the bait odor but chose not too move.

For these reasons the following improvements were implemented in the execution of the final trials:

- The room where animals were held and the experimental room were kept at under low-light conditions from 9 am to 6 pm, and after this time lights were switched off. Extra care was taken when moving the whelks from tank to tank and no movement was allowed near the raceway tank once experiments were running.
- It was decided to use the raceway tank system to evaluate the responses of whelks to different baits, rather than the choice chamber system.
- The choice chamber system was only used to assess the response of European lobster to the different baits against salted herring.
- Since experiments using the raceway tank were not time-effective this tank was divided longitudinally into 4 lanes as explained in the methodology section of the final trials
- The scoring system was improved and the final scoring system is shown in Table 2.1

FINAL TRIALS

Materials and methods

<u>Collection and maintenance of whelks</u>

A total of 13 more whelks were collected from the Firth of Clyde oveer a period of 2 weeks during the month of September 2009 from creel pots baited with salted herring. Moreover, 3 more whelks (the only survivors from a total of 24) were provided and sent n ice by Burgon Ltd. to the University of Glasgow. Burgon Ltd. also provided during this time 6 European lobsters (*Homarus gammarus*) that were also used in the trials. In both cases animals were numerically identified and stored in holding tanks with an inflow of fresh seawater. Animals were starved for at least 2 weeks before any experiments were run.

<u>Tank configuration and experimental protocol</u>

Raceway tank

In order to increase the time efficiency of the trials the raceway glass tank (181.5 x 48 x 48 cm) was divided longitudinally with grey PVC sheets to create 4 lanes. In order to ensure that all lanes had similar amounts of bait odors, baits were introduced via a ‘feeder tank’. From this feeder tank a unidirectional flow of water was delivered to the raceway tank through a hose connected to a vertical section of plastic pipe with a T shaped horizontal section of pipe at the end with 8 holes drilled equidistant along its length (each tank lane was served by 2 holes from the sparge pipe).

Individual whelks were placed in each lane to prevent any communication between whelks and therefore preventing any aggregatory / reproductive behaviour which may influence results. Whelks were transferred from the holding tank submerged in plastic containers to prevent aerial exposure and additional handling stress. Whelks were placed along the centre line of the tank facing in a random direction. Experiments were carried out under low-light conditions. Animals were left to acclimatize for 30 min before the test bait was introduced to the bait pot or feeder tank. Temperature was recorded at the beginning and at the end of the experiment. Experiments lasted for 60 minutes and the time of any responses noted. According to the results obtained in the preliminary trials the responses of whelks were scored as summarized in Table 2.1.

Table 2.1 Scoring system used in the final trials to assess the responses of whelks to the baits in the raceway system

Score	Response
Very negative	Whelk moves agaisnt sparge pole and reaches the end of tank
Negative	Whelk moves agaosnt sparge pole but does not reach end of tank
Closed	No response, whelk is closed
No response	No response, but whelk has siphon out
Positive	Whelk moves towards sparge pole but does not reach it
Very postitive	Whelk reaches sparge pole

After each experiment the whelks were placed back in the holding tank, the water was drained from the tank using a siphon and the bait pot and tank were thoroughly washed using a cloth then rinsed out.

Choice chamber tank

European lobsters (*Homarus gammarus*) were used in these final trials, due to the lack of response of whelks using this system. Experiments were carried out in a square 118 x 118 cm tank with static seawater and a pot placed at each corner of the tank. Animals were acclimated for 20-25 min in the choice chamber tank with static seawater before any bait was placed in the pots. Each test bait was presented along with salted herring and responses of the lobsters were recorded over a period of 20 min. Baits were placed in a random fashion in the pots situated at each corner. Baits were placed in plastic pots with mesh allowing the odor to leach out while maintaining the position of the bait and preventing the lobster from feeding.

The walls of the tank were divided into 4 sections and a positive response was recorded when a lobster spent significantly more time in one of the baited pots or was actively trying to eat the bait; in this case the time of positive contact was recorded. Experiments were video taped in case further analysis was necessary.

Bait preparation

Salted herring was provided by the crew of the Research vessel 'Aora' from the University Marine Biological station Millport and brown crab *Cancer pagurus* processing waste was provided by Burgon (Eyemouth) Ltd..

