# Mussel Larvae Monitoring 2019

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BIM Ireland's Seafood Development Agency

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The 2019 campaign was partly carried out through the INTERREG BLUEFISH Project and EMFF.

# 2019 Mussel Larvae Monitoring

## Background

Subtidal seed mussel recruitment on the East coast of Ireland is highly variable; in the period 2003 to 2006 transplanted seed mussel from the Irish Sea reduced from over 25,000 tonnes to 3,600 tonnes, but then recovered to over 18,000 tonnes in 2008 before collapsing to less than 3,000 tonnes in 2013. Recruitment on the seabed does not appear to be as prolific as in the past (under 10,000 tonnes per year since 2010). To understand local recruitment cycles, BIM has been monitoring the mussel larvae population at various locations since 2015 as well as investigating brood stock maturation and conditioning since 2016.

To date, it appears that the amount of larvae in the water has no direct relationship with the amount of seed mussel observed on the seabed which is in agreement with other publications (Ólafsson, Peterson and Ambrose Jr., 1994) and more recent surveys (Bourgès, 2019). Nevertheless, the data gathered during this monitoring program gives us valuable knowledge of local population connectivity: it appears that the seed mussel recruitment in the Rusk Channel is partially connected with the Wexford Harbour brood stock and that other seed settlements on the east coast depend on other sources of wild brood stock . This limited connectivity was highlighted by the deployment of GPS drifters in 2018 and in 2019 which showed that local winds speed and direction have a direct effect on the surface layer therefore on possible early larvae dispersal (Pulfrich, 1996). Indeed it appears that larvae emitted from Wexford harbour could potentially be flushed out of the coastal system by wind-driven currents (Verdier-Bonnet *et al.*, 1997) or be driven to unsuitable settling locations (Robins *et al.*, 2013). In addition, brood stock monitoring has confirmed "trickle spawning" patterns with rapid reconditioning after partial spawning as per (R. Seed, 1969).

Since the start of the monitoring program in 2015 there has been no annual repetitive pattern of what observed down the years.

## Objectives

The purpose of this mussel monitoring program is to study the reproduction, larval development and settlement of mussels, allowing for better planning of mussel seed fishing and relaying to improve mussel production tonnage.

The key objectives being:

- Monitoring localised seawater temperatures and salinities which can have a significant influence on mussel condition (meat yield) and growth (Bayne, 1965; R. Seed, 1969).
- Quantifying mussel larval stages in the plankton and their dispersal
- Locating, mapping and estimating seed mussel tonnage.

To achieve this samples of mussels were collected to assess their state of maturity by performing meat yield measurements (also known as condition index CI). Plankton hauls were taken for cohort analysis (quantification) of mussel larvae and seed beds were located using side scan sonar.

The settled seed mussel beds found were measured, quantified and mapped. The information collected on these is available on the BIM website (http://www.bim.ie/our-publications/aquaculture/). Some pertinent findings from those reports are included here to provide a complete picture of the life stages of the mussels within the study areas.

## Sampling Locations

As with previous years, the sampling stations were located at Wexford Bar, the Rusk Channel, North Arklow, North Howth and Castlemaine Harbour.

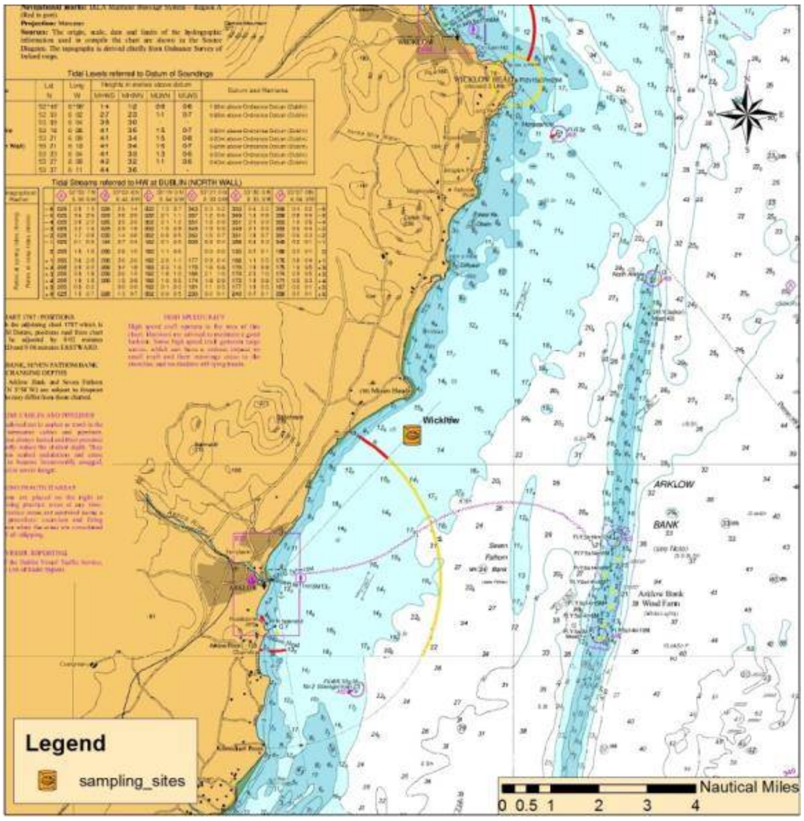
**Table 1: Sampling locations coordinates (WGS84)**

| Location | Latitude | Longitude |
|---|---|---|
| Wexford Bar | 52° 19.741' N | 006° 18.351' W |
| Rusk Channel | 52° 28.689' N | 006° 12.067' W |
| Arklow | 52° 50.580' N | 006° 03.450' W |
| Castlemaine Harbour | 52° 05.583' N | 009° 57.676' W |
| North Howth | 53° 25.850' N | 006° 05.173' W |

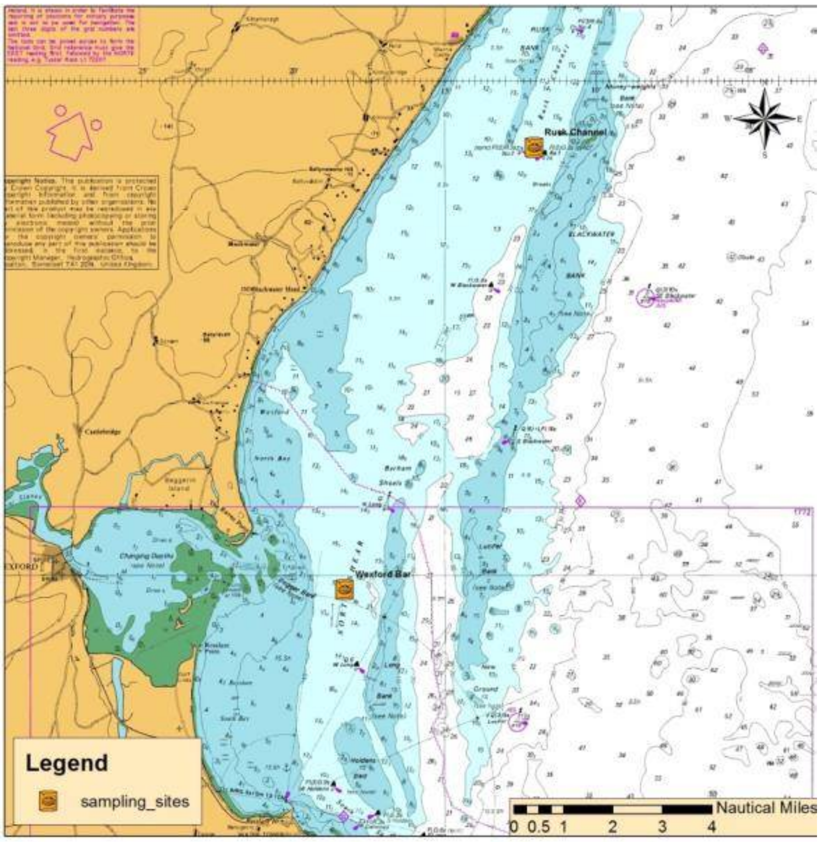
Figure 1 depicts the geographical locations of the five study areas around Ireland. Figures 2, 3, 4 and 5 illustrate the detailed locations of the sampling sites.

### Figure 1: Sampling locations around Ireland

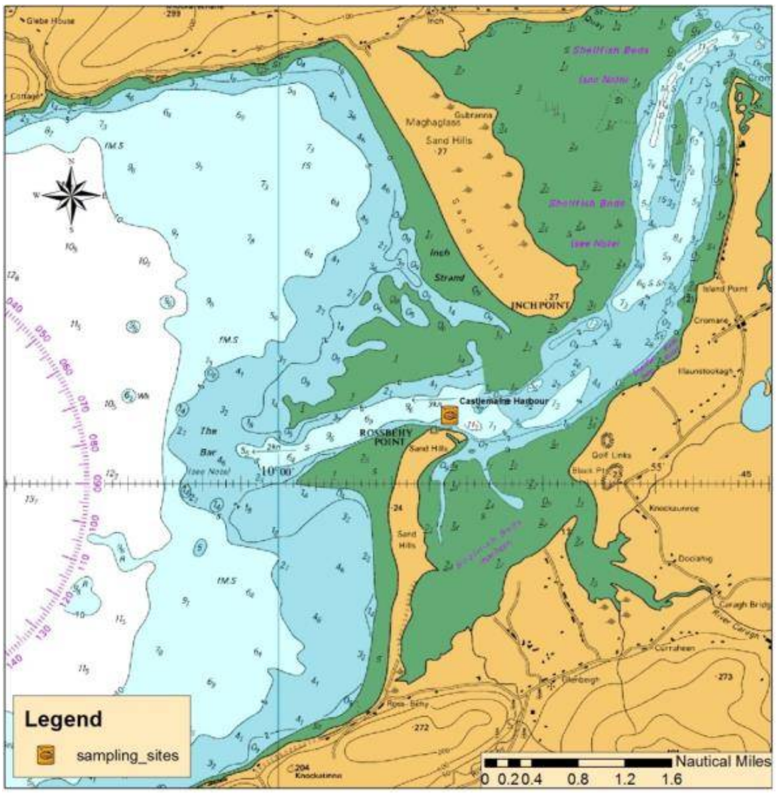
### Figure 2: Sampling Station on the Wicklow Coast



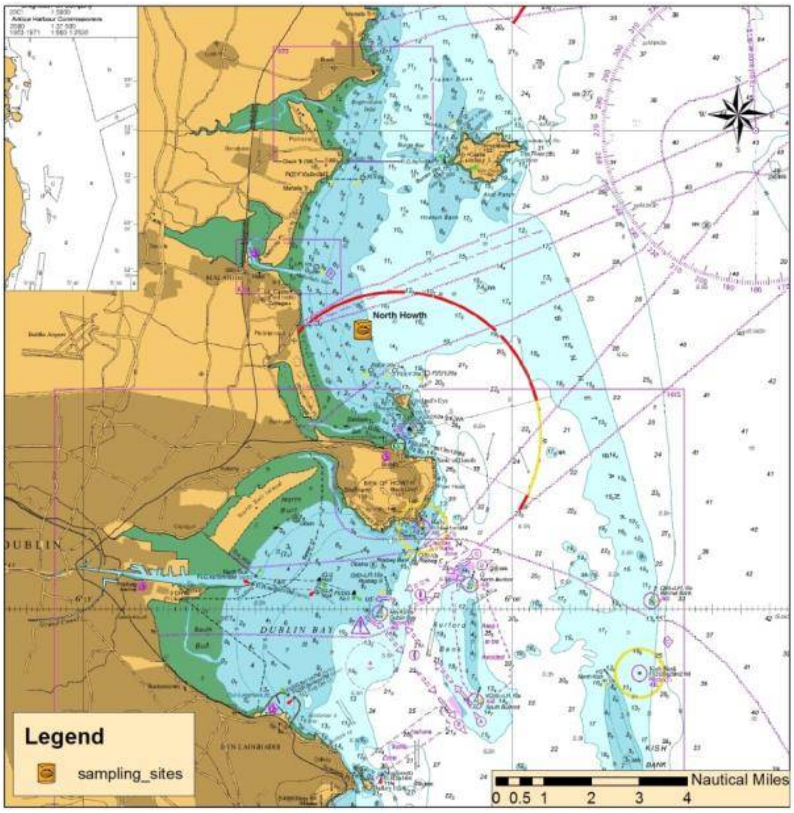

### Figure 3 Sampling Stations on the Wexford Coast (Wexford Bar and Rusk Channel)



### Figure 4: Sampling Station in Castlemaine Harbour




### Figure 5: Sampling Station for North Howth



## Sampling Method

At the outset it was planned to take weekly plankton samples at most of the sites. Local fishermen undertook the sampling for the Wexford Bar and at the Rusk Channel, South Wicklow and North Howth. A mussel farmer collected the samples in Castlemaine Harbour.

The mussel larvae samples were collected with 100 µm mesh plankton net, which was weighted at the cod end to allow for a vertical haul through the water column. The net was deployed within several meters of the seabed and hauled slowly to the surface. Once on the boat deck, the contents of the net were gently washed into a labelled jar and fixed with Lugol's iodine. At each sampling station, the following information was recorded:

- Date and time of sampling
- Depth (from the sounder reading)
- Weather conditions (wind) and sea state
- Water temperature
- Current speed and direction

The larval samples were then posted to Clear Seas Aqua in Bantry, Co. Cork for analysis. This analysis involved sieving and using microscopy to identify mussel larvae and to classify their age according to their stage of development (See Appendix 1 for the calculation of larval numbers collected in a plankton net). In addition to larval sampling, the industry samplers were also provided with an Oxyguard Temperature and Salinity probe with a 6 m cable to measure these parameters.

## Meat Yield Monitoring 2019

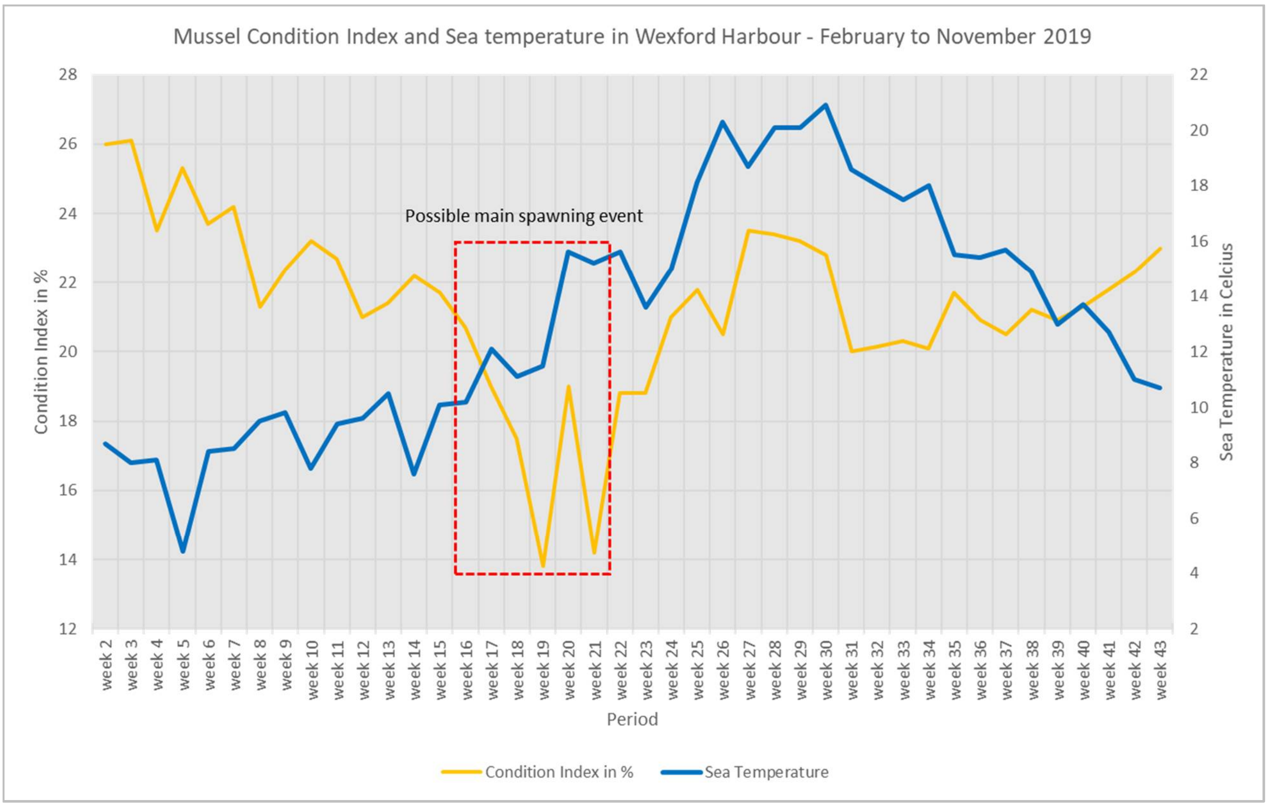
The condition index (CI) or meat yield of mussels is a recognised methodology for assessing the maturity of adult mussels and their propensity to spawn (Chipperfield, 1953; Davenport and Chen, 1987; King, McGrath and Gosling, 1989). Meat yield is the relationship between the total weight of edible mussel tissue and shell (see Appendix 2). Typically, meat yields are seen to increase over the autumn and winter months, followed by a notable decline in weight when a spawning event occurs in the spring. However, it should be noted that mussels may also release gametes at other times of the year and are known to trickle spawn (R. Seed, 1969).

To monitor the maturity of adult mussel, samples were collected from licenced sites with industry support in Wexford and Castlemaine Harbour/Cromane. Sampling in 2019 was undertaken from January 11$^{th}$ (week 2) to November 8$^{th}$ (week 43) for Wexford Harbour. Castlemaine was sampled weekly for condition index too, only for a shorter period from January 11$^{th}$ to April 12$^{th}$ due to circumstances outside our control (see Appendix for detailed tables). Also, BIM staff carried out sampling of the wild population in Malahide and Rogerstown from Week 13 to Week 47. The detailed results per location are presented in the following graphs (Figures 6, 7 and 8).

## Wexford Harbour

The early sampling, as in 2018, shows possible partial spawning in Wexford between Week 4 and 5, it is also possible that the condition index decrease is due to seawater temperature drop during this period. It appears, that a possible significant spawning event occurred between Week 17 and Week 19, CI dropped by more than 5 points, while the sea temperature increased by 4.1ºC between Week 18 and Week 19 which could have induced spawning (Chipperfield, 1953). Following this event, mussels appeared to recondition rapidly through Week 20 and possibly spawned again between Week 20 and 21. This rapid rise and fall of the CI could also mean that the mussels sampled on Week 20 had not spawned as all the samples were from the same area in Wexford Harbour.
Another spawning event may have occurred between Week 30 and Week 31 (end of August), though there is a limited correlation with sea temperature variation at the time (drop by 2.3 ºC).

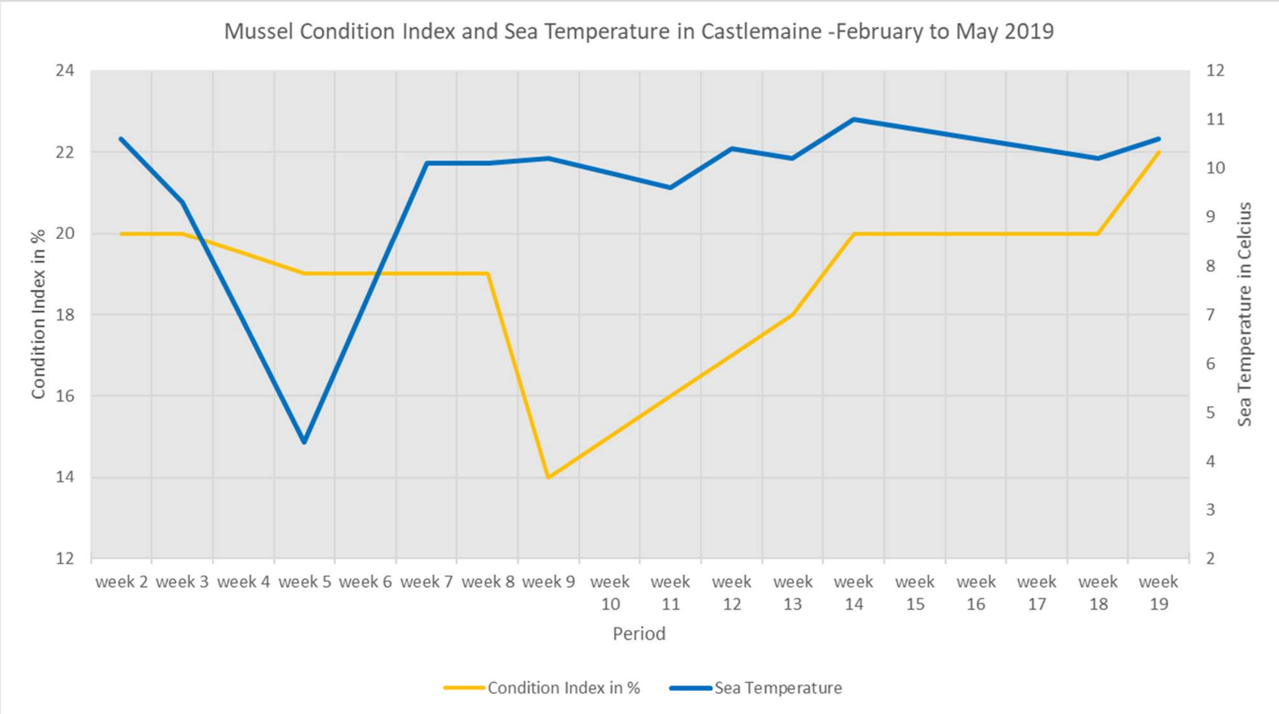
### Figure 6: Condition Index for mussels from Wexford Harbour in 2019




## Castlemaine Harbour

For Castlemaine, despite the small sample and reduced sampling period, a spawning may have occurred between Week 7 and Week 9 (mid-February to start of March). Probably due to an increase of temperature of 4.7 ºC over two weeks. This possible spawning did not result in a harvestable seed mussel settlement at the time; seed transplanting only occurred in late October with seed reaching 20 mm in length, therefore this cannot be interpreted as being related to earlier spawning activity.

## Figure 7: Condition Index for mussels from Castlemaine Harbour in 2019

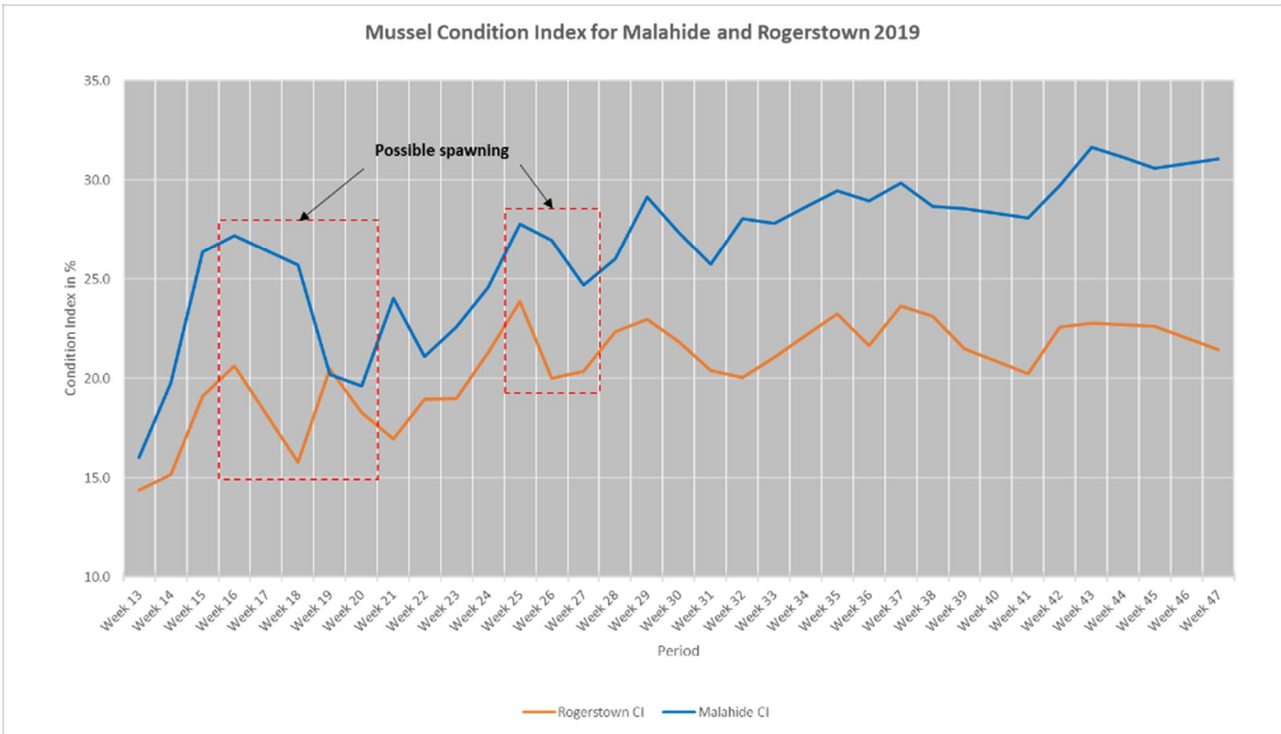



## Malahide and Rogerstown

The CI monitoring on the brood stock in Malahide and Rogerstown started later in the year due to logistical problems. Those two mussel brood stock beds are different in that they are intertidal which is at variance with Wexford Harbour. It is worth noting, that these mussel beds are wild populations and not exploited by the industry. The CI in Malahide, although starting nearly at the same level with Rogerstown on Week 13, reached a much higher level on Week 16 and during reconditioning.

