

# Native Oyster Spawning Assessment Lough Foyle Summer 2016

*An assessment of oyster spawning activity at 5 locations within the Lough Foyle oyster fishery employing spawning stage analysis, larval density counts and environmental monitoring.*

**Ciarán McGonigle/Catherine Jordan/Kelsie Geddis**  
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## Executive Summary

Native oyster spawning was monitored weekly on five oyster beds within the Lough Foyle oyster fishery from June-September 2016. Environmental conditions and bivalve larval density was also recorded at these locations.

The findings show that successful spawning is occurring in oysters ranging in size from 50mm-110mm. 4.8% of all oysters sampled during the period were in the brooding phase with larvae visible on the gills as a milky white, grey or black larval mass. 35% of all oysters sampled were either in the brooding phases or spent giving a better representation of the overall spawning activity within the population in 2016. Water temperatures were high for a prolonged period in 2016 and were already above the 16 °C threshold by the beginning of June. Bivalve larvae were present in low to moderate numbers on the beds sampled relative to previous years. These results would suggest there was a limitation to successful spawning and settlement of larvae onto oyster beds in 2016.

This information will inform any enhancement works conducted within the fishery. Initial attempts have been made during the IBIS research project towards understanding the importance of shell cultch habitats on the settlement phase of oysters in Lough Foyle (Bromley, 2015).

## 1.0 Introduction

### 1.1 Background

The Lough Foyle oyster fishery is one of the last remaining productive native oyster fisheries in Europe. The fishery has been harvested intensively in the past and efforts to develop its full potential and manage the fishery in a sustainable manner have failed due to a lack of legislation. In September 2008, the Loughs Agency of the Foyle Carlingford and Irish Lights Commission began to regulate the fishery for the first time. The Agency licenses oyster fishing vessels in Lough Foyle and they are permitted to operate from 19<sup>th</sup> September – 31<sup>st</sup> March. This report outlines the findings of a project undertaken between June and September 2016 to assess the spawning activity of *Ostrea edulis* (European native oyster) in Lough Foyle. It draws upon the knowledge acquired from previous reports and research work conducted during the IBIS research project on spawning activity, larval dynamics and fecundity (Bromley, 2015).

A stock assessment of the Lough Foyle native oyster fishery has been conducted either bi-annually or annually since 2004. Adult and juvenile distribution and abundance is recorded during the surveys as is the presence/absence of shell cultch (Figure 1-3). It was the results from these surveys which have formed the basis of site selection for this assessment work. Oyster density, location of spatfall and availability of suitable cultch for larval settlement were the major factors that were considered during site selection as well as logistical restrictions such as water depth and distance between beds.



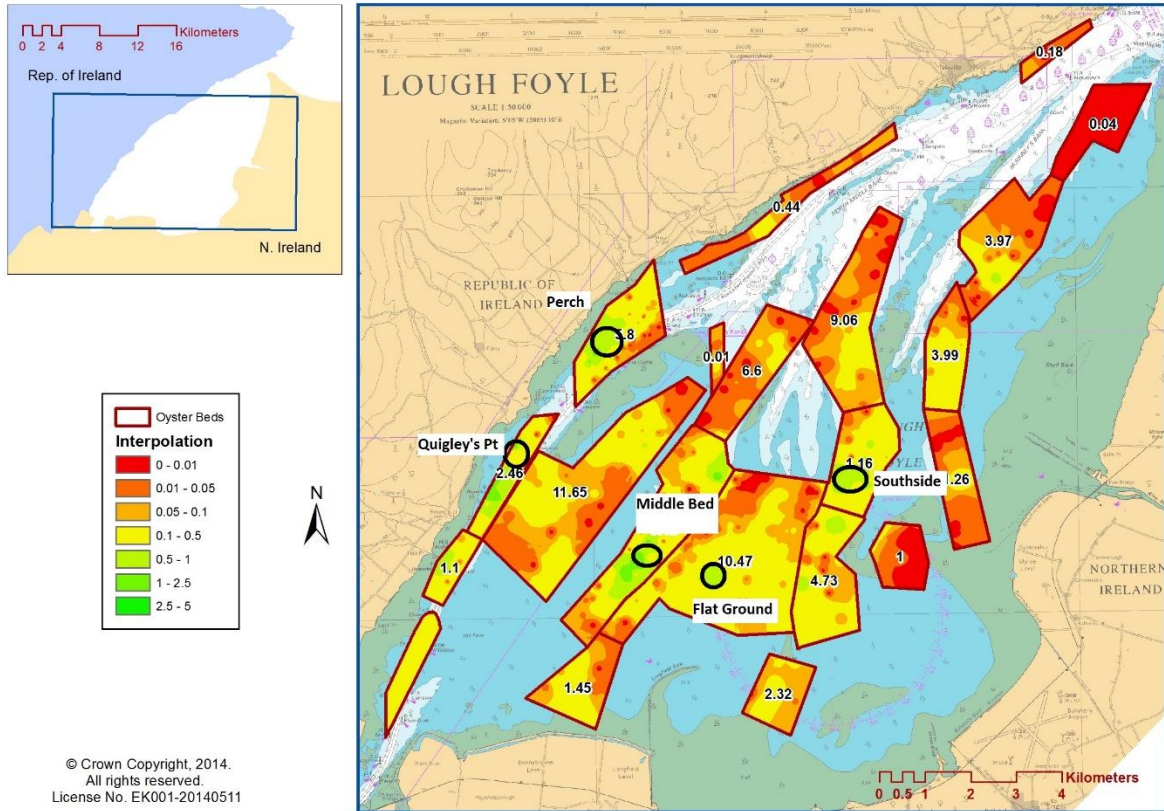


Figure 1: Oyster density in Lough Foyle Spring 2016 and location of spawning sample points

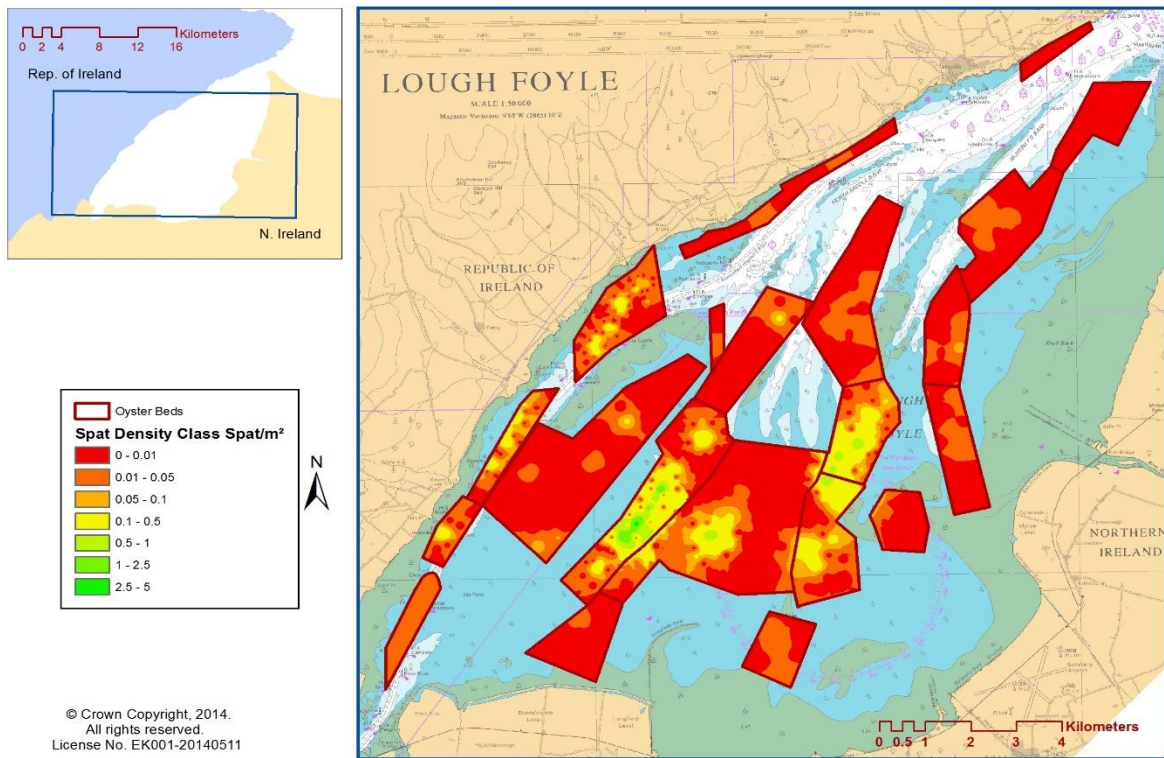


Figure 2: Spat Density Spring 2016

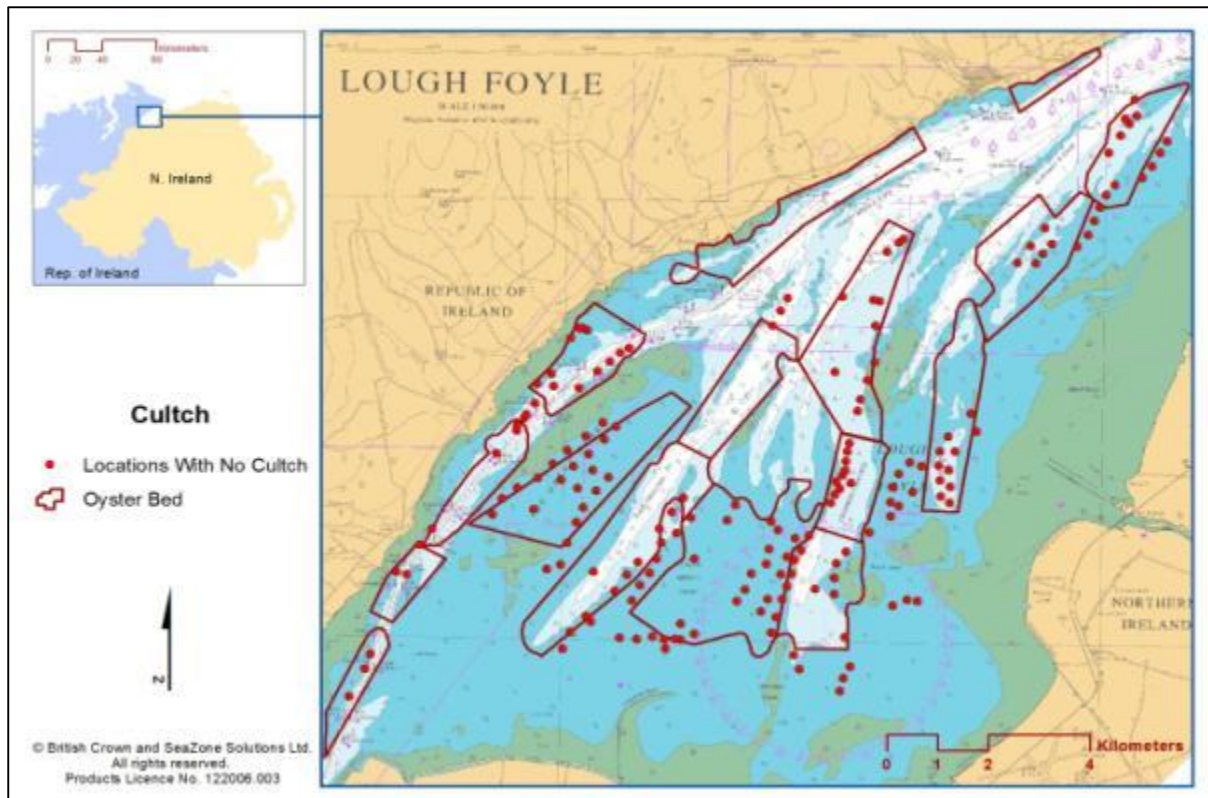


Figure 3: Location of areas without suitable cultch within the Foyle oyster fishery

## 1.2 Aims and Objectives

The aim of this project was to identify when and where there is an abundance of bivalve larvae present in the water column in Lough Foyle and to relate this to spawning activity in oysters and environmental drivers such as water temperature and salinity.

Objectives:

- Record environmental variables (temperature, salinity, DO, turbidity) weekly at 5 oyster beds
- Assess the larval density at each oyster bed weekly
- Assess gonad stage of oysters weekly on 5 beds
- Record daily water temperatures at 5 beds

It is imperative to have a record of bivalve larval dynamics occurring on oyster beds for use as a baseline for potential enhancement projects. In areas where bivalve larvae are present but there is no suitable cultch and no notable spatfall occurring mitigation may be needed to address the issues limiting success.



### 1.3 Native Oyster Spawning

Naturally occurring oyster beds are becoming increasingly rare throughout the world (Hawkins *et al.*, 2008; OSPAR Commission, 2009; Beck *et al.* 2011). It is estimated that 85% of oyster reefs worldwide have been lost (Airoldi *et al.*, 2009). This is mostly as a result of overexploitation. However, the decline in stocks may also be attributed to severe winters such as the east coast of England fishery destroyed by severe winter conditions in 1962/63 (Davidson, 1976; Crisp, 1964). The availability of food, climate change, invasive species (e.g. *Crepidula fornicata*), hydrodynamic regime changes, disease and availability of suitable habitat for juvenile settlement are all factors in the sustainability of these populations.

Native oysters are considered to be ecosystem engineers as a result of the role they play in the nutrient cycling process within estuaries and because they provide habitats for many other species. It is for this reason; along with the hugely important commercial value of the native oyster fishery to an area each year; that means of habitat regeneration, ways of promoting more sustainable fishing practices (such as minimum 80mm landing size) and monitoring of disease (e.g. *Bonamia ostreae*) are developed to promote sustainable fisheries (Gouletquer, 2005-2011).

Native oysters require between 4-8 weeks of good conditioning in early spring, with adequate food supply and correct temperatures, before spawning readiness will occur (FAO, 2004). The greater the conditioning prior to breeding season then the more probable that population-wide spawning events will occur simultaneously when optimum conditions, 15-16°C in previous studies in Lough Foyle, and good food supply present. This species of oyster is larviparous. This means that instead of releasing eggs, fertilization is internal and they brood larvae within the mantle cavity and after a length of time (up to 14 days) they then release this larvae into the water column. The larvae may remain in the water column for up to 14 days before settling onto a suitable substratum.

Table 1 shows an estimate of average number of larvae released by oysters of a specified age (Walne, 1974). It illustrates that there is a relationship between age/size and the quantity of larvae brooded however this can be influenced by condition and there can be substantial variation within this relationship. This is a combination of the oyster being physically more capable of retaining greater numbers of larvae within the mantle cavity as it grows larger and increased conditioning in older/larger oysters resulting in older oysters being more valuable to the recruitment of the species annually. Recent local studies have suggested that these

figures may not be fully representative of the true fecundity of oysters in Lough Foyle and this must be borne in mind when interpreting these results (Bromley, pers. com, 2016).

Table 1: Average fertility for successive age groups of oysters (Walne, 1974)

Approximate Age (years)	Mean Diameter (nm)	Fertility (number of larvae)
1	40	100,000
2	57	540,000
3	70	840,000
4	79	1,100,000
5	84	1,260,000
6	87	1,360,000
7	90	1,500,000

Successful spawning in native oysters is reliant on individuals being in close proximity and, for this reason, the highest density oyster beds are generally the most reproductively successful and have the largest spatfall events. In American (eastern) oysters (*Crassostrea virginica*) fertilisation efficiency has been shown to reduce by 50% when oysters are 10cm or more apart. This results in what is known as the ‘Allee effect’ where successful repopulation of the stock can become impossible even if fishing mortality is removed and stocks are protected (University Marine Biological Station Millport. 2007).

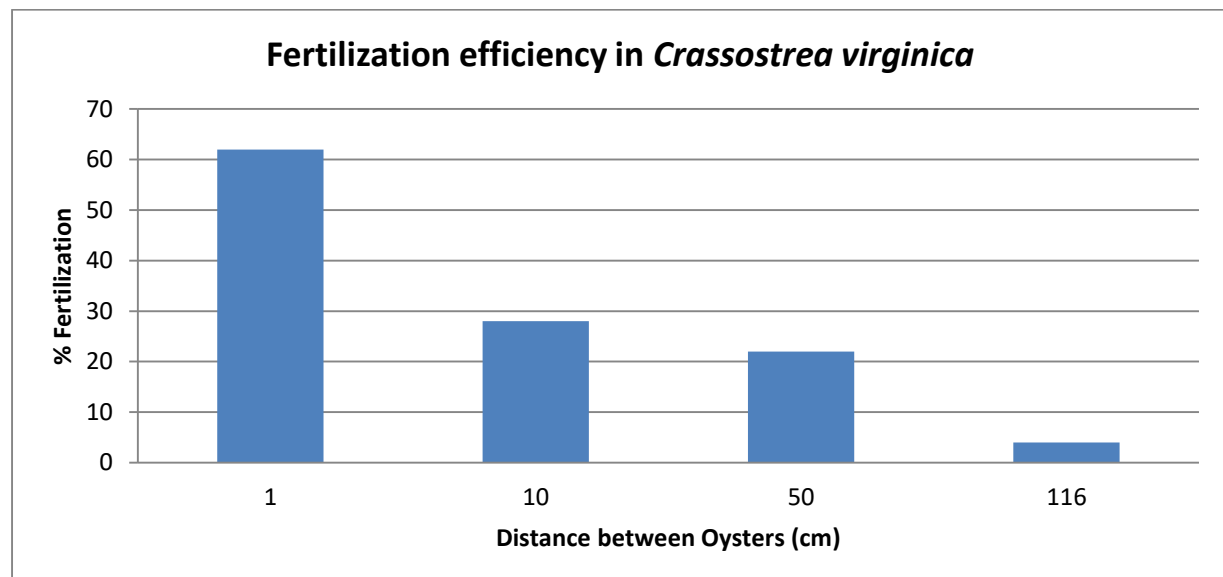


Figure 4: Fertilisation efficiency as a function of oyster separation (taken from Paynter, 2003)

## 2.0 Methodology

The 5 sites chosen for collecting samples for this project were Quigley's Point, Perch, Middle Bed, Flat Ground and Southside (Figure 1). These beds were selected based on the high densities of oysters present within them. The three methods of data collection and analysis are described in detail in sections 2.1-2.3.

