

**Size at maturity of the European lobster, *Homarus gammaus*, in Welsh waters with reference to sustainability and stock size structure.**

**Natalie Hold, Charlotte Heney, Harriet Lincoln, Alec Moore, Charlotte Colvin, Rebecca Turner, Lewis Le Vay, Ian McCarthy**

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Corresponding author: n.hold@bangor.ac.uk

Bangor University Sustainable Fisheries and Aquaculture Group

Centre for Applied Marine Sciences, School of Ocean Sciences, Bangor University

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Contents

[Definition of some key terms 2](#_Toc113447828)

[Executive Summary 3](#_Toc113447829)

[Crynodeb Gweithredol 3](#_Toc113447830)

[Introduction 4](#_Toc113447831)

[What is maturity and why are we interested in it? 4](#_Toc113447832)

[How is size at maturity used to assess sustainability of the lobster stocks? 4](#_Toc113447833)

[Methodology 5](#_Toc113447834)

[Field Sampling 5](#_Toc113447835)

[Timing of the ovary staging survey 6](#_Toc113447836)

[Laboratory protocol 6](#_Toc113447837)

[Ovary staging and developing a staging guide for the European lobster. 6](#_Toc113447838)

[Data analysis 7](#_Toc113447839)

[Morphometric maturity 7](#_Toc113447840)

[Physiological maturity 7](#_Toc113447841)

[Functional maturity 10](#_Toc113447842)

[Results 10](#_Toc113447843)

[Morphometric maturity 10](#_Toc113447844)

[Physiological maturity 11](#_Toc113447845)

[Functional maturity 14](#_Toc113447846)

[Discussion 15](#_Toc113447847)

[References 17](#_Toc113447848)

# Definition of some key terms

**Allometric Growth**: Different parts of an animal grow at different rates e.g. abdomen widens more quickly than the carapace lengthens in maturing female lobsters

**Berried**: A female lobster who is carrying eggs

**Isometric Growth**: Body parts grow at the same rate

**Vitellogenesis**: The physiological process of ovary maturation that occurs annually, biennially.

# Executive Summary

The size at maturity of female lobsters in Wales was estimated using three different methods: Dissection and analysis of ovary maturation (Physiological), observations at sea on the proportion of animals carrying eggs (functional) and analysis of the rate at which the abdomen widens in relation to the carapace length (morphological).

The onset of maturity in female lobsters appears to occur around 73 mm – 75 mm Carapace Length (CL). At this size, during moulting, there is a rapid widening of the abdomen in relation to the growth of the CL, which enables a female lobster to carry larger number of eggs.

Combining results from all three methods, our estimates suggest that 50% of females will have had a chance to reproduce between 88 mm and 91 mm CL. This means that the MLS of 90mm is marginally protecting 50% of female lobsters to first reproduction. However, lobsters show discontinuous growth (moulting), and an extended brooding period (September – June). Therefore, at the current MLS these females are, on average, reaching maturity and bearing eggs during the moult cycle that brings them vulnerable to fishing. The life history of lobsters in Wales (moult May/June, spawn September, hatch the following summer), means that it is possible they are vulnerable to fishing for almost a year before they have had a chance to **hatch** their first brood of eggs due to maturing at the MLS combined with the legal landing of berried lobsters in Wales**.**

90% of female lobsters are physiologically mature at 92 mm CL or 102 mm CL for 90% functionally mature.

# Crynodeb Gweithredol

# Introduction

## What is maturity and why are we interested in it?

This study relates to the maturity status of **female** European lobsters, *Homarus gammarus*. There are two aspects of maturity. Firstly, when a juvenile animal progresses through puberty to spawn for the first time. Secondly, once mature, female lobsters will show a cycle of moulting and spawning over either an annual, biennial or a possibly longer period. From a fisheries management and stock sustainability point of view, both aspects of maturity are important. In this study we are interested in identifying at what size animals in the studied population will mature for the first time. This is called size at maturity and allows managers and fishers to protect the stock from fishing mortality before they have had a chance to reproduce to sustain the population. Not all animals will mature at the same size, some will be smaller, others much larger so an understanding of the average size and range of maturity is needed. Traditionally scientists and managers would aim to protect at least 50% of the population to spawning size, but it may be desirable to protect a larger proportion than this, especially if there is a significant difference in the reproductive success of larger animals compared to smaller ones (Froese, 2004; Linnane et al., 2008; Tully et al., 2001).