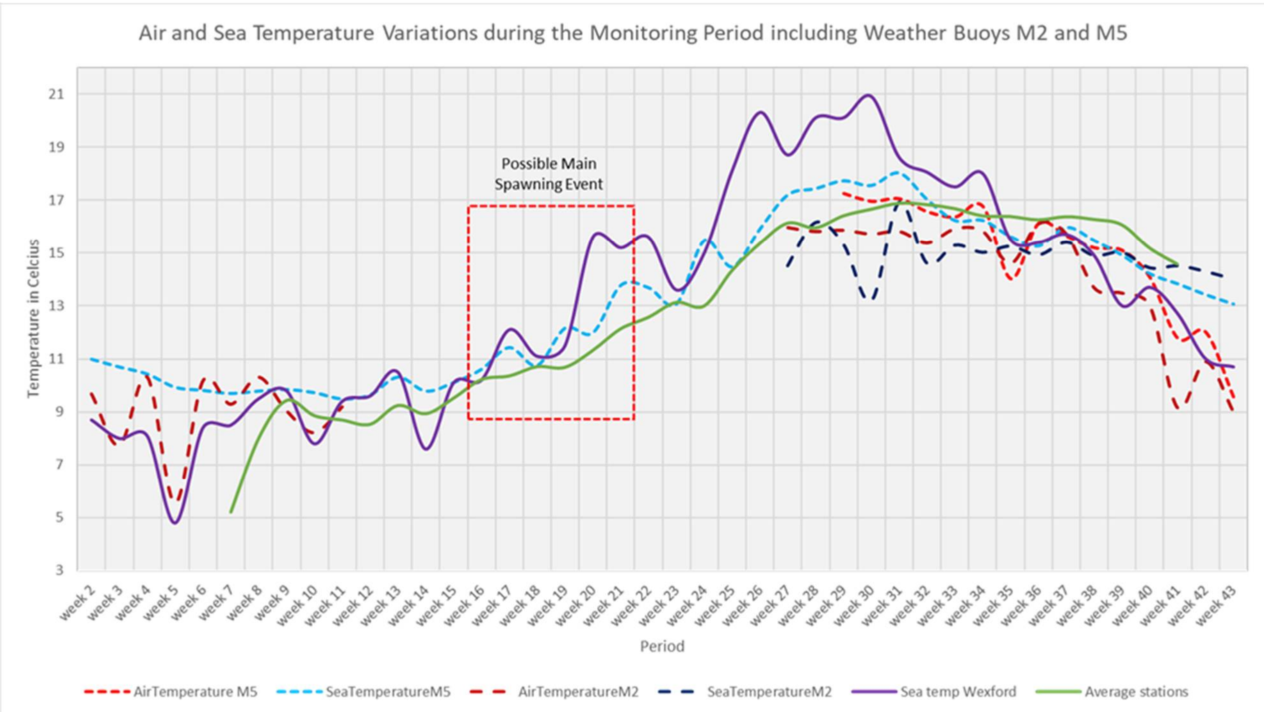
It appears that some possible spawning took place between the Week 16 and Week 20 (see Figure 8). Another possible event took place from Week 25 to Week 27; however, there was no correlation with larvae observed at the North Howth sampling station (see 2019 detailed results per locations). Unfortunately, temperature and salinity readings for those two brood stocks were limited during the monitoring period. Nevertheless, readings from Met Buoy M2 might give indicative results of temperature for the time.

**Figure 8: Condition Index for Mussel from the Malahide and Rogerstown Brood stock (Week 13 to Week 47)**



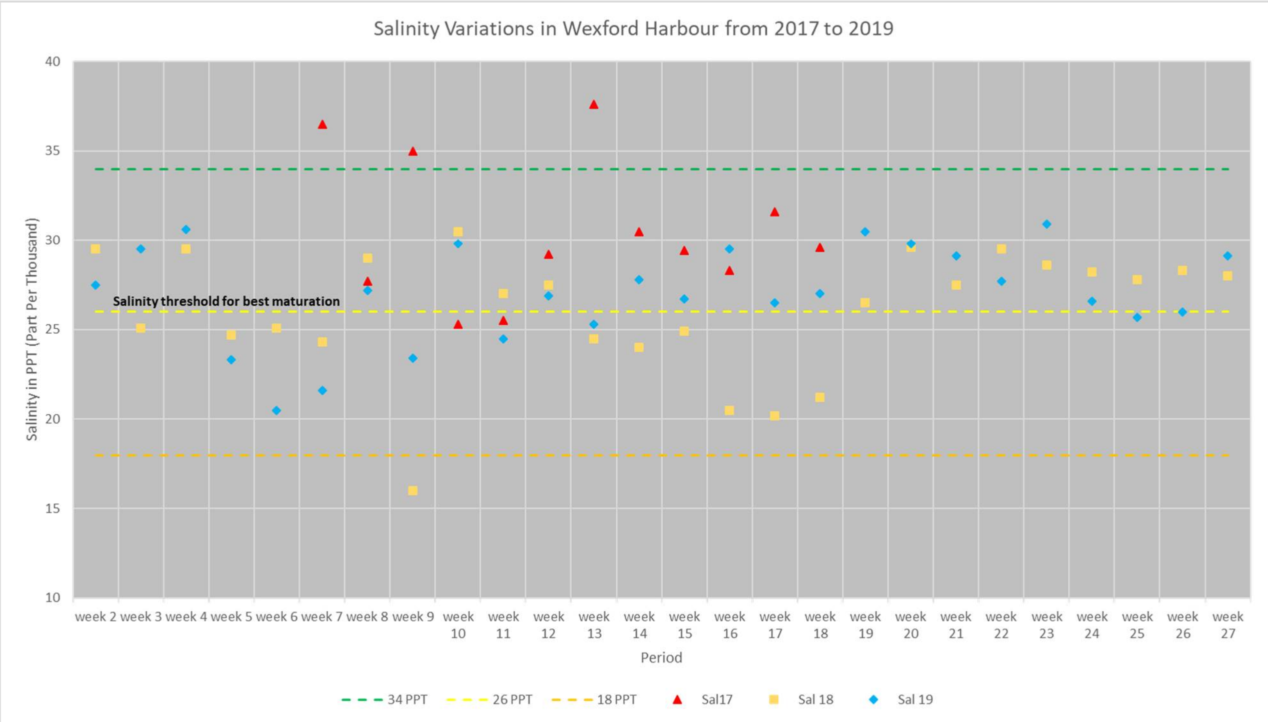

Temperature (Air and Sea) and salinity are two essential factors for mussel maturation (Chipperfield, 1953; Bøhle, 1972). Sea temperature itself is often a trigger inducing spawning.

**Figure 9: Air and seawater temperature recordings the 2019 monitoring period**



Gonad ripening starts to take place around 7˚C (Chipperfield, 1953); this likely affected the mussels in Wexford Harbour before Week 6 (see Figure 9). It appears that the water temperature in Wexford harbour is following the air temperature at Met Eireann (or) Buoy M5 rather than the sea temperature, at least until Week 11. The variations of the sea temperature in Wexford are more significant than the variations at Met Buoy M5. These variations may be due to the freshwater coming from the Slaney River. Indeed, the sudden temperature drop on Week 5 corresponds to a rapid decrease in the salinity on the same week (see Figure 10).

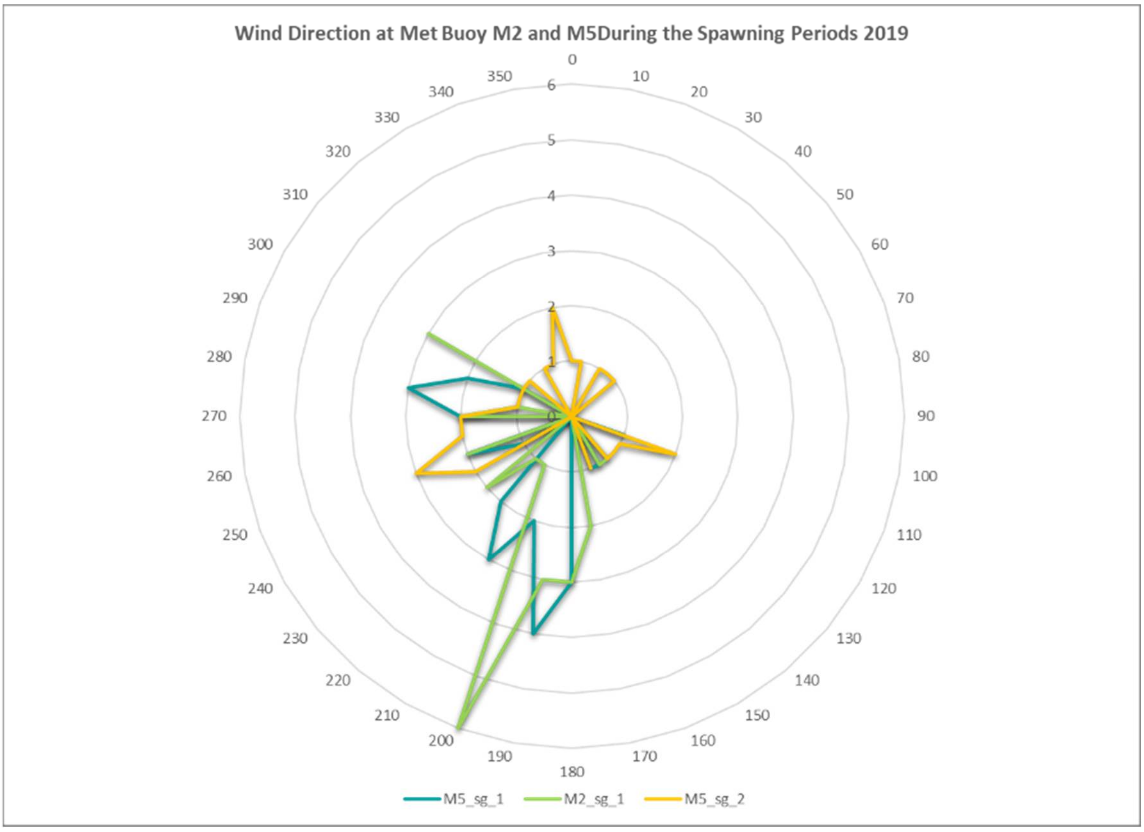
### Figure 10: Salinity in Wexford Harbour During Pre-Spawning Period from 2017 to 2019




The average salinity in the harbour over the 2019 monitoring period was 26.58 PPT (Part Per Thousand), which is a slight increase from 2018. From week 5 to Week 14, salinity remained low. The combination of low water temperature and low salinity can affect adult mussel maturation (Chipperfield, 1953; Bøhle, 1972) and therefore, can affect spawning timing and gamete quality. During this period, which corresponds to a possible spawning event,  salinity remained below 24 PPT (or ,75% seawater concentration at 34 PPT in the graph on Figure 10), which can also be detrimental to larvae development (Brenko and Calabrese, 1969).

During the two potential spawning periods (from Week 7 to Week 11 and from Week 18 to Week 22), the prevailing wind direction was southwest according to the Met Buoys M2 and M5. Unfortunately, data from the Met Buoy M2 was missing for the second period, which corresponds to potential spawning in Malahide (see Figure 11). Prevailing strength during the first period was between Force 5 and 6, and between Force 3 and 4 for the second period.

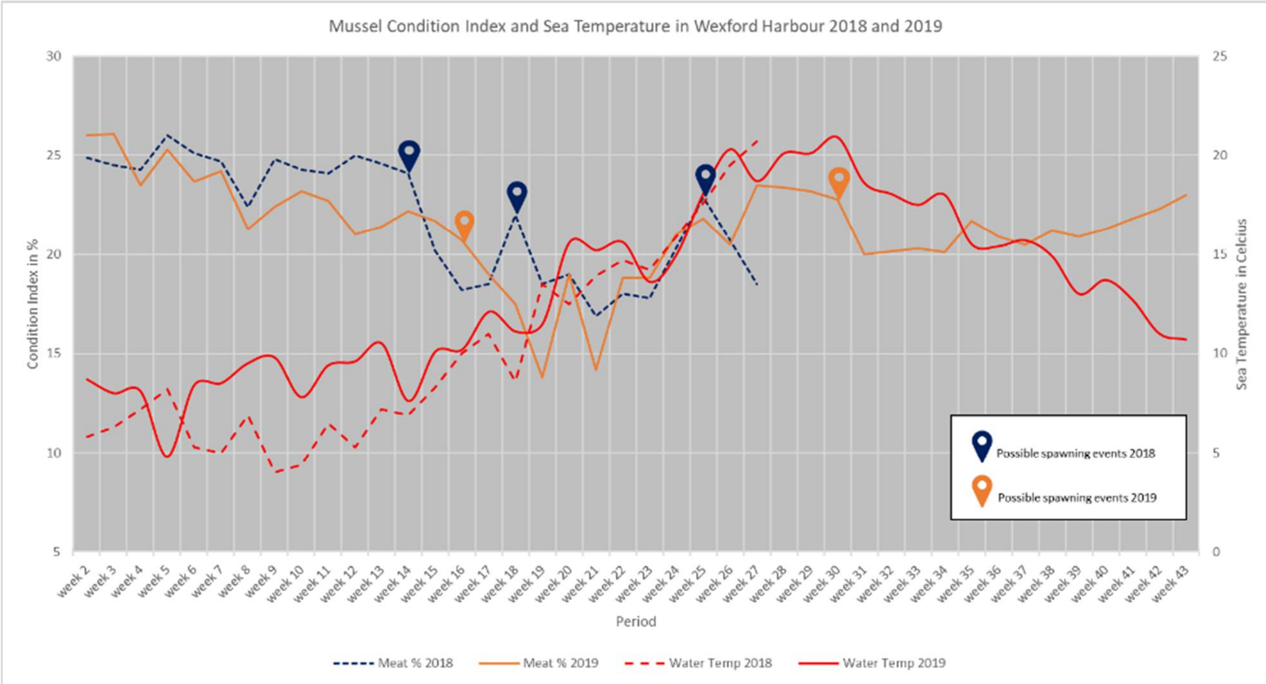
### Figure 11: Wind direction at Met Buoy M2 and M5 during possible spawnings




The Condition index was slightly better in 2018 than in 2019 through the sampling period (see Figure 12), this could be explained by multiple factors, such as food availability, stocking density, the origin of the mussels (none of these factors are being monitored during this program).

Despite the overlapping between the CI monitoring and the larvae monitoring, no early larvae were observed at the Wexford Bar sampling station in 2019 again, only small quantities of older larvae were found between Week 19 and Week 21. It was a similar case for the monitoring of Malahide and Rogerstown populations (see 2019 detailed results per location).

### Figure 12: Conditon Index and Water temperature in Wexfiord Harbour 2018 versus 2019




Also, with the CI, gonad squash on large mussel and half-grown mussel was carried out on a few occasions. This analysis is carried out following an assessment scale detailing the level of maturation of the mussels' soft body and the concentration of gametes visible under the microscope (Chipperfield, 1953; R. Seed, 1969; King, McGrath and Gosling, 1989). Unfortunately, only a few samples from overwintered seed were processed using this method and no follow-on monitoring was carried out on the population.

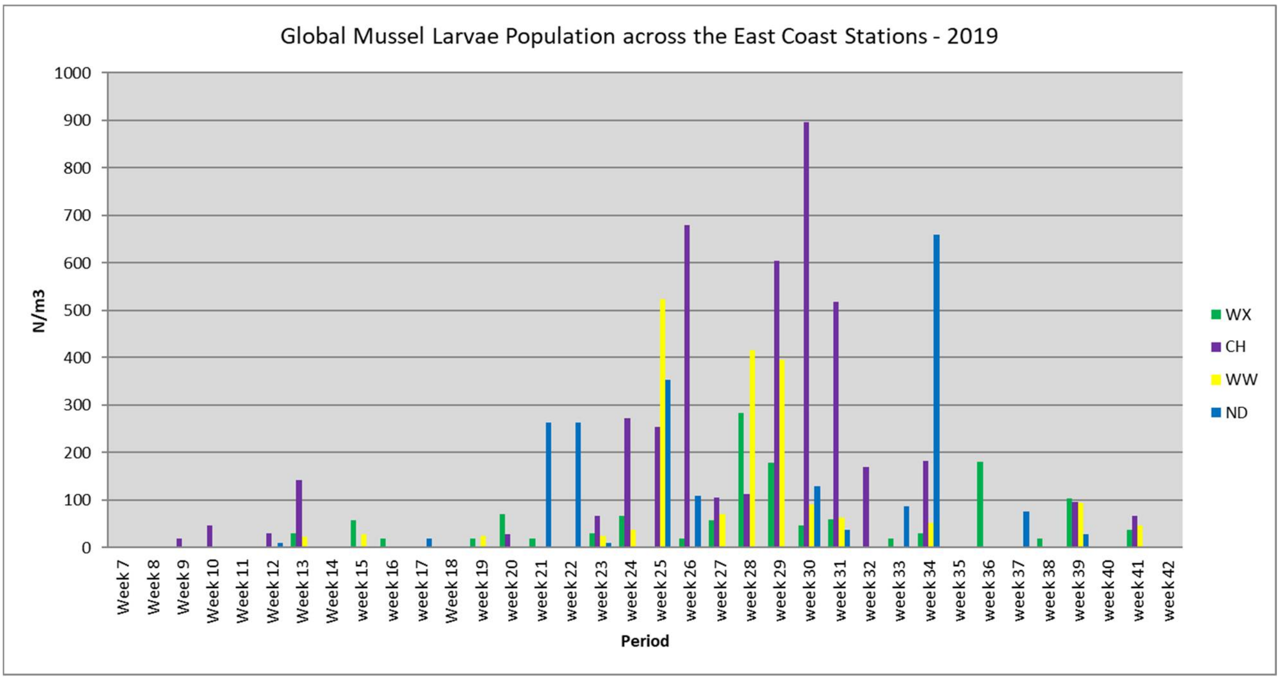
### Figure 13: Adult mussel development from redeveloping (L) to developed/ripe (R)

## 2019 Results

The monitoring period took place from Week 7 (mid-February) to Week 43 (mid-October), which replicates the period set in 2018. A total of 144 samples, (175 were planned), were collected over the 5 sampling stations in 2019; this represents a 67% success for sample collection, which is more than a 10% increase on 2018. The missing samples on the East coast were mainly due to adverse weather conditions. There was a high level of debris and copepods throughout all the samples and the sampling period. The dominating phytoplankton species appear to have been *Coscinodiscus sp.* and *Odontella sp.* (see sample logging sheet in Appendix 5).

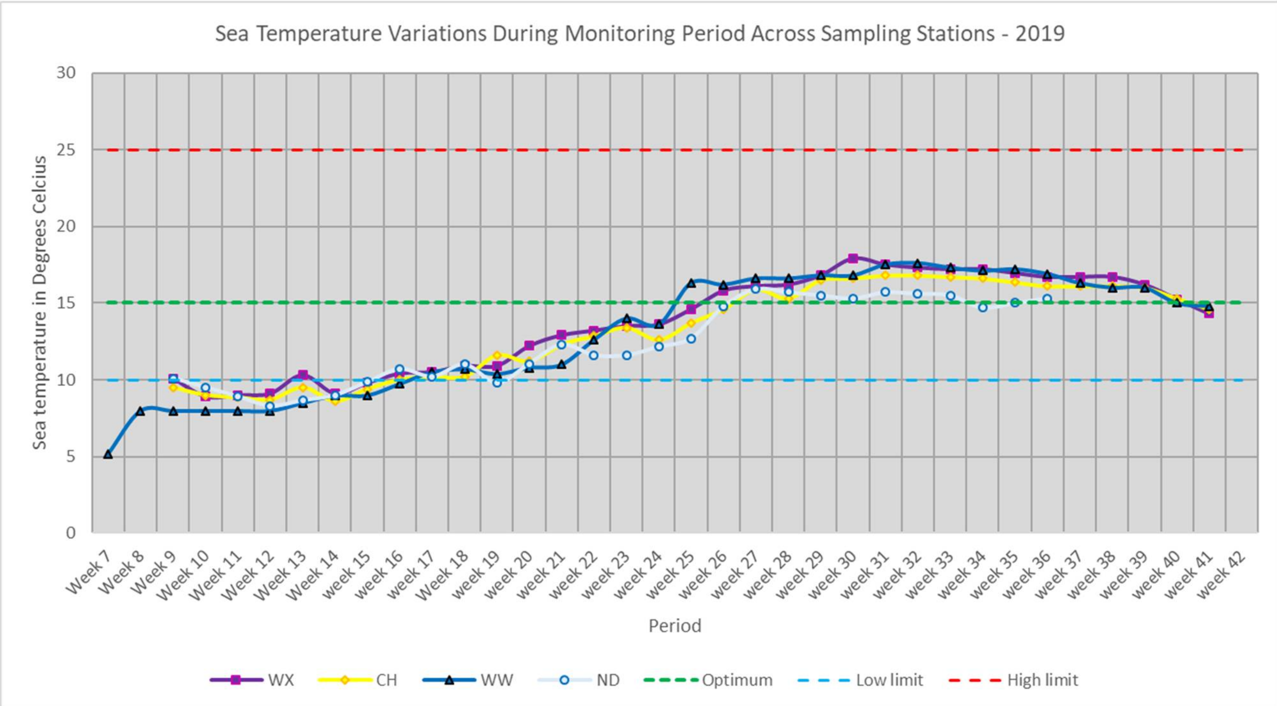
The numbers of larvae recorded at each station were significantly higher than previous years (apart from 2015), with the bulk of the larval population between Week 24 (mid-June) and Week 31 (end of July to start of August). Another peak was observed in North Dublin (ND) on Week 34 (3rd week of August). A smaller number of larvae were observed before Week 21 (3rd week of May). Most larvae were observed at the Rusk Channel station (See Figure 14 and Table 2). Only a small number of larvae were observed in Castlemaine during the first week of sampling. However, the sampling period was reduced at this location. The Castlemaine results are, therefore, not included in the following graphs and tables.

**Figure 14: Number of mussel larvae per m3 at Wicklow (WW), Rusk Channel (CH), Wexford Bar (WX) and North Howth (ND)during the sampling period**




Sea temperature on the various stations (see Figure 15) was slightly higher on average than in 2018 (+0.55˚C), being a bit warmer in early spring and cooler in summer. By Week 26, all stations had reached the optimum temperature for larval development (Brenko and Calabrese, 1969; Widdows, 1991).

## Figure 15: Weekly Sea Temperature at Sampling Stations on the East Coast




Salinity at all stations (see Figure 16) does not appear to be an issue for larvae development (Brenko and Calabrese, 1969), apart from Week 9 at ND station and Week 37 at WW station where is dropped to values closed to 20 PPT.