### 2.1 Gonad Stage Analysis



Figure 5 a-d: Spawning stages of Native Oyster; (a) white sick; (b) grey sick; (c) black sick

A sample of 30 native oysters was collected using a traditional oyster dredge from 5 locations within the Foyle oyster fishery as identified in Figure 1. These 30 oysters were selected based on size and weight with oysters less than 50mm and 30g rejected from the samples. The first 30 oysters to meet these criteria were selected, labelled and stored in mesh bags. These samples were frozen immediately on return to the lab

Samples were thawed completely on draining trays lined with paper roll to remove water content. Care was taken when opening the oysters to prevent losing any reproductive material. Oyster length and wet weight were recorded prior to shucking and weighing wet flesh weight and assigning spawning stage class based on the classification of Helm *et al.* 2004.

Table 2: Description of Spawning Stage for Native Oysters

Stage	Description
Mature/Developing	Gonad full or filling
White Sick	Gills covered in white sick gonad empty
Grey Sick	Gills with visible grey larvae present
Black Sick	Gills with visible black/purple colour larvae
Spent Gonad	No gonad material remaining

## 2.2 Larval Counts

A plankton net of 500mm diameter and 60 micron mesh size was deployed vertically at each sample location. A manual flow meter was attached to the mouth of the plankton net and used to calculate the distance the net had travelled on each deployment. The sample was washed from the plankton net by using a seawater deck hose applied to the exterior of the plankton net and net bucket. The sample was collected in a 250 ml plastic bottle and labelled with site code and time and date information. The volume of water sampled at each site was calculated using the following formula;

$\Pi r^2 h$  – where r = radius of the net and h = distance towed.

Three 1ml sub-samples were taken from the 250ml sample using a 1ml sampling pipette following thorough mixing of the sample by hand. The sample pipette was changed between each sub-sample. The 1ml sample was transferred onto a glass Sedgewick Rafter counting cell on which all bivalve larvae were counted. Larval counts were averaged for the 3 sub-samples and these values were converted to density of larvae per metre cubed using the following formula;



Figure 6: Plankton net

Bivalve Larvae in Sample = [(mean number per 1ml \* Sample Volume ml) / (Volume of Water Sampled)]

Bivalve Larvae per m<sup>3</sup> = [Bivalve Larvae in Sample] / [Volume of Water Sampled m<sup>3</sup>]

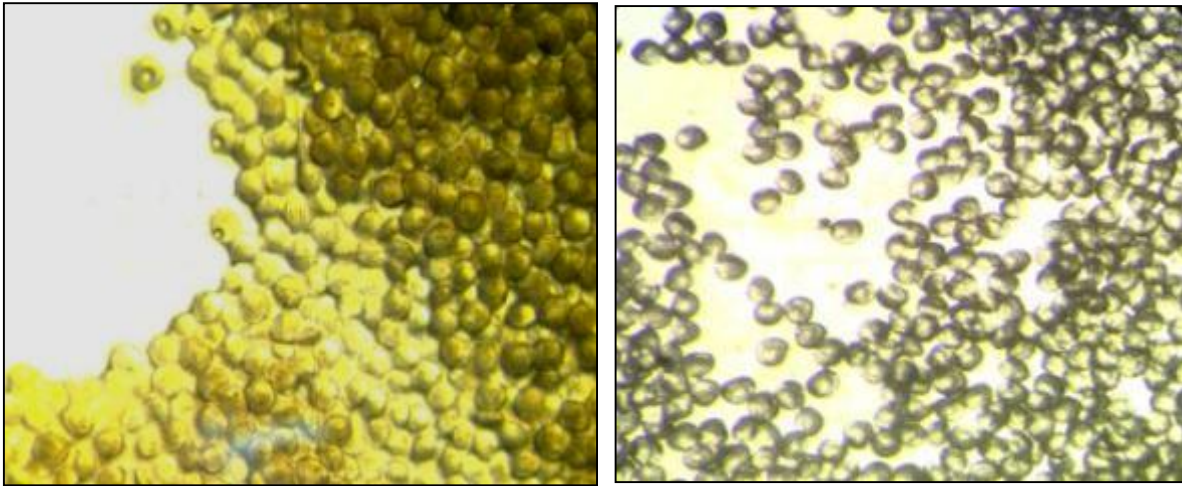


Figure 7 a-b: Native oyster larvae removed from a black sick brooding female (left) and grey sick female (right)

### 2.3 Environmental Monitoring

A Seabird 19+ CTD was deployed at each of the 5 sample stations each time a plankton sample and oyster sample were collected. The water temperature, dissolved oxygen, salinity, turbidity and fluorescence were recorded on the downcast of this CTD with care taken not to disturb the seabed when lowering the unit. These data were converted to depth averaged data in 1m batches. The data were tabulated and graphed in MS Excel. Daily water temperature was recorded at each site using Onset® UA-001-64 HOBO temperature loggers.



Figure 8: Seabird 19+ CTD water sampler

## 3.0 Results

The survey was conducted over a period of 17 weeks. It was not possible to collect larval samples for analysis from all beds on every week due to adverse weather, tidal restrictions or resource availability. Oyster samples were not collected on all sites every week for the same reasons.

Despite this, correlations can be observed in the results across the sampling regime, especially between higher temperatures occurring and increased presence of bivalve larvae in the water column.

There was a rise in the number of bivalve larvae present in the plankton samples as soon as the water temperature has increased to 16°C. Peak numbers of larvae are observed in August and September at most sites.

The mean temperature from all beds during the second week of June was 16.9°C (Figure 9). These high water temperatures were not sustained for long and a period of unseasonably cold and wet weather in mid-June led to a rapid decrease in mean water temperatures for the rest of June and early July. A return to warm, dry and bright weather conditions in late July to early September led to another peak in water temperatures, this time of 16.97 °C on 6<sup>th</sup> September. The greatest average number of bivalve larvae across all beds (17,158 per m<sup>3</sup>) occurred in mid-August. This is a much lower figure than the peak recorded in late August 2011 of 97,799 per m<sup>3</sup>.

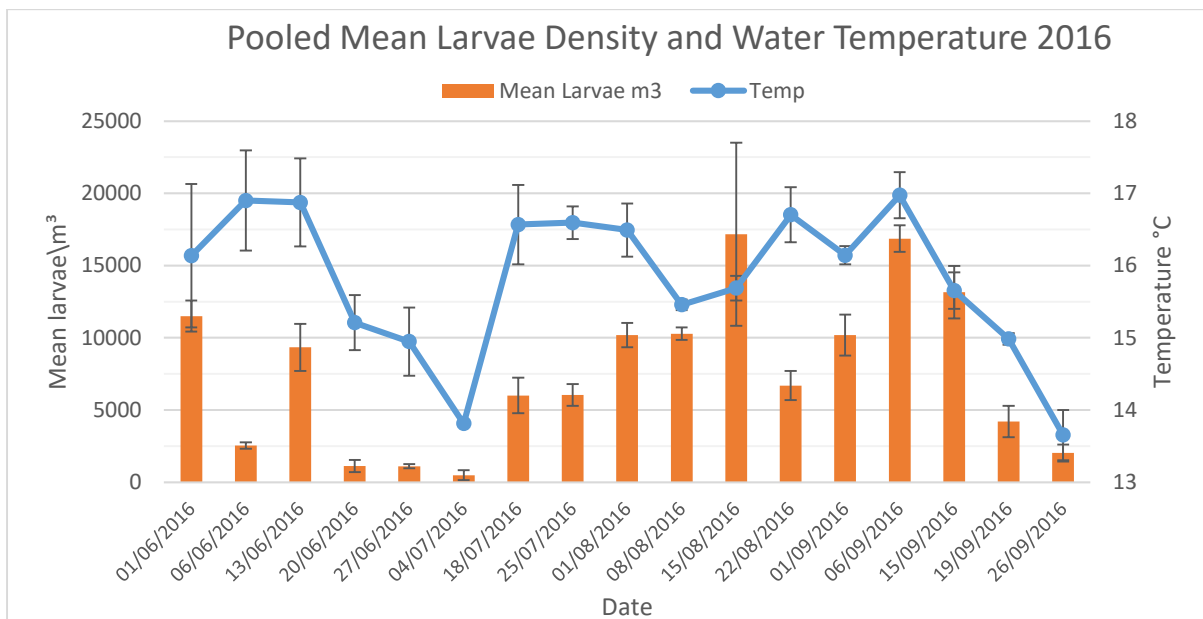


Figure 9: Weekly mean larval density and mean water temperatures (pooled data all sites)

The majority of oysters collected for this project were between 52 and 97mm in length (Figure 10). This was primarily as a result of the selection criteria defined in the methodology. Oysters of this size are those which would be expected to be of greatest importance to spawning events during a particular year. Oysters >80mm are less abundant because they are removed by the commercial fishery each year.



The mean length of oysters sampled for this survey was 68.5mm. Weight ranged from 27.5g- $\geq$ 120g, with an average weight of 64.9g. The majority of oysters recorded for this survey weighed between 37.5 and 92.5g (Figure 11). Spawning was recorded across a range of lengths and weights (Figures 12 and 13). 68.7% of the oysters observed in a brooding stage were white sick, 17.8% were grey sick and 13.3% were black sick. The mean length of oysters in a brooding stage was 67.2mm. Brooding stages were observed at a range of weights, the mean weight of oysters in these stages was 62.5g.

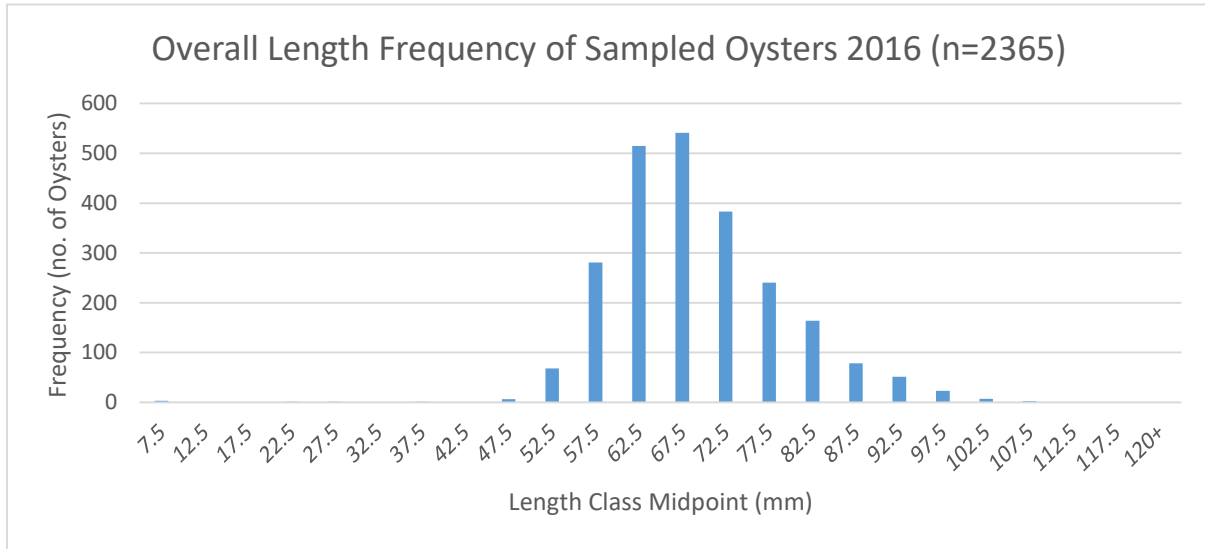


Figure 10 Overall Length Frequency of Oysters Sampled in Lough Foyle Summer 2016

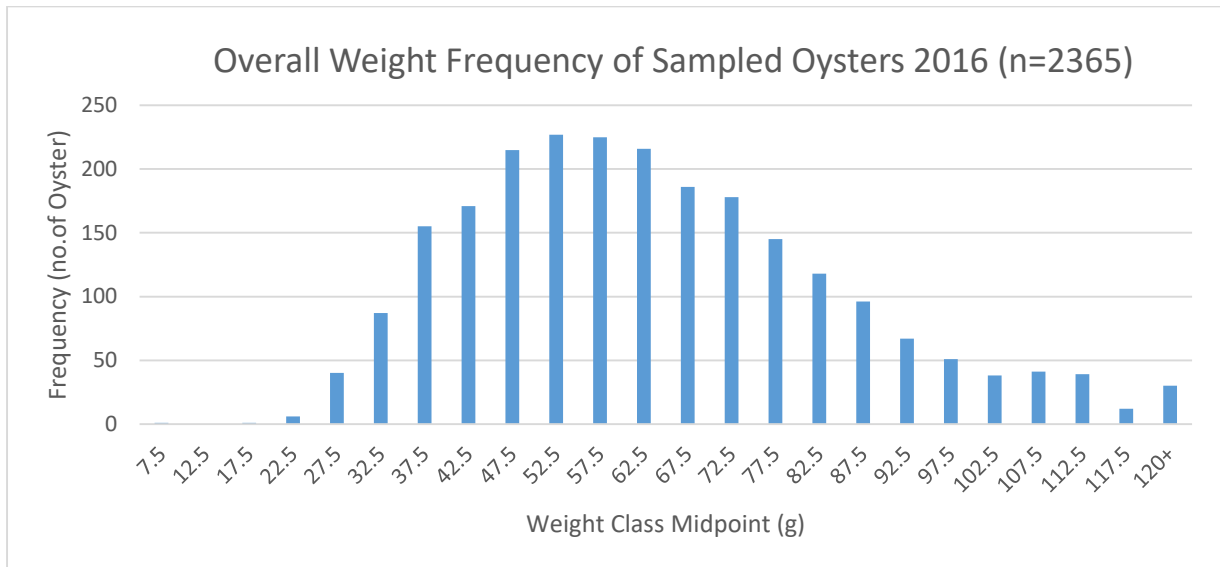


Figure 11 Overall Weight Frequency of Oysters Sampled in Lough Foyle Summer 2016

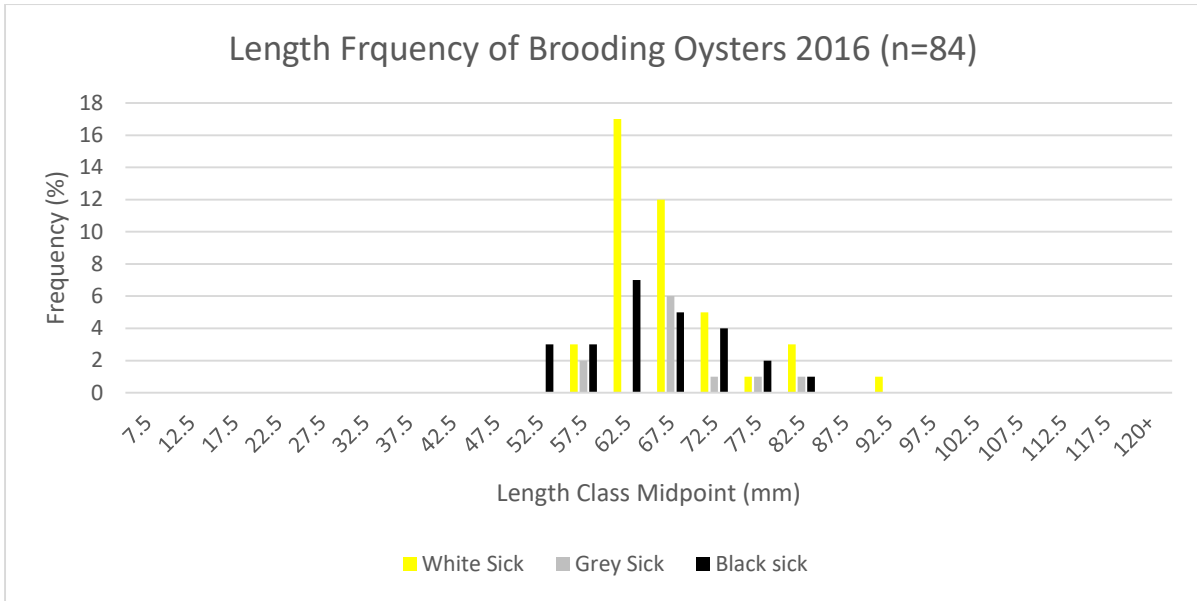


Figure 12 Proportional Length Frequency of Brooding Oysters - Lough Foyle Summer 2016

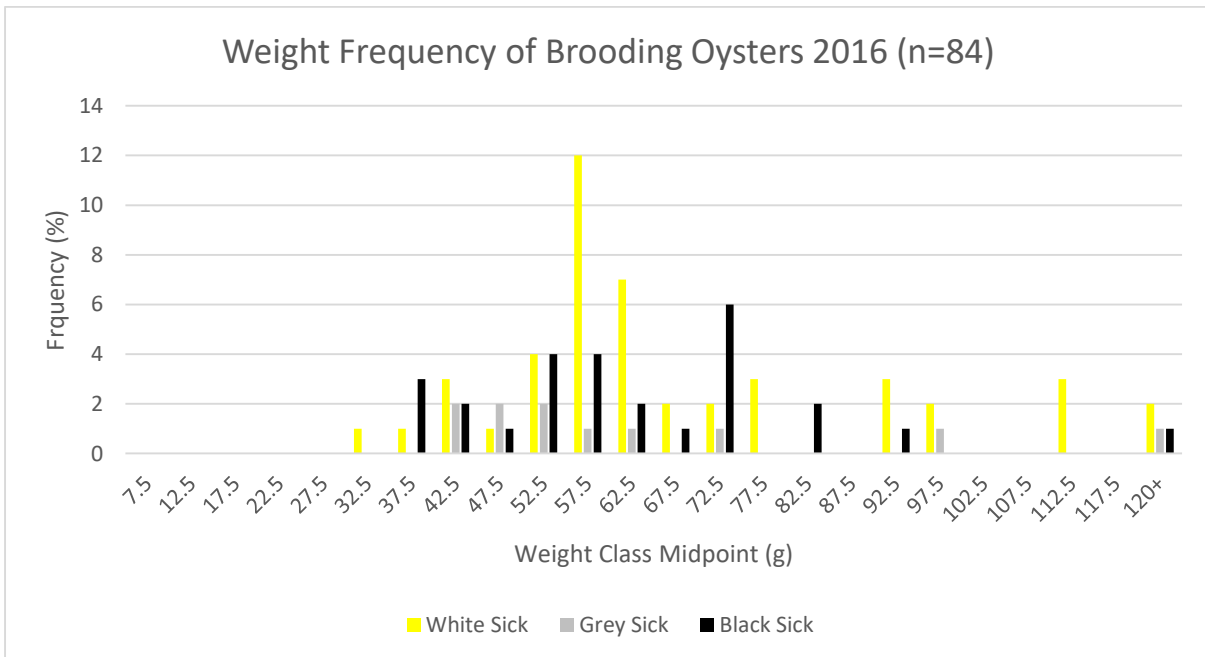


Figure 13 Proportional Weight Frequency of Brooding Oysters - Lough Foyle Summer 2016

The pooled results of gonad staging for the period showed a gradual rise in broodstock conditioning over the early part of the summer. It is interesting to note that the first signs of brooding were detected in week 1 on 1<sup>st</sup> June and that the water temperatures were already above 16°C at this early stage in the summer. Brooding stages were observed in all samples taken following this temperature threshold being met and the proportion of spent individuals in the samples rises gradually until the end of the sampling period. The proportion of oysters

in the brooding stages is low during the majority of August. Another small increase in water temperature in early September appears to have helped redevelopment of gonads however does not appear to have stimulated any significant spawning event as evidenced by the lack of brooding oyster records for September.

