Artificial Lobster Habitat Project
Experiment Report

Matthew T. Coleman
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1. Overview

1.1 Aim of Research
To assess gabions as suitable sites for juvenile European Lobster’s Homarus gammarus settlement and their use as a low cost habitat enhancement tool.

1.2 Rational
Attempts at locating juvenile European lobsters Homarus gammarus in-situ has been limited or periodic (Howard & bennet, 1979; Jensen et al, 1994). In contrast to its American Cousin Homarus americanus extensive research into population structure and geographical variation in stocks has highlighted strong correlations between environmental variables affecting its abundance and seasonal variations in distributions, successfully aiding in its management.

American research has highlighted cobble habitat as the primary habitat preference for early benthic phase (EBP) H. americanus (5mm – 40mm carapace length (CL)) due to the creation of interstitial spaces (Hudon, 1987; Wahle & Steneck, 1991). Similar habitat preferences have been exhibited in EBP H. gammarus within experimental studies (Linnæ et al, 2000; Ball et al, 2001), but has not been observed in naturally occurring populations but is believed to be the case. These studies however have highlighted the lack of suitable EBP lobster habitat as a potential significant bottleneck in recruitment (Caddy, 1986; Wahle & Steneck, 1991; Wahle & Steneck, 1992), with these habitats becomes highly saturated over the course of a settlement season due to their limited availability (Wahle & Incze. 1997). Wahle & Steneck (1991) demonstrated that within 60.2km of Maine coastline only 11% was identified as suitable EBP lobster habitat and was sparsely distributed. Such specific requirements needed for settlement can have significant effects on populations, creating recruitment bottlenecks. Potentially decreasing reproductive potential outside of current existing management strategies, such as V-notching and maximum landing sizes.

However research into the use of artificial habitat has shown success in increase carrying capacity. Bologna & Steneck (1993) investigated the use of artificial kelp forests as habitat enhancement tool for adult Homarus americanus, showing positive benefits of increased carrying capacity in comparison to non- enhanced areas and alongside areas of existing habitat. More specifically to EBP lobsters, artificial reef structures within Poole Bay have demonstrated effectiveness by harbouring EBP H. gammarus lobsters (27mm CL) and subsequent larger lobsters, including berried hens (Jensen et al, 1994).

2. Methods
Two experiments were conducted to investigate juvenile European lobster Homarus gammarus substrate settlement preference between November 2014 and April 2015. The two experiments comprised of an abundance experiment and a size preference experiment. The abundance experiment investigated habitat preference temporality between substrate types over the whole time frame. The size preference experiment investigated substrate preference relating to individuals inhabiting the trial gabion when it was removed and destructible sampled at the end of the time frame. This experiment set out to establish if different substrate preference was dependant on lobster size and lobster requirements changed over time.
2.1 Experimental Animals
Orkney Sustainable Fisheries Ltd Lobster Hatchery, Lamb Holm provided 536 stage 8 juvenile lobsters. Lobsters were on grown from stage 4 to stage 8 individuals prior to introduction to experimental tanks in a two cylinder Aquahive system (Shellfish Hatchery Systems Ltd.).

Upon introduction to the experimental tanks, aquahive disks containing 67 lobsters were floated for 15 minutes allowing acclimatization in each tank. Individuals were then randomly released into the centre of the tank.

2.2 Experimental Units

2.2.1 Experiment Tanks
Eight experimental tanks (Figure 1) were used and arranged in two separate groups of four tanks. Each set of four tanks was serviced by a separate filtration unit. Filtration units were matured for one week prior to the introduction of EBL. This was achieved through the running of the system and introduction of one adult lobster per tank of the course of this time period.

![Figure 1. Dimensions of Experimental Tanks (cm): H:60,L:116,W:97](image)

2.2.2 Gabion Structures
Thirty two trial gabions (Fig 2) were used within this study, comprising of 4 treatment types of varying aggregate size; small, medium, beach pebble and large. Each treatment gabion had a corresponding mesh size (table 1), one of each trial gabion was placed into each experiment tank, each experimental tank held four gabions (fig 3).

<table>
<thead>
<tr>
<th>Gabion Type</th>
<th>Mesh Size (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1.08</td>
</tr>
<tr>
<td>Medium</td>
<td>1.86</td>
</tr>
<tr>
<td>Beach Pebble</td>
<td>4.65</td>
</tr>
<tr>
<td>Large</td>
<td>7</td>
</tr>
</tbody>
</table>

*Table 1. Gabion type and corresponding mesh size in cm².*
2.3 Abundance Experiment
Gabions were systematically sampled (Fig 3) weekly through timed searches of 5 minutes per trial gabion. This was done using a DBPOWER endoscope inspection camera. Lobster presence was recorded in accordance to gabion type. This information was then used to investigate lobster abundance in relation to gabion type.