## Figure 16: Weekly Salinity at Sampling Stations on the East Coast

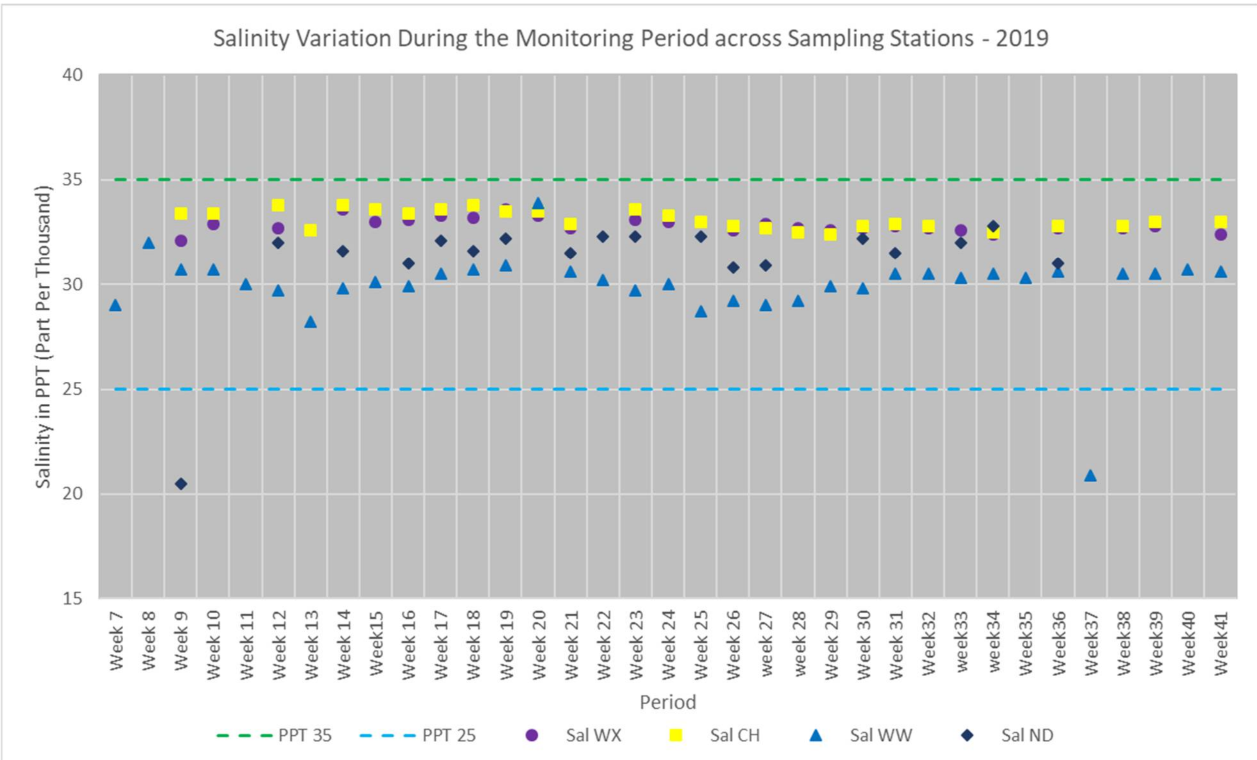


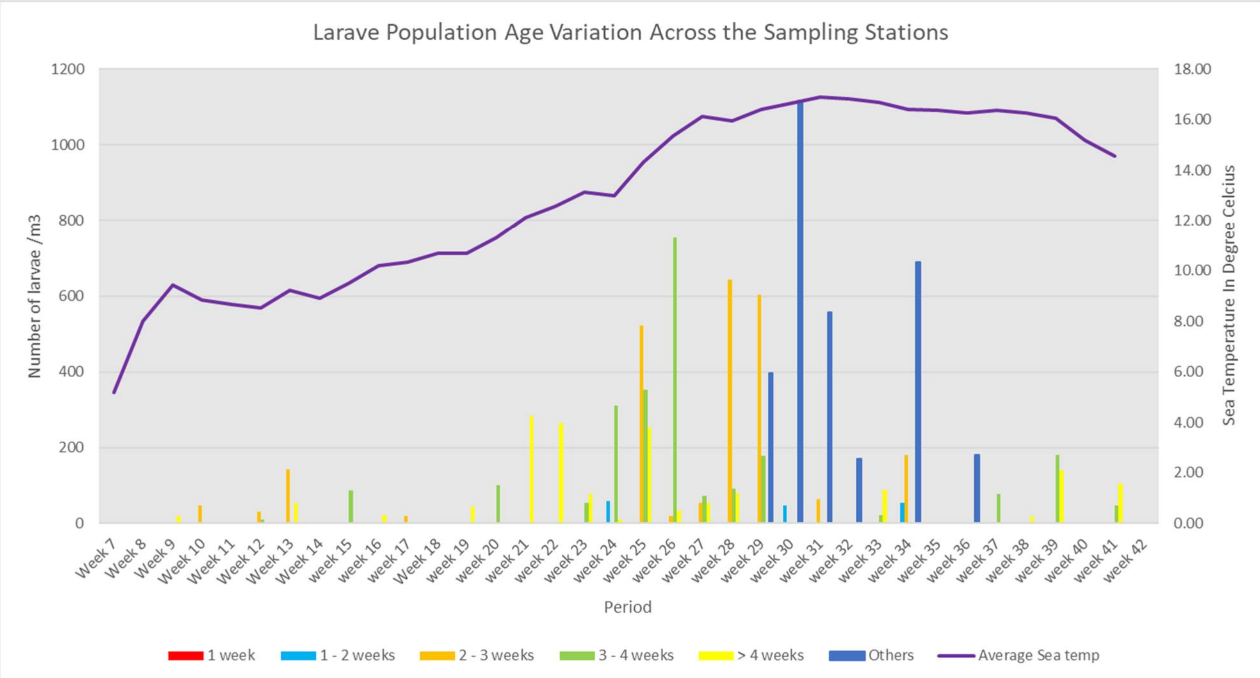
**Table 2: Numbers of larvae per m3 at Wexford Bar, Rusk Channel, Wicklow and North Howth 2019**

| Period | WX | CH | WW | ND |
|---|---|---|---|---|
| Week 7 | NS | NS | 0 | NS |
| Week 8 | NS | NS | 0 | NS |
| Week 9 | 0 | 19 | 0 | 0 |
| Week 10 | 0 | 47 | 0 | NS |
| Week 11 | NS | NS | 0 | NS |
| Week 12 | 0 | 30 | 0 | 10 |
| Week 13 | 31 | 142 | 23 | NS |
| Week 14 | 0 | 0 | 0 | 0 |
| Week 15 | 57 | 0 | 28 | NS |
| Week 16 | 20 | 0 | **0** | 0 |
| Week 17 | 0 | 0 | 0 | 19 |
| Week 18 | 0 | 0 | 0 | 0 |
| Week 19 | 19 | 0 | 24 | 0 |
| Week 20 | 71 | 28 | 0 | NS |
| Week 21 | 20 | 0 | 0 | 263 |
| Week 22 | NS | NS | 0 | 264 |
| Week 23 | 30 | 66 | 24 | 10 |
| Week 24 | 66 | 273 | 38 | NS |
| Week 25 | 0 | 254 | **523** | 353 |
| Week 26 | 19 | **679** | 0 | 109 |
| Week 27 | 57 | 53 | 71 | 0 |
| Week 28 | 283 | 90 | 416 | NS |
| Week 29 | 179 | **604** | 396 | NS |
| Week 30 | 47 | **896** | 91 | 130 |
| Week 31 | 60 | **519** | 63 | 38 |
| Week 32 | NS | 169 | **0** | NS |
| Week 33 | 20 | NS | 0 | 87 |
| Week 34 | 30 | 182 | 53 | **660** |
| Week 35 | NS | NS | 0 | NS |
| Week 36 | 180 | 0 | 0 | 0 |
| Week 37 | 0 | NS | **0** | 76 |
| Week 38 | 19 | NS | **0** | NS |
| Week 39 | 104 | 95 | 94 | 28 |
| Week 40 | NS | NS | **0** | NS |
| Week 41 | 38 | 66 | 47 | NS |
| NS - No Samples | 7 | 9 | 0 | 15 |

Looking at larval age (see Figure 17), it appears that for the second year in a row, samples failed to yield young larvae (1 week old or less). The second age class (1 to 2 weeks old) was also on the decrease since 2017. One possible reason for this decrease is the mesh size used for sampling (100 µm) may allow smaller larvae escape. The number of young larvae has been low since the start of the monitoring program in 2015.

The bulk of the larvae collected (74% of the total) were between 2- and 4-weeks old and mainly found from Week 24 to Week 29, suggesting that larvae originated from fertilisation Week 20 at the earliest and Week 25 at the latest. These numbers may indicate limited connectivity with the possible spawning events from the Wexford brood stock (from Week 16 to Week 22) and therefore that larvae forming the seed mussel settlements could be coming from other sources on the coast. There was a significant number of larvae that could not be aged between Week 29 and week 36 across the sites.

**Figure 17: Larvae age variations during the sampling period on the East Coast**



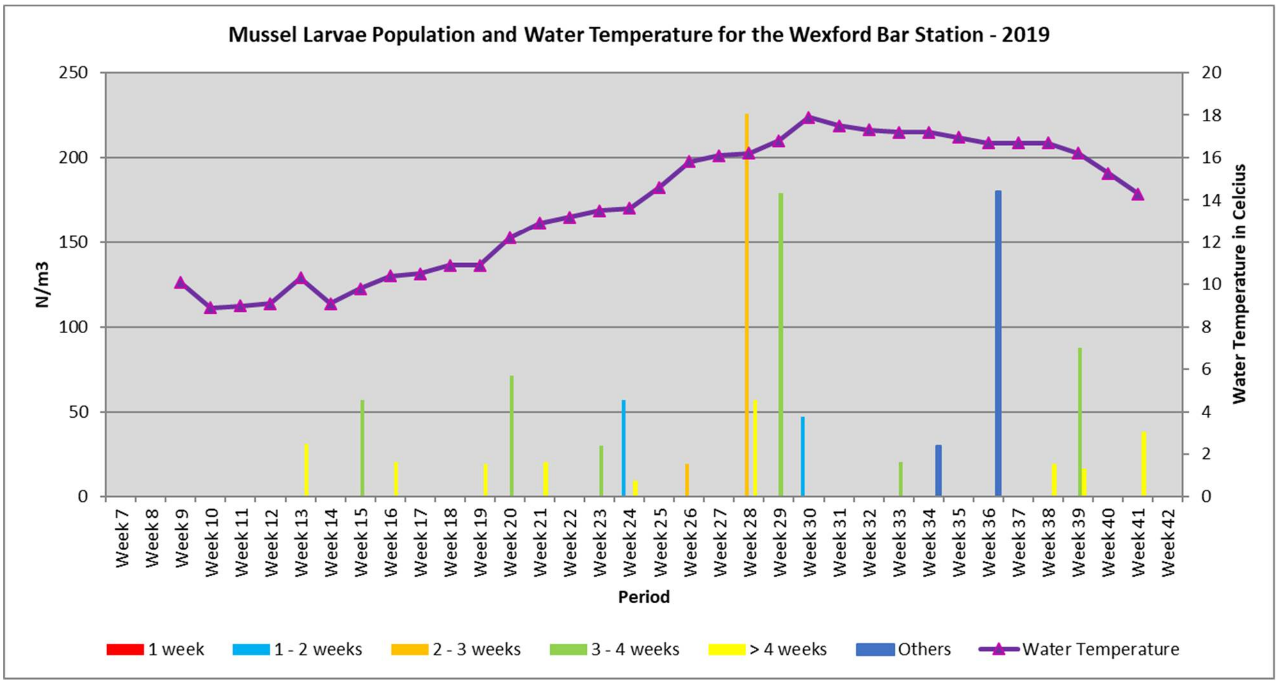
## 2019 detailed results per locations

This section of the report deals with the specific findings for each area. As in the last three years, there were five age classes of mussel larvae identified using microscopy and these were: larvae less than 1 week old , D larvae 1 to 2 weeks old , D larvae 2 to 3 weeks old , D larvae 3 to 4 week old and D Larvae that were over 4 weeks old .

### Wexford Bar

The numbers of larvae per $m^3$ and their estimated age are shown in Table 3, and graphed in Figure 18 with ambient seawater temperatures. 7 samples were missed due to weather. There was no seed mussel settlement within the direct vicinity of the Wexford Bar Station. The closest settlement found was between the Long Bank and the Lucifer Bank.

**Figure 18: Mussel D-larvae population and seawater temperature at Wexford Bar (Week 7 to Week 42)**




No larvae were observed in the samples before Week 13 (end of March). During the possible spawning period in Wexford Harbour (From Week 15/16 to Week 21), small numbers of young larvae were observed at the station, which could mean that either larva stayed within the harbour or that retention time within the system was short. The missing sample on Week 22 could have possibly answered this question. The small number of young larvae on Week 24 may be a residual of remnant spawning. It doesn't appear to be the case for the larvae observed on Week 28 and Week 29 as during this period mussels within the harbour seemed to be reconditioned, which could mean that those larvae originated from another location on the coast. Also, the larvae population between those two weeks could be connected (from 2 to 3 weeks old on Week 28 to 3 to 4 weeks on Week 29), this was observed in the Rusk Channel in 2016.

## Table 3: Mussel D-larvae population at the Wexford Bar (number per m$^3$)

| Period | 1 week | 1 - 2 weeks | 2 - 3 weeks | 3 - 4 weeks | > 4 weeks | Others | Water Temperature | Total Larvae / week |
|---|---|---|---|---|---|---|---|---|
| Week 7 | | | | | | | | NS |
| Week 8 | | | | | | | | NS |
| Week 9 | | | | | | | 10.1 | 0 |
| Week 10 | | | | | | | 8.9 | 0 |
| Week 11 | | | | | | | 9 | NS |
| Week 12 | | | | | | | 9.1 | 0 |
| Week 13 | | | | | 31 | | 10.3 | 31 |
| Week 14 | | | | | | | 9.1 | 0 |
| Week 15 | | | | 57 | | | 9.8 | 57 |
| Week 16 | | | | | 20 | | 10.4 | 20 |
| Week 17 | | | | | | | 10.5 | 0 |
| Week 18 | | | | | | | 10.9 | 0 |
| Week 19 | | | | | 19 | | 10.9 | 19 |
| Week 20 | | | | 71 | | | 12.2 | 71 |
| Week 21 | | | | | 20 | | 12.9 | 20 |
| Week 22 | | | | | | | 13.2 | NS |
| Week 23 | | | | 30 | | | 13.5 | 30 |
| Week 24 | | 57 | | | 9 | | 13.6 | 66 |
| Week 25 | | | | | | | 14.6 | 0 |
| Week 26 | | | 19 | | | | 15.8 | 19 |
| Week 27 | | | | | | | 16.1 | 57 |
| Week 28 | | | 226 | | 57 | | 16.2 | 283 |
| Week 29 | | | | 179 | | | 16.8 | 179 |
| Week 30 | | 47 | | | | | 17.9 | 47 |
| Week 31 | | | | | | | 17.5 | 60 |
| Week 32 | | | | | | | 17.3 | NS |
| Week 33 | | | | 20 | | | 17.2 | 20 |
| Week 34 | | | | | | 30 | 17.2 | 30 |
| Week 35 | | | | | | | 16.95 | NS |
| Week 36 | | | | | | 180 | 16.7 | 180 |
| Week 37 | | | | | | | 16.7 | 0 |
| Week 38 | | | | | 19 | | 16.7 | 19 |
| Week 39 | | | | 88 | 16 | | 16.2 | 104 |
| Week 40 | | | | | | | 15.25 | NS |
| Week 41 | | | | | 38 | | 14.3 | 38 |
| Week 42 | | | | | | | | 0 |

No sample was collected, and an estimated value has been used for graphical purposes.

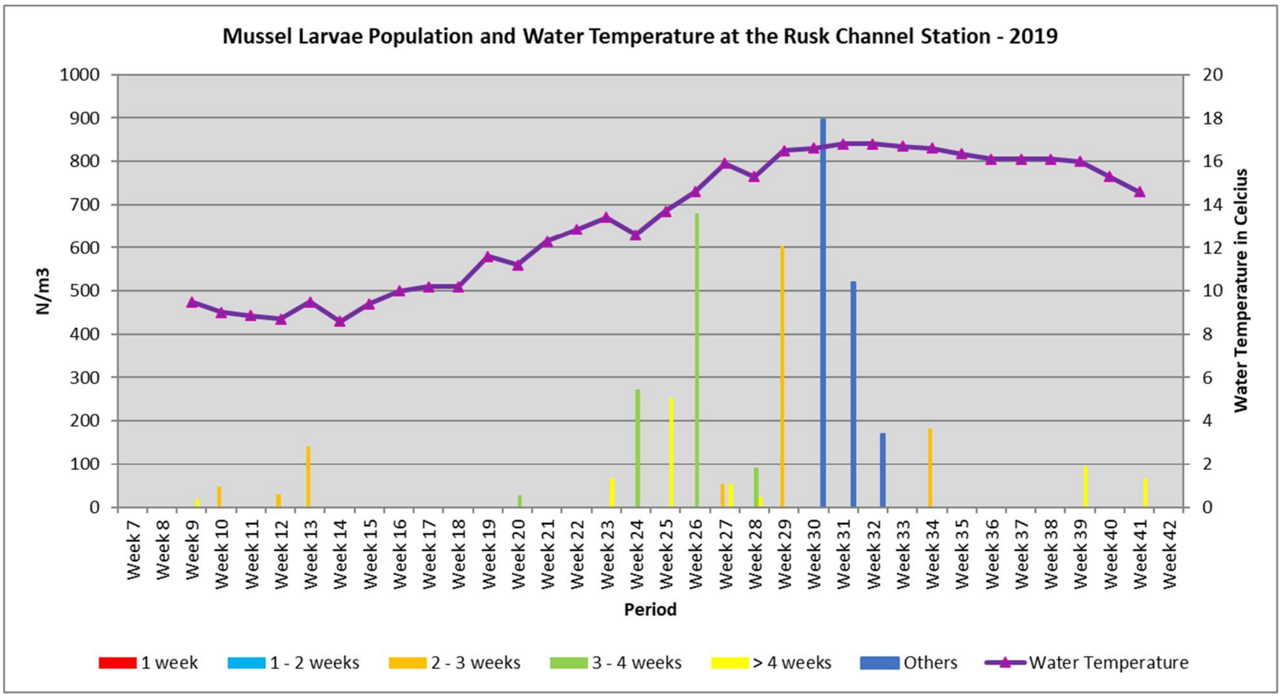
The young (early stage) larvae observed on Week 30 may be related to a spawning event between Week 30 and Week 31. The spike in larvae number on Week 36 (unclassified larvae) does not appear to be related to any spawning event from Wexford Harbour. It is also the case for the larvae on Week 38, which could indicate that those larvae did not originate from the harbour brood stock.

Overall, the water temperature at this station was slightly higher than that recorded in 2018, it reached optimum (the highest) temperature from Week 26 to Week 40, with a peak at 17.9˚C on Week 30 (1st week of August). The lowest temperature recorded during the monitoring period was 8.9˚C on Week 10.

## Rusk Channel

The data collected at the Rusk Channel station is highlighted in Figure 19 (ambient water temperature, number of larvae and age through the sampling period). The figures breakdown is shown in Table 4. Only nine weeks of sampling were missed in 2019 at this station.

### Figure 19: Mussel D-larvae population and seawater temperature in the Rusk Channel (Week 7 to Week 42)




The number of larvae at the Rusk Channel station contributes significantly to the overall increase of larvae in 2019. Again, no young larvae have been observed at this station. A small number of older larvae were found early in the year (from Week 9 to Week 13 – end of February to the end of March), which could indicate some spawning on Week 6 at the earliest and Week 10 at the latest. There may be some possible relation with a spawning in Wexford Harbour between Week 7 and Week 8, although the track of the GPS drifters deployed in 2018 and 2019 would not be in agreement with this hypothesis. There were very few larvae were observed until Week 23. Again, the larvae found during this period appear to be more developed which would indicate a possible spawning on Week

20 at the earliest and Week 22 at the latest, corresponding to the peak in numbers on Week 26 at this station.

**Table 4: Mussel D-larvae population in the Rusk Channel (number per m³)**

| Period | 1 week | 1 - 2 weeks | 2 - 3 weeks | 3 - 4 weeks | > 4 weeks | Others | Water Temperature | Total Larvae / week |
|---|---|---|---|---|---|---|---|---|
| Week 7 | | | | | | | | |
| Week 8 | | | | | | | | |
| Week 9 | | | | | 19 | | 9.5 | 19 |
| Week 10 | | | 47 | | | | 9 | 47 |
| Week 11 | | | | | | | 8.85 | |
| Week 12 | | | 30 | | | | 8.7 | 30 |
| Week 13 | | | 142 | | | | 9.5 | 142 |
| Week 14 | | | | | | | 8.6 | 0 |
| Week 15 | | | | | | | 9.4 | 0 |
| Week 16 | | | | | | | 10 | 0 |
| Week 17 | | | | | | | 10.2 | 0 |
| Week 18 | | | | | | | 10.2 | 0 |
| Week 19 | | | | | | | 11.6 | 0 |
| Week 20 | | | | 28 | | | 11.2 | 28 |
| Week 21 | | | | | | | 12.3 | 0 |
| Week 22 | | | | | | | 12.85 | |
| Week 23 | | | | | 66 | | 13.4 | 66 |
| Week 24 | | | | 273 | | | 12.6 | 273 |
| Week 25 | | | | | 254 | | 13.7 | 254 |
| Week 26 | | | | 679 | | | 14.6 | 679 |
| Week 27 | | | 53 | | 53 | | 15.9 | 106 |
| Week 28 | | | | 90 | 23 | | 15.3 | 113 |
| Week 29 | | | 604 | | | | 16.5 | 604 |
| Week 30 | | | | | | 896 | 16.6 | 896 |
| Week 31 | | | | | | 519 | 16.8 | 519 |
| Week 32 | | | | | | 169 | 16.8 | 169 |
| Week 33 | | | | | | | 16.7 | |
| Week 34 | | | 182 | | | | 16.6 | 182 |
| Week 35 | | | | | | | 16.35 | |
| Week 36 | | | | | | | 16.1 | 0 |
| Week 37 | | | | | | | 16.1 | |
| Week 38 | | | | | | | 16.1 | 0 |
| Week 39 | | | | | 96 | | 16 | 96 |
| Week 40 | | | | | | | 15.3 | |
| Week 41 | | | | | 66 | | 14.6 | 66 |
| Week 42 | | | | | | | | 0 |

No sample was collected, and an estimated value has been used for graphical purposes.

A significant quantity of unclassified larvae was observed between Week 30 and Week 32, making it difficult to decipher the relationship with the settlement occurred in the area.

As at the Wexford Bar Station, some residual older larvae (>4weeks old) were observed on Week 39 and 41. The ambient sea temperature at this location was similar to that recorded at the Wexford Bar, although a little cooler, reaching 16.8˚C (maximum) on Week 30 and 31 and a minimum of 8.6˚C on Week 14. Salinity was very similar during the sampling period (see Figure 14).

A patch of overwintered seed, with large individuals, was found along the shore close to Ballyvaldon (see Seed Mussel Survey Reports 2019 – BIM Website). 30 mussels were assessed for maturation on Week 28 (mid-July), only 20% were ripe for spawning (all female), the rest was considered to be developing/redeveloping on the scale established by Chipperfield (see Appendix 3). The ratio of female/male was nearly 1 to 1 (44% female/56% male).