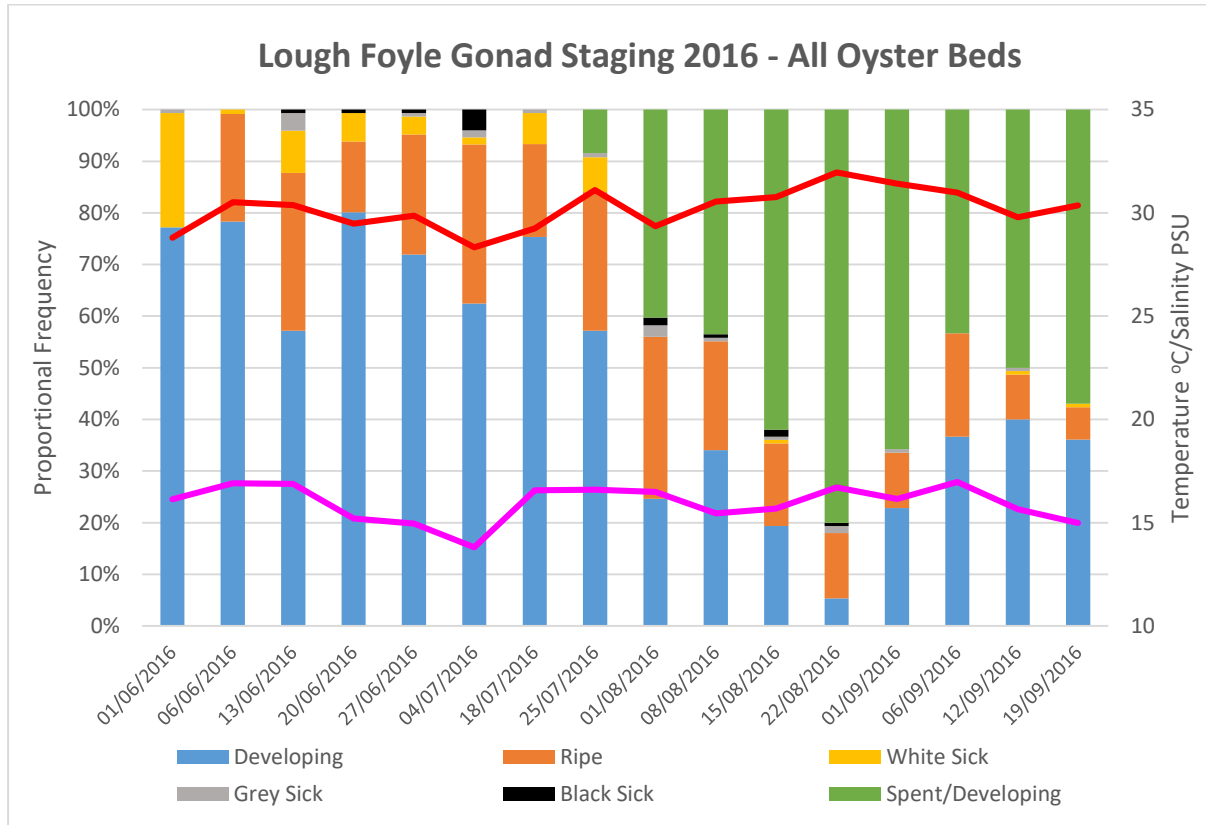


Figure 14: Pooled weekly gonad stages and water temperature

Table 3: Summary data for all sites sampled summer 2016

Bed Name	Min Temp (°C)	Max Temp (°C)	Max Larvae per m3	% Oysters Brooding	% Brooding & Spent	Mean Length (mm)	Mean Weight (g)
Southside	13.21	17.77	24531	2.09	41.1	65.64	55.98
Flat Ground	13.36	17.53	21008	3.30	33.1	69.15	63.03
Perch	13.79	17.78	14939	5.32	34.4	68.34	69.21
Quigley's Pt	13.79	17.05	32809	4.69	30.4	70.68	61.25
Middle Bed	13.83	16.54	16451	2.95	32.9	68.97	71.51

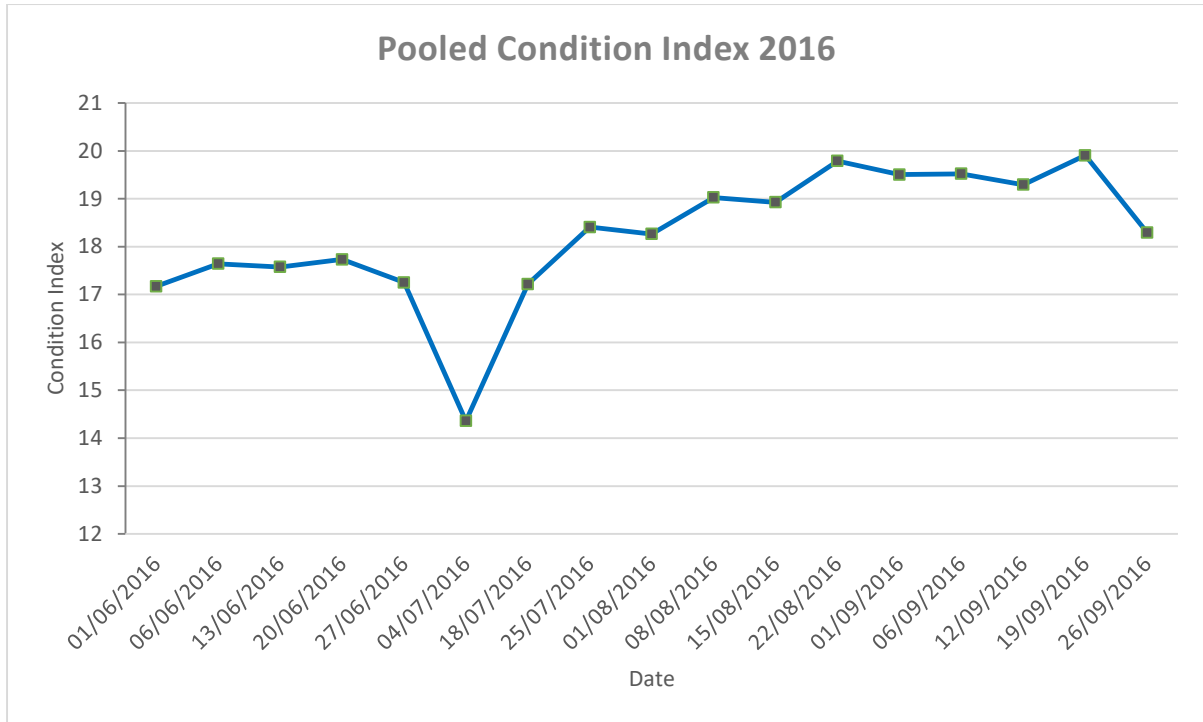


Figure 15 Pooled condition Index 2016

The pooled data from all beds for condition index shows one pronounced drop in condition throughout all beds in early July. This is likely to follow the highest period of spawning activity within the population. The sampled population regained condition following this however there were no other marked decreases in condition after July. This may signify poor spawning success for the remainder of the summer. The spawning event in early July coincides with a drop in water temperatures and this may have had an impact on the survival of any larvae broadcast at this time. The reduction in water temperatures in early July may have a significant role to play in determining whether a successful widespread spatfall occurs annually or not. Water temperature records from 2011-2016 would indicate that temperatures were always above 16°C during early July in years when spatfall was widespread.

### 3.1 Flat Ground

Table 4: Flat Ground summary info

<b>Bed Name</b>	<b>Flat Ground</b>
<b>Area (hectares)</b>	<b>970</b>
<b>Average Density (oysters/m<sup>2</sup>)</b>	<b>0.93</b>
<b>No. of Oysters</b>	<b>6,893,899</b>
<b>Total Biomass (t)</b>	<b>206</b>

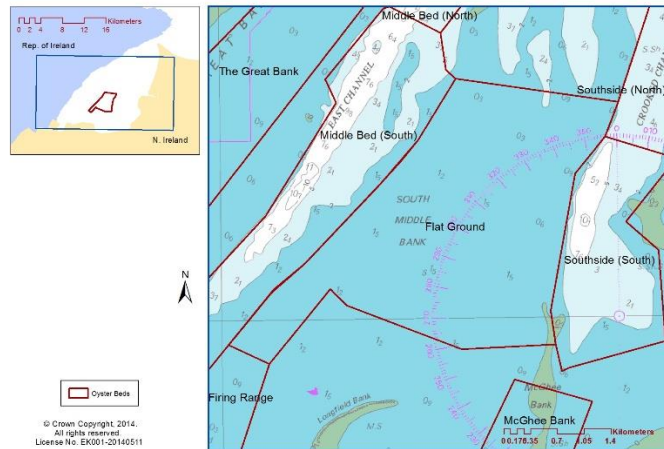


Figure 16: Location of Flat Ground

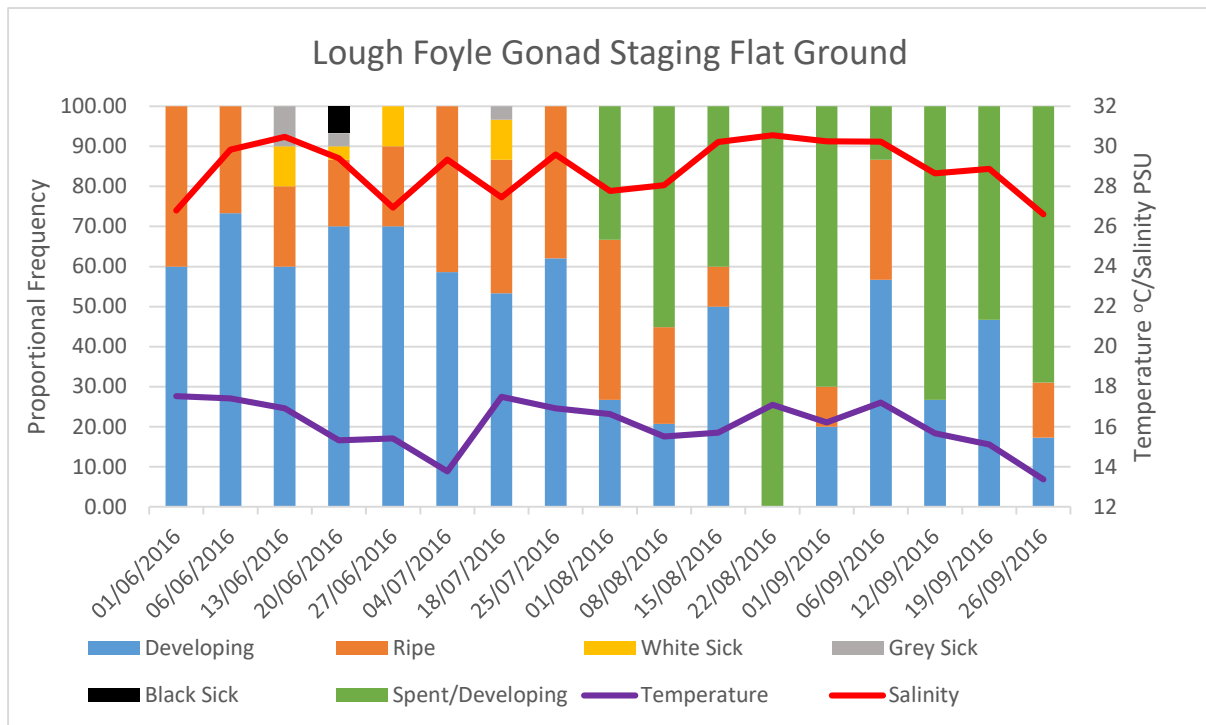


Figure 17: Spawning Stage and Water Temperature/Salinity Flat Ground

The gonad stage results for the Flat Ground (Figure 17) shows evidence of a gradual rise in gonad condition in the sampled population in the early part of the summer. There appears to be a peak in spawning activity roughly 2 weeks after the peak water temperature was recorded on the 1<sup>st</sup> June. Approximately 20 % of the samples were either white sick or grey sick during that week. Spawning activity was low as the water temperature dropped in July and remaining low for the remainder of the summer even with the elevated water

temperatures in August and September. In total, 3.3% of the sampled population exhibited brooding activity with 33.1% of samples being observed in the brooding or spent phases.

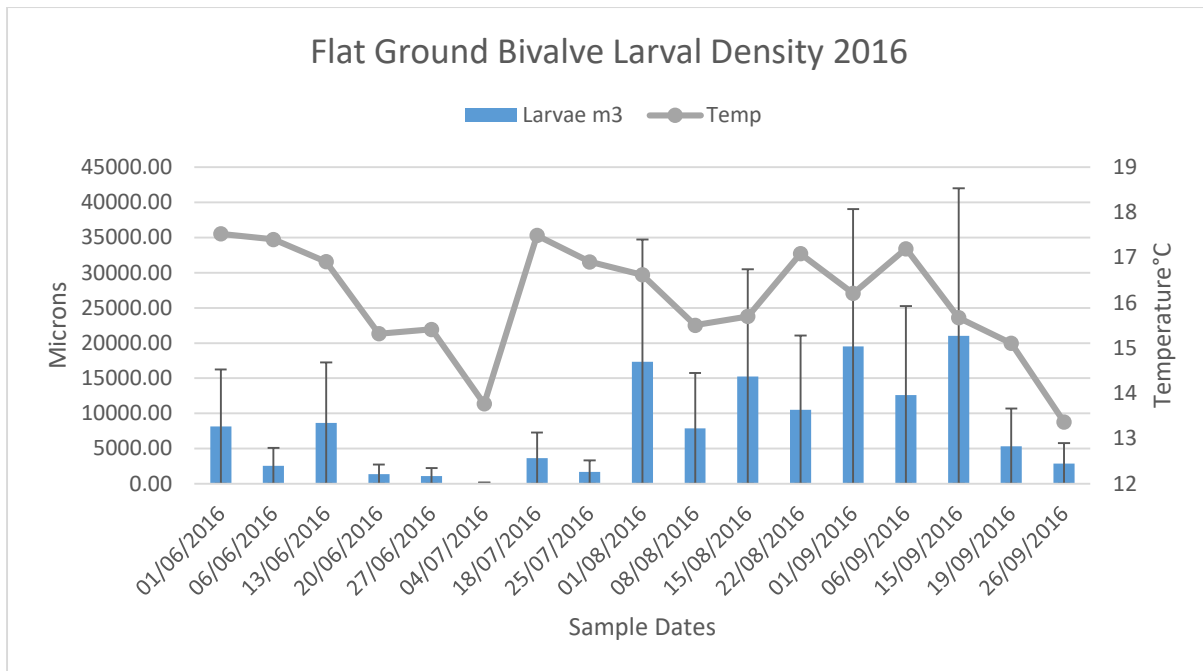


Figure 18: Larval Density and Water Temperature Flat Ground

Bivalve larval counts exhibit 4 peaks throughout August and larval densities are greater on spring tides than during neaps (Figure 18). The numbers of bivalve larvae recorded on the Flat Ground were consistently higher than those recorded on the other beds, with the maximum count being 21,008 bivalve larvae per  $m^3$ . Water temperatures in June were extremely high compared to previous records.

A total of 480 oysters were sampled from the Flat Ground, 3.3% of which were observed in one of the three brooding phases. Oysters sampled from this bed had a mean length of 70.2mm and mean weight of 62.5g. Oysters observed in the brooding phases ranged in Length from 52.5mm–82.5mm (Figure 19) and ranged in weight from 42.6–128.2g (Figure 20). The quantity of brooding oysters observed was insufficient to determine any bias in length or weight frequency within the sampled population.