There are various methods of assessing if an individual is mature and often there is a trade-off between ease and cost of collecting the data and the accuracy of the method. Therefore, it can be beneficial to combine more than one approach to get a fuller understanding of the situation. For female lobsters, we will be looking at the following approaches:

1. Morphometric maturity. The abdomen width in relation to the length of the lobster widens at moult as they reach sexual maturity.
2. Physiological maturity / Ovary maturation. Female lobsters need to be able to progress through a process known as vitellogenesis, which is where cells in the ovary known as oocytes mature into eggs that can then be spawned and fertilised
3. Functional maturity. Some females may show an ability to progress into vitellogenesis but may not actively mate, spawn or fertilise eggs at their current size. Functional maturity looks at the proportion of the population that can successfully hatch eggs. Traditionally, this is assessed by looking at the proportion carrying eggs.

Functional maturity is the most important measure for the sustainability of the stock as it relates to the size at which lobsters are able to contribute to future generations and replenish fished animals. It does, however, have a set of difficulties in its calculation and therefore we will investigate morphometric and physiological maturity as well to help create a fuller picture.

An understanding of the annual/biennial reproductive cycle is also important. When studying physiological maturity, individuals of many species can be mature but show a resting ovary (i.e. one that is not actively progressing through vitellogenesis), especially in a biennial reproductive cycle. This resting ovary can look very similar to an immature ovary. When studying functional maturity, the annual/biennial (or longer) reproductive cycle will affect how many individuals you would expect to see carrying eggs in any one year, and hence the interpretation of the numbers observed carrying eggs. For example, previous observations of the number of very large egg carrying females (which we can very confidently assume as mature due to their size), is often much lower than 100% (Agnalt et al., 2007; Laurans et al., 2009; Tully et al., 2001).

## How is size at maturity used to assess sustainability of the lobster stocks?

A principal concept in fisheries management is that deaths within a population (natural or fishing causes) should not exceed births and growth to maintain a population. It is therefore essential that there are enough adult lobsters of breeding size/age to reproduce enough offspring to replace those dying each year. A common and simple management measure to address this requirement is to set a minimum landing size (MLS) large enough that animals have a chance to reproduce before being at risk from fishing. Traditionally the MLS was set at a size where **at least** 50% of the population will have had a chance to breed at least once before recruiting into the fishery - this is a metric called L50. The choice of L50 is based on general principles to avoid fishery collapse; however, different species and populations may require more or less protection for maturity depending on life history traits. To manage a fishery sustainably and towards MSY, a **target** reference point has been suggested that approaches a size where the majority of animals can reproduce at least once (Froese & Sampang, 2012), for example the size at which 90% of the females are mature (L90). This can be estimated as 1.2x L50 where other empirical estimates are not known.

The size at maturity, L50 or L90, are also used in other size-based stock health indicators. These indicators can be used by management to ensure a natural size range is retained in an exploited population, which is covered in descriptor 3 of the Marine Strategy Framework Directive, as well as advice from ICES for data limited stocks (Froese & Sampang, 2012; ICES, 2017). There are several measures that aim to assess the conservation of small individuals that will be recruiting into the spawning stock biomass and the commercial fishery. Reference points are usually one of two types: **Limit reference point** that indicates a value of the indicator reference at which, if not achieved, would indicate that the stock is at risk of being overfished, i.e. there is serious concern over the health of the stock. The second type is **a target reference point**. These are the targets for management and are usually proxies for the health of the stock when fishing at or around maximum sustainable yield (MSY). These indicators can be tracked over time to monitor trends alongside other indicators such as catch per unit effort (CPUE) and conservation of larger animals to provide a fuller picture of the stock health.

This report will estimate size at maturity (L50 and L90) for female lobsters across Wales. These estimates will be compared with the current minimum landing size of 90 mm carapace length. These estimates will be available to be used in size-based stock health estimates in the future.

# Methodology

## Field Sampling

Observer trips to collect morphometric data on-board fishing vessels in north and south Wales have been undertaken regularly in 2014 and again in 2019 and 2021. For all lobsters caught the carapace length (CL), width of the second abdomen segment (AW), sex and egg carrying status were recorded.