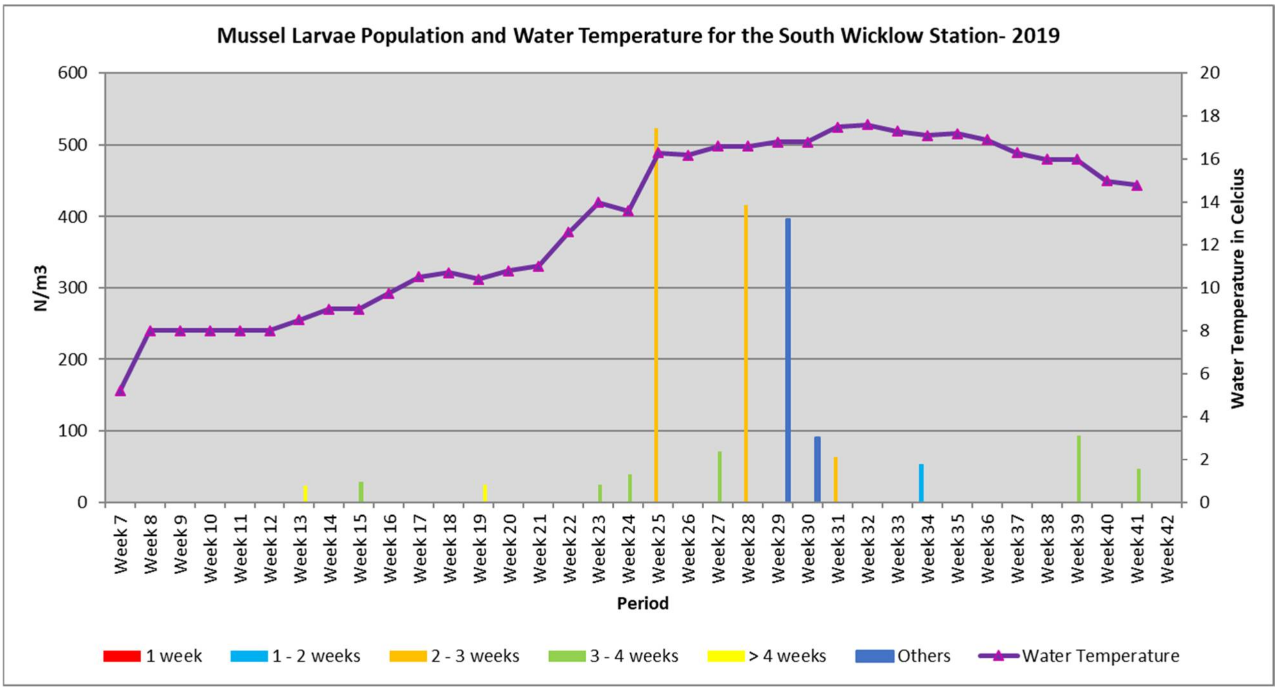
Other seed mussel settlements were observed along the shore. In the Rusk Channel, the size range across the bed suggested multiple settlements, especially in the channel bed in which nearly a third of the population comprised mussels between 24 and 28 mm in length and another third comprised mussels between 10 and 14 mm.

**Figure 20: Seed Mussel from the Rusk Channel (7/08/2019)**

### South Wicklow/Arklow

Table 5 shows a breakdown of the number and ages of larvae found at the South Wicklow sampling station. Again, this data has been graphed and the ambient water temperature added in Figure 21 below. All weeks were sampled at this location in 2019.

### Figure 21: Mussel D-larvae population and seawater temperature in South Wicklow (Week 7 to Week 42)




There were no larvae observed at this station until Week 13 and numbers were low until Week 25. Those larvae are likely to have originated from local brood stock; this could be related to the overwintered seed mussel found South of Wicklow Head as the gonad squash analysis carried out on Week 29 showed both developing or redeveloping males and females. Another possibility is that the larvae originated from the mussel population on the Arklow Bank wind turbines, although no mussel was found on the top of the bank.

Drifters were deployed at both locations to assess potential larval dispersal (see Drifter Deployments chapter p. 29 for details). According to the direction of the drifter deployed along the Arklow Bank, there could be a potential relationship between the number of 2 to 3 week old larvae observed on Week 25 at this station and the 3 to 4 weeks old larvae observed in the Rusk Channel a week after.

Low numbers of older larvae were observed, which might mean that retention at this location was limited in 2019. Also, no seed mussel settlement was found around the location. As for the other stations, a certain number of larvae could not be classed by aged.

The lowest temperature was observed at this station, reaching only 5.2˚C on week 7, although the optimum temperature for larval development was reached earlier than in the Rusk Channel. Salinity was slightly lower than other stations probably due to the combination of the Avoca River and low tidal movement on this part of the coast.

### Table 5: Mussel D-larvae population in South Wicklow (number per m³)

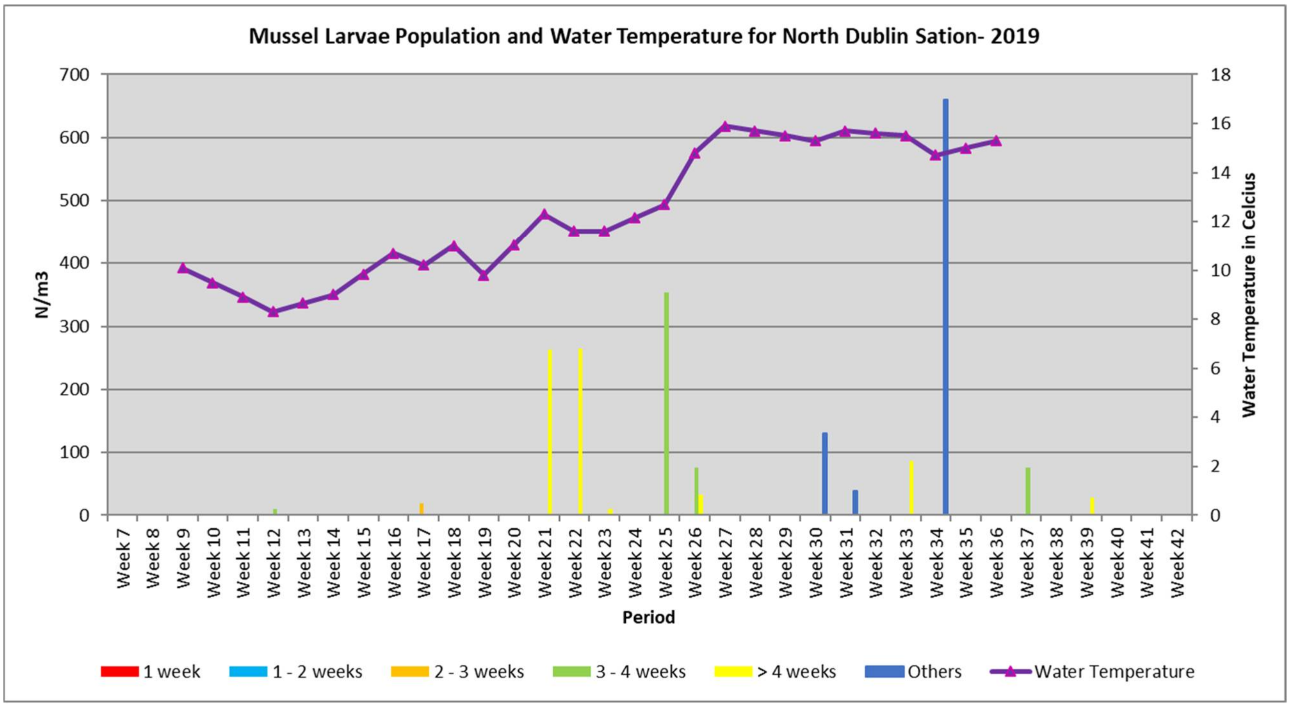
| Period | 1 week | 1 - 2 weeks | 2 - 3 weeks | 3 - 4 weeks | > 4 weeks | Others | Water Temperature | Total Larvae / week |
|---|---|---|---|---|---|---|---|---|
| Week 7 | | | | | | | 5.2 | 0 |
| Week 8 | | | | | | | 8 | 0 |
| Week 9 | | | | | | | 8 | 0 |
| Week 10 | | | | | | | 8 | 0 |
| Week 11 | | | | | | | 8 | 0 |
| Week 12 | | | | | | | 8 | 0 |
| Week 13 | | | | | 23 | | 8.5 | 23 |
| Week 14 | | | | | | | 9 | 0 |
| Week 15 | | | | 28 | | | 9 | 28 |
| Week 16 | | | | | | | 9.75 | 0 |
| Week 17 | | | | | | | 10.5 | 0 |
| Week 18 | | | | | | | 10.7 | 0 |
| Week 19 | | | | | 24 | | 10.4 | 24 |
| Week 20 | | | | | | | 10.8 | 0 |
| Week 21 | | | | | | | 11 | 0 |
| Week 22 | | | | | | | 12.6 | 0 |
| Week 23 | | | | 24 | | | 14 | 24 |
| Week 24 | | | | 38 | | | 13.6 | 38 |
| Week 25 | | | 523 | | | | 16.3 | 523 |
| Week 26 | | | | | | | 16.2 | 0 |
| Week 27 | | | | 71 | | | 16.6 | 71 |
| Week 28 | | | 416 | | | | 16.6 | 416 |
| Week 29 | | | | | | 396 | 16.8 | 396 |
| Week 30 | | | | | | 91 | 16.8 | 91 |
| Week 31 | | | 63 | | | | 17.5 | 63 |
| Week 32 | | | | | | | 17.6 | 0 |
| Week 33 | | | | | | | 17.3 | 0 |
| Week 34 | | 53 | | | | | 17.1 | 53 |
| Week 35 | | | | | | | 17.2 | 0 |
| Week 36 | | | | | | | 16.9 | 0 |
| Week 37 | | | | | | | 16.3 | 0 |
| Week 38 | | | | | | | 16 | 0 |
| Week 39 | | | | 94 | | | 16 | 94 |
| Week 40 | | | | | | | 15 | 0 |
| Week 41 | | | | 47 | | | 14.8 | 47 |
| Week 42 | | | | | | | | 0 |

No temperature sample was collected, and an estimated value has been used for graphical purposes.

### North Howth

The population variation and ambient water temperature are shown in Figure 22 below, and the breakdown is detailed in Table 6. 15. Samples were missed at this location, mainly due to poor weather conditions. There were also problems with the temperature and salinity probe.

### Figure 22: Mussel D-larvae population and seawater temperature in North Howth (Week 7 to Week 42)




There were relatively good numbers of larvae collected at this station over two distinctive periods: Week 21 and 22, Week 25 and Week 34. No larvae were observed before Week 17, although only a small number was found. None of those larvae accumulations seems related to potential spawning from brood stock in Malahide and Rogerstown (see Figure 8). Water temperature at this station was the coolest across the sampling locations and barely reached optimum levels from Week 27 to Week 33. There was very little to no larvae younger than 3 to 4 weeks old observed at this station, although there was a significant number of larvae unclassified.

In 2018, it was hypothesised that those larvae were coming from the Malahide brood stock, but in 2019 this relation cannot be seen. Following these observations and as part of the BLUEFISH Project, a drifter was deployed from the marina in Malahide. It stopped emitting a month after while south of the Isle of Man (see Drifter Deployments p.29for details). There was no correlation between the track of the drifter and the location of the sampling station. However, after avoiding Dublin Bay, the drifter appeared to have stayed for some time south of Dalkey before heading east. No seed settlement was found around Howth or the Lambay Sound in 2019.

**Table 6: Mussel D-larvae population in North Howth (number per m³)**

| Period | 1 week | 1 - 2 weeks | 2 - 3 weeks | 3 - 4 weeks | > 4 weeks | Others | Water Temperature | Total Larvae / week |
|---|---|---|---|---|---|---|---|---|
| Week 7 | | | | | | | | |
| Week 8 | | | | | | | | |
| Week 9 | | | | | | | 10.1 | 0 |
| Week 10 | | | | | | | 9.5 | |
| Week 11 | | | | | | | 8.9 | |
| Week 12 | | | | 10 | | | 8.3 | 10 |
| Week 13 | | | | | | | 8.65 | |
| Week 14 | | | | | | | 9 | 0 |
| Week 15 | | | | | | | 9.85 | |
| Week 16 | | | | | | | 10.7 | 0 |
| Week 17 | | | 19 | | | | 10.2 | 19 |
| Week 18 | | | | | | | 11 | 0 |
| Week 19 | | | | | | | 9.8 | 0 |
| Week 20 | | | | | | | 11.05 | |
| Week 21 | | | | | 263 | | 12.3 | 263 |
| Week 22 | | | | | 264 | | 11.6 | 264 |
| Week 23 | | | | | 10 | | 11.6 | 10 |
| Week 24 | | | | | | | 12.15 | |
| Week 25 | | | | 353 | | | 12.7 | 353 |
| Week 26 | | | | 76 | 33 | | 14.8 | 109 |
| Week 27 | | | | | | | 15.9 | 0 |
| Week 28 | | | | | | | 15.7 | |
| Week 29 | | | | | | | 15.5 | |
| Week 30 | | | | | | 130 | 15.3 | 130 |
| Week 31 | | | | | | 38 | 15.7 | 38 |
| Week 32 | | | | | | | 15.6 | |
| Week 33 | | | | | 87 | | 15.5 | 87 |
| Week 34 | | | | | | 660 | 14.7 | 660 |
| Week 35 | | | | | | | 15 | |
| Week 36 | | | | | | | 15.3 | 0 |
| Week 37 | | | | 76 | | | | 76 |
| Week 38 | | | | | | | | |
| Week 39 | | | | | 28 | | | 28 |
| Week 40 | | | | | | | | |
| Week 41 | | | | | | | | |
| Week 42 | | | | | | | | |

(yellow) No sample was collected, and an estimated value has been used for graphical purposes.

### Castlemaine Harbour / Cromane

Due to the lack of samples, this station is not included in this report. No drifter was deployed in Castlemaine in 2019. However, some seed settlements were found later in the year in the channel between Inch Point and Rossbeigh.

## Drifter deployments

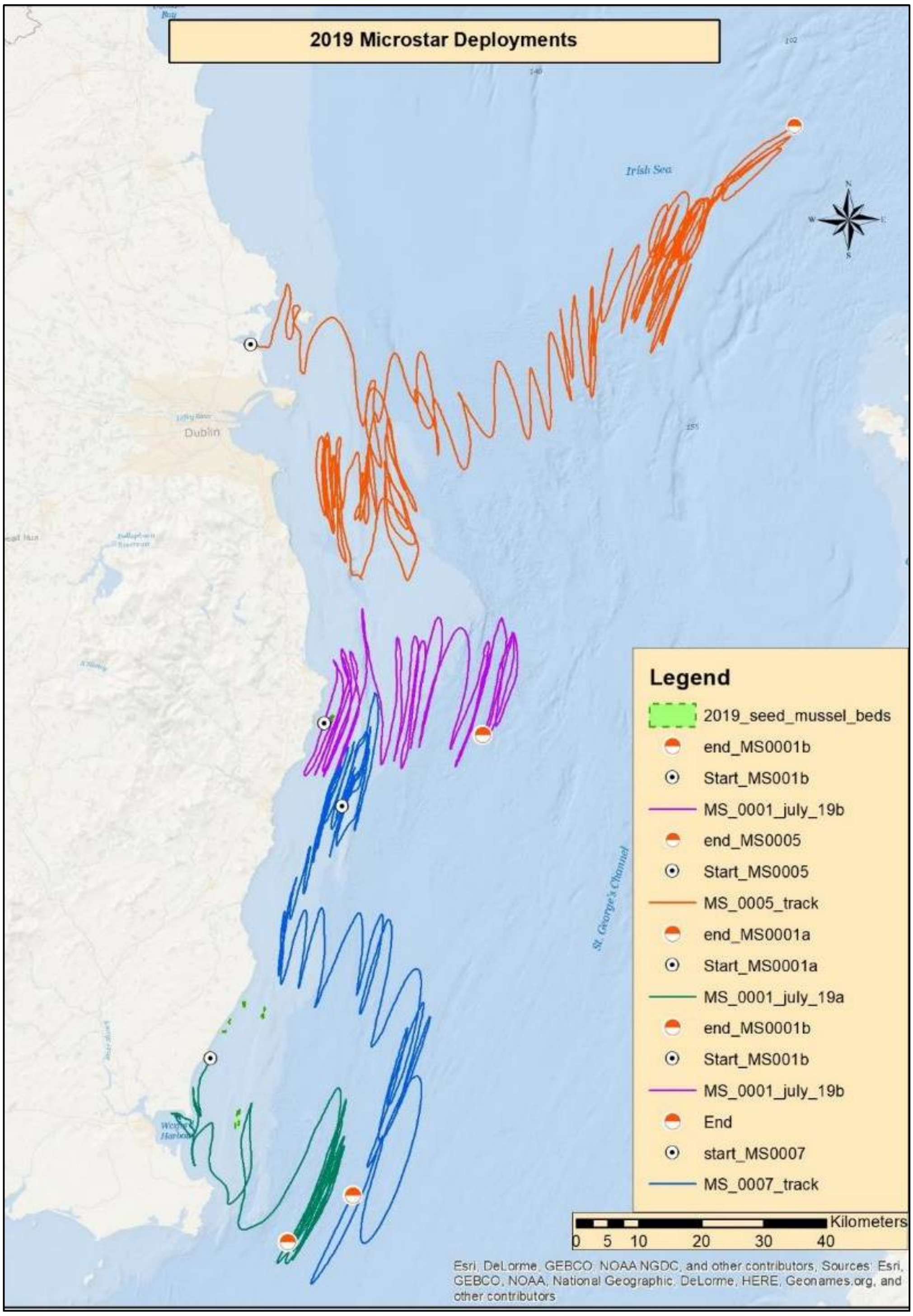
As part of the BlueFish Project, BIM is investigating coastal ecosystem (shellfish seed) resources, including benthic mussels. The GPS drifters provide a great tool to understand local water current dynamics. As they have been proven to assess the local tidal currents and the effect of wind on the surface layer (Haase *et al.*, 2012; Le Gendre *et al.*, 2014) and thereby potential direction for larval drift.

Pacific Gyre provided the Microstar drifters. These GPS tracked drogues are composed of two parts: the buoy that housed the batteries and the transmitter (for position and water temperature), and the kite composed of a plastic tubing frame and fabric. The ensemble represents 1.5 meters when deployed, from the top of the buoy to the bottom of the kite.

**Figure 23: Detail of the Microstar GPS drifter**

Following on from 2018, the Microstar GPS drifter were deployed at 4 locations on the east coast. Launch locations were selected following known and potential brood stock that could provide larvae for potential recruitment: Blackwater Point, the inner Arklow Bank, the 2019 overwintered seed mussel bed south of Wicklow Head and Malahide estuary (see Figure 24).

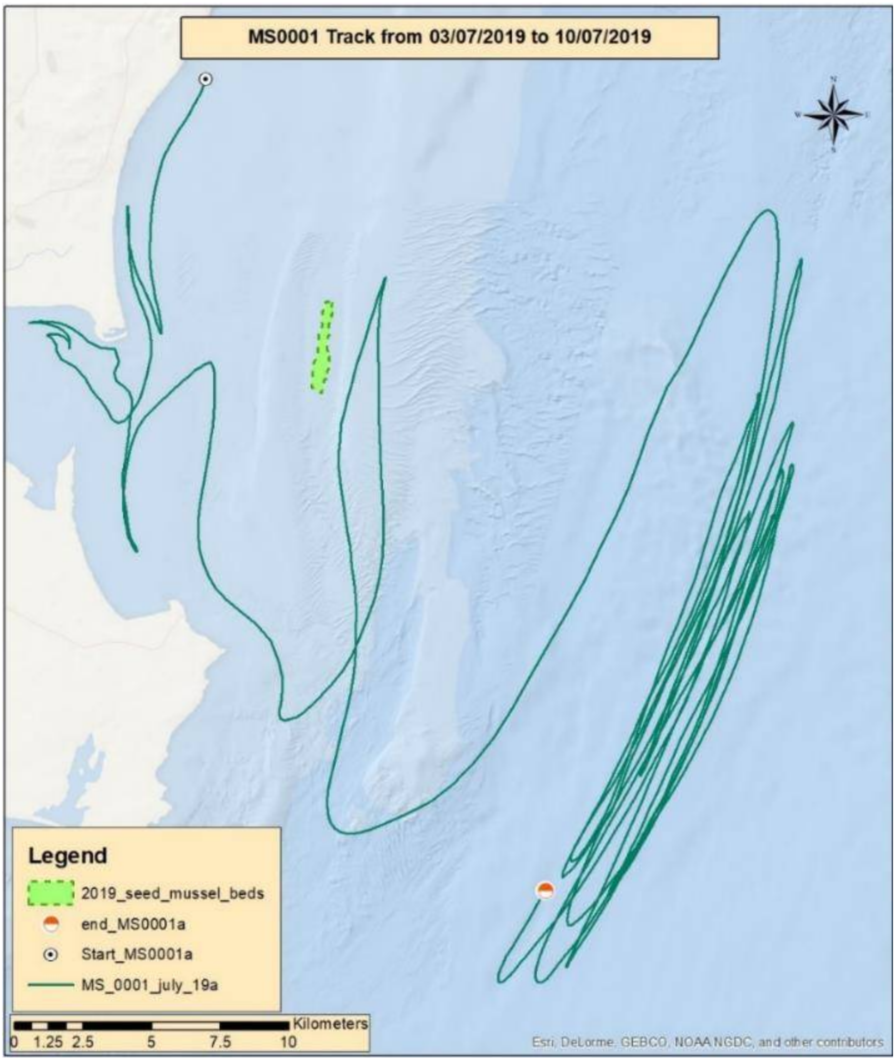
**Figure 24: 2019 Microstar deployments on the east coast**



### Blackwater Point

MS 0001 was deployed on the 03/07/2019 along the shore at Blackwater Point, Co. Wexford, at the slack of high water. This site was chosen for its potential mussel population on and near the rock armour. Location was transmitted every 10 minutes.

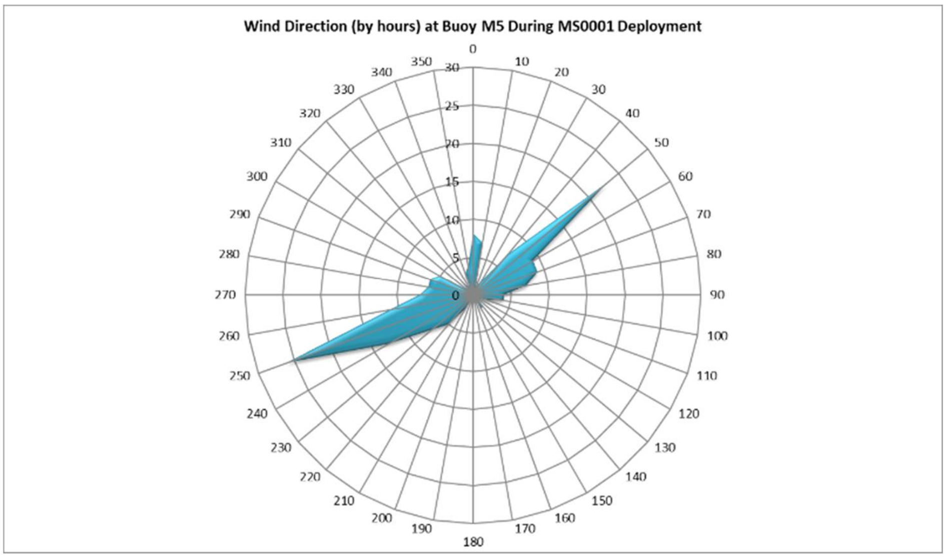
**Figure 25: Microstar MS 0001 early July track**

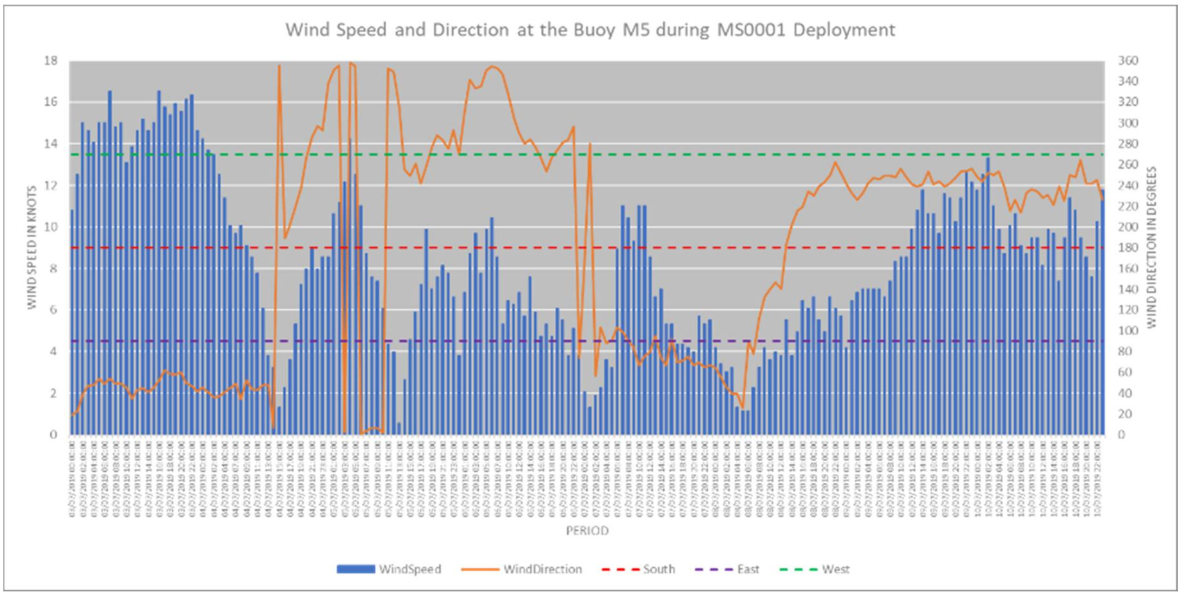



The drifter started heading south on the ebb. The following flood carried it in Wexford North Bay. During the second ebb tide, the drifter was carried in the front of Wexford Harbour (on the 4/07/2019). The drifter entered the harbour with the incoming flood. It stayed on the north part of the harbour until the 5/07/2019, probably being caught in the shallow waters. By the 06/07/2019, the drifter passed behind the Long Bank and further away by the end of the same day. For the next 3 days (until the 10/07/2019), the drifter appears to stay in an eddy approximately 8.5 nautical miles from Rosslare Point where it was recovered on the 10th of July. No survey was carried out along this part of the track as the depth would have been too high for the survey equipment.