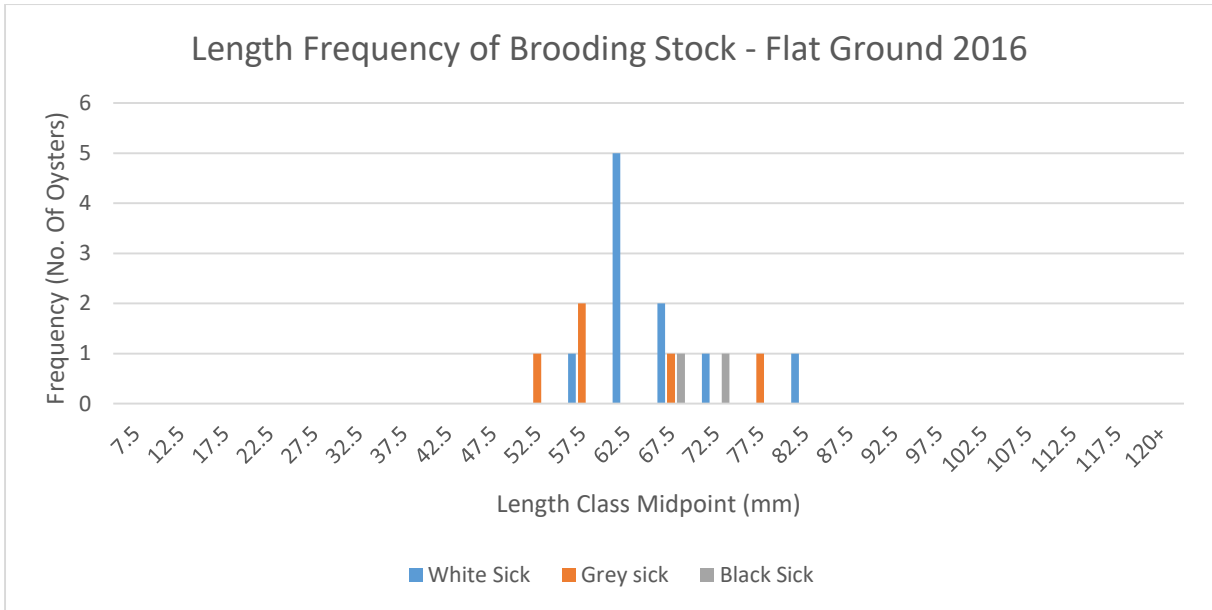


Figure 19 Length Frequency of Oysters at Spawning Stage- Flat Ground 2016

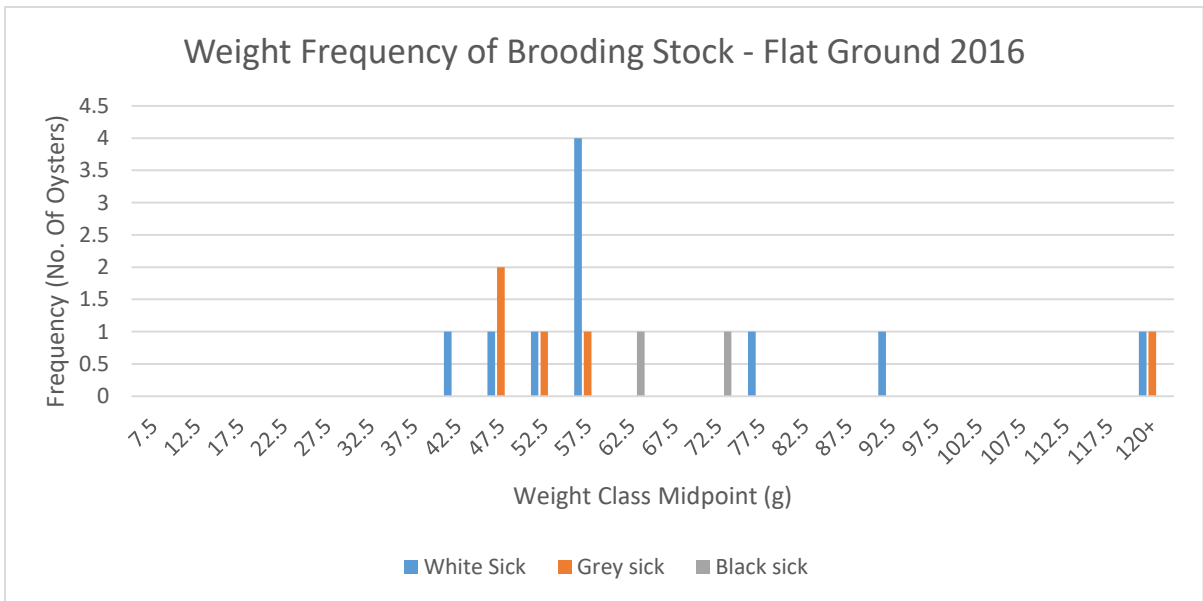


Figure 20 Weight Frequency of Oysters at Spawning Stage- Flat Ground 2015

The condition index for the oysters sampled on the Flat Ground Bed does not exhibit any particular trend towards loss or gain in condition for any particular period of the summer (Figure 21). This may be a result of the very low proportion of the population spawning masking any trends.

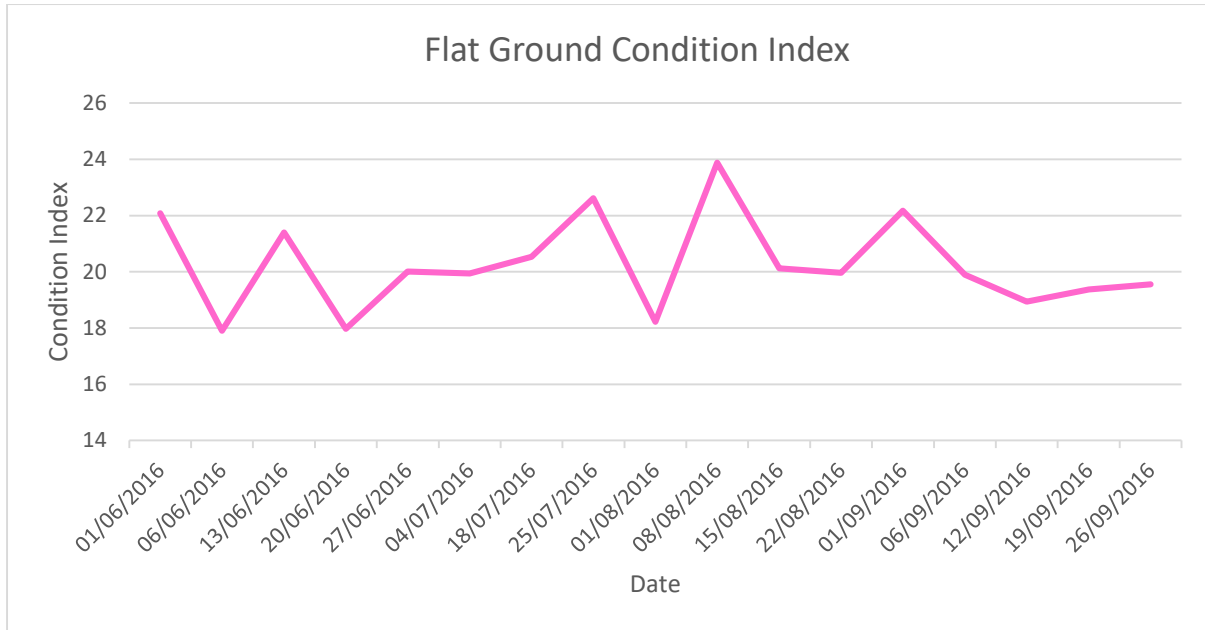


Figure 21 Condition Index Flat Ground

### 3.2 The Perch Bed

Table 5: Perch summary info

<b>Bed Name</b>	<b>The Perch</b>
<b>Area (hectares)</b>	<b>276</b>
<b>Average Density (oysters/m<sup>2</sup>)</b>	<b>0.40</b>
<b>No. of Oysters</b>	<b>829,618</b>
<b>Total Biomass (t)</b>	<b>37.3</b>

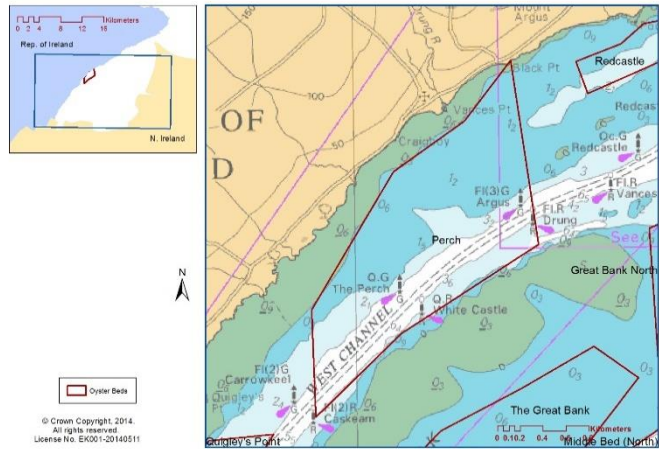


Figure 22: Location of the Perch Bed

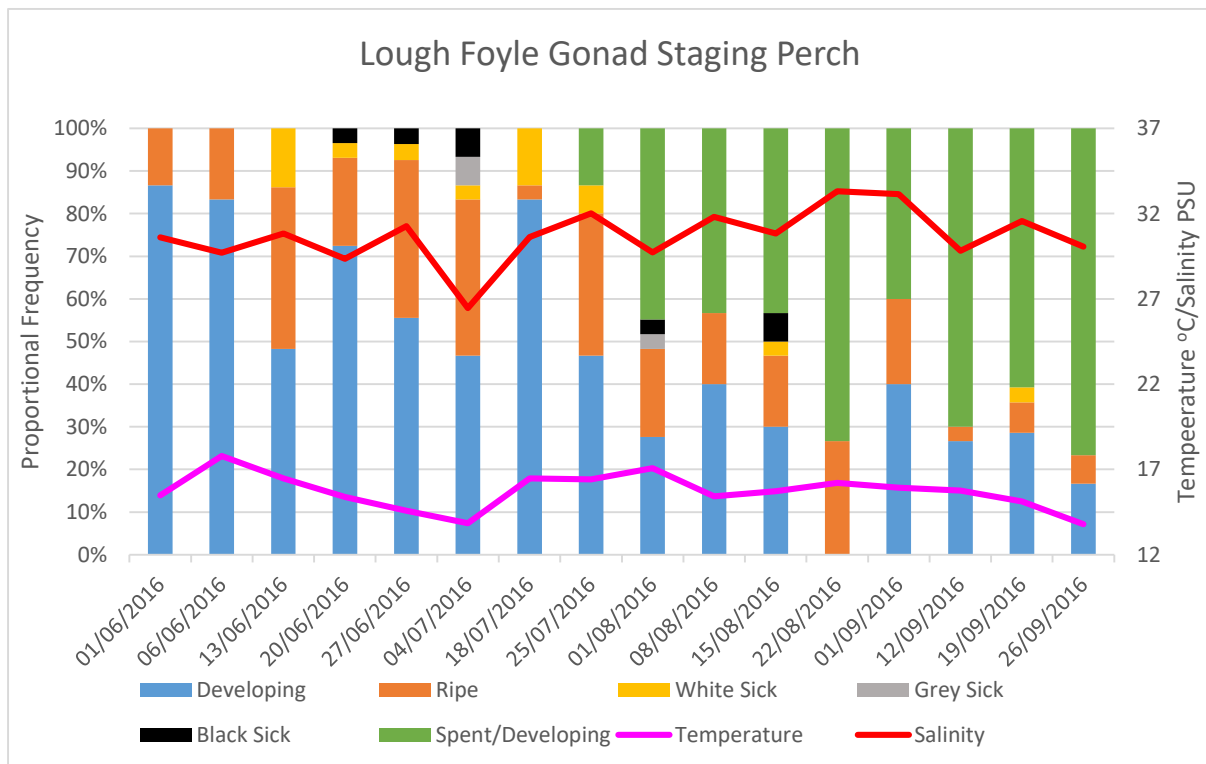


Figure 23: Spawning Stage and Water Temperature and Salinity Perch

A similar trend was observed in Perch as to that for Flat Ground, with spawning activity increasing gradually in line with a rise in water temperature during June and early July. There was some limited evidence of brooding in August when water temperatures rose above 16 again however there was practically no brooding from 22 August to the end of the sample period. In total only 5.3% of the sampled population were found to be in brooding phases, with 34.4% observed in either brooding or spent phases.

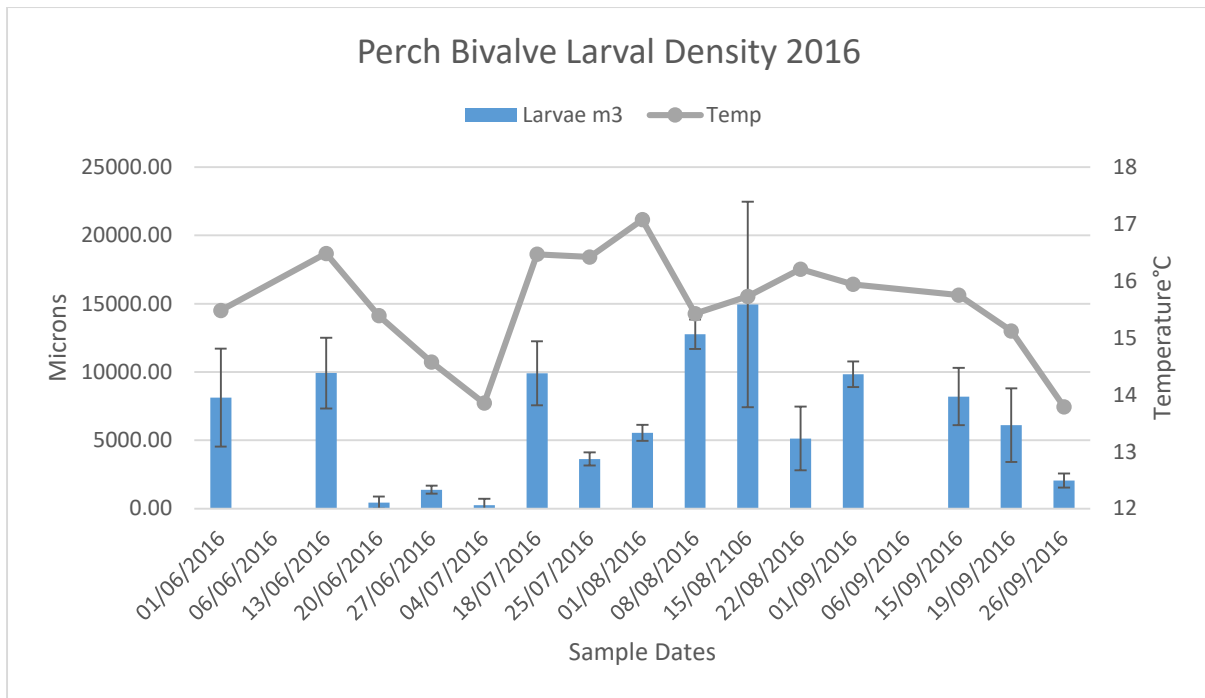


Figure 24: Larval Density and Water Temperature on the Perch

No obvious peaks occurred in the bivalve larvae recorded across the sampling period (Figure 24). Larval density was at or above 10,000 per m<sup>3</sup> on 5 occasions during the period, showing pulses of activity at this station. Water temperatures reached a peak at the beginning of June and again in late July. The greatest number of larvae (14,939 per m<sup>3</sup>) was recorded on 15<sup>th</sup> August. This was in contrast with the peak in 2011 of 119,420.91 per m<sup>3</sup>, suggesting that sub-optimal conditions were present in 2016.

478 oysters from the Perch were sampled over the course of this study. The mean length of the sampled oysters was 69.7mm, with a mean weight of 59.5g. Overall 4.9% of these oysters were observed in one of the brooding stages (Figure 23). Brooding oysters ranged between 52.5-92.5mm in length (Figure 25) and 39.2 -173.9g in weight (Figure 26).

The quantity of brooding oysters observed was insufficient to determine any bias in length or weight frequency within the sampled population

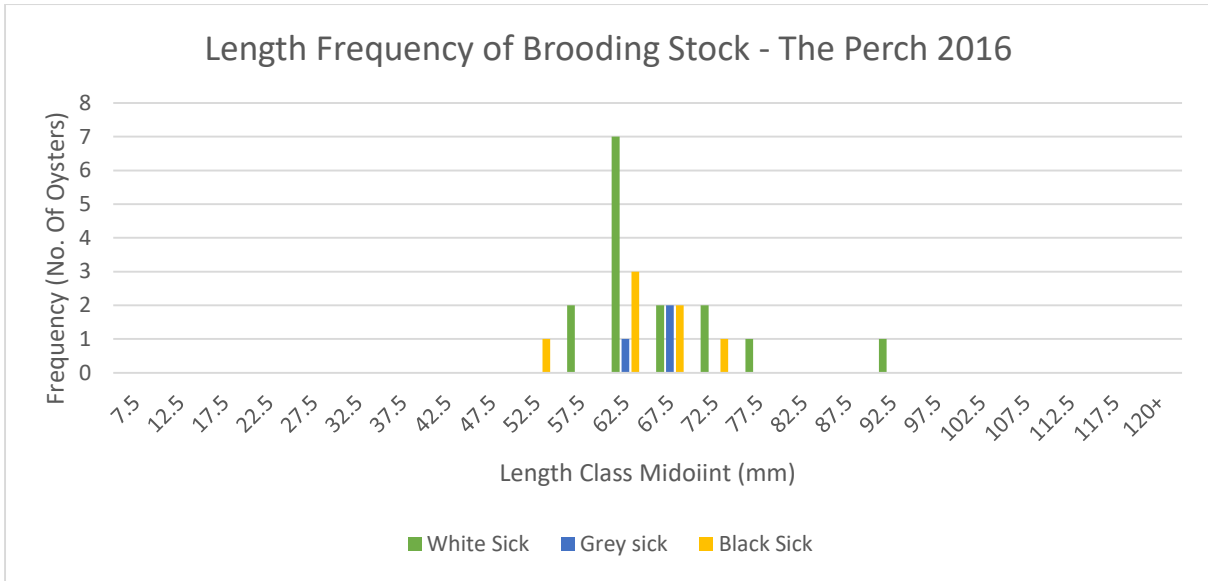


Figure 25 Length Frequency of Oysters Spawning Stage- Perch 2016

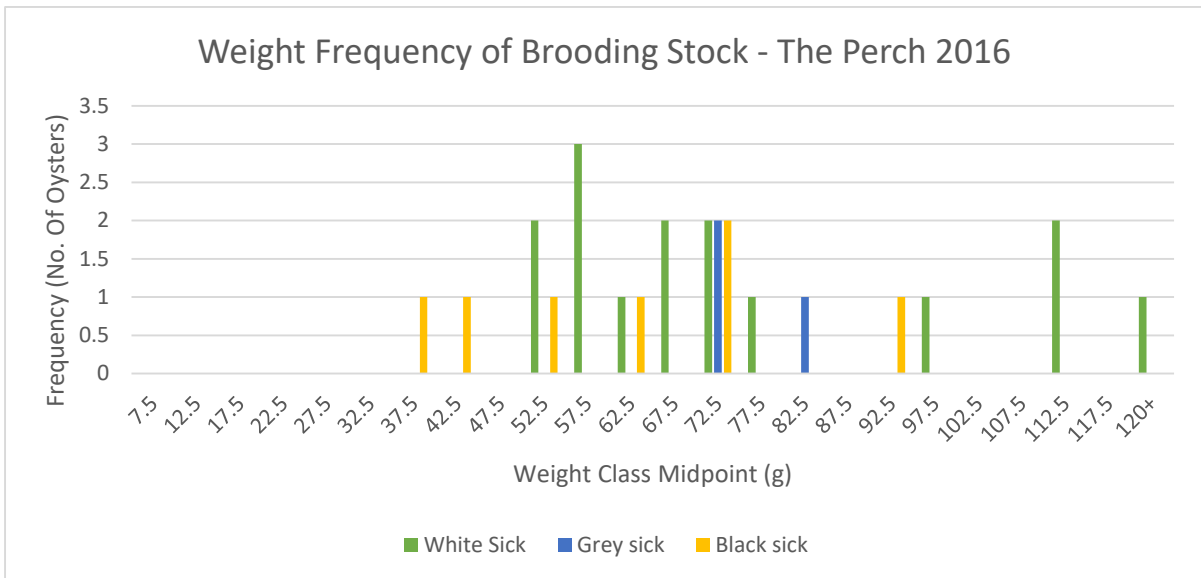


Figure 26 Weight Frequency of Oysters Spawning Stage- The Perch 2016

The condition index for the sampled oysters shows a drop in early July reinforcing the fact that this was the main spawning event within the population in 2016 (Figure 27). Condition dropped once more in Late July and late August/early September.