Bait descriptions:

Crab meaty shell bits: A mix of more crushed shell with some meat

Crab claw waste: Mostly claw and shell fragments with very low meat content

Crab offal waste: A mixture of internal organs

Crab brown waste

Baits were made up to 100-110 g, packed in tights and frozen to -20 °C. Baits were allowed to defrost for 30 min in a container with fresh seawater at room temperature prior to use in experiments.

Execution of experiments

Parameters that were randomized were: the order of the whelks or lobsters, the time of the day that which each bait was tested and also the lanes in which each whelk was placed. All of this parameters were randomised to prevent any effects of repeated treatments on whelks or lobsters from biasing the results.

Each bait type was tested between 12 and 15 times using 15 different whelks. In the trials with European lobsters 6 replicates were performed for each bait.

Results

Raceway tank experiments

While in the preliminary trials not all the crab wastes were tested due to a low number of whelks available, in the final trials all the crab wastes were tested and the codes used for them in the the figures and tables of this section are shown in Table 2.2

Table 2.2 Labeling of the different bait tested in the final trials

Label	Bait type
A	Crab meaty bits
B	Crab claws
C	Crab offal
D	Crab brown meat
H	Salted herring
0	No bait

As shown in Table 2.1 the new scoring system developed and applied in the final trials gave a better understanding of the type of response that the whelks gave to the different baits. For instance what was scored as ‘no response’ in the preliminary trials was now classified in either ‘no move’ when the animal had the siphon out but chose not to move, or ‘closed’ when the animal had the operculum closed and siphon was not out (Table 2.3). Given this fact it was possible to eliminate those animals that were closed during the trials, and results excluding closed animals are represented in Figure 2.3

Table 2.3 Percentage of whelks that responded very positive, positive, negative, did not move or were closed in the raceway tank during the final trials using different bait types. A) crab meaty bits, B) crab claws, C) crab offal, D) crab brown meat, H) salted herring and 0) no bait.

Bait tested	Response type (% of animals)				
	Very positive	Positive	Negative	No move	Closed
A	16.67	16.67	16.67	16.67	33.33
B	33.33	16.67	8.33	25.00	8.33
C	25.00	16.67	0.00	8.33	41.67
D	16.67	16.67	8.33	41.67	16.67
H	33.33	20.00	0.00	20.00	26.67
0	13.33	20.00	0.00	33.33	26.67

The responses of the whelks in the raceway system varied according to the different baits tested (Figure 2.1). The baits that gave the highest percentage of very positive responses were herring (45.45 %) followed very closely by crab offal (42.86 %). On the other hand the lowest very positive responses were obtained in trials with no bait (18.18 %) or trials with crab brown meat (20 %).

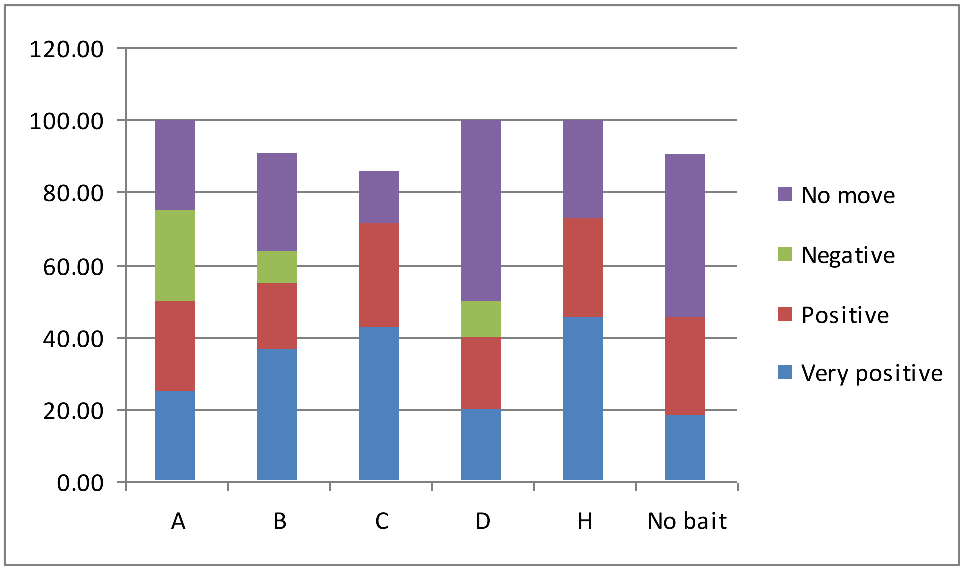

Figure 2.1 Percentage of whelks that responded very positive, positive, negative or did not move in the raceway tank final trials using different bait types. A) crab meaty bits, B) crab claws, C) crab offal, D) crab brown meat and H) salted herring. Total number of whelks tested in crab waste trials was 12 and the total number of whelks tested in the salted herring and no bait trials was15.