Lobster sample collection for dissection was undertaken in collaboration with the fishing industry in north and south Wales during September, October and November 2019. Dispensation for landing lobsters less than 90 mmm carapace length was obtained for each collaborating fisherman from Welsh Government. Scientists attended fishing trips during September to November 2019 and retained lobsters in a size-stratified manner between 65 mm and 140 mm carapace length. There was a target of 10 animals per 10 mm size category. The first 10 females caught from each size category were included in the analysis. If an animal was seen to be carrying eggs, she was measured and details recorded before being returned to the sea as functional maturity is exhibited through the presence of eggs. Other lobsters were retained for dissection in the laboratory. Undersized lobsters were provided free of charge and current market value was provided for any lobsters of market size. All lobsters were taken back to the School of Ocean Sciences immediately after the fishing trip and placed in large aquarium tanks at the local ambient water temperature with their claws banded. Lobsters were processed in the laboratory within a few days to avoid any effects of capture on the results. It was preferable to keep the lobsters alive prior to laboratory processing to avoid the effect of freezing and thawing on the oocytes.

### Timing of the ovary staging survey

The majority of published research into the reproductive cycle of clawed *Homarus* lobsters has been undertaken on the American lobster, *Homarus americanus* (Waddy & Aiken, 2005). Many researchers have applied these findings to the European lobster due to the fact that they are closely related species (Lizárraga-Cubedo et al., 2003; Tully et al., 2001). Waddy & Aiken, (2005) suggest that size at maturity studies should take place in the spring for two reasons. Firstly, they state that it can be difficult to determine the maturity of a female immediately after hatching as their ovaries will be immature. Secondly, ovaries mature during a few weeks in spring, **just before spawning**. The reproductive cycle of the European lobster in the Irish Sea/Celtic Sea differs to that described for the American lobster, as spawning is in early autumn, with a peak of newly spawned females being observed from September onwards (personal observation, although some can occur in most months). Therefore, if ovary maturation occurs during a few weeks prior to spawning, as suggested, the best time for a size at maturity study will be late summer/early autumn. This should ensure that any female, due to spawn in the current season, will either be carrying eggs already; or their ovaries will be progressing through vitellogenesis II, where the ovaries swell, turn a dark green and the eggs (ova) become larger in size (ovary stage 5, 6, 7).

## Laboratory protocol

For laboratory processing, each lobster was placed in a box of iced salt water for 20 minutes and then placed in a freezer at -20C for 1.5 – 2 hours. The iced salt water rapidly reduced the core temperature of the lobster leaving them in a stupor or comatose state in the quickest, most humane way possible. The period in the freezer was enough to kill the animal but not enough to freeze the ovaries solid and risk rupturing the oocytes.

Once dead, the weight of the whole lobster and the CL and AW recorded, and a panel was cut out of the dorsal surface of the carapace. The dorsal musculature and heart were carefully removed to reveal the ovaries. The ovaries can extend into the back of the head but care must be taken dissecting in this area not to pierce the stomach. The ovaries also extend into the tail and so some of the tail shell segments were also removed.

The whole ovary was removed and weighed to the nearest 0.01g. Ten individual ova were removed from the ovary and placed in a small amount of seawater in a petri dish. These were then photographed under a Q-Scope digital microscope (Model QS.13100-W) at 25 x magnification. This was connected live to a laptop and the software Q-Focus, where a calibrated image was taken, the diameter of the eggs were measured and recorded on the image and saved for later reference if needed.

### Ovary staging and developing a staging guide for the European lobster.

Initial ovary staging was carried out using the visual indicators described by Aiken and Waddy (1980) for the American lobster; primarily colour, mean oocyte size and ovary factor. Photographs were taken of each lobster’s ovaries and their oocytes for future reference and to allow refinement of the classification system to the European lobster. For this study we used sequential numbering of the stages rather than some stages being split into a or b categories. This was to allow easier statistical analyses using this ordinal scale. A collaboration through the ICES crab and lobster working group was also used to ensure this new staging protocol was appropriate to European lobsters throughout their range. Dissection data was available in Wales, the Isle of Man, Orkney and Ireland. Researchers from each location compared data and images and a standardised staging protocol was agreed (Table 1).