The drifter travelled over 425 kilometres over 7 days. Between the 5th and the 6th of July, the drifter passed close by the east Long Bank seed settlement which could indicate that the larvae that settled there could be coming from either Wexford Harbour or further up the coast. The track pattern is like last year launch at Wexford Bar in May; however, at the time, the drifter was recovered before it went further south.

### Figure 26: Wind Direction and speed during the deployment of MS0001



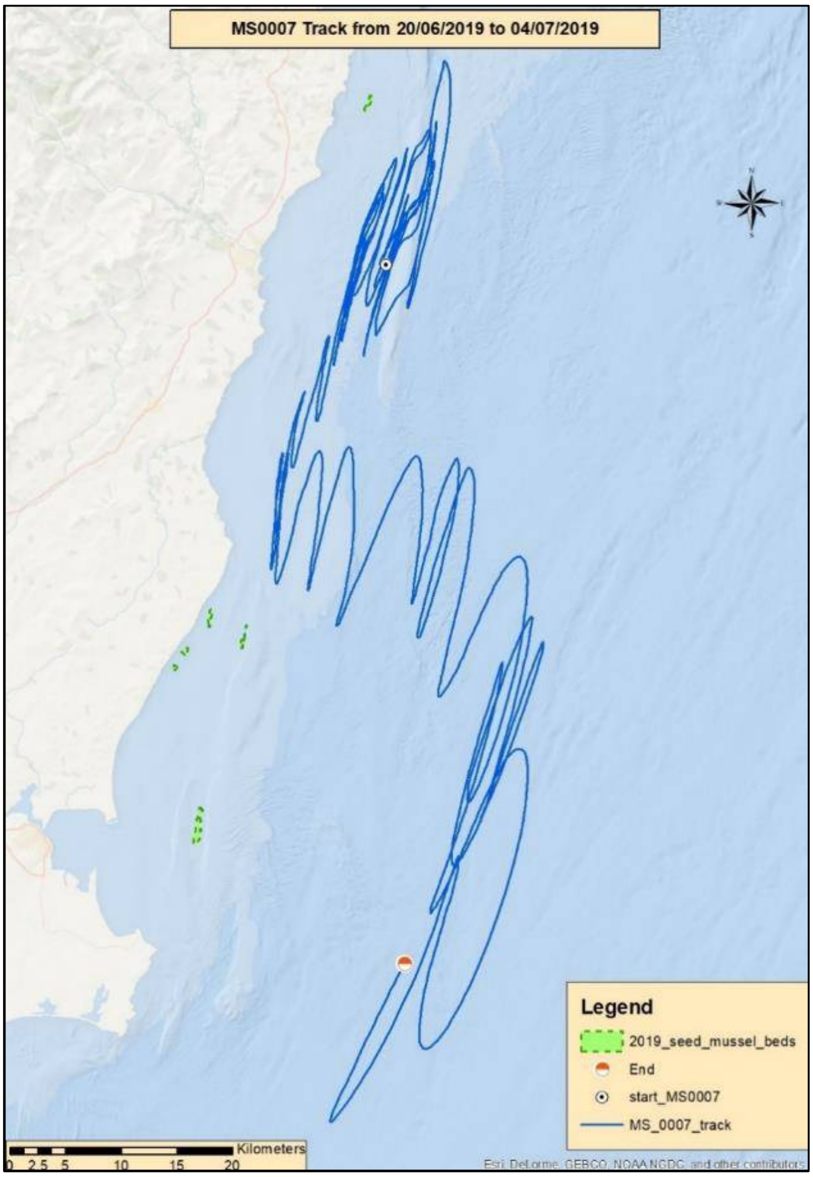




The wind direction and strength measured at the Met Buoy M5 at the start of the deployment likely affected the drifter (northeast in direction and reaching more than 16 knots) to follow the coast. The wind dropped for several days following this period and then picked up again on the 8th of July and established itself in south-westerly airflow, which would have carried the drifter further east from the coast. During the deployment of MS 0001 drifter, the wind strength was mostly Force 4/5 with few gusts Force 6 at the start. Southwest winds dominated the period.

## Arklow Bank

MS 0007 was deployed on the west side of the Arklow Bank following local reports of mussels at the base of the wind turbines. However, an acoustic survey along the west side of the bank failed to highlight benthic mussel population. The drifter was deployed for 15 days, encompassing both neap and spring tides. Location was transmitted every 10 minutes.

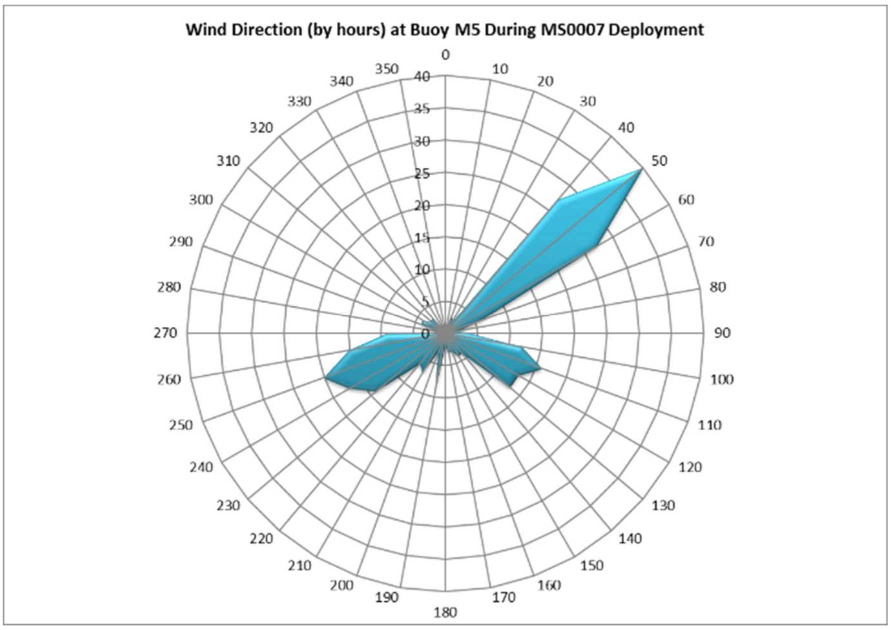
**Figure 27: Microstar MS-0007 track from June to July**

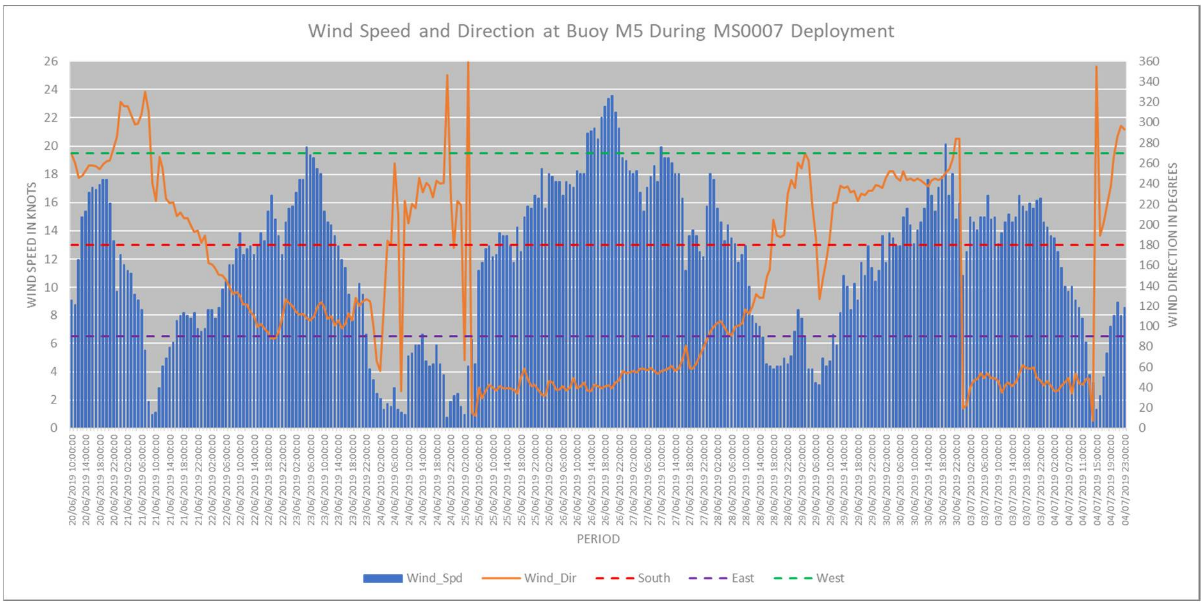



The drifter was deployed at the end of a spring tide on June 20th, until June 26th and it remained around the Arklow Bank. However, on the 22nd the drifter nearly reached Wicklow Head, passing 6 kilometres east of the seed mussel settlement found north of Brittas Bay. From the 26th, MS 0007 started moving south alongside the Glassgorman Banks, driven by fresh northeast winds at the time. On the 27th and 28th, the drifter passed 2 kilometres away from the north entry of the Rusk Channel. For the next four days (until July 1st), south-westerly winds drove MS 0007 further east until it reached an eddy nearly 20 nautical miles from the Blackwater Bank. The drifter then, stayed in this north/south pattern, stretching over 47 nautical miles until it was recovered on July 4th.

MS 0007 covered 1,365 kilometres over the 15 days it was deployed. Although no mussels were found along the Arklow Bank, it can be hypothesised that mussels on the turbines themselves could be providing larvae for both south Wicklow Head beds and beds located outside Courtown, Co. Wexford. Further investigation should be carried out for mussel brood stock potential on the turbines.

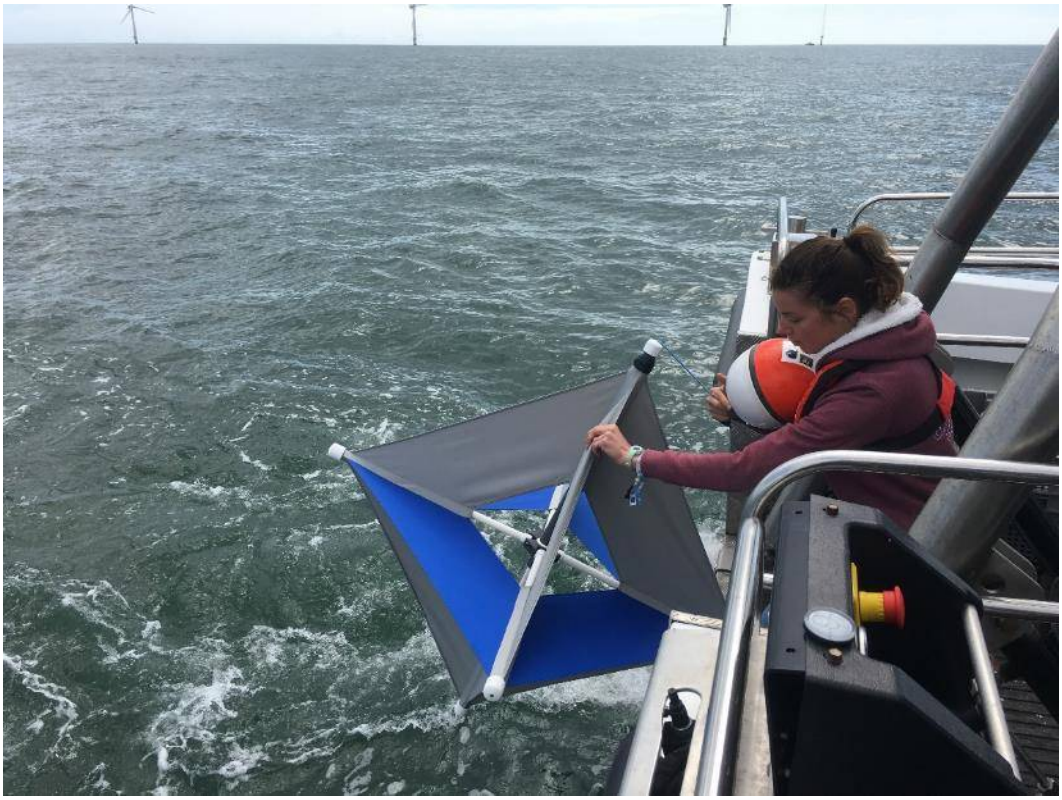
**Figure 28: Windspeed and direction at Buoy M5 during MS0007 deployment**



Looking at the start of the deployment, wind records from the Buoy M5 were highly variable both in strength and direction until June 20th. During this period, a north-easterly airflow steadily increased up to Force 5/6, which would explain why the drifter was moving rapidly south. The following period saw winds rapidly shifting to the southwest until the 30th. Unfortunately, data is missing for the 1st and 2nd of July. The wind shifted again back to a north-easterly airflow which would have pushed the drifter further south. Over the 15 days, north-easterly winds were dominant.

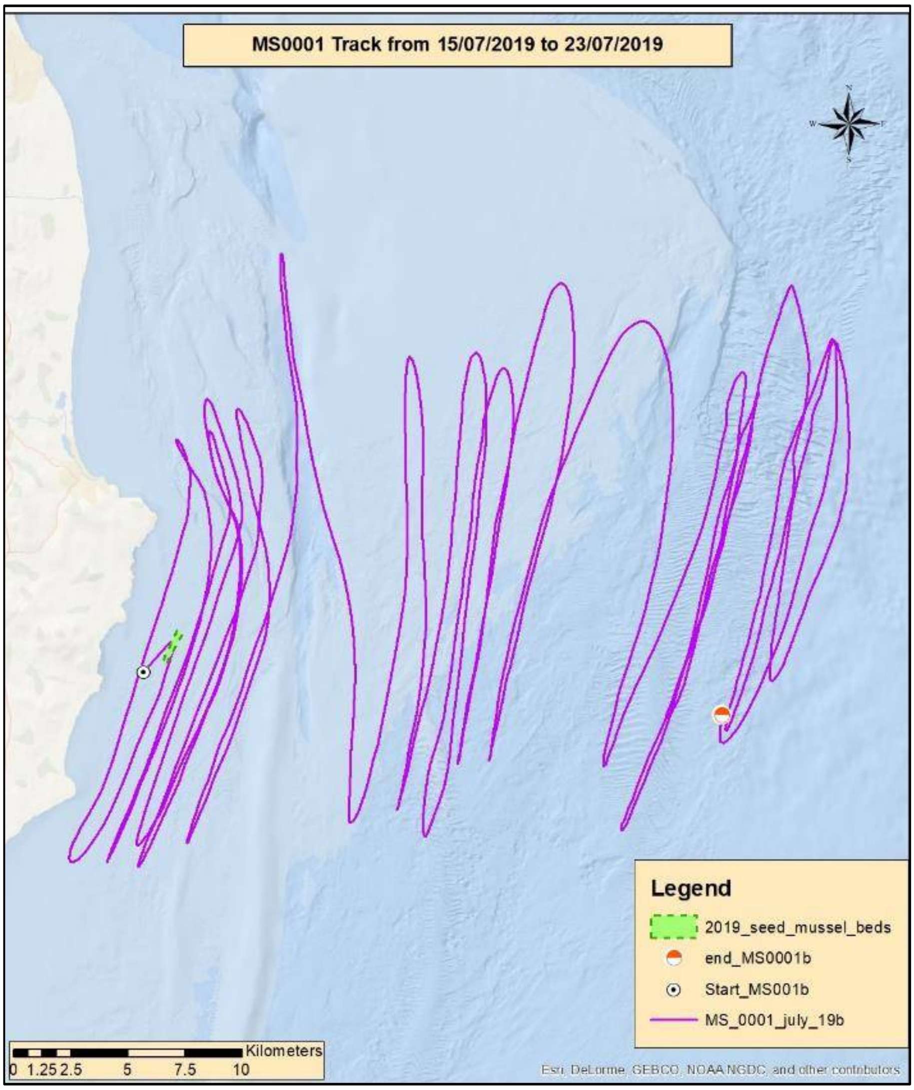
**Figure 29: MS 0007 deployment**



### South Wicklow Head

MS 0001 was deployed again later in mid-July from the overwintered seed mussel found south of Wicklow Head. The drifter was recovered after 8 days. Location was transmitted every 10 minutes.

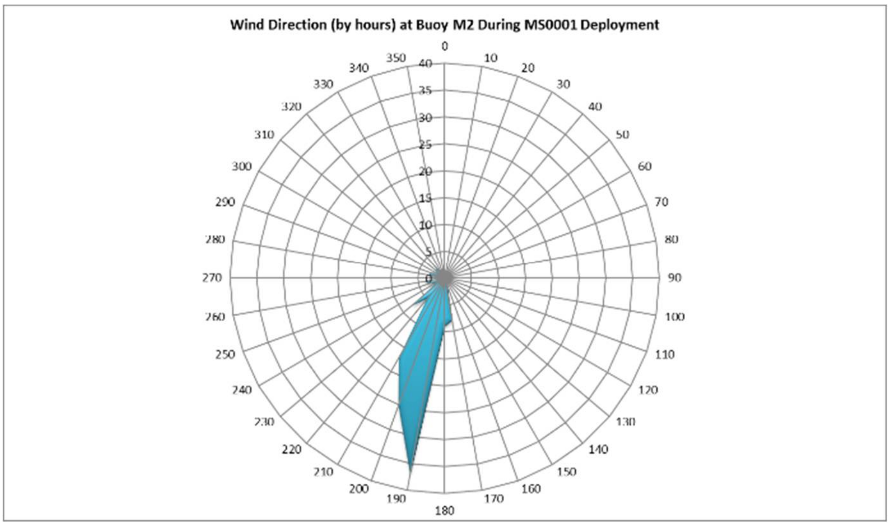
### Figure 30: MS 0001 track

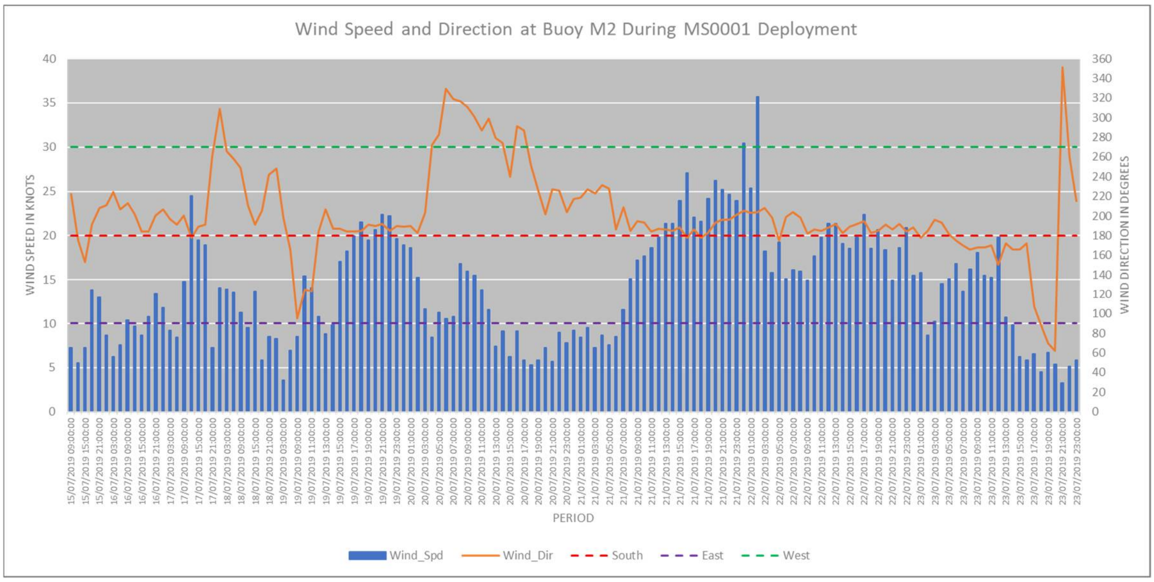



The drifter was deployed at the high-water slack on July 15th, during spring tide. MS 0001 stayed within 6 nautical miles of the shore for 2 days, covering an area from Mizen Head to slightly north of Wicklow head, which corresponds to the usual surveyed area for seed mussels. On the 17th, the drifter moved to the trench east of Wicklow head during the flood and reached the height of Six Miles Point north of Wicklow town, likely due to southerly wind increase for this day. On the following ebb, MS 0001 travelled behind the Arklow Bank and extended 5 nautical miles east within 24 hours, although wind speed and direction on July 18th were moderate. The tide had likely the most effect on the drifter, as the 18th had the most extensive range. For two day the drifter stayed in an area going from the India Bank to the east of the Arklow Bank. There was another 5 nautical miles jump going east on the 20th, potentially due to fresh southerly winds on the 19th. MS 0001, then stayed east of the India Bank in deeper water and was pushed up further north between the 21st and 22nd due to strong southerly winds (up to Force 7 and 8). The main direction of the wind during the deployment of MS 0001 was south-southwest and averaging between Force 3 and 5. It was recovered on the 23rd before being out of range.

MS 0001 travelled 1,019 kilometres over the 8 days it was deployed, it was recovered 51 kilometres from the coast. It was initially thought larvae settling around Wicklow were coming from a greater distance due to the strength of local currents but considering the travelling pattern of the drifter, it is likely that the seed mussels settling south of Wicklow Head are coming from larvae produced locally. However, no adult mussel beds have been observed in this location since thorough seed mussel surveys started in 2008.

## Figure 31: Wind direction and speed at the Met Buoy M2 during MS 0001 deployment

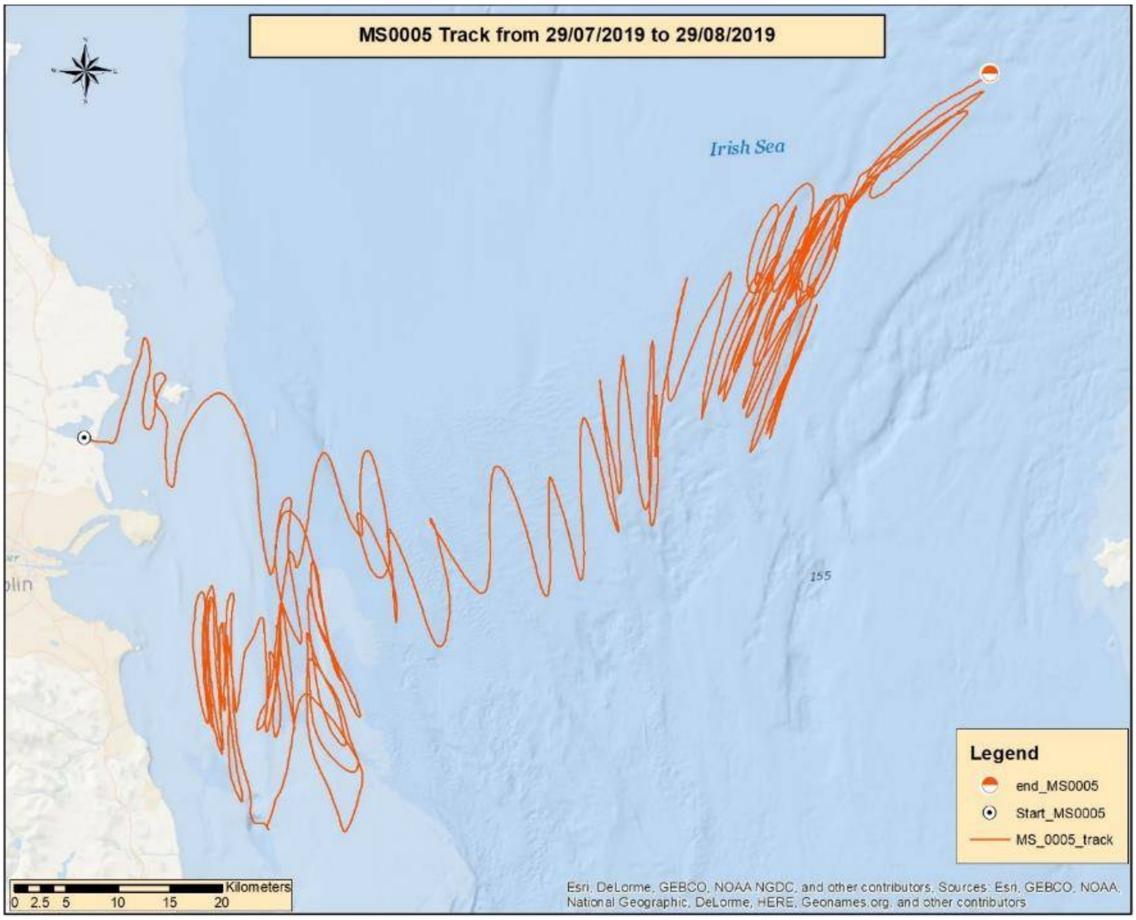


## Malahide Marina

MS 0005 was deployed from the northern shore of the estuary in Malahide on July 29th several hours after high water during spring tide. The site was chosen for the sizeable intertidal mussel brood stock located in the shallow waters of the inlet.