As shown in Table 2.4, when positive and very positive responses are combined then the percentage of total positive response to salted herring (72.73 %) was again very similar to the total positive responses obtained with crab offal (71.43 %). While baits with crab meaty bits and crab brown meat, and no bait, yielded a lower rate (between 40-50 %). Finally, baits with crab claws gave intermediate values with a total of 54.55 % of positive responses (36.36 % of these responses being very positive).

Table 2.4 Percentage of whelks that responded very positive, positive, negative or did not move in the raceway tank final trials using different bait types. A) crab meaty bits, B) crab claws, C) crab offal, D) crab brown meat and H) salted herring. Total number of whelks tested in crab waste trials was 12 and the total number of whelks tested in the salted herring and no bait trials was15.

Bait tested	Response type (% of animals)		
Bait	Positive	Negative	No move
A	50.00	25.00	25.00
B	54.55	9.09	27.27
C	71.43	0.00	14.29
D	40.00	10.00	50.00
H	72.73	0.00	27.27
No bait	45.45	0.00	45.45

In very positive responses, the time taken to reach to the sparge pipe (82 cm) is plotted in Figure 2.2. Very similar times were recorded for most of the baits tested, including herring, crab meaty bits, crab offal, crab brown meat and no bait while longer times were obtained with crab claws, suggesting a lower dispersal of the odor of this bait.

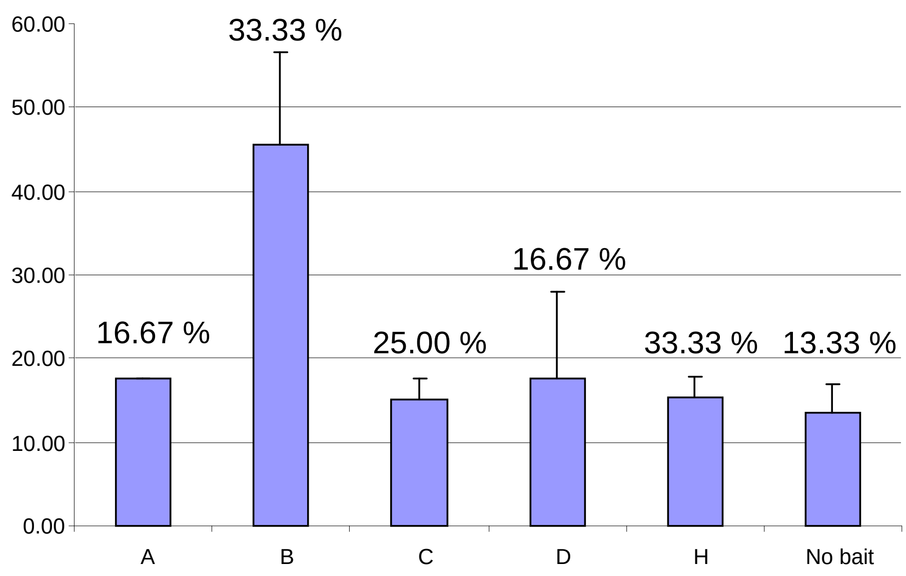

Figure 2.2 Average time taken for the whelks scoring a very positive response to reach the sparge pipe in the raceway tank final trials using different bait types. A) crab meaty bits, B) crab claws, C) crab offal, D) crab brown meat and H) salted herring. Above each bar it is represented the percentage of whelks that have a very positive response in each category.

The activity rate of each whelk was calculated and as shown in Table 2.5 activity rates ranged from 0 to 100 % with an average of 49.89 %, similar to the values obtained in the preliminary trials and confirming the suitability of this system to assess bait attractiveness to whelks.