## Data analysis

### Morphometric maturity

The rate of change in the Abdomen Width : Carapace Length (AW:CW) ratio data from 1678 female lobsters across Wales in 2014 and 2019 were analysed for inflection points that could indicate changes in growth associated with maturity. Initial investigation into the shape of the relationship between the carapace length (CL) and the AW:CL used a Generalised Additive Model (GAM) in R. The model showed no significant differences between regions (north and south Wales) or years. The GAM also indicated multiple inflection points could be possible. A combined dataset (all years and regions) was then used to estimate inflection points using segmented regression in R (Muggeo, 2003, 2008, 2017). Segmented models were used with one, two and three inflection points and each of these were compared to the base linear regression using AIC to choose the preferred model. The model with the lowest AIC was preferred. If the difference between models was less than 2 AIC points then the simplest model was preferred.

### Physiological maturity

To estimate L50 it was necessary to categorise each animal in a binary manner as either mature or immature. Whilst the extremes of maturing ovaries are straight forward to classify, the decision as to how to classify stage 4 ovaries can be subjective. We surveyed in September and October, and therefore, there could be several weeks of further ovary maturation within the main spawning season. Stage 4 covered a wide range of development, some being very early, with very small oocytes and thin ovaries even though the colour had progressed. Other ovaries were smaller than the definition for stage 5 but it was clear that the oocytes were enlarging and the weight of the ovary was increasing. We therefore used a criteria where a stage 4 ovary had to also have the oocyte size > 1.00 mm AND ovary factor >100 to classify some stage 4 ovaries as likely to spawn this year and others likely to moult first. Whilst there is some literature that suggests once vitellogenesis II has started it will progress to spawning (Waddy & Aiken, 2005), it is also reported that moulting and it’s associated hormones can have an inhibitory effect on vitellogenesis (Raviv et al., 2008), and therefore it is possible that later developing ovaries may halt and resorb rather than spawn. Further work is required to definitively answer these questions around the reproductive cycle, but observations during November showed evidence of some resorption within small stage 4 ovaries. This approach in classifying stage 4 ovaries as mature or immature was preferred over classifying all stage 4 ovaries as mature, and as an additional precautionary measure we also assessed a second scenario where only stage 5 ovaries were considered mature.

The following classification system was used to classify individuals as either mature or immature at **their current carapace length** for two scenarios:

Scenario 1

1. MATURE Carrying freshly spawned eggs.
2. MATURE, likely to spawn this year. >= Stage 4 with oocytes > 1mm **AND** ovf > 100,
3. MATURE, not due to spawn this year. < stage 5, evidence of previous spawning (yellow ova or evidence or recent hatching through egg attachment cement on pleopods).
4. IMMATURE, not due to spawn this year. No evidence of previous spawning. Stages 1-3, Stage 4 with oocytes <1mm **OR** ovf <100

Scenario 2 – precautionary approach

1. MATURE Carrying freshly spawned eggs.
2. MATURE, likely to spawn this year. >= stage 5,
3. MATURE, not due to spawn this year. < stage 5, evidence of previous spawning (yellow ova or evidence or recent hatching through egg attachment cement on pleopods),
4. IMMATURE, not due to spawn this year. <= stage 4, no evidence of previous spawning.

Once classified as physiologically mature/immature the data were analysed using a binomial regression in R (R Core Team, 2021), individuals were placed into 10mm CL size class bins with the central CL of each bin assigned. The regression included carapace length as a continuous covariate and region as a factor (north and south Wales), including the interactions. A backwards selection protocol was used to determine the parameters to include in the final model. If factors were found to be insignificant and removed from the model, the “c-binding” of the response variable within r was repeated without that factor level. This was to ensure that the final model only included one data point at each x-value.

The “dose.p” function in the R package “MASS” (Venables & Ripley, 2002) was used to extract the CL at 50% and 90% mature and the proportion mature at 90 mm CL (the current MLS).