2.4 Size Preference Experiment
Destructive sampling occurred on individual trial gabions. Water from each tank was drained prior to the removal of each gabion. Upon removal gabions were carefully removed to cause limited disturbance and damage to juvenile lobster contained within, the surrounding area was additional checked for lobsters that fell out of lifted gabions. Gabion substrate was carefully removed and any lobsters encountered were recorded in accordance to substrate type and photographed with a scale bar. Photos were taken to allow
imageJ (2004) analysis to be undertaken. Photographs for analysis were taken using a Fuji finepix HS20exr on macro setting.

ImageJ (2004) analysis was undertaken to investigate size distribution of lobster on substrate type. Prior to analysis image quality screening occurred, with the clearest image selected for each sample. The scale for analysis was set using the scale bar provided within each image. Carapace length was measured on each juvenile lobster, spanning the back of the eye socket to the base of carapace (Fig 4).

2.5 Feeding
Prior to transitioning to experiment tanks aggregate gabions were soaked in a continuous flow of fresh salt water within the OFS lobster ponds for one week. This deployment allowed the formation of encrusting colonise on the structures and the removal excess grit. Experimental tanks were fed twice weekly on a diet of 40g dried pacific krill, this quantity was reduced to 20g from December to February due to reduced water temperatures. Krill was soaked overnight to enable water absorption and facilitate the sinking of food items.

2.6 Statistical Analysis
Statically analysis was undertaken to investigate EBL abundance (N=429) in relation to different substrate types (small, medium, beach pebble, Large), this distribution of abundance is interpreted as a habitat preference. Analysis of habit preference relating to EBL size was also investigated (N=22).

All univariate statistical analysis was undertaken in R version 2.15.1

Prior to univariate analysis data was checked for homogeneity of variance and transformed to meet test requirements. In the case of non-homogeneity, non-parametric equivalent analysis was undertaken.

2.6.1 Abundance Experiment
To investigate lobster abundance over time and between gabion types a linear model was used. This tested lobster abundance against two explanatory variables; gabion type and month. The original model was then simplified to establish the minimum adequate model through the use of R STEP package. Significant interactions were identified through the use of ANOVA. A P value of less than 0.05 was sued to define a significant difference between the variables.

2.6.2 Size Distribution Experiment
EBL distribution in accordance to size was investigated through a linear model. This testes lobster size against the explanatory variable gabion type. Significant interactions were identified through the use of ANOVA. A P value of less than 0.05 was sued to define a significant difference between the variable.
Figure 4. Measuring Juvenile Lobsters in ImageJ. Measurements were taken from the base of the eye socket to the base of the carapace.

3. Results

3.1 Abundance Experiment

Lobster abundance was significantly affected by gabion type ($F_{3,382} = 9.4$, $P <= 0.001$), with lobster abundance varying temporally ($F_{1,382} = 163.5$, $P <= 0.001$) and both spatially and temporally combined ($F_{3,383} = 8.7$, $P <= 0.001$). Abundance significantly decreased between January – March (Table 1, Appendix 1), with abundance within the large gabion type declining within January, but subsequent increases in observations in month February and March (Table 2, Appendix 1). Increases in lobster abundance were also observed within beach pebble gabion in March ($P = 0.02$).

Overall temporal and spatial changes in lobster habitat preference are seen to occur (Appendix 1). Initial settlement is demonstrated in November with all gabion types being used equally with a small preference toward coarser sediment in the large gabion. From January to March we see a transition of lobster habitat preference to gabions containing increasingly coarse sediment, with an opposite interaction demonstrated in Fine sediment, becoming less favourable over time with a gradual decline in density (Appendix 1).

Table 1. Changes in overall monthly observed lobster abundance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>-0.11</td>
<td>0.7</td>
</tr>
<tr>
<td>January</td>
<td>-2.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>February</td>
<td>-2.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>March</td>
<td>-2.46</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Table 2. Changes in lobster abundance relating to the interaction of large gabion and month.