Table 2.5 Activity rates (%) of the whelks used in the choice chamber tank experiments in the final trials

Whelk ID	Activity rate (%)	Mean	S.E.
1	33.33		
2	83.33		
3	80.00		
4	60.00		
5	40.00		
6	50.00		
7	83.33	49.89	7.65
8	80.00		
9	20.00		
10	40.00		
11	25.00		
12	0.00		
13	33.33		
14	100.00		
15	20.00		

Choice chamber tank experiments

As shown in Table 2.6 the bait preference of the lobsters was not always clear. In many cases the lobsters wandered around between pots before settling in the middle of the tank and therefore it was not possible to discriminate which bait they preferred or they would take first. From trials in which clear responses were obtained (whether because the lobster actively tried to feed from one of the baited pots or because it spent more time near one of the baited pots) results indicate that herring was preferred against any of the crab wastes tested. However when crab offal was offered against salted herring this bait was taken first in 2 of the 6 trials, giving a bait preference of 33 %. If ‘no responses’ are eliminated then the bait preference for crab offal was 40 % in contrast to herring that had a bait preference of 20 %.

Table 2.6 Responses of European lobsters in the choice chamber experiments from the final trials. A) crab meaty bits, B) crab claws, C) crab offal, D) crab brown meat and H) salted herring. For each bait tested 6 replicates were done and all the test baits where offered against salted herring (control bait)

		Test bait taken first				
Bait Type	No. of test	YES	NO	No clear	No response	% Bait preference
A	6	0	2	2	2	0
B	6	0	2	1	3	0
C	6	2	1	2	1	33
D	6	0	2	3	1	0
0	6	0	0	0	6	0

The activity rates for each lobster were calculated and as shown in Table 2.7 the activity rates ranged from 25 to 100 % with an average of 70.83 % indicating that in theory this methodology could be effective in assessing bait attractiveness when using lobsters. However, the scoring of behavioral responses was not always straightforward as many factors were involved and therefore in many cases a 'no clear' response was obtained.

Table 2.7 Sex and activity rates of the whelks used in the choice chamber tank experiments in the preliminary trials

Lobster ID	Sex	Activity rate (%)	Mean	S.E.
1	F	25		
2	M	75		
1 claw	F	50	70.83	11.93
1 claw+ant	F	75		
5	F	100		
6	M	100		

Conclusions from laboratory trials

- The most promising crab waste to be used as bait in trap fishing for whelks (*Buccinum undatum*) is crab offal waste
- The attractiveness of the different baits was also tested using European lobsters but the assessment of the responses was complex. However promising results were also obtained using crab offal waste

Recommendations

In light of the results obtained in these trials it is recommended that further assessments are carried out using the crab waste identified as a potential usable waste, by using baited creels in the natural environment.

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Annexe 1. Table with response scoring system used in the Annexe 2 section

Score	Response
-2	Whelk moves agaisnt sparge pole and reaches the end of tank
-1	Whelk moves agaosnt sparge pole but does not reach end of tank
0	No response, whelk is closed
1	No response, but whelk has siphon out
2	Whelk moves towards sparge pole but does not reach it
3	Whelk reaches sparge pole

Annex 2. Table containing detailed information on the raceway tank final trials conducted with whelks

Whelk ID	Bait	Date	Time	Lane	Response	Time end	Distance 60' (cm)
14	A	07/10/2009	11.50	3	-2	-24.36	
1	A	07/10/2009	11.50	1	1		
15	A	07/10/2009	11.50	4	-2	-49.49	
4	A	07/10/2009	11.50	2	0		
5	A	13/10/2009	15.40	1	2		32
9	A	13/10/2009	15.40	3	0		
2	A	13/10/2009	15.40	4	3		
13	A	13/10/2009	15.40	2	0		
3	A	16/10/2009	15.00	1	2		
6	A	16/10/2009	15.00	2	0		
7	A	16/10/2009	15.00	3	3	17.5	
12	A	16/10/2009	15.00	4	1		
13	B	06/10/2009	16.00	1	3	57.3	
10	B	06/10/2009	16.00	4	3	12.22	
11	B	06/10/2009	16.00	2	0		
6	B	06/10/2009	16.00	3	3	55.13	
7	B	15/10/2009	10.45	2	2		67
8	B	15/10/2009	10.45	3	random		
15	B	15/10/2009	10.45	1	1		
1	B	15/10/2009	10.45	4	-1		-45
9	B	19/10/2009	12.15	1	1		
2	B	19/10/2009	12.15	4	3	57.48	
5	B	19/10/2009	12.15	3	1		
3	B	19/10/2009	12.15	2	2		65
1	C	12/10/2009	11.30	3	1		
10	C	12/10/2009	11.30	2	0		
8	C	12/10/2009	11.30	4	3	12.32	
7	C	12/10/2009	11.30	1	2		35
2	C	13/10/2009	15.00	2	3	13.14	
6	C	13/10/2009	15.00	3	2		10
9	C	13/10/2009	15.00	4	0		
14	C	13/10/2009	15.00	1	3	20.13	
13	C	15/10/2009	12.45	4	0		
12	C	15/10/2009	12.45	1	0		
4	C	15/10/2009	12.45	3	random		
5	C	15/10/2009	12.45	2	0		