Table 1. Comparison of ovary staging of the American and European lobsters.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Homarus americanus* (Aiken & Waddy, 1980) | | | *Homarus gammaus* (present study) | | |
| Stage | Ovary colour | Oocyte diameter and Ovf | Stage | Ovary colour/appearance | Oocyte diameter and Ovf |
| Stage 1 | Ovary White | Oocytes < 0.5 mm  Ovary factor <100 | Stage 1 | String like white ovaries. No visible oocyte formation in the follicles. | Ovf <50  Oocytes < 0.5 mm |
| Stage 2 | Ovary yellow, beige, pale green | Oocytes <0.8 mm  Ovary factor < 100 | Stage 2 | Ovary thin, strap like. Yellow/lime green.  Many empty/white follicles | Ovf 100  Oocytes < 0.5 mm |
| Stage 3 | Ovary light to medium green | Oocytes < 1.0 mm  Ovary factor <200 | Stage 3 | Ovary thin, strap like. Light to medium green. Larger oocytes beginning to develop but still empty follicles present. | Ovf <100  Oocytes < 1 mm |
| Stage 4a  (Autumn) | Medium to dark green | Oocytes 0.1-1.6 mm  Ovary factor < 200 | Stage 4 | Ovary thin, strap like filling <50% of dorsal cavity. Dark green. Most follicles show green oocytes. Evidence of previous spawning may be evident through presence of yellow oocytes/flecks in ovary. | Ovf <200  Oocytes 0.5 – 1.6 mm |
| Stage 4b  (spring) | Medium to dark green | Oocytes 0.8 – 1.6 mm  Ovary factor 200 - 325 | NA Study carried out in autumn to coincide with period preceding spawning. | | |
| Stage 5 | Dark green | Oocytes 1-1.6 mm  Ovary factor >325 | Stage 5 | Plump dark green ovaries – no longer strap like. Fills >50% of dorsal cavity. Evidence of previous spawning may be evident through presence of yellow oocytes/flecks in ovary | Ovf 200 - 550  Oocytes > 1.2 – 2.3 mm |
| Stage 6 | Dark green | Oocytes 1.4 – 1.6 mm  Ovary factor > 400 | Stage 6 | Plump, bulging, dark green ovaries filling dorsal cavity. More granular in appearance than stage 5. Evidence of previous spawning may be evident through presence of yellow oocytes/flecks in ovary. | Ovf >250  Oocytes 1.5 – 2.6 mm |
| Stage 6a | Dark green | Post ovulation – oocytes free in ovary | Stage 7 | Bulging, dark green, ovaries taking up the whole dorsal cavity. Oocytes free in the ovary. Evidence of previous spawning may be evident through presence of yellow oocytes/flecks in ovary | Ovf >300  Oocytes 1.5 – 2.6 mm |
| 7  (Spent) | White or yellow. May have some green residual oocytes. | Large flaccid ovary. | Stage 8 | Large flaccid white/cream ovaries. Not strap like as in stage 2/3. Some yellow ova may remain and in some animals may see residual green oocytes especially at the dorsal tips. | Flacid ovary |

### Functional maturity

Data from observer trips in the months of October, November and January were used to calculate the proportion of female lobsters carrying eggs across carapace length size bins. These months were chosen as it is important to use the peak spawning season as opposed to months where moulting, hatching and vitellogenesis occur (Laurans et al., 2009). Outside the peak spawning season some animals will not be carrying eggs but will be preparing to spawn at their current size. In Wales and much of the Irish Sea spawning commences in late summer and early autumn such that by October/November time most females will have spawned if they are going to that season. Observer trips were not conducted in December, February or March. Females were measured and their berried status recorded. Data was available from the years 2014, 2015, 2019, 2020, 2021 and 2022. It is likely that the proportion of mature females spawning annually or biennially will vary over time due to responses to environmental drivers and therefore using data from more than a single year is advised to account and standardise for this variability.

The data was split into size classes of 3 mm. For most of the size range there were sufficient data in these bins, however, for the outer ranges, neighbouring bins were merged to increase the sample size and decrease variance associated with small sample size. This approach was chosen over an increase in bin size across the range due to the rapid increase in proportion mature with increasing carapace length such that, resolution would be lost with these larger bin sizes in this.

These data were then used in a 3 parameter logistic regression using the “drm” function in the r package “drc” (Ritz et al., 2015). The three parameter logistic regression fixes the lower asymptote at zero but allows the upper asymptote to vary. This was necessary as, due to their potential Biennial spawning pattern, 100% berried at large sizes is not often observed in a single season. The CL corresponding to 50% and 90% of the estimated upper asymptote was calculated as an estimate of functional maturity (L50 and L90) using the “EDR” function.