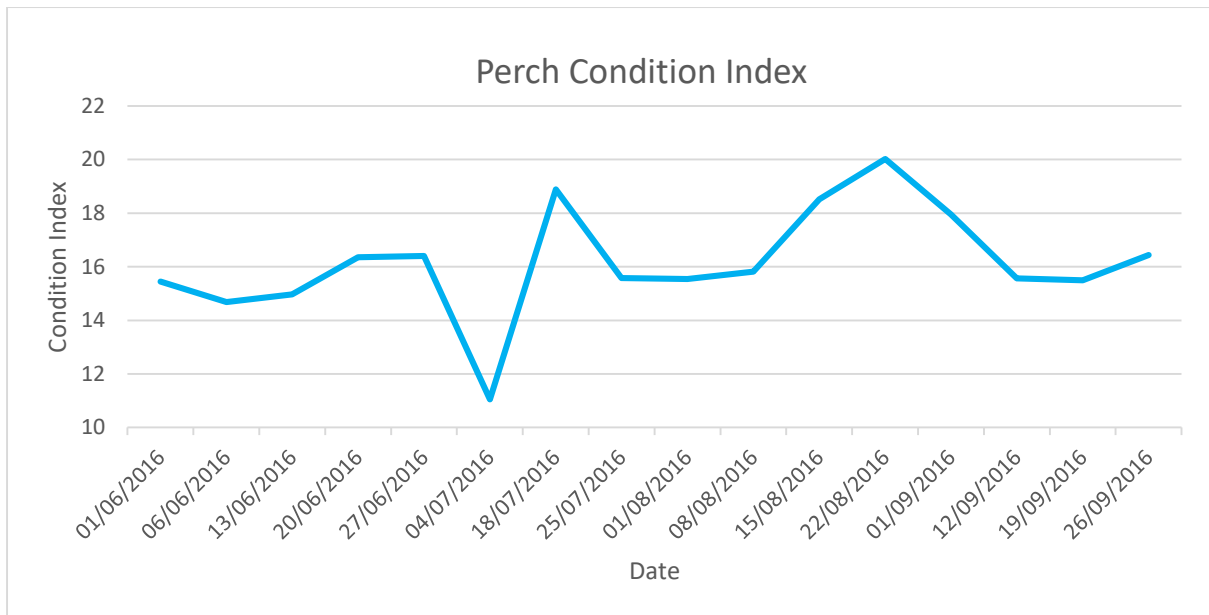


Figure 27 Perch Condition Index



### 3.3 Quigley's Point

Table 6: Quigley's Point summary info

<b>Bed Name</b>	<b>Quigley's Pt</b>
<b>Area (hectares)</b>	<b>140</b>
<b>Average Density (oysters/m2)</b>	<b>0.40</b>
<b>No. of Oysters</b>	<b>533,334</b>
<b>Total Biomass (t)</b>	<b>24</b>



Figure 28: Location of Quigley's Point Bed

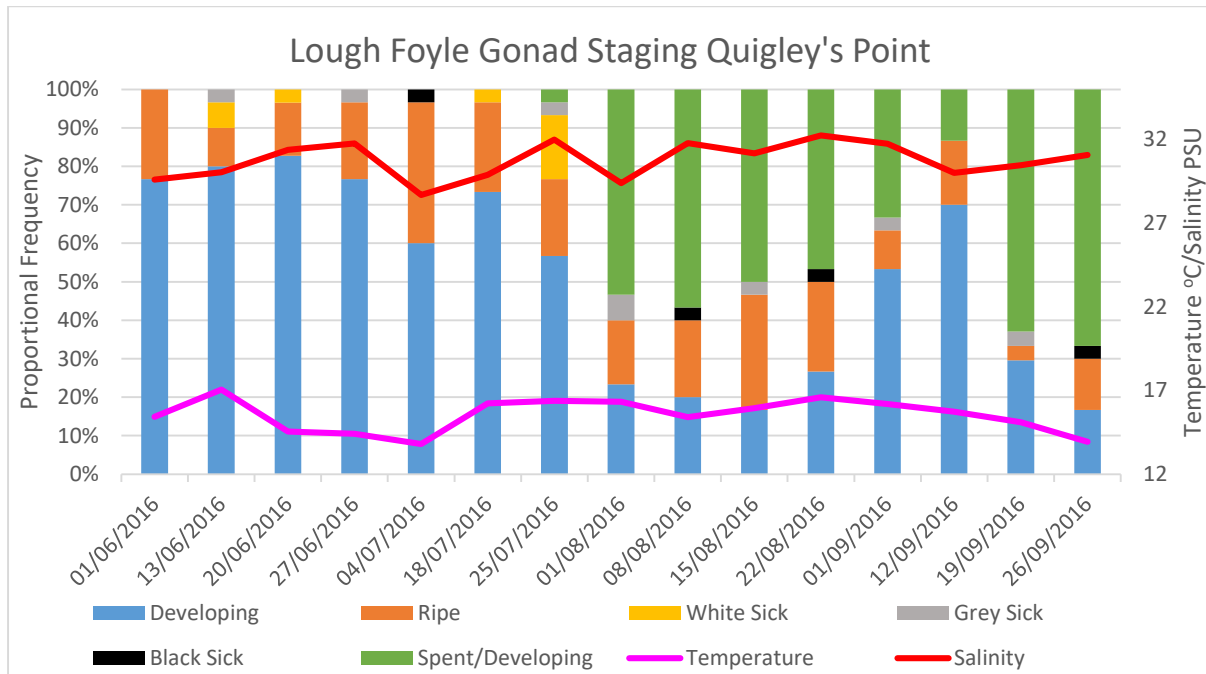
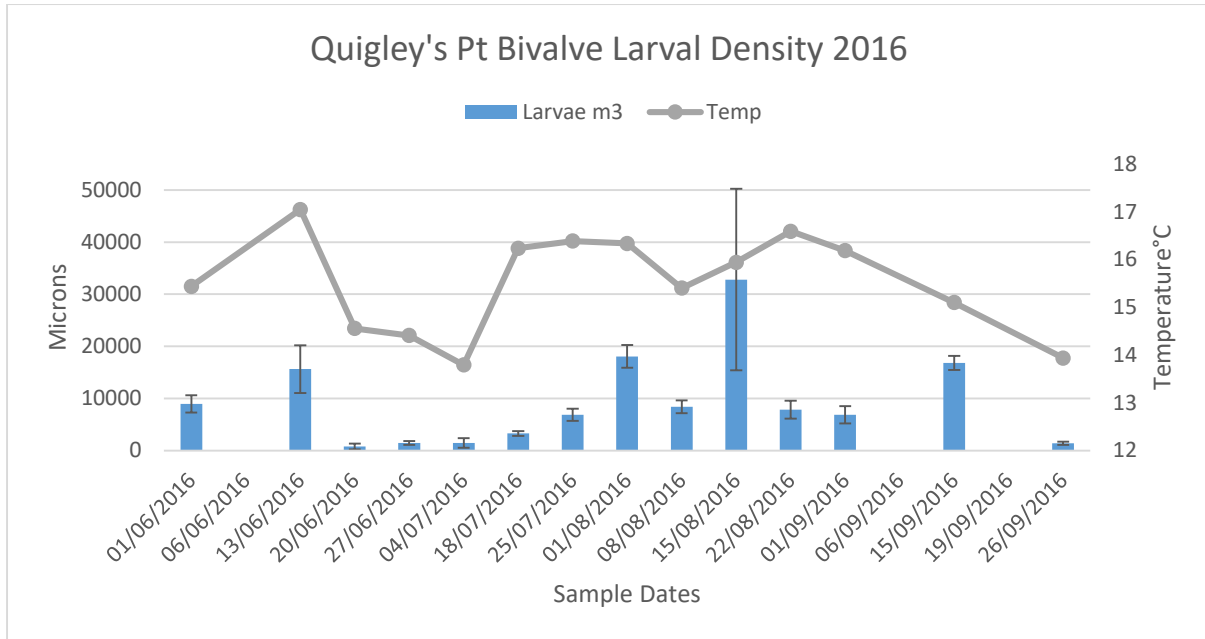


Figure 29: Spawning Stage and Water Temperature/Salinity Quigley's Point Bed

The bed at Quigley's Point is small in area (140ha) with a relatively high density of oysters present. This bed exhibited some of the most sustained brooding activity of any of the oyster beds in 2016. 15% of the sampled population was in the white or grey sick phase on 25 July and black sick oysters were observed throughout July and August and even on the final week of sampling at the end of September. In total only 4.69% of the sampled population exhibited brooding activity, with 30.4% in the brooding or spent phases.



**Figure 30: Larval Density and Water Temperature Quigley's Point Bed**

There was 1 distinct peak in larval numbers on the Quigley's Point Bed in mid-August. The maximum larval density was 32,809.5 per m<sup>3</sup> which was the highest single count from all beds and shows the relative importance of this area. This figure is only a small fraction of the peak count of 193,281 larvae per m<sup>3</sup> observed in 2011.

417 oysters were sampled from Quigley's Point throughout the 15 weeks survey. The oysters sampled had an average length of 69.6mm and average weight of 61.5g in weight. The 4.69% recorded in a brooding phase ranged from 35.3 – 134.6g in weight. Brooding oysters ranged in size from 52.5mm to 85mm (Figure 31) and ranged in weight from 32.5g to 120g+ (Figure 32). The quantity of brooding oysters observed was insufficient to determine any bias in length or weight frequency within the sampled population

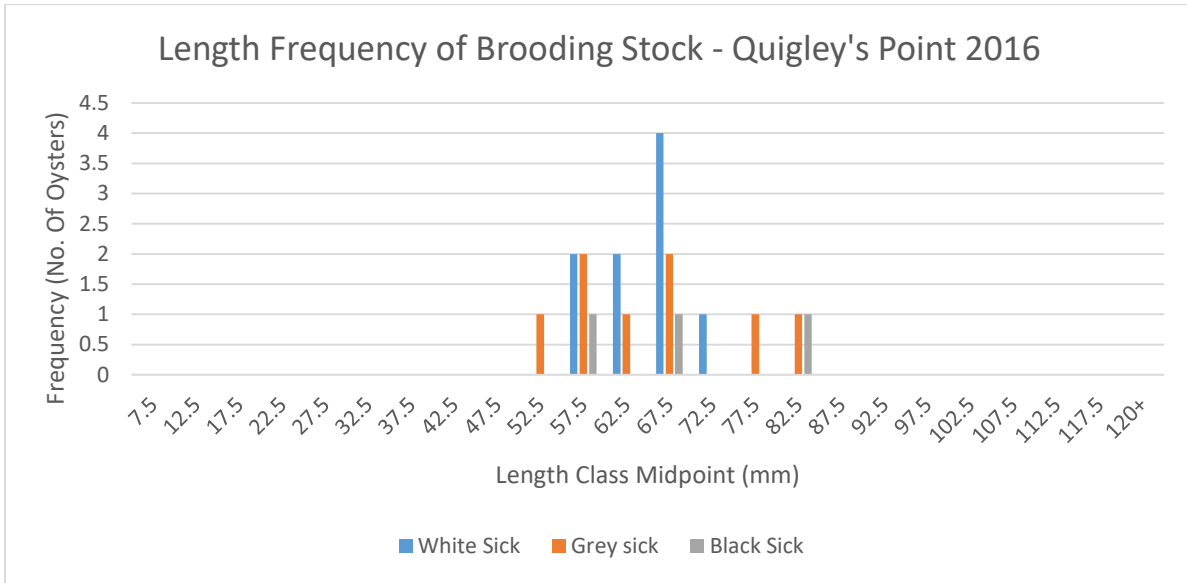


Figure 31 Length Frequency of Oysters at Spawning Stage- Quigley's Point 2016

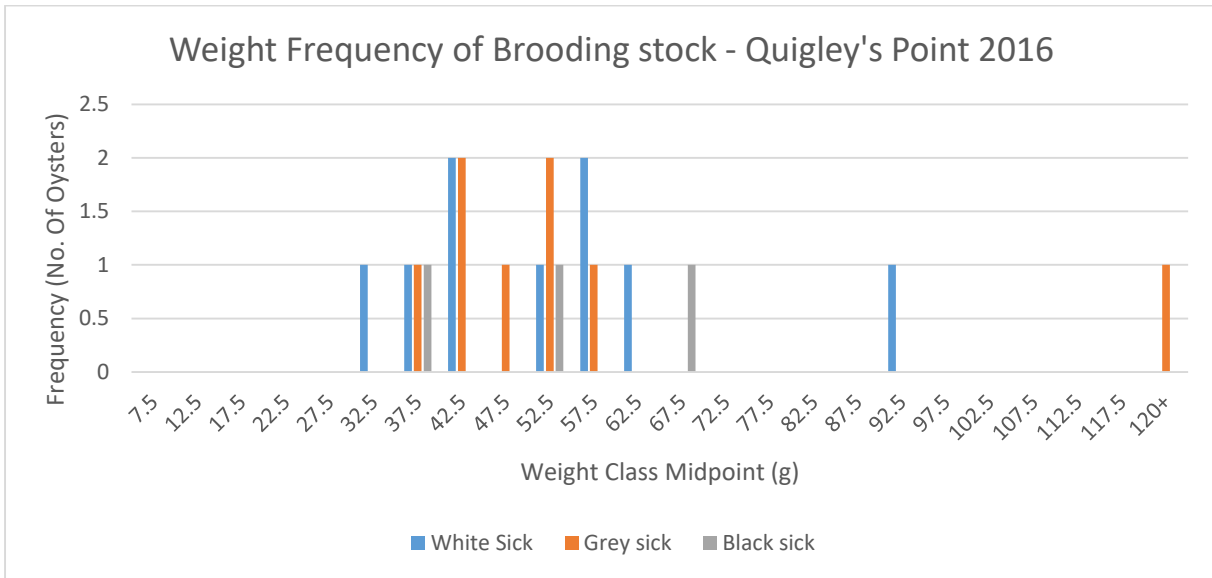


Figure 32 Weight Frequency of Oysters at Spawning Stage- Quigley's Point 2016

The condition index for Quigley’s Point Bed shows a similar trend to that observed on the Perch Bed with a drop in condition obvious at the beginning of July and another towards the middle of August and again in early September (Figure 33). These trends match well with the gonad stages observed and the pattern of spent and developing oysters recorded on the bed.