Annex 2. Continuation

Whelk ID	Bait	Date	Time	Lane	Response	Time end	Distance 60' (cm)
3	D	07/10/2009	14.00	4	2		44
12	D	07/10/2009	14.00	3	0		
8	D	07/10/2009	14.00	1	1		
13	D	07/10/2009	14.00	2	0		
15	D	13/10/2009	13.00	3	1		
4	D	13/10/2009	13.00	4	1		
1	D	13/10/2009	13.00	2	1		
10	D	13/10/2009	13.00	1	3	28.02	
2	D	15/10/2009	15.00	1	3	7.14	
6	D	15/10/2009	15.00	4	2		67
7	D	15/10/2009	15.00	3	1		
11	D	15/10/2009	15.00	2	-1		26
7	H	06/10/2009	12.13	4	2		73
9	H	06/10/2009	12.13	3	3	12.46	
2	H	06/10/2009	12.13	2	0		
5	H	06/10/2009	12.13	1	1		
3	H	12/10/2009	13.30	4	3	19.37	
11	H	12/10/2009	13.30	3	0		
6	H	12/10/2009	13.30	1	0		
12	H	12/10/2009	13.30	2	0		
8	H	16/10/2009	12.45	2	2		8
13	H	16/10/2009	12.45	4	3	14.1	
1	H	16/10/2009	12.45	1	2		45
4	H	19/10/2009	16.00	1	3	8.33	
10	H	19/10/2009	16.00	2	1		
14	H	19/10/2009	16.00	3	3	22.04	
15	H	19/10/2009	16.00	4	1		
9	0	07/10/2009	16.00	1	0		
2	0	07/10/2009	16.00	3	2		15
11	0	07/10/2009	16.00	4	1		
6	0	07/10/2009	16.00	2	1		
5	0	13/10/2009	11.25	4	2		5
13	0	13/10/2009	11.25	3	0		
12	0	13/10/2009	11.25	1	0		
3	0	13/10/2009	11.25	2	0		
10	0	16/10/2009	11.00	3	1		
14	0	16/10/2009	11.00	4	2		35
15	0	16/10/2009	11.00	2	1		
4	0	16/10/2009	11.00	1	random		
1	0	19/10/2009	14.00	4	1		
7	0	19/10/2009	14.00	2	3	17.02	
8	0	19/10/2009	14.00	3	3	10.04	

Annex 3. Table containing detailed information on the choice chamber final trials conducted with European lobsters

Lobster ID	Bait tested	Location bait	Date	Time	Tape/Video	Accl/Exp time	Bait prefered
1 claw	H/C	1/3	12/10/2009	11.30	3/12	20'/10'	?
6	H/B	2/4	12/10/2009	12.15	3/13	19'/5'	H
1 clw+ant	H/D	3/1	12/10/2009	13.05	3/14	17'/20'	?
5	H/A	4/2	12/10/2009	14.20	3/15	25'/12'	H
1	No bait		12/10/2009	15.40	4/16	18'/20'	No response
2	H/C	2/4	12/10/2009	16.30	4/17	20'/10'	C
5	No bait		13/10/2009	11.00	4/18	25'/10'	No response
2	H/A	3/1	13/10/2009	11.45	4/19	20'/15'	?
1 claw	H/B	4/2	13/10/2009	12.50	4/20	18'/10'	?
6	H/D	1/3	13/10/2009	13.45	4/21	20'/5'	H
1 clw+ant	H/C	2/4	13/10/2009	14.40	4/22	25'/10'	? C
1	H/B	3/1	13/10/2009	16.30	4/23	17'/10'	No response
6	H/A	4/2	15/10/2009	10.25	5/24	25'/12'	H
1 claw	H/D	1/3	15/10/2009	11.30	5/25	18'/15'	H
5	H/B	2/4	15/10/2009	12.30	5/26	17'/20'	?
1	H/C	3/1	15/10/2009	13.30	5/27	18'/12'	No response
2	No bait		15/10/2009	14.45	5/28	17'/15'	
1 clw+ant	H/A	4/2	15/10/2009	15.45	6/29	20'/10'	No response
1 claw	No bait		16/10/2009	10.30	6/30	23'/10'	
2	H/D	1/3	16/10/2009	11.15	6/31	20'/20'	No response
1 clw+ant	H/B	2/4	16/10/2009	12.30	6/32	18'/15'	? H
6	H/C	3/1	16/10/2009	13.30	6/33	20'/15'	?
5	H/D	4/2	16/10/2009	15.00	7/34	17'/15'	?
1	H/A	1/3	16/10/2009	16.00	7/35	15'/15'	H
1	H/D	2/4	19/10/2009	11.5	7/36	24'/10'	No response
5	H/C	3/1	19/10/2009	13.30	7/37	20'/18'	C
1 claw	H/A	4/2	19/10/2009	14.15	7/38	21'/20'	No response
6			19/10/2009	15.30	8/39	17'/10'	
2	H/B	1/3	19/10/2009	16.30	8/40	18'/17'	No response