### Figure 32: MS 0005 track

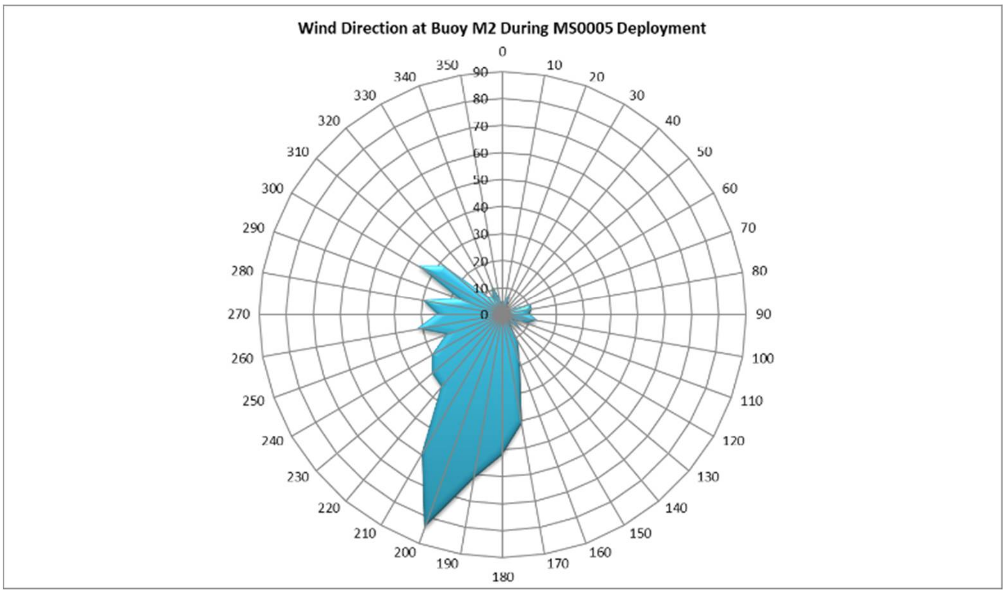


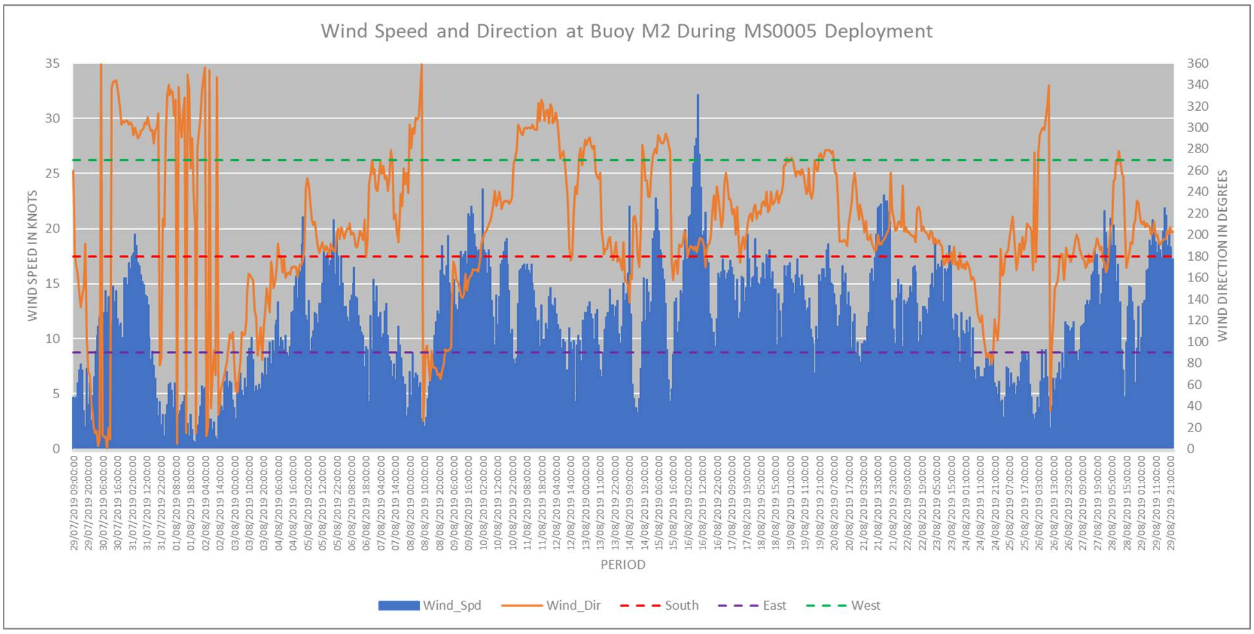

MS 0005 was deployed the longest (1 month full), mainly because there was no vessel available to retrieve it before it was out of range. At first, the drifter travelled north in the Lambay Sound, in which seed mussel have been known to settle every so often. Within 24 hours, it reached 3 kilometres east of Ireland's Eye, indicating a low level of larvae retention within the Malahide inlet which could potentially limit self-recruitment. The drifter was then, carried south as far as the East Codling Buoy, probably due to moderate northerly breeze which dominated the period until August 2nd. On the 3rd of August, MS 0005 reached the green buoy west of the Codling Bank on the ebb. The drifter pattern observed at this stage suggests that it got entangled for a short time. On the flood, MS 0005 moved west of the Kish Bank/Bray Bank. It travelled up and down with the tide in this area for 4 days until the 7th. This pattern, between the 3rd and the 7th, could have facilitated potential larvae settlement. However, the area was not surveyed at the time due to limited survey time. The wind speed and direction, during this period, don't seem to influence the drifter track,

although south to west winds reached Force 4 to Force 6 on the $4^{th}$ and the $5^{th}$. It returned east of the Kish Bank during the $8^{th}$ until late on the $9^{th}$, the drifter being possibly maintained in the area by fresh easterly winds. From August $10^{th}$, MS 0005 is moving east reaching the vicinity of the Met Buoy M2 on the $14^{th}$, possibly helped by southerly winds established earlier in the period.
On the $15^{th}$, the buoy reached the Irish Sea midway point, and its north/south oscillation gradually shifted in a southwest/northeast direction until the $17^{th}$. The drifter stayed on this track for over 60 kilometres from Carmel Point on Anglesey, from the $17^{th}$ to the $22^{nd}$, likely pushed by strong south-westerly breezes. Winds slackened and backed southeast to east from the $23^{rd}$ to the $26^{th}$. Then, the wind veered southwest and increased between 4 and 6 from the $27^{th}$. The transmission was lost on the 28, likely due to low battery. The buoy without its drifter was recovered near an oyster farm near the Solway Firth in mid-October.

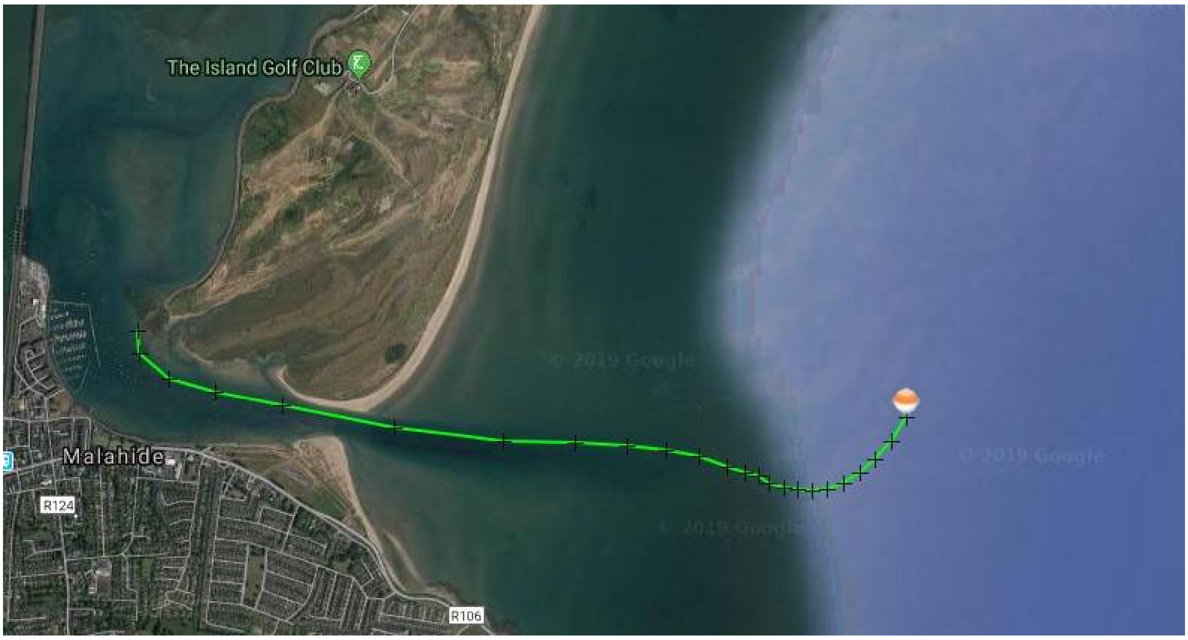
MS 0005 travelled nearly 2,500 kilometres from Malahide until it stopped transmitting. When transmission stopped, the drifter was 160 kilometres from its starting point and had nearly crossed the Irish Sea. Its track indicates that potential larvae produced from the Malahide brood stock at the end of August may have been driven offshore and probably died (Mc Quaid and Phillips, 2000; Robins *et al.*, 2013). The prevailing wind strength during the deployment of MS 0005 was Force 4, representing over 300 hours.

**Figure 33: Wind direction and speed at the Met Buoy M2 during MS 0005 deployment**





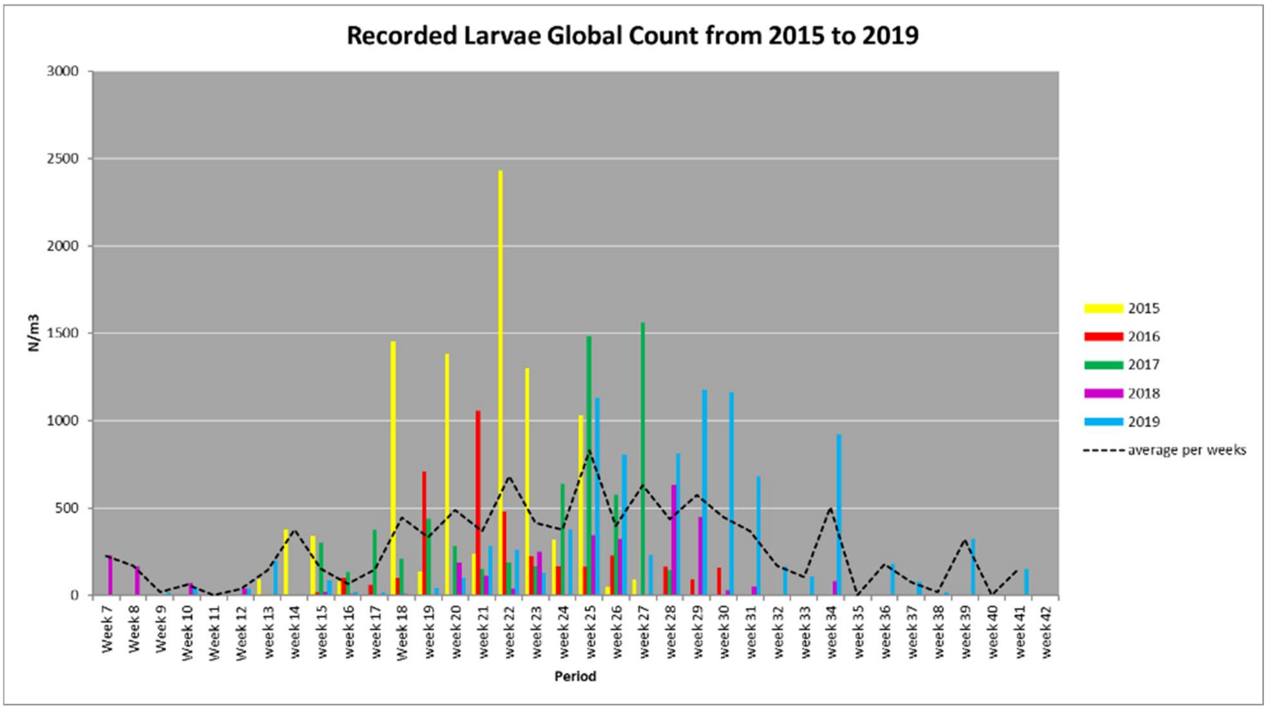

## Figure 34: MS 005 track 4 hours after deployment



## Comparison of findings

It is the fifth year in the larvae monitoring program, and the amount of data gathered is increasing every year since the start in 2015. Over which time a greater understanding in the mussel larvae dynamics, population connectivity and seed mussel settlement to a certain extent is starting to emerge.

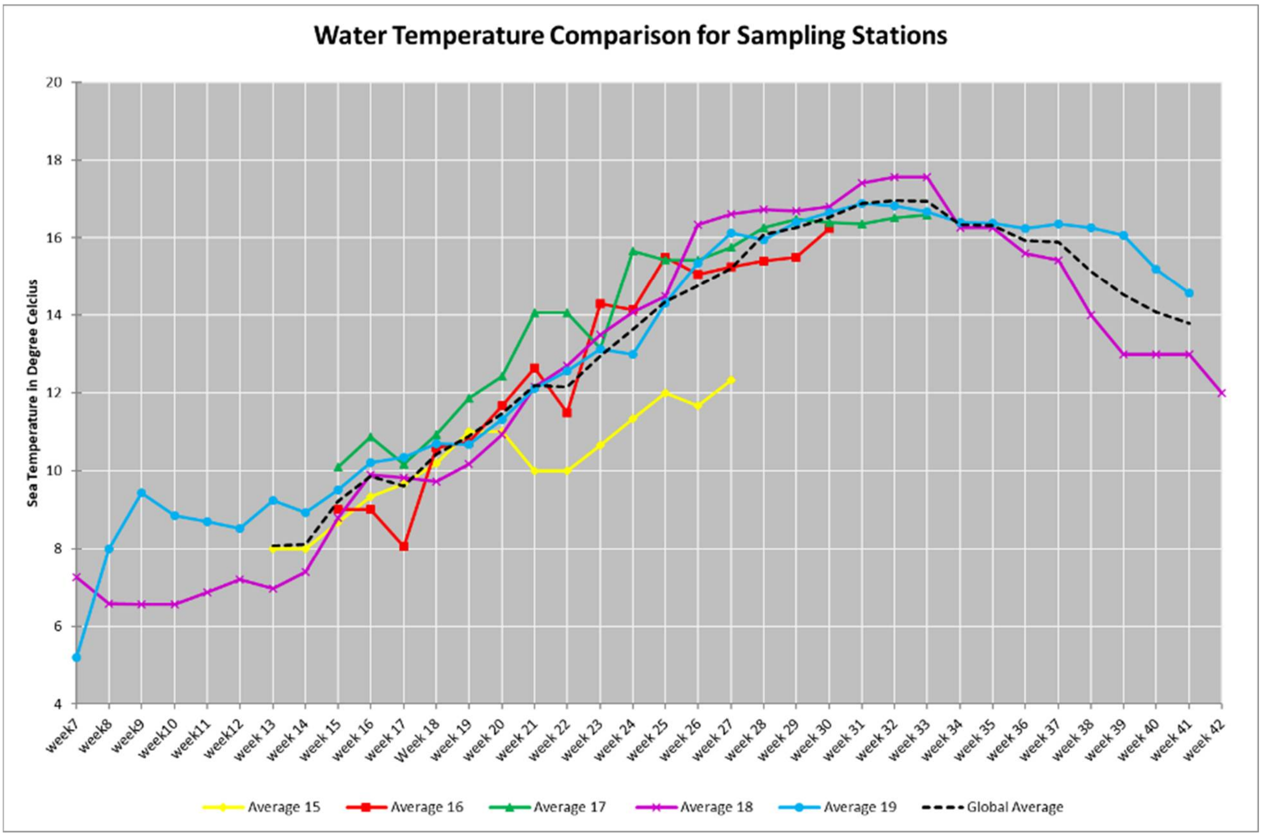
**Figure 35: Global mussel larvae population variation at the sampling station since 2015**




There were a lot more larvae recorded in 2019 than in 2018. High mussel larvae concentrations (above 1000 larvae /$m^3$) were found later in comparison with previous years: Week 18 in 2015, Week 21 in 2016, Week 25 in 2017, Week 28 with a lower level in 2018 and finally Week 25 in 2019 (see Figure 35). This trend may influence spat settlement timing which is directly connected to potential scheduling of fisheries activity. It was the case in 2017 and 2018 but not in 2019 that seed mussel reached 2 to 14 mm between the Long Bank and the Lucifer Bank by Week 19/20. It could indicate that this seed may have been produced between Week 10 and Week 13, which doesn't seem to correlate with the number of larvae found at Wexford Bar for this period. It is also the case for the settlement found in the Rusk Channel, that the size of the seed does not relate to the larvae population found at the sampling station.

The number of larvae, in 2019, remained stable for a prolonged period from Week 25 to Week 30 with the last peak on week 34. This was also the case in 2015 too, only somewhat earlier in season. The extended sampling period showed that larvae were present until Week 41, which was not the case in 2018 as the last larvae recorded was on Week 34 although sampling took place until Week 40.

## Figure 36: Average Water Temperature across the Sampling Stations since 2015



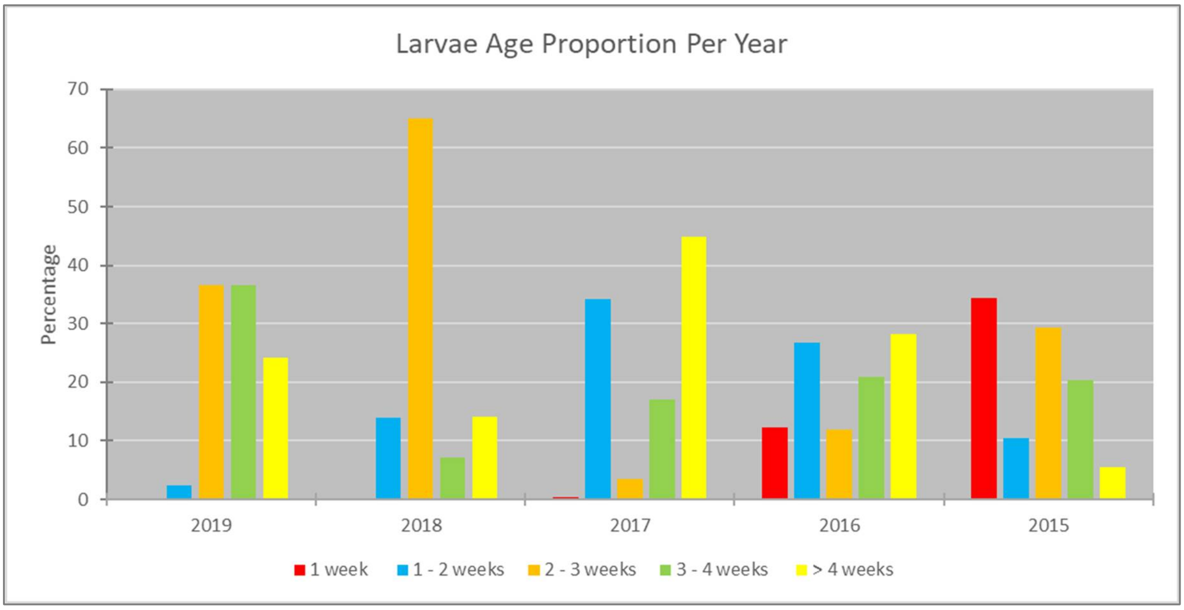

Water temperature across the sampling stations in 2019 was slightly above average for most of the sampling period. However, the first record on Week 7 was below 2018 readings by nearly 2˚C. From Week 8 the temperature increased rapidly, by 2˚C above 2018 readings for the same period. This increase would have had a positive effect on larvae development, as mentioned previously, which may correlate with the settlement found on the Wexford coast. There were fewer variations within the sampling period in 2019 than in previous years, excluding the first 2 weeks, during which the 2019 average sea temperature increased by more than 4˚C (see Figure 36).

## Table 7: Mussel Larvae Population Variation from 2015 to 2019

| Year | Wexford Bar | Rusk Channel | Wicklow |
|---|---|---|---|
| **2015** | 7795 | 3968 | 864 |
| **2016** | 2012 | 1503 | 194 |
| **2017** | 3481 | 2079 | 797 |
| **2018** | 322 | 743 | 318 |
| **2019** | 1350 | 4289 | 1891 |
| ***Samples Taken 2015*** | *12* | *9* | *10* |
| ***Samples Taken 2016*** | *13* | *14* | *6* |
| ***Samples Taken 2017*** | *21* | *20* | *24* |
| ***Samples Taken 2018*** | *20* | *20* | *41* |
| ***Samples Taken 2019*** | *28* | *26* | *35* |

Although sampling has increased in the last three years, there seems to be no correlation between the number of samples collected and the number of larvae observed (see table 7). However, a trend in larvae age population is beginning to emerge. The number of young larvae recorded (1 week old) has decreased since 2015 and were not found in 2018 and 2019. It is a similar case for larvae of 1 to 2 weeks old from 2017 to 2019 too. This trend is not observed in other age classes (see Figure 37). It is likely due to sampling mis-timing as the sampling nets have not changed since the start of the program. The detailed age variation graphs can be seen in Appendix 4.

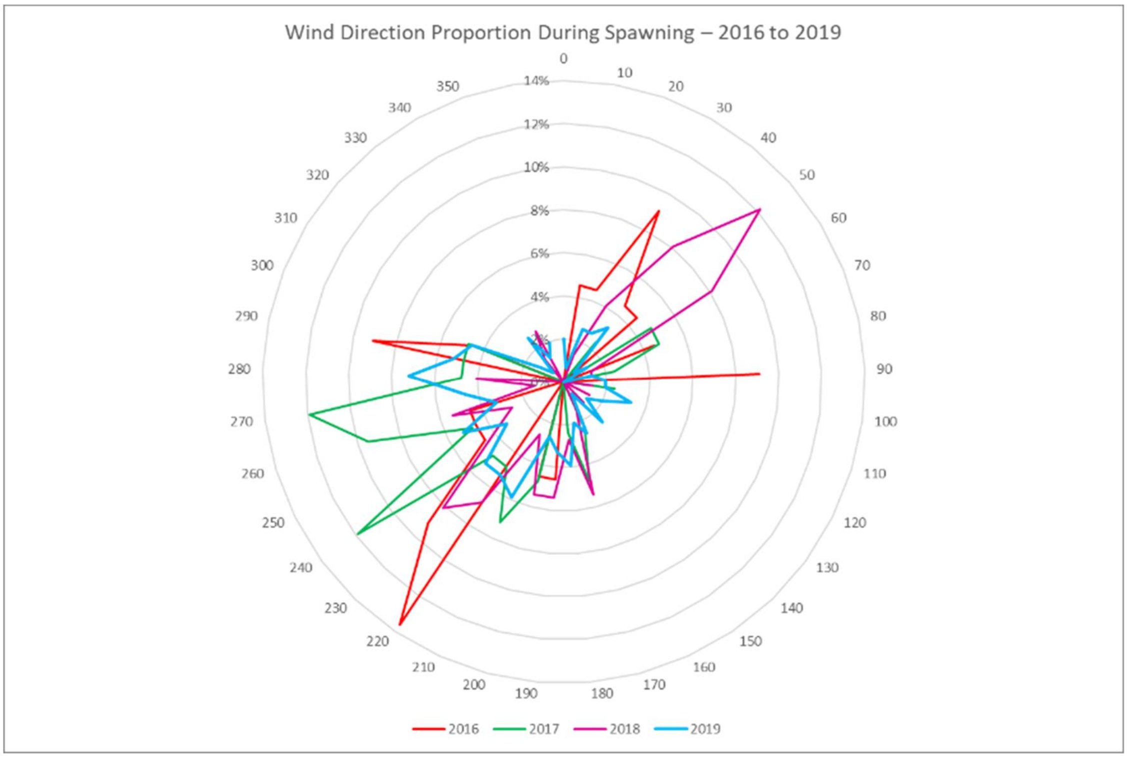
**Figure 37: Larvae age proportion variations from 2015 to 2019**




An analysis of wind direction at the Met Buoy M5 appears very polarised in 2016, 2017 and 2018, which could have influenced larvae dispersal during those years with west and southwest winds driving larvae offshore in the Irish Sea and northeast winds sending larvae in a southerly direction. In comparison, 2019 wind directions appear to be more variable and evenly distributed (with a slight prevalence of southwest winds) which could have helped retaining larvae closer to coast, possibly explaining higher number of larvae in 2019 in comparison with previous years (see figure 38).