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Estimate</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Gabion: December</td>
<td>-1.13</td>
<td>0.04</td>
</tr>
<tr>
<td>Large Gabion: January</td>
<td>0.56</td>
<td>0.32</td>
</tr>
<tr>
<td>Large Gabion: February</td>
<td>0.91</td>
<td>0.05</td>
</tr>
<tr>
<td>Large Gabion: March</td>
<td>1.43</td>
<td>0.02</td>
</tr>
</tbody>
</table>

3.2 Lobster Size Preference
Size distribution of lobsters in accordance to trial gabion was investigated through the use of general linear model with Gaussian distribution. Habitat preference was seen to be significantly dictated by lobster size ($F_{3,18} = 7.37, P=0.002$), with large lobster preferring the largest aggregate type ($P=0.006$, Fig 5.). The range and mean size of lobster varied between gabion types. One lobster was found within small substrate gabion and was 0.84cm in carapace length (CL), whilst those found within medium substrate gabions had a size range of 0.8 – 1cm CL with a mean of 0.94. Lobster found in pebble substrate gabions had a size range of 0.7-1.2cm CL with a mean of 1.02. Lobster found within large substrate gabions had a range of 1.08 – 1.3cm CL, with a mean of 1.2cm.

Figure 5. Size distribution of juvenile lobsters in accordance to gabion type. (Whisker indicate largest and smallest individual, 1st quartile, median and 3rd quartile)
3.3 Temperature

Water temperature varied considerably over the duration of the experiment (Fig 6). Changes were expected due to known seasonal cooling; however, tank temperatures varied considerably greater than expected (Fig 6). An overall trend in declining water temperatures is observed from the start of the experiment, with a spike in April. This spike can be attributed to measures taken to stabilise water temperature and reduce the effect of passive water cooling. This included the construction of a windbreak and the introduction of one 100w water heater into each filtration unit. Resulting in the rise in water temperature observed in April.

![Figure 6. Monthly variability of experimental tank water temperature](image)

4. Discussion

Juvenile lobsters are seen to demonstrate some degree of transitional behaviour between different coarseness of habitat through its development process; this can be linked to changes in size due to moulting. This observation is in line with previous experiments investigating juvenile European lobster habitat preference (Linnane et al., 2000). Where migrations onto coarse habitat that provided larger mesocosm were preferred by larger individuals and corresponded with higher densities of juveniles being found in these areas over time.

In this experiment, the density of lobsters remained low despite high seeding density. Differences in this study compared to that of Linnane could be related to number and size of settlement areas available. Settlement areas in the Linnane study were larger (1m²), greater in number and sparsely distributed amongst undesirable habitat. This allowed for the movement of individuals to a less populated area if one reached carrying capacity. Within the OSF experiment settlement areas were considerably smaller at .07m²,
and were limited to one habitat type per 1.1m². Making avoidance and migration impossible, increasing lobster interaction and mortality risk through potential constant attempts at settlement.

Lobster density within the preferred habitat (Cobble) in the Linnane study was highest at 18/m², whilst that of OSF study within the same habitat was one per 0.07m². When settlement areas are scaled to allow comparable density per m², the OSF study demonstrates a potential lobster density of 14/m² illustrating similar density levels. However the limited density within the OSF study highlights that juvenile lobsters are capable of maintaining a territory and excluding the settlement of others when habitat is limited, providing an example of the minimum space requirement per lobster for successful settlement.

The number of juvenile lobster recovered at the end of the experiment was only 3% (n=18) of the original number introduced. This dramatic decline from stocking density could be attributed to a number of factors. Firstly the decline could be due to the variability of water temperature throughout the experiment and potential result of thermal shock, secondly low survival rates could be a result of high levels of mortality due to con specific predation and high density of these experiments, indicating a potential limitation in experimental design. A large number of individual were observed during timed searches as missing one or both chela throughout the course of the experiment, strengthening the idea that high stocking densities were increasing the occurrences of aggressive interactions. A combination of both variability in water temperature and high stocking density would lead individuals to be highly vulnerable post moult, potentially increasing chances of environmental mortality (unstable conditions) or predation mortality.

Though a high level of predation and overall mortality is documented under experimental conditions, natural survival is low within this species. Historical studies evaluating the survivability of juvenile lobsters from stock enhancement indicated a survivability of approximately 1.6% to recruitment (Bannister & Addison, 1998). Therefore observed low survivability rates of this experiment are within the upper limits of observed natural mortality, with potential reduced levels of additional mortality form conspecific, resulting in the higher survival rate recorded here.