Annex 4. Table containing more detailed information on the choice chamber final trials conducted with European lobsters

Lobster ID	Bait tested	Location bait	Date	Bait prefered	Response
1 claw	H/C	1/3	12/10/2009	?	At 10" tries C. At 3'30" tries H. At 4' tries C and settles near C
6	H/B	2/4	12/10/2009	H	At 17" tries H. At 1'44" goes for H. At 3' goes for H. At 4'30" clearly goes for H
1 clw+ant	H/D	3/1	12/10/2009	?	First contact at 1'57" for D. At 4'15" goes for H. Moves around. Not clear
5	H/A	4/2	12/10/2009	H	At 4'30" goes for H
1	No bait		12/10/2009	No response	Settle in the middle. No move
2	H/C	2/4	12/10/2009	C	First contact is H but between 5'20"-7'30" goes for C
5	No bait		13/10/2009	No response	Settle in the middle. No move
2	H/A	3/1	13/10/2009	?	No clear. Moves between pots
1 claw	H/B	4/2	13/10/2009	?	Moves around. At 5' settles is 1. No response
6	H/D	1/3	13/10/2009	H	At 3'15" goes clearly for H
1 clw+ant	H/C	2/4	13/10/2009	? C	Not clear but more contact with C (2'20" and 3'08")
1	H/B	3/1	13/10/2009	No response	No response. No move
6	H/A	4/2	15/10/2009	H	Initially interested in both. At 10'30" tries clearly to feed on pot containing H
1 claw	H/D	1/3	15/10/2009	H	At 5'54" tries to eat H. Settles down in position 4
5	H/B	2/4	15/10/2009	?	Very random. 8'58" tries to eat H. Moves between 4 pots
1	H/C	3/1	15/10/2009	No response	No response. No move. Settles in 4
2	No bait		15/10/2009		Moves around for 4'. Settles after that
1 clw+ant	H/A	4/2	15/10/2009	No response	Interested in the middle of the tank. No response after that
1 claw	No bait		16/10/2009		Moves randomly for 2'. Settles in 2
2	H/D	1/3	16/10/2009	No response	Starts movement after 2'. At 4' settles in 4. No response
1 clw+ant	H/B	2/4	16/10/2009	? H	Starts movement at 2'47". Around 11' goes for H. Not very clear
6	H/C	3/1	16/10/2009	?	Not clear! Spends more time in H
5	H/D	4/2	16/10/2009	?	From 3'30" to 7' moves around. First explores H then after 11' explores D. Settles in 3
1	H/A	1/3	16/10/2009	H	At 6'27"; 8' and 9' tries to eat H
1	H/D	2/4	19/10/2009	No response	No move. No response. Settle in 1
5	H/C	3/1	19/10/2009	C	2'30" starts moving. At 15'07" tries to eat C then settles in 2
1 claw	H/A	4/2	19/10/2009	No response	No response. Settles in 3
6			19/10/2009		Moves randomly for 2'. Settles in 1. No move
2	H/B	1/3	19/10/2009	No response	Moves randomly. At 4' settles in 2. No move