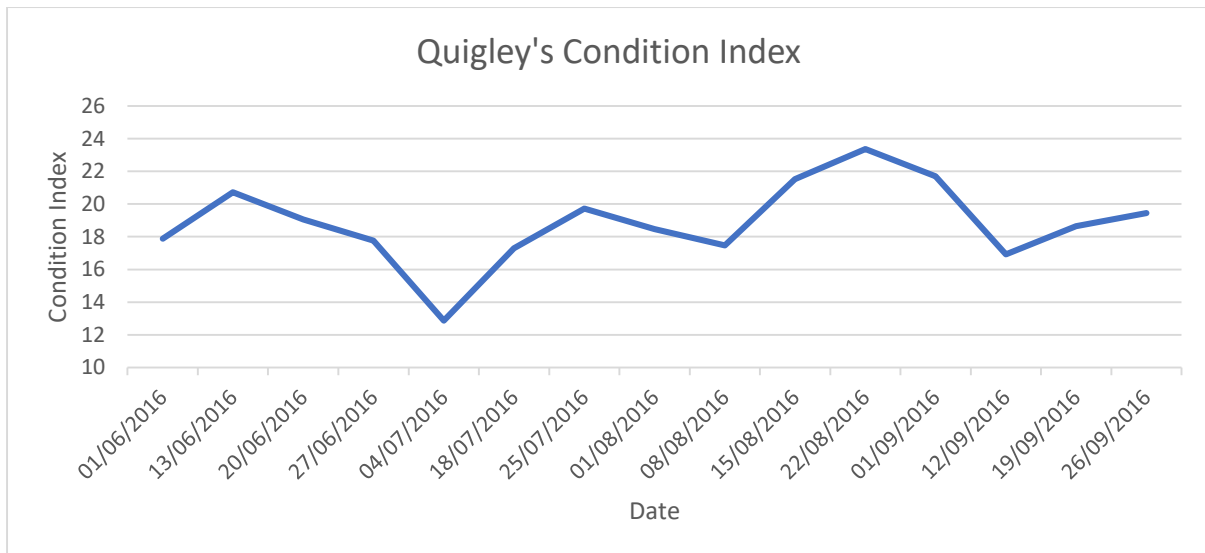


Figure 33 Condition index Quigley's Pt

### 3.4 Southside Bed

Table 7: Southside summary info

<b>Bed Name</b>	<b>Southside</b>
<b>Area (hectares)</b>	<b>578</b>
<b>Average Density (oysters/m2)</b>	<b>0.44</b>
<b>No. of Oysters</b>	<b>3,478,855</b>
<b>Total Biomass (t)</b>	<b>106</b>

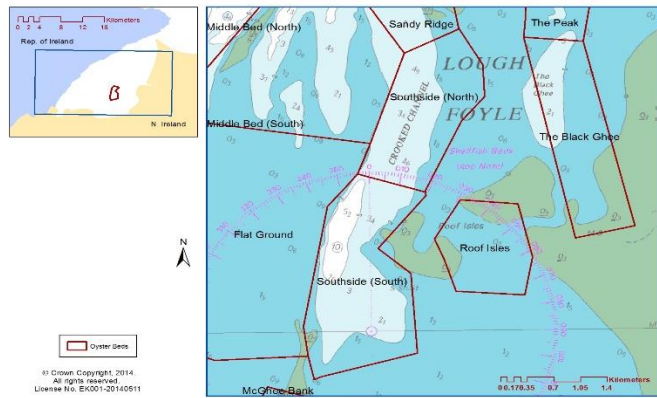


Figure 34: Location of Southside Bed

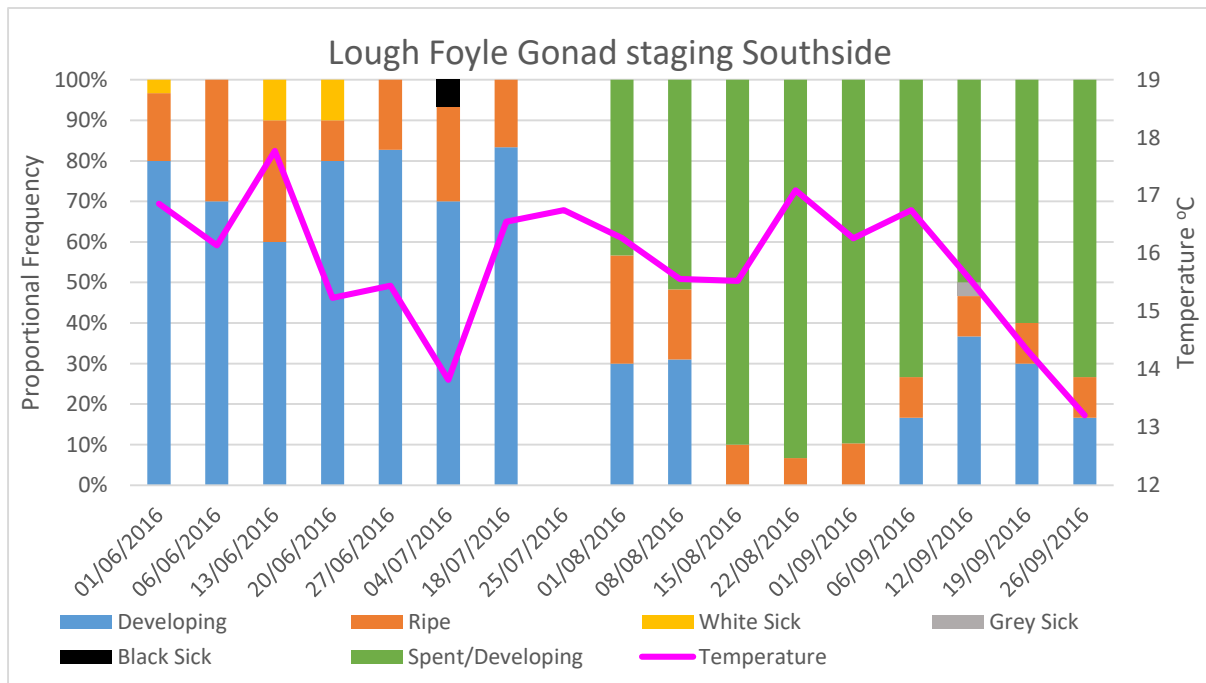


Figure 35 Spawning stage and water temperature/salinity Southside

The Southside Bed exhibited very low levels of brooding activity, with the only obvious activity recorded in mid to late June and early July. 10% of the sampled population was brooding on the 13<sup>th</sup> and 20<sup>th</sup> June. Total brooding oysters in the sampled population was low (2.08%) compared to other beds however 41.1% of the sampled population were either in the brooding or spent phases so it is possible that some brooding activity was missed during the periods.

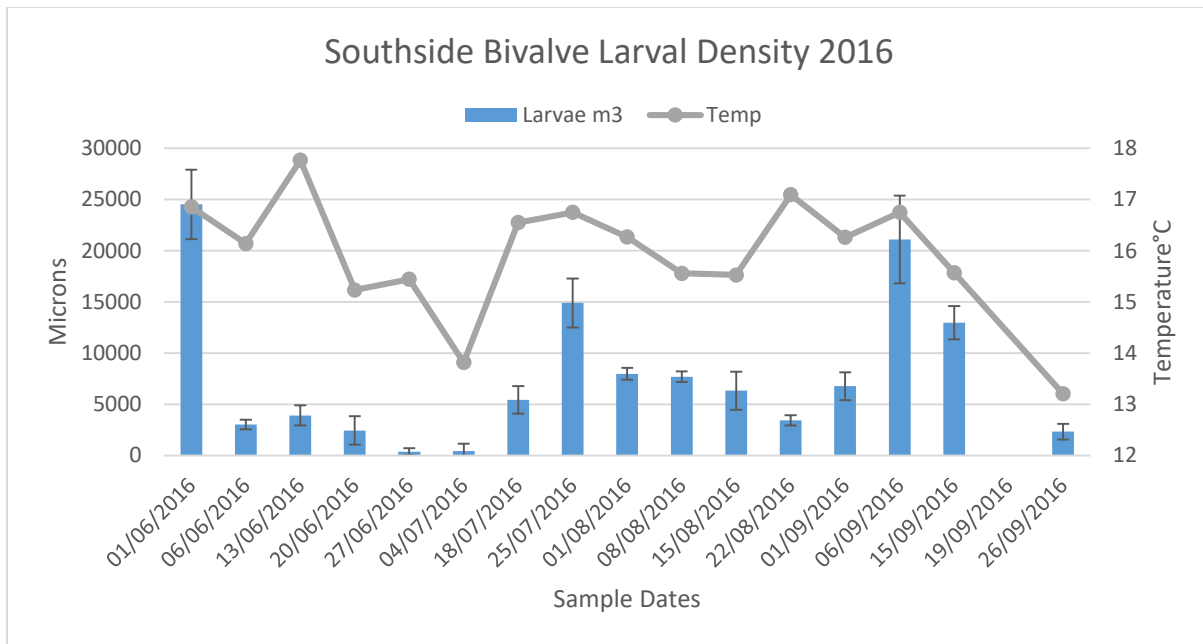


Figure 36 Larval density and water temperature Southside

Larval numbers were high relative to other sites with a peak count of 24,531 per m<sup>3</sup> at the beginning of June and another peak at the beginning of September. Water temperatures peaked in mid-June at 17.7°C, with a further peak of 17°C in late August potentially helping to stimulate a late spawning event. Although larval densities appear to have been high the gonad development and the proportion of brooding oysters observed would suggest that these larvae may either not have been from this bed or were not native oyster larvae.

478 oysters were sampled from the Southside over the 16 week period. The mean length of these oysters was 69.7mm and mean weight was 59.5g. Condition index was variable over the period with drops in condition in early June, mid-July and early-August (Figure 37).

Brooding oysters were present in very low numbers relative to other beds assessed. Length of the oysters observed in the brooding phases ranged from 62.5mm-82.5mm (Figure 38) and the weight ranged from 42.5g-112.5g (Figure 39). The low numbers of oysters observed in the brooding phases make it impossible to determine any trends in the length frequency for this spawning population.



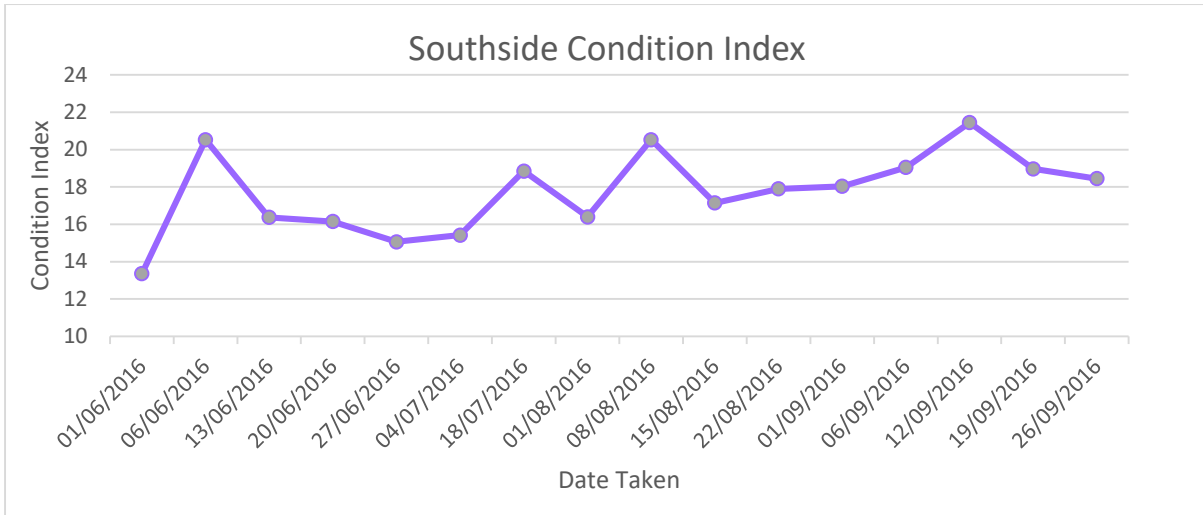


Figure 37 Condition Index Southside

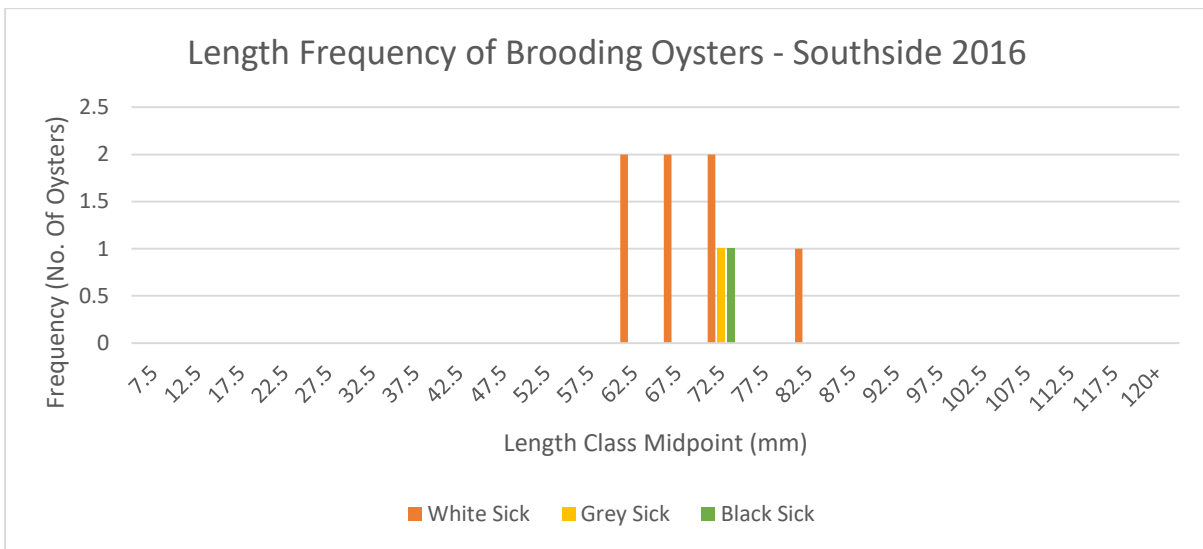


Figure 38 Length Frequency of oyster at spawning stage Southside 2016

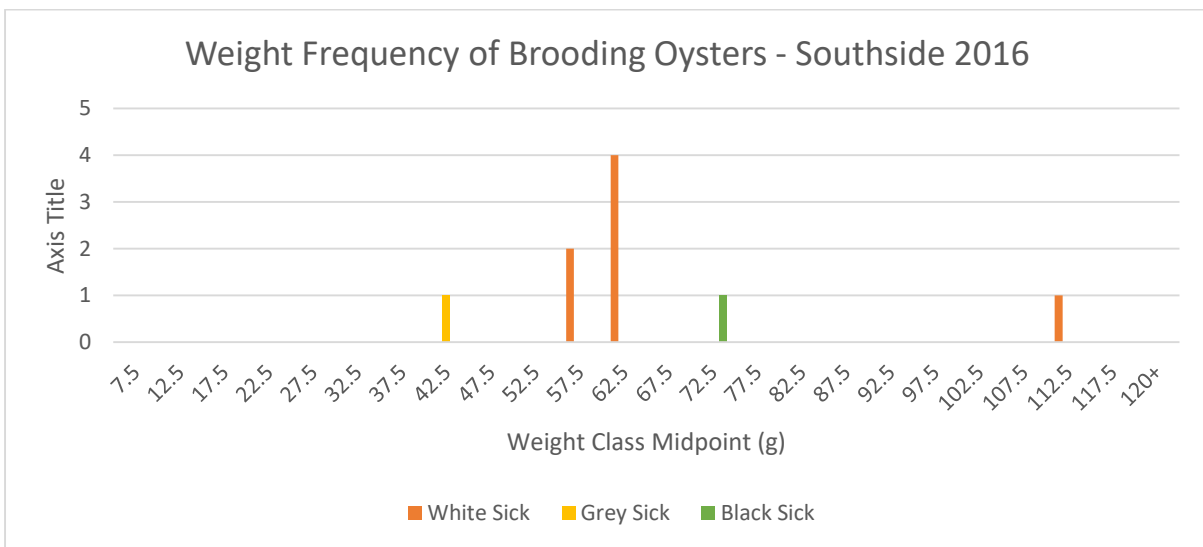


Figure 39 Weight Frequency of oysters at spawning stage Southside 2016

### 3.5 Middle Bed

Table 8: Middle Bed summary info

<b>Bed Name</b>	<b>Middle Bed</b>
<b>Area (hectares)</b>	<b>531</b>
<b>Average Density (oysters/m2)</b>	<b>0.24</b>
<b>No. of Oysters</b>	<b>3,153,705</b>
<b>Total Biomass (t)</b>	<b>94.6</b>

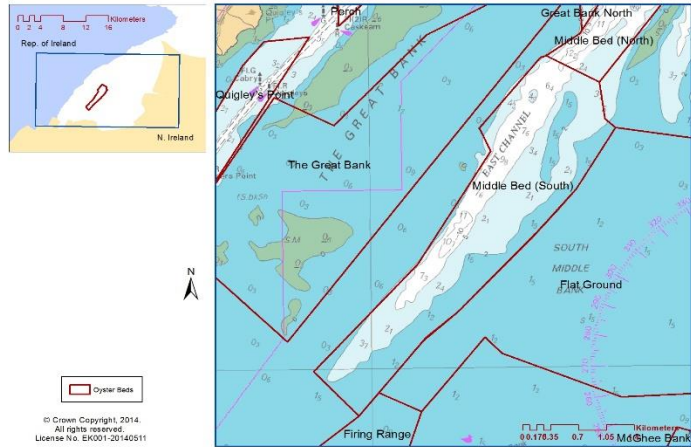


Figure 40 Location of Middle Bed

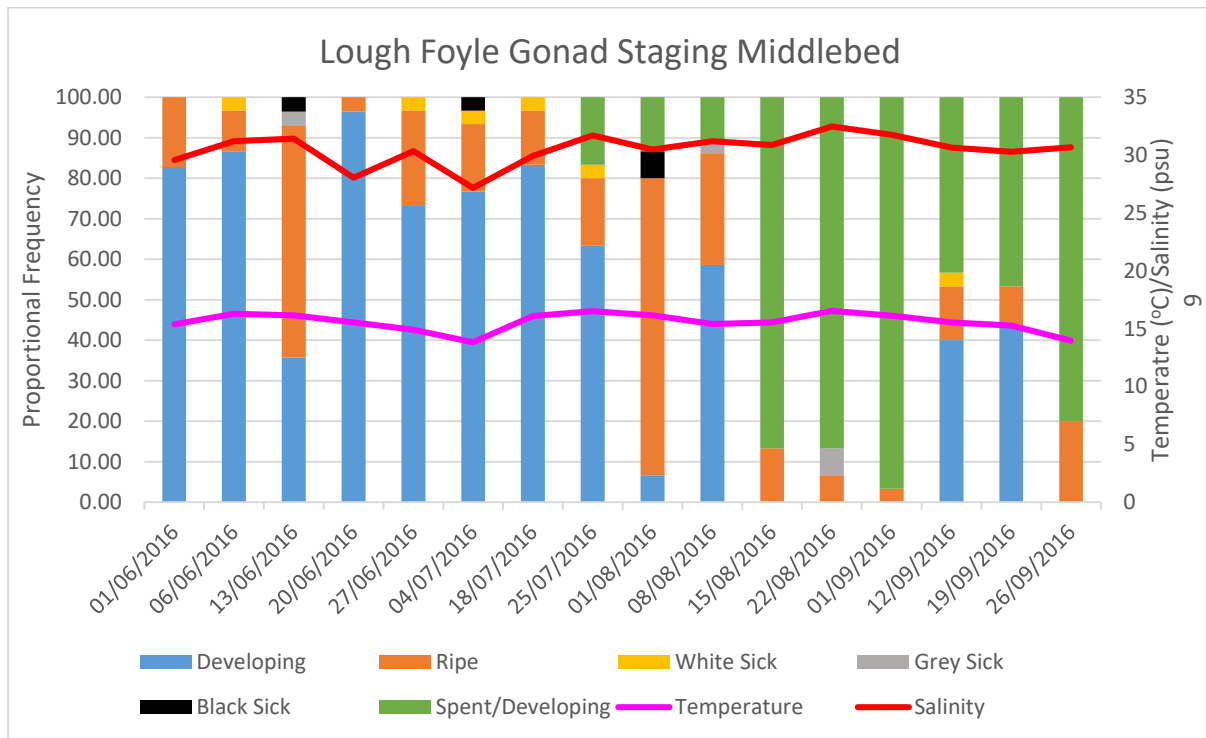


Figure 41 Spawning stage and water temperature/salinity Middle Bed

There was limited evidence of brooding in the population sampled throughout the survey period. There was almost no brooding in the sampled oysters after mid-August. Water temperatures exhibited the same trend as the other sampled oyster beds, with a peak in early June and another peak in late August. A total of 2.95% of the sampled population were recorded as brooding; the second lowest figure of all the beds sampled in 2016. 32.97% of the sampled population was either in the brooding or spent phases.