# Results

## Morphometric maturity

An analysis of the relationship between the carapace length and the abdomen width to carapace length ratio indicated that three inflection points’ best fitted the data collected (table 3; Figure 1). Smaller individuals showed isometric growth, i.e. the CL and AW are growing at roughly the same rate. This is very similar to the growth seen in Males. At around 73mm CL, this changes to allometric growth where the abdomen is growing relatively more rapidly than the CL resulting in a higher AW:CL ratio in females. Between the first inflection point at 73mm and the second at around 88mm this rate of change is rapid resulting in a steep slope. After 88mm CL the growth is still allometric, however the rate of change, or the steepness of the slope is shallower, indicating a less rapid widening of the AW in relation to CL. At around 121mm, CL the growth changes again. The confidence around this inflection point and the type of growth is poorer, due to the lower amount of data for larger females. However, it appears that the growth either changes to isometric growth or even that the CL grows more rapidly than the AW.

Table 3 Estimated inflection points and confidence intervals for the segmented regression for female European lobsters, Abdomen width : Carapace length ratio ~ Carapace length.

|  |  |  |
| --- | --- | --- |
| Estimated inflection point (mm) | Lower CI (mm) | Upper CI (mm) |
| 73.5 | 71.4 | 75.6 |
| 87.5 | 85.3 | 89.6 |
| 121.1 | 115.6 | 126.7 |



**Figure 1 The segmented regression relationship between carapace length and the abdomen width to carapace length ratio in female European lobsters. Data points and solid line show the relationship for females, whilst the grey dotted line shows the linear model for male growth. The red dots and lines along the x-axis show the estimated inflection points and their confidence intervals.**

## Physiological maturity

Under scenario 1, there was a significant difference between north and south Wales and the two sets of data were analysed separately. For north Wales, the L50 was estimated to be 83 mm, the L90 was estimated to be 92 mm CL, with approximately 85% of females reproducing at least once before becoming vulnerable to fishing mortality with the 90 mm CL MLS (Figure 2). However, the confidence intervals are wider under this scenario than scenario 2, most likely due to the lower samples sizes when the data are split into region. For south Wales, the L50 was estimated to be 87 mm, the L90 to be 92 mm and approximately 80% of females reproducing at least once before becoming vulnerable to fishing mortality with the 90 mm CL MLS (Figure 3).



Figure 2. Physiological maturity of female lobsters in north Wales under scenario 1 (Mature >= Stage 4 with oocytes > 1mm **AND** ovf > 100).



Figure 3. Physiological maturity of female lobsters in south Wales under scenario 1 (Mature >= Stage 4 with oocytes > 1mm **AND** ovf > 100).

Under scenario 2 there was no significant difference found between north and south Wales and a single analysis for the whole of Wales was undertaken (Figure 4). For this scenario, the CL at which you would expect 50% of female lobsters to be physiologically mature (L50) is 88 mm and the L90 was 97 mm CL. At 90 mm CL approximately 60% of females would have had a chance to reproduce at least once, by 100 mm CL 95% would have had a chance to reproduce at least once. The confidence intervals around this model are quite narrow, indicating confidence in the relationship.



Figure 4 Physiological maturity of female lobsters in Wales under scenario 2; all stage 4 ovaries classed as immature.

## Functional maturity

Size classes above 120 mm had high variance in proportion mature and an overall drop in proportion mature compared to the size classes around 110-115. This is likely due the small sample sizes for these larger animals and an increasing likelihood of spawning biennially. Including these data would likely leverage the upper asymptote downwards with the effect of underestimating the L50. Therefore, these larger size classes were eliminated from the analysis.

The estimated L50 for functional maturity was 90.1 mm and the L90 was 102 mm CL (Figure 6). The data shows a maximum of ~70% of females berried. This suggests a mixture of annual and biennial spawning. The smallest berried female observed was 75 mm CL.



Figure 6. 3-parameter Logistic regression model showing functional maturity of female lobster in Wales.