Considering that previous reports have shown no relationship between larvae numbers and seed mussel tonnage found, the graphs comparing estimated tonnage and seed settlement areas with larvae numbers are now being removed from the larvae monitoring reports.

### Figure 38: Wind Direction (in percentage) at the Met Buoy M5 during spawning periods since 2016



## Discussion:

2019 has seen the number of mussel larvae recorded at each station increased in comparison with 2018. Although no distinctive or replicated patterns have been observed since 2015, this monitoring program has given a great insight into the variations and the factors influencing larvae population dynamics along the east coast of Ireland.

The extended CI and sea temperature monitoring have shown that for the past two years, it is likely that there are multiple possible spawning events on the east coast (Wexford Harbour and Malahide). Water temperature and salinity are significant factors influencing maturation of brood stock and spawning periods. Gonad squashes analysis is giving more reliable evidence about the stage of maturation of the mussels; however, this requires more time and regular access to mussel samples. Also, a library of various features observed under the microscope needs to be established so that analysis can be carried out with more confidence. Indeed, it could be difficult to precisely differentiate between certain stages of maturation for the untrained eye.

The bulk of the larvae population across the various stations in 2019 appears to have been later than previous years. Nevertheless, some seed mussel settlements were already well developed by then. It clearly indicates that the larval population and seed mussel beds at a similar location have a minimal connection. Although in the case of the Rusk Channel settlement in 2019, it possible to hypothesise that part of the settlement was produced by larvae observed in the area, this would correlate with various publications about the importance of conspecifics (i.e. other mussels) for spat secondary settlement (Bayne, 1964; R. Seed, 1969).
It is worth noting, also, that less and less young larvae are being caught in our sampling; there was no 1-week old larvae observed in 2019 and very little 1 to 2 weeks old. It needs to be investigated by using a smaller mesh size net and timing this sampling session with possible spawning events. It also appears that wind direction and speed is a potentially significant factor of larvae dispersal. The polarisation of wind direction from 2016 to 2018 was not replicated in 2019. It could explain a higher level of larvae retention in coastal waters.

The various deployments of GPS drifters indicate that mussel settlements in the Rusk Channel and the Cahore Point area, are not likely to be coming from larvae emitted from Wexford Harbour but instead, from a more local source, possibly around Blackwater Point. Considering the drifter track deployed along the Arklow Bank, it would be worth investigating for possible mussel brood stock in the area as close as possible to the wind turbine as the acoustic surveys of the shoulders of the bank didn't show any patterns of mussel aggregations.

In 2020, it is planned to carry out an extensive survey timed with a possible spawning event from the Wexford Harbour brood stock. Drifters will be deployed at a different time from the Wexford Bar to assess the effect of local tidal currents. At least, one ADCP will be deployed in the location to compare currents within the water column and their potential effect on larvae dispersion. Larvae are known for vertical migration depending on their age (Sprung, 1984; Blanton *et al.*, 1995; Pulfrich, 1996). Multiple sampling stations will be established within the location and sampling will be carried out at a various time during the day. Temperature and salinity readings will be collected for each vertical tow. Finally, it is planned to deployed settlement samplers at strategic locations along the east coast so that vertical distribution can also be assessed.

## Acknowledgements

BIM wish to thank all of those involved in the sampling and analysis without whom this report could not have been produced.

## Appendix:

- Calculation methods
- Age population Graphs
- Wind graphs
- Sampling Logging Sheet
- References

**Appendix 1:** The numbers of larvae per $m^3$ from a sample site were calculated using the formula $\pi r^2 h$ to obtain the volume of water sampled through a plankton net (where $\pi = 3.14159$, $r^2$ = radius of the net squared and h = height of water/ distance the net was towed through the water column). A further calculation was then undertaken to consider the portion of the sample analysed in relation to the overall volume of sample water collected.

**Appendix 2:** The meat yield or condition index (C.I.) calculation used in these studies was based on the following calculation:

$$\frac{\text{Cooked meat weight}}{\text{Total Wet Weight}} \times 100 = \text{percentage meat yield or condition index}$$

A preferred method from a statistical analysis perspective is:

$$\frac{\text{Cooked meat weight}}{\text{Cooked meat weight + Shell Weight}} \times 100 = \text{percentage meat yield or condition index}$$

**(see Davenport and Chen 1987)**

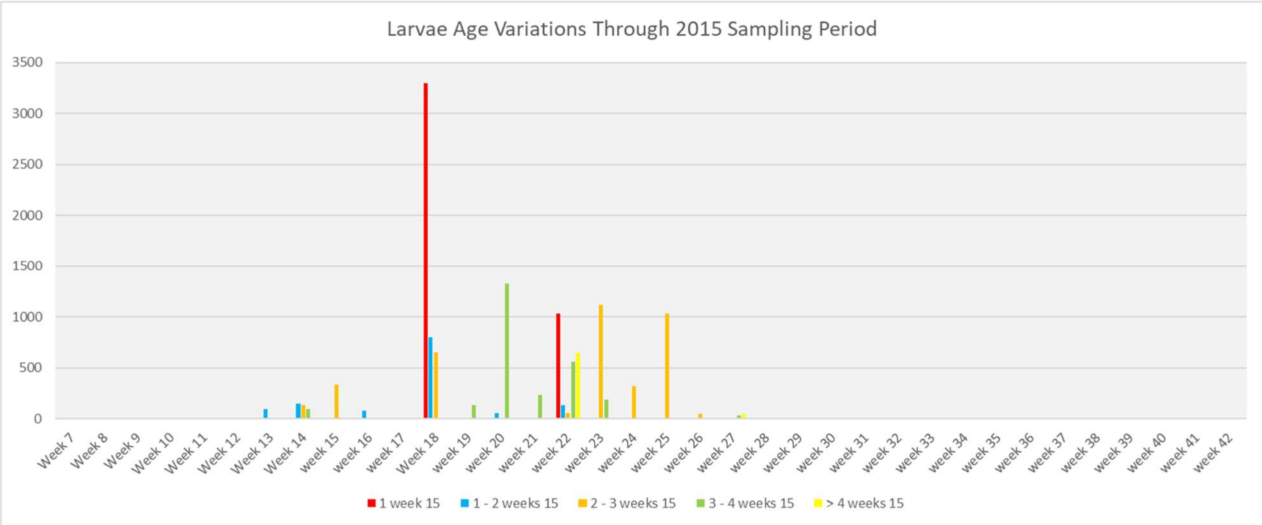
This methodology is "unaffected by prior freezing of samples" and involves the most easily measured parameters, shell weight and cooked meat weight (Davenport and Chen, 1987).

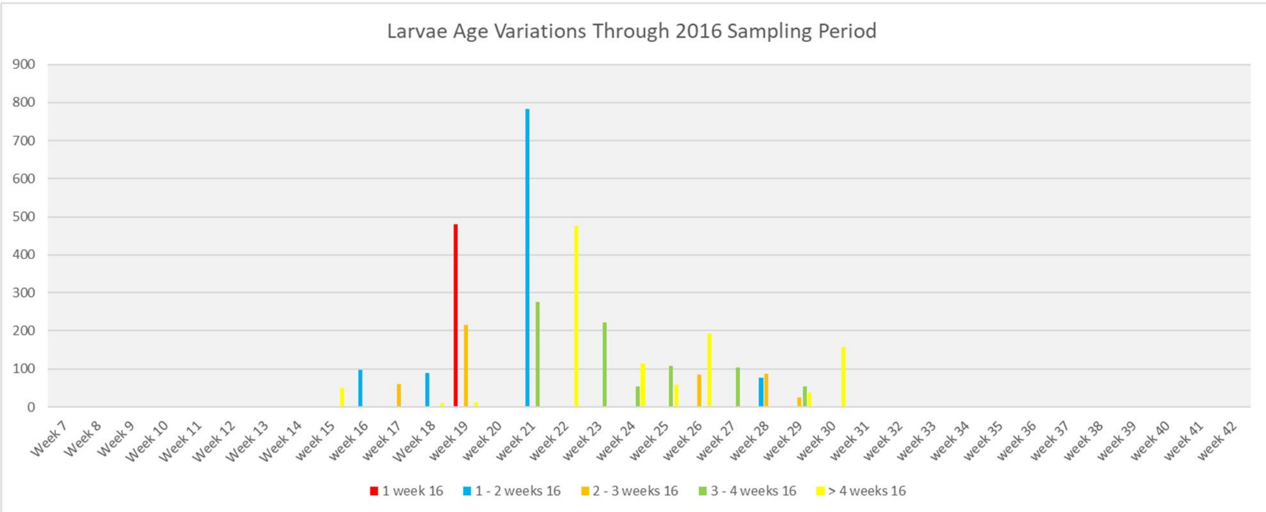
**Appendix 3:** Mussel maturation assessment scale as described in (Chipperfield, 1953; King, McGrath and Gosling, 1989).

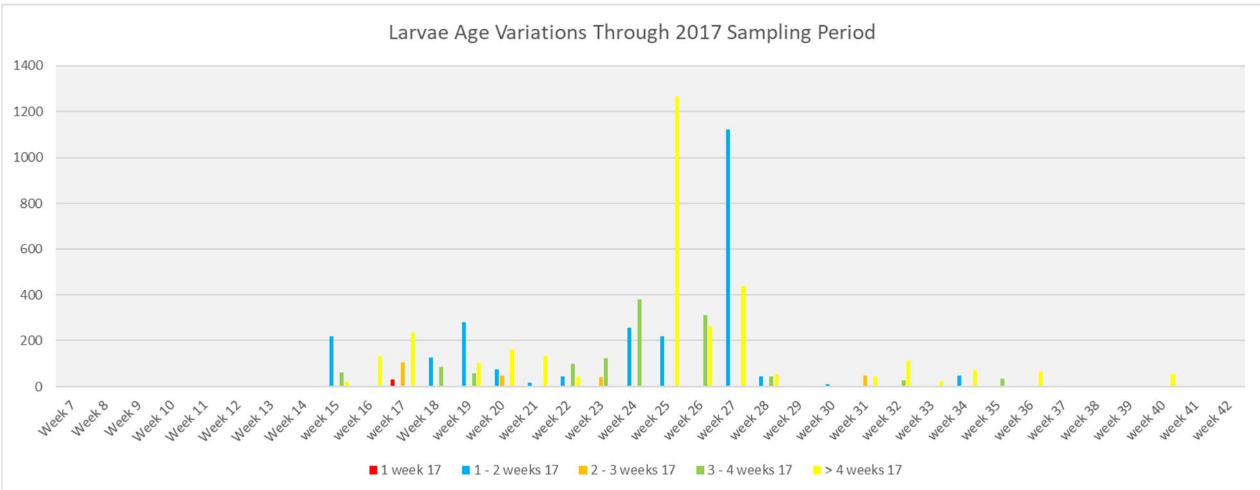
| Category | Description |
|---|---|
| 0 (Resting) | Mantle thin and transparent or relatively thick and opaque depending on fat reserves. Smooth appearance. Genital ducts obliterated by the growth of connective tissue. No traces of sexuality. |
| 1 (Immature) | Mantle thin and relatively transparent. Follicles are distinguishable as small opaque areas within brownish mantle in case of females and orange in case of males. |
| 2/3C (Developing / Redeveloping) | Mantle relatively thick and opaque. Male mantle brownish ground colour almost obscured by opaque follicles. Some active sperm. Female mantle orange. Oocytes (45-69 um) arranged loosely in follicles. |
| 3A (Ripe) | Mantle extremely thick and opaque. Mass of gonad higher than stage 2. Very little connective tissue seen between follicles. The male mantle is milky white and full of active sperm. Female mantle apricot colour due entirely to colour of oocytes (63-79 um) which now lie packed tightly together in the follicles. |
| 3B (Spawning) | Mantle relatively thick but general reduction in density of gametes. Appearance of empty spaces. |
| 3D (Spent) | Mantle semi-transparent. Only a few residual gametes remaining in the follicles. Amoebocytes visible. |