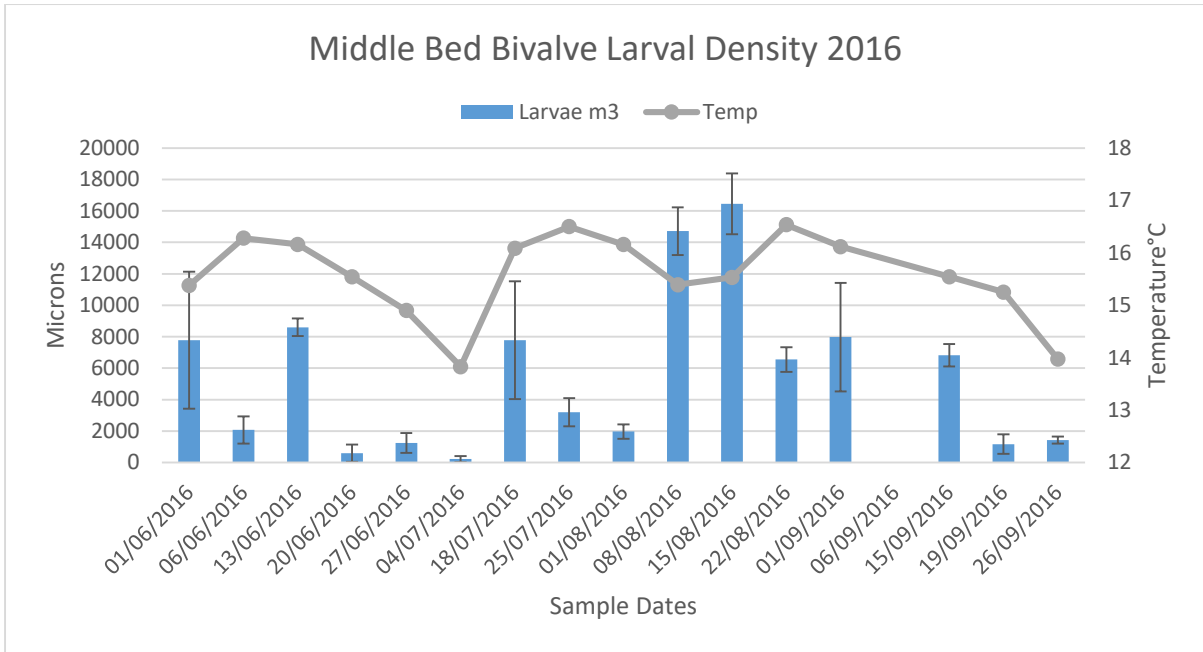


Figure 42 Larval Density and water temperature Middle Bed

A peak in larval numbers occurred in early August at 16,451 per m<sup>3</sup>, coming shortly after the second peak in water temperature of 16.49°C.

459 oysters were sampled from Middle Bed over the 16 weeks’ survey. The mean length recorded for the sampled oysters was 69mm and mean weight was 71.2g. 2.9% of these oysters were observed to be in a brooding stage (Figure 41). The oysters in the brooding phases ranged in Length from 62.5mm-75mm (Figure 43) and ranged in weight from 53.5 – 97.7g (Figure 44)

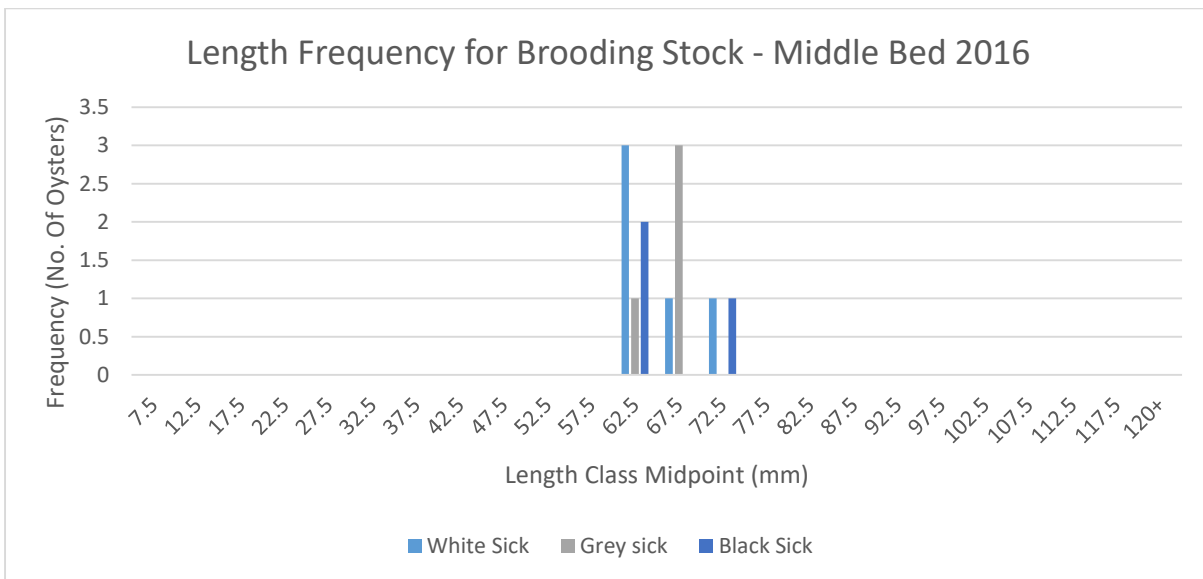


Figure 43 Length Frequency of oysters at spawning stage Middle Bed

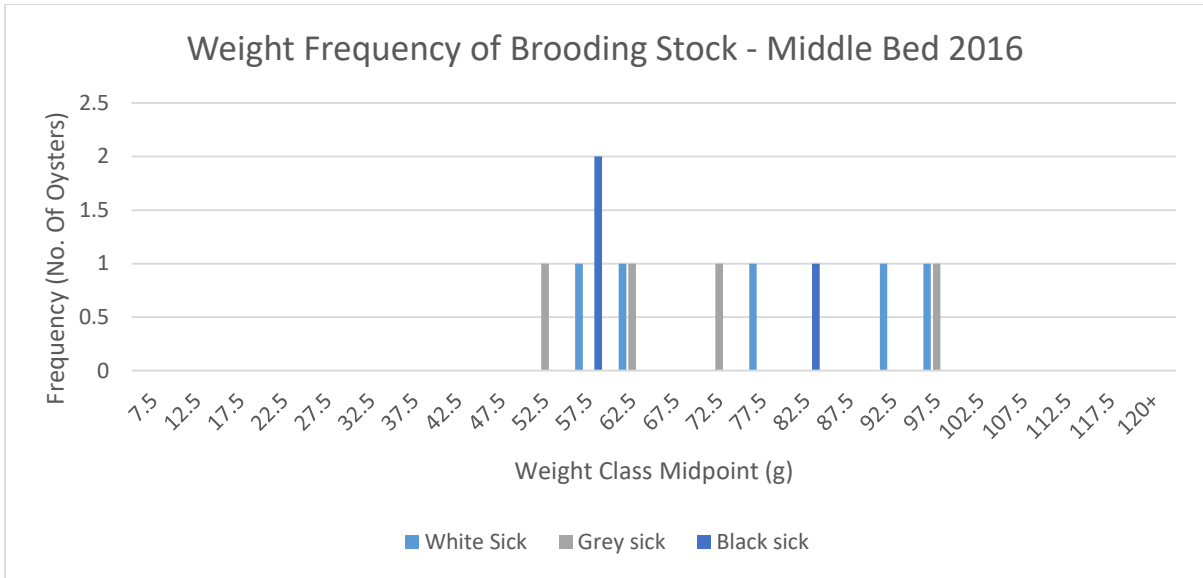


Figure 44 Weight Frequency of oysters at spawning stage Middle Bed

The condition index for oysters sampled on the bed shows a drop from late June onwards coinciding with relatively high larval counts on 04/07 and a small proportion of brooding observed within the bed at this time.

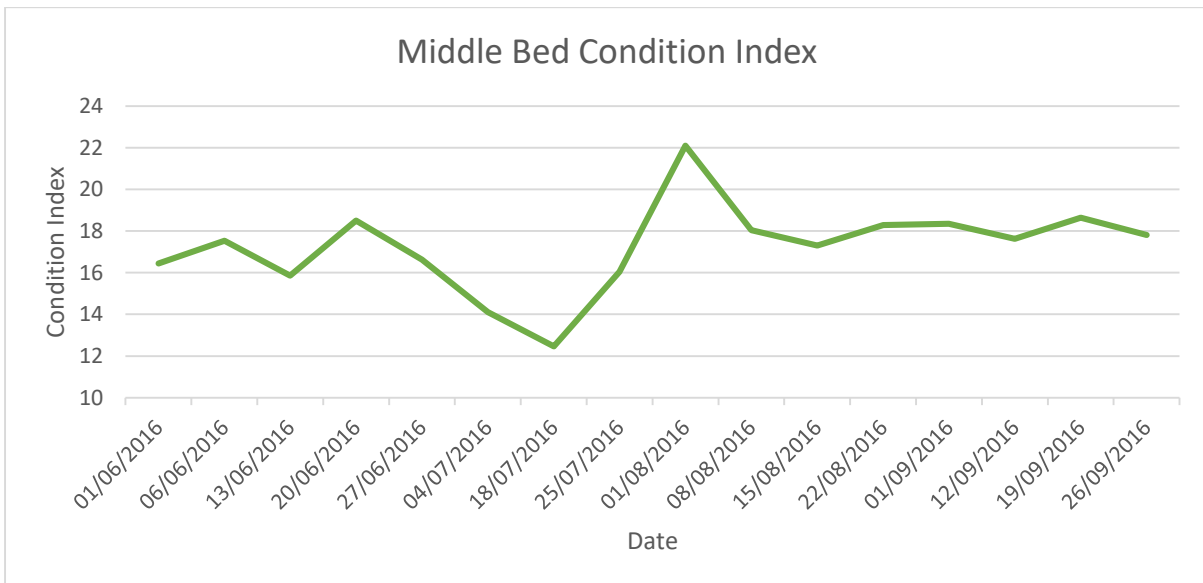


Figure 45 Condition Index Middle Bed

## 4.0 Discussion

Previous studies on oyster spawning activity have suggested a relationship between water temperature rising to 16°C and above, broodstock conditioning and increased larval densities. The sustained elevation of water temperature acts as a trigger for the oysters to spawn. Oysters retain larvae within the mantle cavity for 1-3 weeks before releasing them into the water column. The development of gonad material within the oysters is a function of the prevailing environmental conditions and peaks in larval density have been linked to peaks in temperature in previous studies. It is likely that primary productivity levels also play a role in determining when larvae are released from the oysters to optimise survival. This project attempted to monitor this activity in real time and draw linkages between the environmental variables and the spawning process.

The total proportion of the sampled population exhibiting brooding was 4.8%. This was not dissimilar to the 2013 spawning survey results when 5.6% of the samples were in the brooding phases.

Larval counts were low relative to the 2011 levels, suggesting that larval supply or survival was hampered by environmental conditions or by the poor broodstock conditioning in 2016. The mean weight of the oysters on all beds is lower in 2016 than in any previous year. This may indicate that the spawning stock is biased towards younger age classes who are not as fecund and whose larvae may not be of sufficient quality to survive in sub optimal conditions. Stock assessments of the population in 2016 have shown that the stock consists of 2-3 year classes on most beds with the majority of oysters originating from spatfall events in 2014 and 2015.

There has been little evidence of any widespread spatfall in the population this summer thus far which may indicate that survival was low immediately post release and many larvae succumbed to the low water temperatures and/or poor food availability in early July. Previous research has suggested that temperature is a critical factor for the successful settlement and metamorphosis of oyster larvae (Korringa, 1940).

The inter-annual variation in water temperature (Appendix II) in Lough Foyle highlights the inherent difficulty facing this oyster population. Weather patterns are erratic and there are no seasonal trends which can be expected from year to year. Peak water temperatures can occur at any time between July and September and there is a large amount of variation around the

maximum temperatures with a gap of over 3°C between 2012 and 2013. Likewise early summer temperatures can range between 12-16 °C. The length of time water temperatures are elevated above 16 °C has ranged from 1 week in 2012 to 9 weeks in 2013 (Bromley, 2015) and 2016.

This variation in the annual cycle has resulted in poor spawning in 4 of the past 6 years with widespread spatfall only being evident in stock assessments in 2011 and 2014. This is a common feature in many bivalve shellfisheries and one which has been addressed to a certain extent by introducing husbandry and culturing techniques to offset poor natural spawning and settlement success. There is a need to address this issue in the Lough Foyle context and investigate methods to supplement the shortfall in natural recruitment. The length frequency of the oyster stocks is another measure of this poor recruitment success with a bias towards 2/3 age classes in the population from those years with good spawning success.

The origin and fate of larvae has not formed part of the scope of this study but this would be an essential piece of work in the future to help best direct conservation efforts and any attempts to increase broodstock size within Lough Foyle or when creating broodstock sanctuaries. The hydrodynamic work already undertaken as part of the carrying capacity studies in Lough Foyle should also form the basis of these investigations allowing appropriate sites to be identified which would result in maximum retention of oyster larvae in the most suitable areas.

The majority of oysters observed at a brooding stage weighed between 62.5 - 87.5g but there is evidence to show that the younger oysters are also spawning with 51.8% of the oysters found at white sick, grey sick and black sick stage weighing less than 60g, although studies have shown that the older, heavier oysters are more fecund, it is still positive that the younger, lighter oysters are still releasing larvae into the fishery.

## 5.0 Conclusions

- The water temperatures were consistently high for much of June, August and September. Water temperature peaked several times during the summer and peak temperatures were greatest on the Southside Bed (>17.7°C).
- Broodstock conditioning appears to have been well advanced by early June with oysters already brooding on 1<sup>st</sup> June in several beds.
- There were 2 distinct peaks in larval numbers in mid-August and early September and no obvious links to water temperatures trends.
- Peak larval numbers were recorded at almost all sites in mid-August and early September.
- In total 4.8% of all sampled oysters were in the brooding phase and 35% of the total sampled population was in the brooding or spent phase.
- Flat Ground Bed recorded most spawning activity with 5.32% of the sampled population brooding and 34.4 in the brooding or spent phases.
- Oysters of below the minimum landing size (80mm) have been shown to successfully reach full sexual maturity and are releasing larvae into the fishery.
- Oysters below 65g have been shown to successfully reach full sexual maturity and are releasing larvae into the fishery.
- No widespread spatfall appears to have taken place in 2016 and even though water temperatures appear to have reached favourable levels for a prolonged period of time brooding activity is low relative to years in which a widespread spatfall have occurred.

## 6.0 Recommendations

1. Trial a cultch laying project on areas of commercial beds which have poor quality habitat to increase available space for spat settlement.
2. Investigate methods to enhance broodstock on low density beds to counteract the 'Allee effect'
3. Ensure densities do not reduce significantly on main oyster beds and aim to improve the density on the main oyster beds to  $>0.05$  oysters/m<sup>2</sup>