Within this experiment time searches were used as the primary tool to estimate distribution and density of juvenile lobster between gabions. The use of this method possesses a number of sampling bias that was not envisioned prior to the start of the project. Firstly the use of time searches sues the video endoscope limited the penetration ability to search gabions effectivity, meaning density estimates were limited to juveniles that inhabited the edge of each gabion. This observation bias therefore excluded any deep inhabiting individuals that could not be observed via endoscopic search, meaning that densities estimates per gabion and habitat types could in fact be higher than observed. Density estimates are potentially limited further due to the effects of varying water temperature, and its effect on juvenile lobster metabolic rates. Declining water temperatures are known to effect crustacea metabolic rates (Symons, 1961), resulting in reduced movement (Wrona, 2004), with such behaviours recorded within wild European lobster populations (Lizarraga et al, 2015). Therefore individuals that resided deep within gabions would not be picked up via timed probing searches due to a lack of movement due to these behavioural responses. Subsequently, recommendation relating to future sampling design would be to incorporate destructive sampling of small trial gabions. The use of destructive sampling possesses its own issues relating to accidental mortality caused by gabion removal and debris shift. However to record accurate density estimates, this sampling method is recommended.
5. Conclusion

In conclusion this experiment provides the base line and scaling from which the design of larger sea trial structures or the design of offshore marine renewable gabion structures could be based upon. The results within the preliminary trial hypothesise the minimum size of a territory that can be maintained by an EBP and the most preferential aggregate material needed to make such structures preferable to juvenile lobster at differing EBP.
Appendix 1. Monthly changes in log EBP lobster abundance per aggregate type over duration or experiment.
References

CAR package


**R Code:**

Size Preference:

```r
> anova(m5)
Analysis of Variance Table

Response: S
   Df Sum Sq Mean Sq  F value Pr(>F)
  tr  3  0.2854  0.09513  7.3726  0.002004 **
Residuals 18 0.23225 0.012903
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> summary(m5)

Call: lm(formula = S ~ tr)

Residuals:
     Min      1Q  Median      3Q     Max
-0.25690 -0.07585  0.02079  0.06232  0.20410

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.841037   0.113585  7.4039 7.25e-07 ***
trb          0.099093   0.127075   0.7804  0.44579
trc          0.183949   0.119158   1.5435  0.14008
trd          0.373694   0.121387   3.0777  0.00649 **

(Intercept) ***
trb
trc
trd **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1136 on 18 degrees of freedom
Multiple R-squared: 0.5513,  Adjusted R-squared: 0.4765
F-statistic: 7.373 on 3 and 18 DF,  p-value: 0.002004
```

```r
> anova(m4)
Analysis of Variance Table

Response: log(N + 0.1)
   Df Sum Sq Mean Sq  F value Pr(>F)
  trt  3 41.370 13.790  9.4880  4.649e-06
mnth  1 237.642 237.642 163.5079  < 2.2e-16
trt:mnth  3 38.200 12.733  8.7619  1.241e-05
Residuals 382 555.200 1.453
```
> summary(m4)

Call:
    lm(formula = log(N + 0.1) ~ trt * mnth)

Residuals:
    Min      1Q  Median      3Q     Max
-2.9691 -0.5712 -0.1998  0.8913  2.6909

Coefficients:  Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.164210  0.241661   0.680  0.49723
trtb        0.502304   0.341760   1.470  0.14247
trtc        0.222889   0.338181   0.659  0.51024
trtd        0.392486   0.338181   1.161  0.24655
mnth2       -0.116066  0.392862  -0.295  0.76784
mnth3       -2.067149  0.412710  -5.009 8.50e-07 ***
mnth4       -2.266975  0.338181  -6.703 7.62e-11 ***
mnth5       -2.466802  0.338181  -7.294 1.84e-12 ***
trtb:mnth2  -0.233138  0.555592  -0.420  0.67500
trtc:mnth2  -0.722285  0.553400  -1.305  0.19264
trtd:mnth2  -1.137518  0.553400  -2.056  0.04053 *
trtb:mnth3  -0.048779  0.583663  -0.084  0.93344
trtc:mnth3   0.630292  0.581580   1.084  0.27918
trtd:mnth3   0.568460  0.581580   0.977  0.32899
trtb:mnth4  -0.402402  0.478260  -0.841  0.40067
trtc:mnth4   0.376578  0.475710   0.792  0.42909
trtd:mnth4   0.914231  0.475710  1.922  0.05540 .
trtb:mnth5  -0.148669  0.478260  -0.311  0.75605
trtc:mnth5   1.056880  0.475710  2.222  0.02691 *
trtd:mnth5   1.437874  0.475710  3.023  0.00268 **

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.159 on 370 degrees of freedom
Multiple R-squared: 0.4303,  Adjusted R-squared: 0.4011
F-statistic: 14.71 on 19 and 370 DF,  p-value: < 2.2e-16