# Discussion

This study used three methods to estimate the size at maturity of female lobsters. Morphological analysis identified three inflection points in the AW:CL relationship. The middle inflection point aligns well with the estimate of physiological maturity. Functional maturity was estimated to be slightly larger but with the confidence intervals overlapping physiological maturity. Looking at all three methods together, our estimates suggest that 50% of females will have had a chance to reproduce between 88 mm and 91 mm CL. This means that the MLS of 90mm is marginally protecting 50% of female lobsters to first reproduction. However, lobsters show discontinuous growth (moulting), and an extended brooding period (September – June). Therefore, at the current MLS these females are, on average, reaching maturity and bearing eggs during the moult cycle that brings them vulnerable to fishing. The life history of lobsters in Wales (moult May/June, spawn September, hatch the following summer), means that it is possible they are vulnerable to fishing for almost a year before they have had a chance to **hatch** their first brood of eggs due to maturing at the MLS combined with the legal landing of berried lobsters in Wales**.**

The morphometric approach shows how the rate of change in the abdomen width to carapace length in female lobsters changes with carapace length. There appears to be a pubertal moult (73 mm CL) at around the size of the minimum observed berried female (75 mm CL). There is then a rapid rate of increase in the relative abdomen width until physiological maturity L50, when this rate of change slows at the second inflection point, but is still allometric. The rate of growth returns towards isometric at approximately the same size as we would expect 100% of females to be functionally mature. This suggests that during the period of onset in maturity until ~120 mm CL energy is being directed into somatic growth that will maximise brood capacity and therefore reproductive output of larger individuals will be important. Current work is underway to understand the fertilisation rate and egg mass size across this size-range of females.

Functional maturity estimates that utilise the proportions of berried females will be affected by the proportion of lobsters that show an annual or biennial reproductive cycle. Studies on the American lobster have indicated that animals reproduce biennially, especially as smaller lobsters, although spawning annually is more common in larger animals (Aiken & Waddy, 1980; Waddy & Aiken, 1986, 2005). We would therefore expect an asymptote of around 50% mature for biennial spawning of smaller females, with a peak above 50% at larger sizes due to increased annual spawning. The seasonal and annual reproductive cycles for the European lobster have not been studied in such detail. However, lobsters in Norway were shown to follow a biennial spawning pattern, with <10% showing spawning in consecutive years (Agnalt et al., 2007). However, the data collected for this study showed a peak in proportion mature (size class ~110 mm CL) with around 70% of females carrying eggs, after which it dropped off again (although data was not sufficient in larger size classes to estimate accurately). These results and those from another study from French a population where nearly 90% of larger females were carrying eggs (Laurans et al., 2009), suggest that there may continue to be some annual spawning even in larger size classes, although there may be a peak in annual spawning at intermediate sizes. The spawning schedule will impact the estimates of functional maturity. If larger size classes have a greater tendency towards biennial spawning than smaller size classes, this can lower the upper asymptote and lead to an underestimate of the size at maturity. We attempted to account for this in this study by removing larger size classes, however a fuller understanding of annual reproductive schedules and what affects them would improve the robustness of this methodology.

Whilst the MLS is currently around the size of L50 (both physiological and functional maturity), the legal landing of berried lobsters means that there is a vulnerability of these first-time spawners to fishing mortality during brooding that could mean that many fail to hatch their first brood. There could be two approaches to improving the sustainability of the stock and the relative socio-economic impact of each should be assessed before deciding on the preferred course of action. Firstly an increase in the MLS could help improve the sustainability of the stock. However, it should be noted that catches inshore are often dominated by smaller lobsters, with larger lobsters being found offshore. This could therefore affect inshore fishers more than fishers with the capability to move further offshore. Secondly, by protecting berried female lobsters, you would ensure that these first-time spawners can complete to hatching before being caught. Anecdotal evidence suggests that lobsters around the MLS size are preferential for retail and restaurants as they are “plate sized”. In addition, it has been suggested by some fishers and buyers in Wales that larger lobsters do not compete economically with imports of *Homarus americanus* from the USA and Canada. However, it has also been reported that in some locations almost all the catch is made up of egg bearing females at certain times of the year and that not being able to land these would also have considerable economic impacts for some fishers. These socio-economic factors should be considered when determining the best management measures and work is currently underway to gather more fisher and market knowledge on these potential implications of increasing the minimum landing size or banning the landing of berried females.

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