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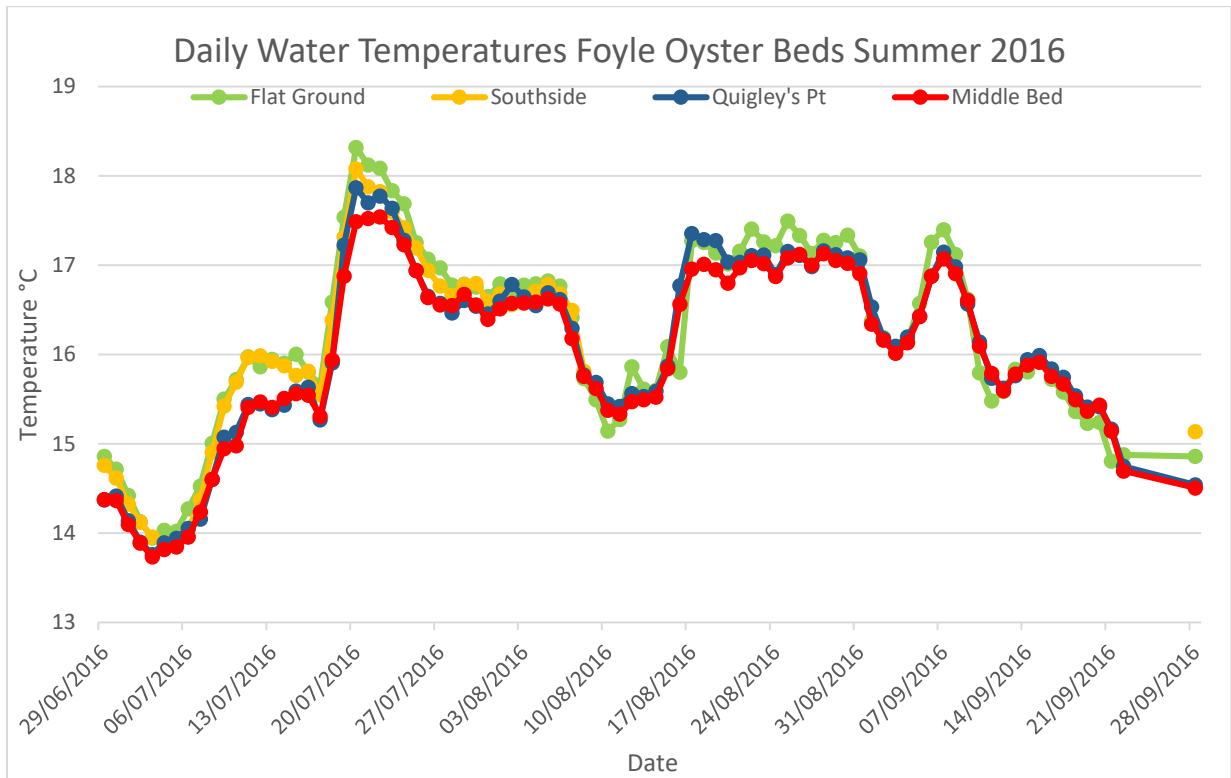
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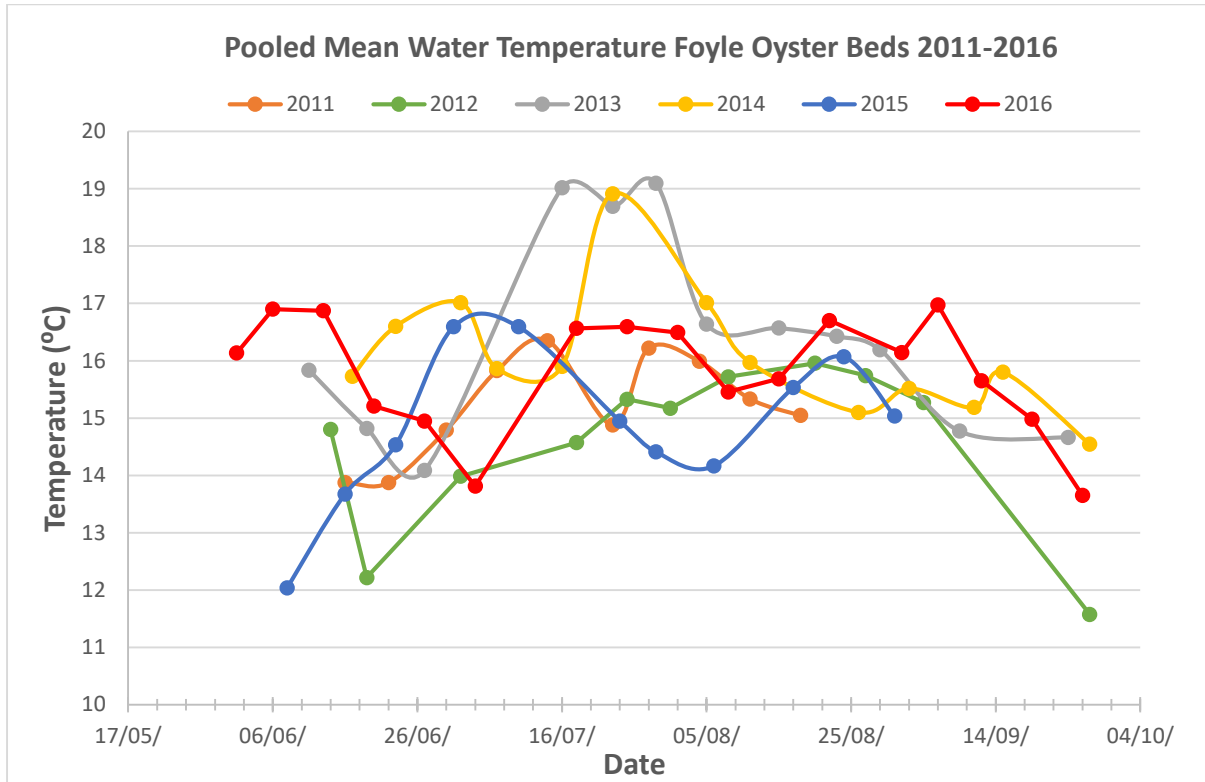
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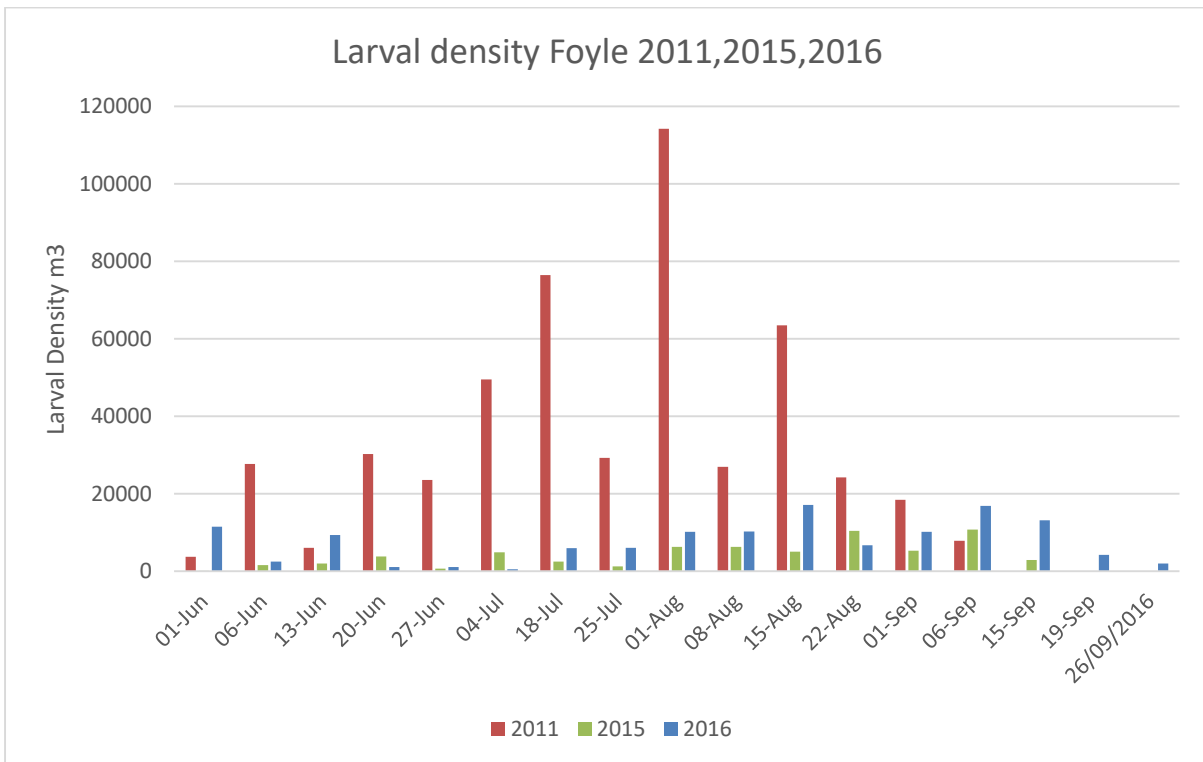
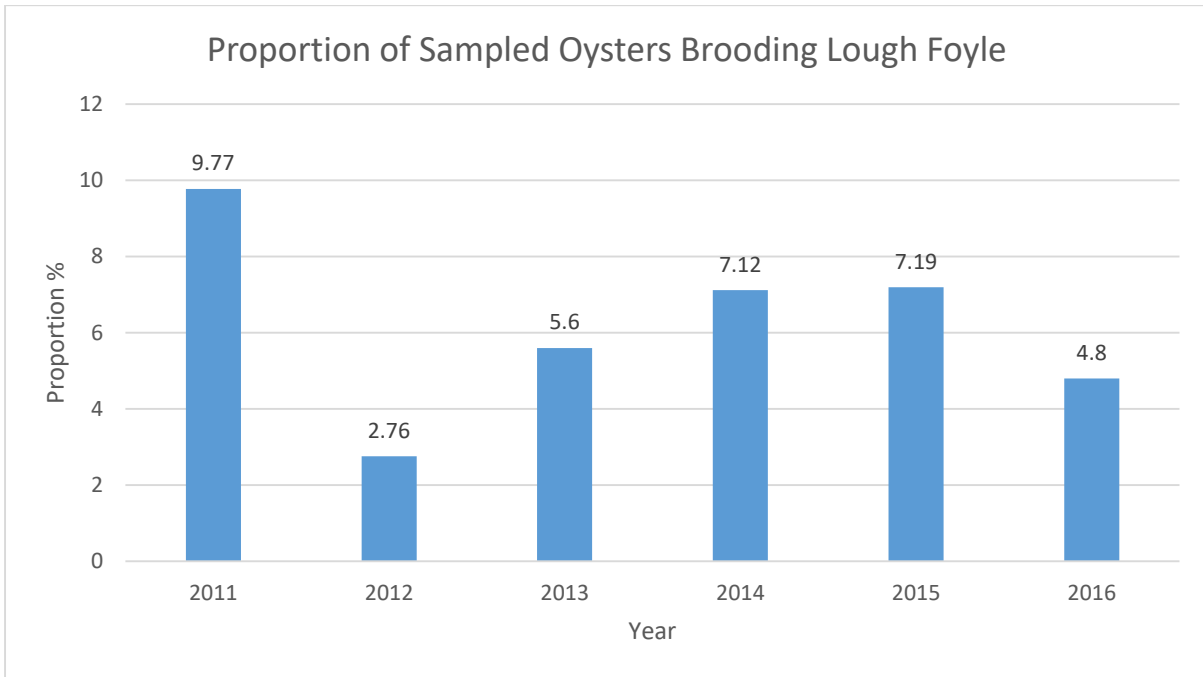
### Appendix I – Daily Water Temperature Records



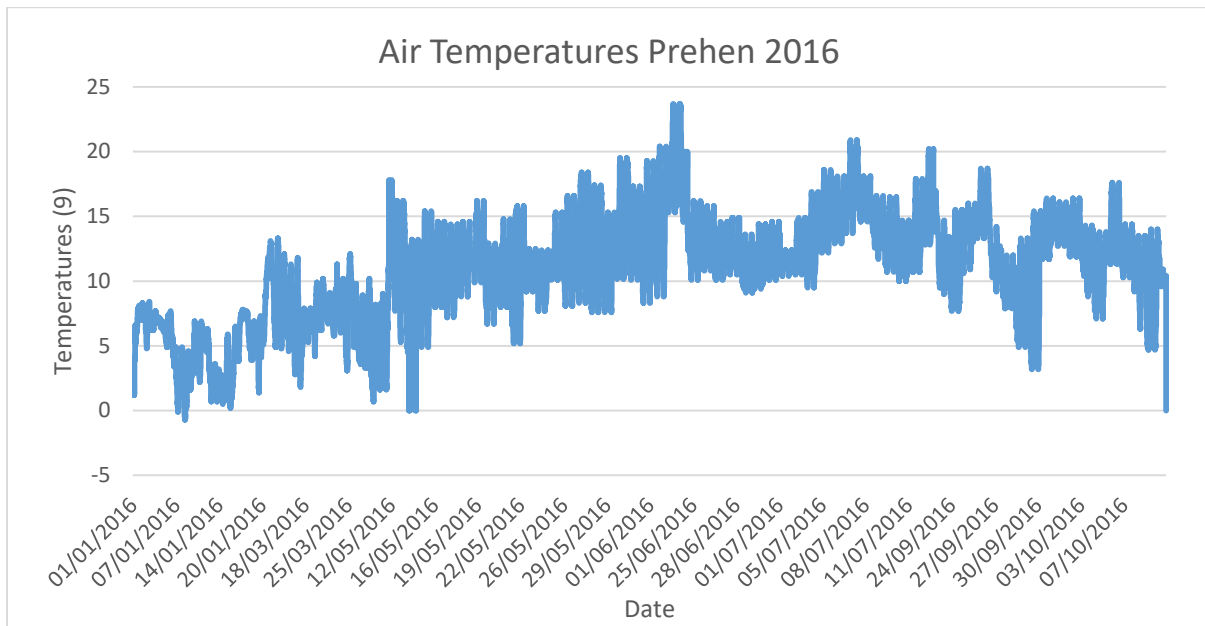
## Appendix II Inter-Annual Variation in Water Temperature



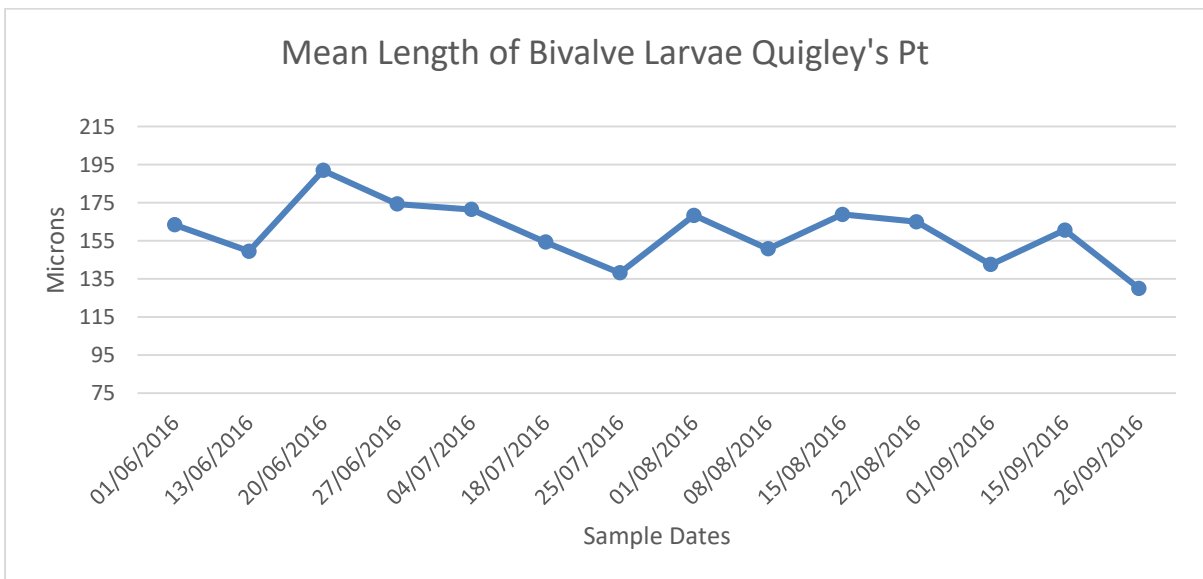
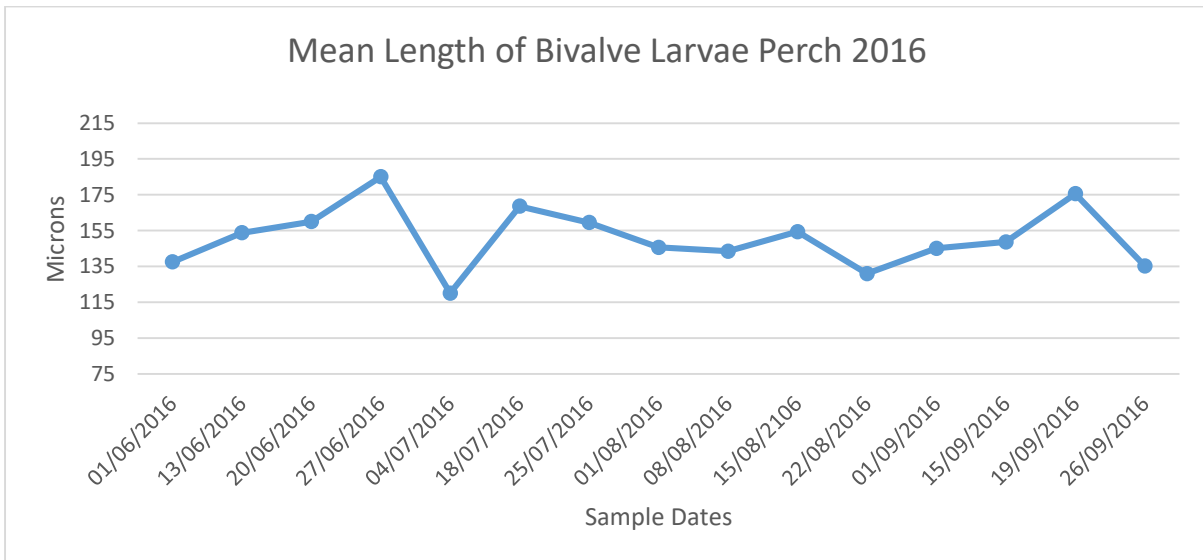
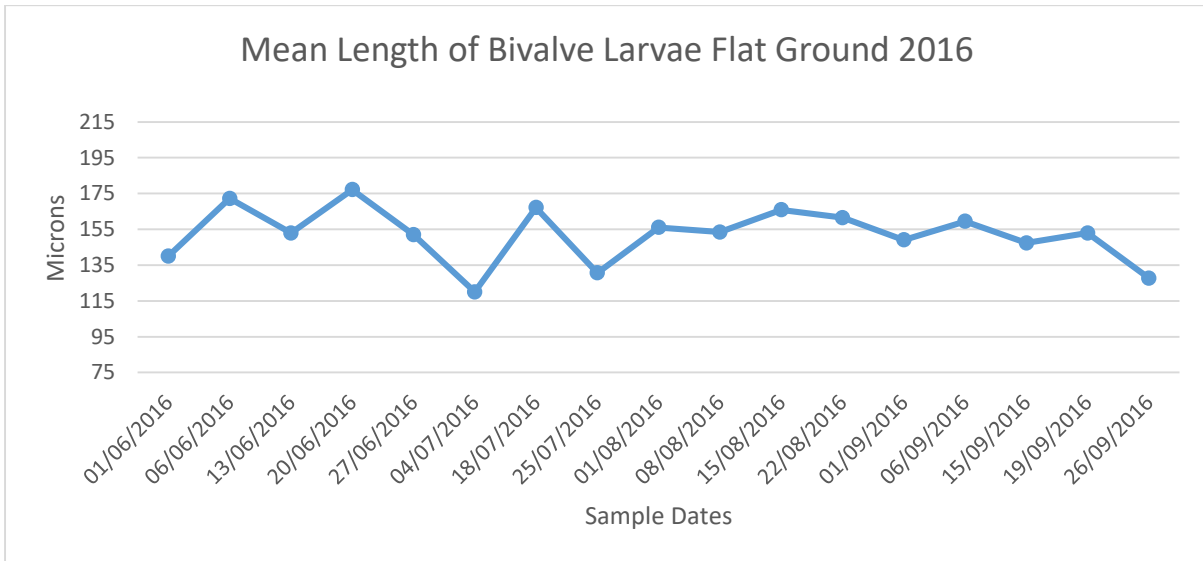
**Appendix III Oyster Brooding Totals/Larval Densities 2011/2015/2016**



### Appendix IV Climate Data



Appendix V Mean Larval Size





Appendix V Mean Larval Size