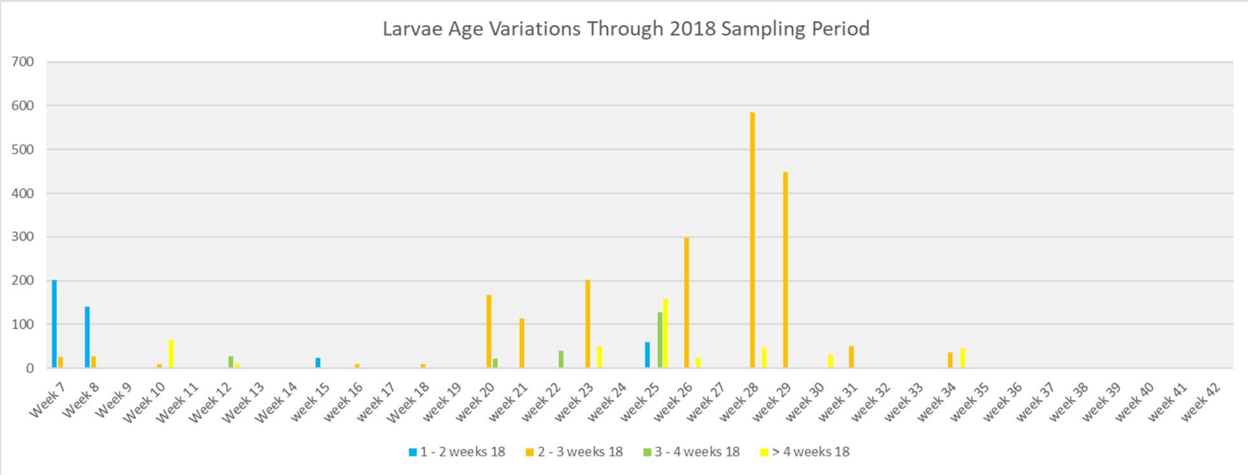
## Appendix 4

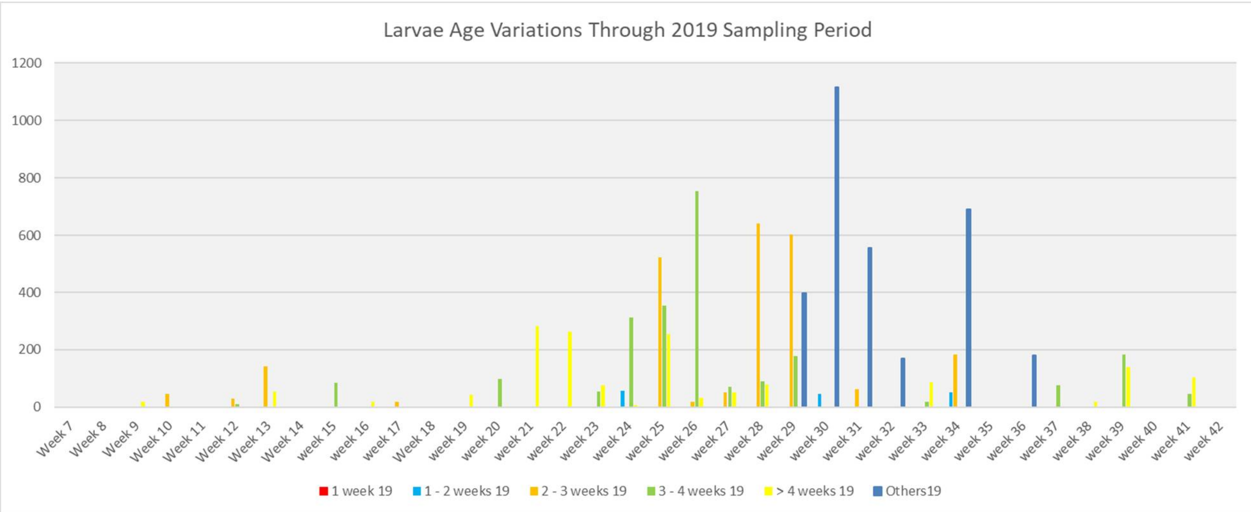
## Larvae age variations since 2015



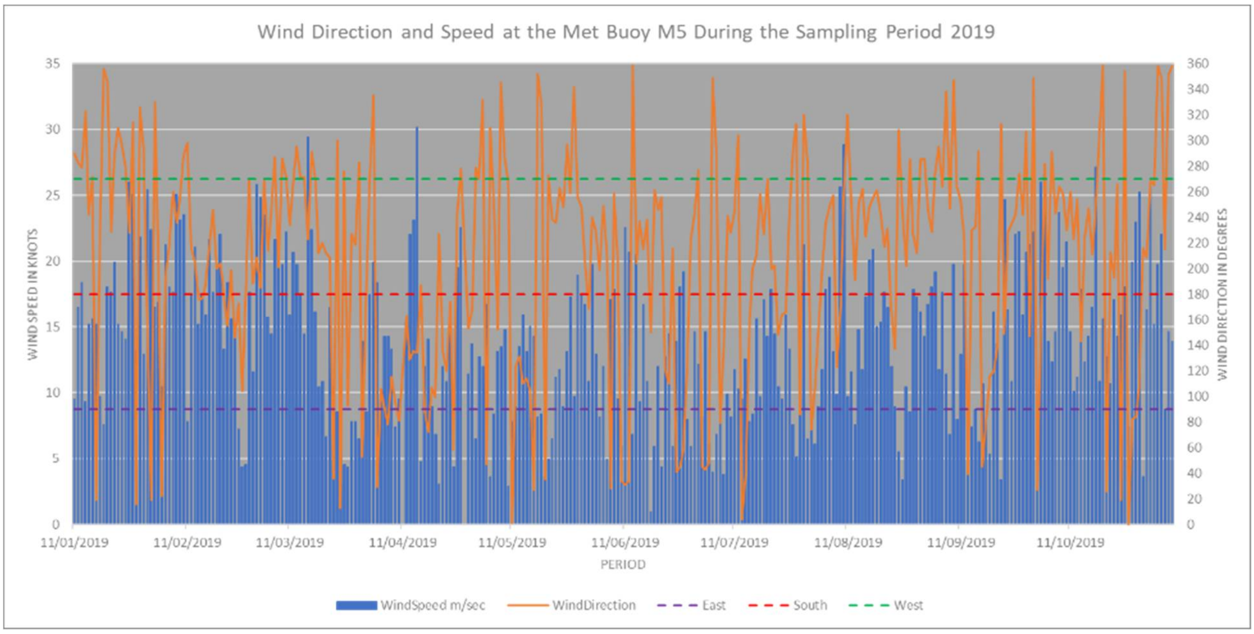



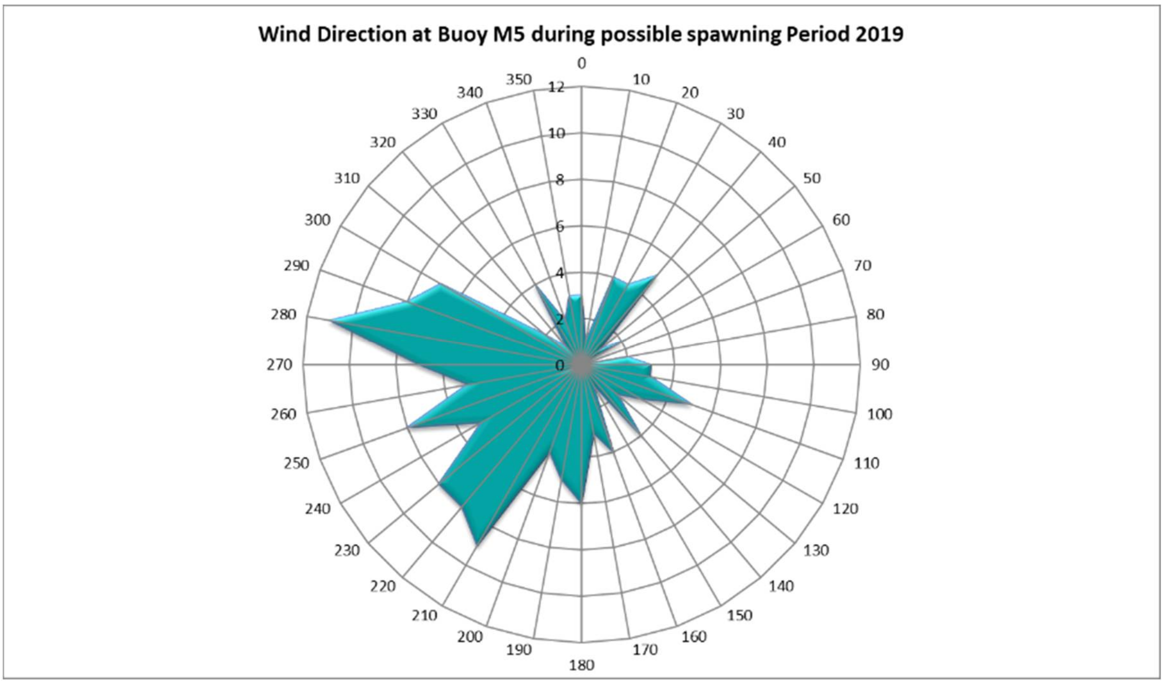



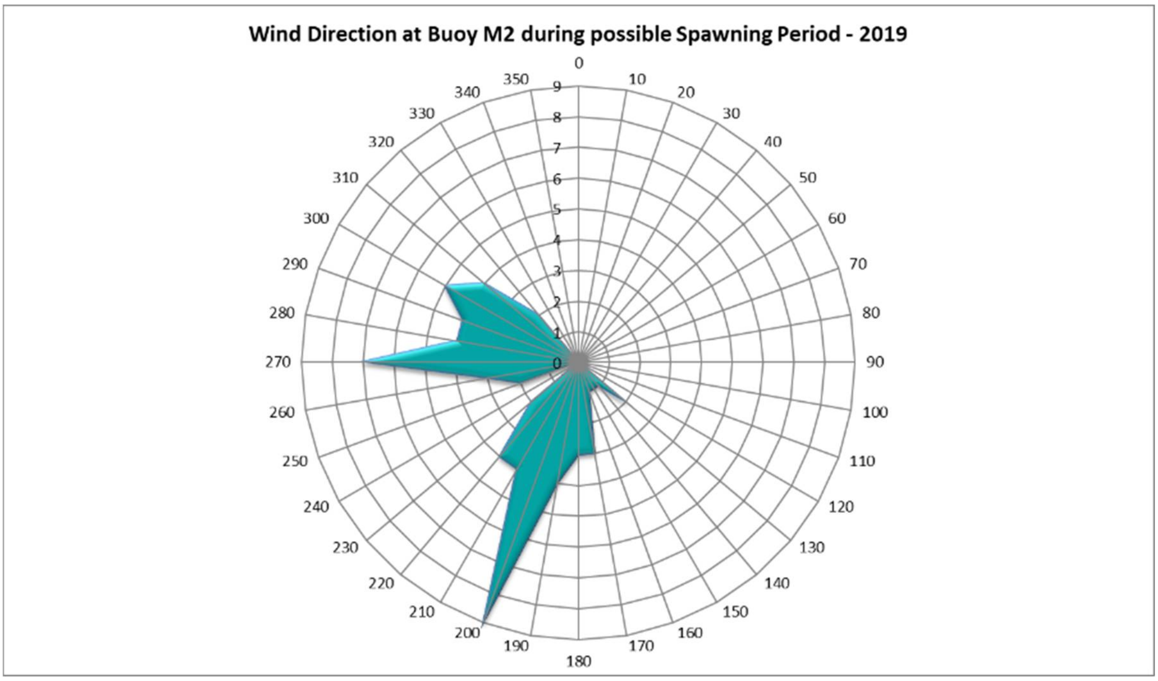


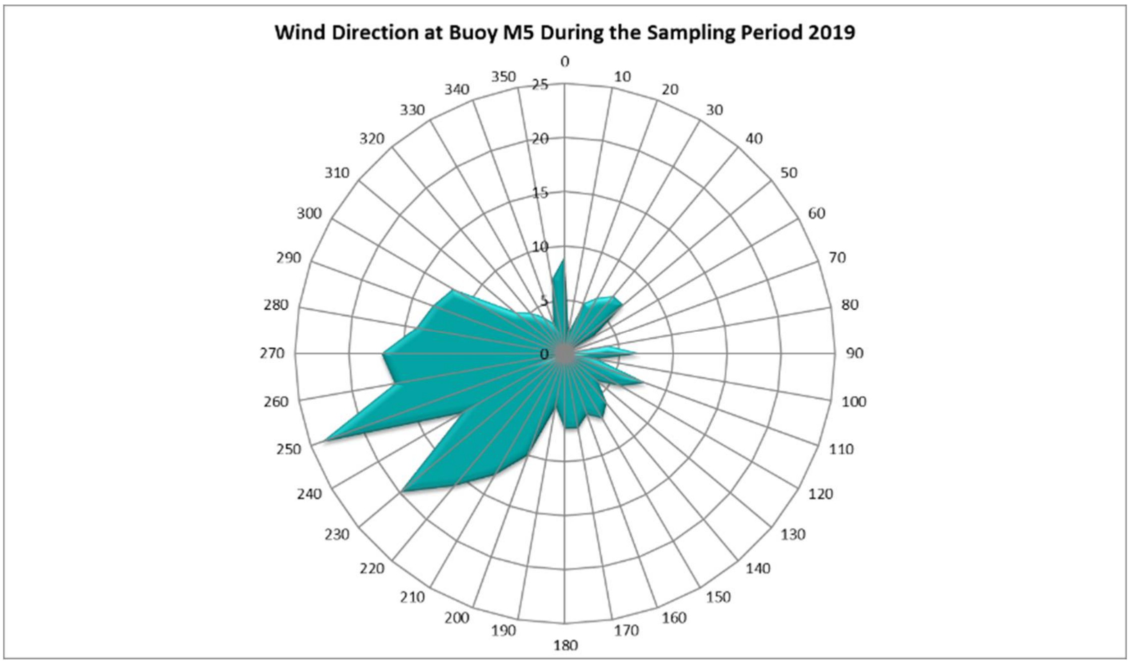



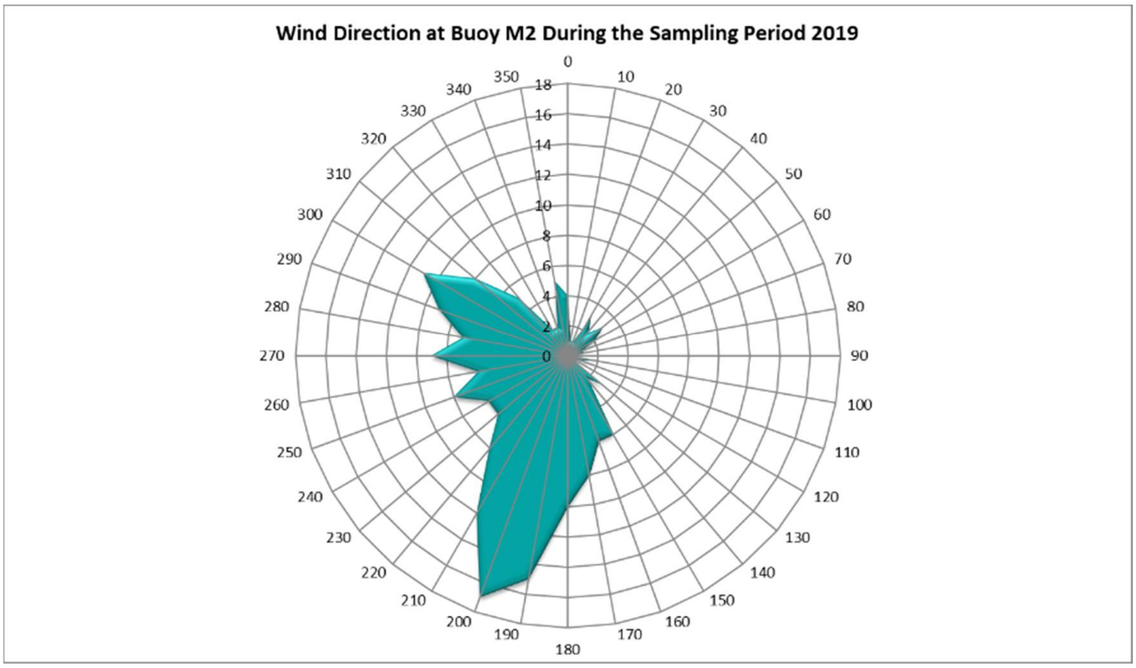

## Wind speed and direction at Met Buoy M5 and M2 during the monitoring program

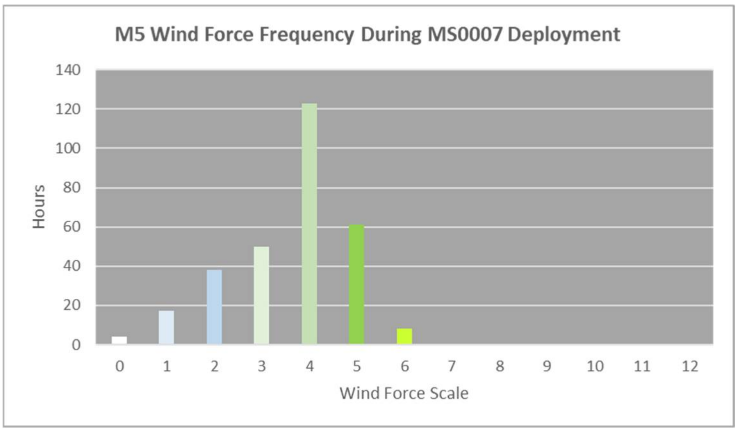


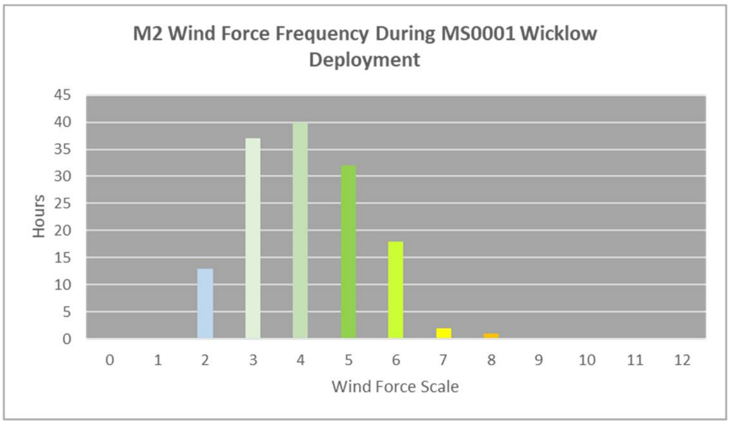

Wind Direction at Buoy M5 during possible spawning Period 2019
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
0
2
4
6
8
10
12

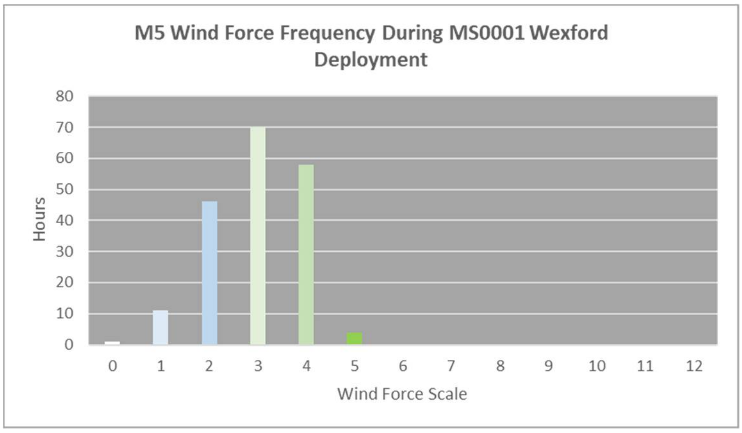

Wind Direction at Buoy M2 during possible Spawning Period - 2019
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
0
1
2
3
4
5
6
7
8
9

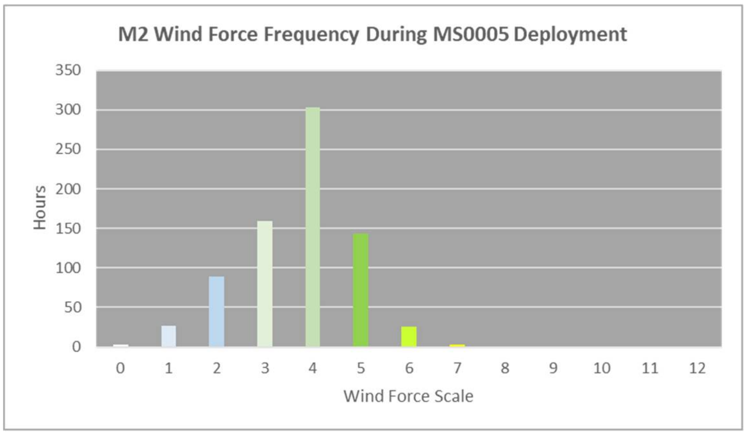

Wind Direction at Buoy M5 During the Sampling Period 2019
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
25
20
15
10
5
0


Wind Direction at Buoy M2 During the Sampling Period 2019
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
18
16
14
12
10
8
6
4
2
0


M5 Wind Force Frequency During MS0007 Deployment
Hours
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Wind Force Scale


M2 Wind Force Frequency During MS0001 Wicklow Deployment
Hours
45
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Wind Force Scale


M5 Wind Force Frequency During MS0001 Wexford Deployment
Hours
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Wind Force Scale


M2 Wind Force Frequency During MS0005 Deployment
Hours
350
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Wind Force Scale

| Week | Code | Tide | Weather | Depth of the net | Sea Conditions | time | Date | Arrival | Water temperature | salinty | Spat/m3 | Larvae stage/age | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CR1 | | | | | | | | | | | | |
| | WX1 | | | | | | | | | | | | |
| Week 7 | CH1 | | | | | | | | | | | | |
| | WW1 | slack | fresh SW | 6m | choppy | 15:00 | 14/02/2019 | | 5.2 | 29 | 0 | na | (12M 5C) High organic particulatre type debris but good preservation.Odonatella species moderate, Coscinodiscus species low.Low vertebrate egg type content, Low phyto cell content in general. |
| | ND1 | | | | | | | | | | | | |
| | CR2 | | | | | | | | | | | | |
| | WX2 | | | | | | | | | | | | |
| Week 8 | CH2 | | | | | | | | | | | | |
| | WW2 | slack | Strong SW | 6 m | choppy | 15:00 | 21/02/2019 | | 8 | 32 | 0 | na | High organic debris, too high Iodine, Coscinodiscus, sand, barnacles low |
| | ND2 | | | | | | | | | | | | |
| spawn 1 | CR3 | | | 5m | | | 25/2/19-3/3/19 | | | | 28 | 2-3 weeks | Too much Iodine, low debris, NB sample not net type- non concentrated sample, some Odontella, low Skeltonemia |
| | WX3 | 1 kt N | 5 kts W | 14.2 m | calm | 15:00 | 28/02/2019 | | 10.1 | 32.1 | 0 | na | High Coscinoduscus bloom, some sand, low Copepods, v.low zooplankton ,med organic debris - peaty |
| Week 9 | CH3 | 1.5 kt S | 5 kts SW | 14.5 m | calm | 20:25 | 28/02/2019 | | 9.5 | 33.4 | 19 | 4-6 weeks | Med debris,high Coscinodiscus bloom wailessi,v few zooplankton, low debris, Odentella |
| | WW3 | 0.5 kt S | calm | 6m | calm | 09:00 | 28/02/2019 | | 8 | 30.7 | 0 | na | High mixed Coscinodiscus Wailessi dominant, v low Copepods |
| | ND3 | | | 5m | | | 4/3/19-10/3/19 | | 10.1 | 20.5 | 0 | na | not net type sample. low level debris, no Copepods, zero Zooplankton, some Skeltonema |
| | CR4 | | | | | | | | | | | | |
| | WX4 | 0.5 kt S | 30 kts W | 14.5 m | choppy | 16:10 | 07/03/2019 | | 8.9 | 32.9 | 0 | na | Med organic debris, high mixed Coscinodiscus bloom - Wailessi dominant, sand, few Copepods ,low Odontella, sea matting low. |
| Week 10 | CH4 | slack | 40 kts W | 14.8 m | rough | 10:10 | 07/03/2019 | | 9 | 33.4 | 47 | 2-3 weeks | High Coscinodiscus bloom - Wailessi dom., Tube worm moderate, barnacles+ zooplankton low few Copepods, med debris, some sand. |
| | WW4 | slack | NW fresh | 6 m | choppy | 14:00 | 06/02/2019 | | 8 | 30.7 | 0 | na | Coscinodiscus wailesii bloom , peaty organic debris, sand, v few Copepods.low Odonatella sp. |
| | ND4 | | | | | | | | | | | | |
| | CR5 | 1 kt S | SW 5 to 6 | | choppy | | 11/03/2019 | | 9.6 | 20.4 | | | |
| | WX5 | | | | | | | | | | | | |
| Week 11 | CH5 | | | | | | | | | | | | |
| | WW5 | 1 kt S | Fresh W | 6m | choppy | 15:00 | 15/03/2019 | | 8 | 30 | 0 | na | 10m depth on sample, Arklow,High Coscinodiscus bloom, low debris, Copepods, low Zooplankton |
| | ND5 | | | | | | | | | | | | |
| | CR6 | 0.5 kt S | SW 20 kmh | 5m | calm | 13:00 | 19/03/2019 | | 10.4 | 7.2 | 0 | na | High debris, no Zooplankton. Navicula + Pennatediatoms, bottom bounce, not net type,Asterionellopsis |
| Possible spawn | WX6 | 0.5 kt S | 20 kts SW | 14 m | choppy | 14:10 | 19/03/2019 | | 9.1 | 32.7 | 0 | na | High debris, Coscinodiscus bloom, Odontella, sand Copepods, 2 bi-valve (not D type) larvae, low Barnacles |
| Week 12 | CH6 | 0.5 kt N | 10 kts SW | 15.1m | calm | 07:35 | 19/03/2019 | | 8.7 | 33.8 | 30 | 2-3 weeks | High debris,high mixed Coscinodiscus bloom, Copepods, 3 bi-valve (not d larvae0, Low Zooplankton |
| | WW6 | 1 kt N | Fresh SW | 6 m (net) | choppy | 15:00 | 21/03/2019 | | 8 | 29.7 | 0 | na | Arklow, High debris. Excessive Coscinodiscuss bloom- Wailessi dominant, sand. No Copepods or Zooplankton. |
| | ND6 | 1 kt N | F5 W | 14 m | choppy | 12:21 | 24/03/2019 | | 8.3 | 32 | 10 | 3-4 weeks | High Coscinodiscusbloom -Walilessi dominant, high Odontella, Ceratium, minor sand, low debris, few Copepods, too much iodine. |
| | CR7 | slack | 2 kts SW | 5 m | calm | 11:18 | 25/03/2019 | | 10.2 | 28.4 | 0 | na | Sample states 22.5 Salinity, Not net type,too much Iodine, extremely low all, 3/4 Navicula |
| | WX7 | 0.5 kt N | 10 kts NE | 14.2 m | calm | 15:30 | 30/03/2019 | | 10.3 | 32.6 | 31 | 4_6 weeks | Odontella bloom Asterionellopsis,Cosinodiscus, Copepods Med debris,sand, sea matting larvae |
| Week 13 | CH7 | 1 kt S | 5 kts W | 14.6 m | calm | 08:20 | 30/03/2019 | | 9.5 | 32.6 | 142 | 2-3 weeks | Odontella bloom, med Coscinodiscus bloom, med debris,sand, Copepods, 2 bi-valve larvae, high Phaeocystis, low barnacles |
| | WW7 | 1 kt S | calm | 6 m (net) | calm | 16:00 | 27/03/2019 | | 8.5 | 28.2 | 23 | 4-6 weeks | High Coscodiscus Bloom, Odontella, Med Debris, sand Sea Matting |
| | ND7 | | | | | | | | | | | | |
| | CR8 | 0.5 kt N | 12 km/h E | 5 m | calm | | 08/04/2019 | | 11 | 24.9 | 0 | na | Too much Iodine, Not net sample, very lowPhyto, No zoo[plankton, Thalassosira, Cyanobacteria, 8.8 deg on sample |
| | WX8 | 1 kt S | 5 kts NE | 14.4 m | calm | 14:50 | 05/04/2019 | | 9.1 | 33.6 | 0 | na | very heavy debris, Sand, Copepods,little or no Iodine, High Odontella, Hit bottom tyupe? |
| Week 14 | CH8 | 1.5 kt N | 10 kts NE | 15 m | choppy | 09:45 | 05/04/2019 | | 8.6 | 33.8 | | | REJECTED Mud, no preservation |
| | WW8 | slack (LW) | East light | 10 m (net) | calm | 11:00 | 05/04/2019 | | 9 | 29.8 | 0 | na | High organic debris, Coscinodiscus bloom, low Odontella bloom, sand, suspect plastic, few Copepods, no preservative |
| | ND8 | slack (LW) | E 3 | 7 m | choppy | 07:30 | 08/04/2019 | | 9 | 31.6 | 0 | na | High Coscinodiscus,Coperpods, Odontella, Ceratium, med high sand, squirts + preservation issue |
| | CR9 | | | 5?m | | | 8/4/19-14/4/19 | | | 26.4 | 0 | na | Not net type,Very little of anything,Too high Iodine,Chateo-socialis moderate |
| | WX9 | | | 15.1 | | | 8/4/19-14/4/19 | | 9.8 | 33 | 57 | 2-4 weeks | sand, Copepods, Coscinodiscus, Odentella, Med debris, low Zooplankton |
| Week15 | CH9 | | | 14.6M | | | 8/4/14-14/4/19 | | 9.4 | 33.6 | 0 | na | Med Coscinodiscus bloom Wailessi, High debris, sand, Odontella, Copepods, excess organic material,low zooplankton, hifh Rhizo |
| | WW9 | slack (LW) | ESE light | 6 m (net) | calm | | 11/04/2019 | | 9 | 30.1 | 28 | 2-4 weeks | Coscinodiscus bloom Wailessa, |
| | ND9 | | | | | | | | | | | | |
| | CR10 | | | 5M | | | 15/4/19-21/4/19 | | 9.8 | 24.3 | 0 | na | High debris, Too much preservative, No Copepods, Minimal zooplankton, Asterionellopsis high Not net type. |
| | WX10 | 1 kt S | calm | 13.6m | calm | 16:45 | 20/04/2019 | | 10.4 | 33.1 | 20 | 4-6 weeks | High sand, Copepods, Low Coscinodiscus,Odontella, Barnacles high,Pollen,, Crab larvae |
| Week 16 | CH10 | 2 kts N | calm | 15.4 m | calm | 08:35 | 20/04/2019 | | 10 | 33.4 | 0 | na | Reject. Excessive sand, preservation issue, Copepods, Coscinodiscus |
| | WW10 | 1 kt N | Light | 6 m (net) | calm | 16:00 | 20/04/2019 | | | 29.9 | | | |
| | ND10 | 1 kt S | E 2 | 13m | calm | 16:00 | 19/04/2019 | | 10.7 | 31 | 0 | na | Med Coscinodiscus bloom, sand, Odontella,Copepods, Tubeworm, Ceratium, Rhizo high, good sample re no Phaeocystis |
| | CR11 | | | 5M | | | 22/4/19-28/4/19 | | 10.2 | 23.9 | 0 | na | Too much preservative, no zooplankton, low debris, high Phaeocystis |
| | WX 11 | slack | 10 kts S | 14 m | calm | 13:45 | 28/04/2019 | | 10.5 | 33.3 | 0 | na | Med debris, Copepods, sand, Odontella, cysts, sea matting, poss bivalve not "d" larvae |
| Week 17 | CH 11 | 1kt N | 5 kts S | 14.3 m | calm | 12:35 | 28/04/2019 | | 10.2 | 33.6 | 0 | na | Phyto type sample, Phaeocystis, very high Odontella, high Barnacles, Copepods, med debris, sand, Coscindoscus, no preservative |
| | WW 11 | slack (ebb) | SW strong | 6m (net) | choppy | 14:00 | 25/04/2019 | | 10.5 | 30.5 | 0 | na | sand, Coscinodiscus, few Odontellaor Copepods, high Phaeocystis, some micro plastic suspects, no preservative. |
| | ND 11 | 1 kt N | sw 4 | 15 m | choppy | 14:54 | 26/04/2019 | | 10.2 | 32.1 | 19 | 2-3 weeks | Med Coscinodiscus bloom, Copepods, Sand, Protoperidinium, Ceratium, high Phaeocystis, Odontells |
| | CR 12 | 0.5 kt W | SW 15 kmh | 5 m | calm | | 30/04/2019 | | 10.2 | 28.4 | 0 | na | Not net type, too much preservation, low diatoms ie Rhizo, little zooplankton |
| spawn | WX 12 | 1 kt S | calm | 14.2 | calm | 13:00 | 01/05/2019 | | 10.9 | 33.2 | 0 | na | High sand, Copepods, Odontella, Phaeocystis, med debris, low seamatting, not typical net sample |
| Week 18 | CH 12 | 1 kt N | 10 kts NW | 14.7 | calm | 07:10 | 01/05/2019 | | 10.2 | 33.8 | 0 | na | organic type debris,Barnacles, sand, V high Phaeocystis, Copepods, Odontella, Coscinodiscus, bad preservation |
| | WW12 | 1 kt S | calm | 11.5 | calm | 09:00 | 02/05/2019 | | 10.7 | 30.7 | 0 | na | No preservative,sand, Coscinodiscus, Low zooplankton, high Phaeocystis. |
| | ND 12 | 1 kt S | 3 W | 13.7 | calm | 14:30 | 02/05/2019 | | 11 | 31.6 | 0 | na | Coscinoscus bloom, Copepods, Sand, High Phaeocystis, Protoperidinium. Low preservation. |
| | CR13 | slack (HW) | N 20 kmh | 7 | calm | 12:10 | 12/05/2019 | | 10.6 | 28.2 | | | |
| | WX13 | 1.5 kt S | light | 14.3 | calm | 07:20 | 12/05/2019 | | 10.9 | 33.6 | 19 | 5-6 weeks | sand, Phaeocystis high bloom, Coscinodiscus,, v little zooplankton, barnacles. NOTE see note in CH13 |
| Week 19 | CH13 | 1 kt N | light | 14.8 | calm | 14:30 | 12/05/2019 | | 11.6 | 33.5 | 0 | na | Sand, low Coscinodiscus,, Copepods, low Odontells, Matting, V High Phaeocystis, Preservation issue. NOTE : Depth, Temp and Salinity should relate to WX13 |
| | WW13 | 1 kt N | SE light | 6 | calm | 08:00 | 10/05/2019 | | 10.4 | 30.9 | 24 | 5-6 weeks | No preservative, excessive organic debris, sand, Phaeosystis excessive, Odontells |
| | ND13 | 1 kt N | 3 Easterly | 15.2 | calm | 12:50 | 09/05/2019 | | 9.8 | 32.2 | 0 | na | ceratium, High Phaeocystis, Sand, Coscinodiscus, Copepods, Protoperidinium, Odontella, Noctoluca |
| | CR14 | | | 5M | | | 13/5/19-19/5/19 | | 10.6 | 28.2 | 0 | na | 1 Copepod, V Low all zooplankton, too much preservative. Sample not like proper net type. |
| | WX14 | 1.5 kt S | 10 kts NE | 13.6 | choppy | 14:25 | 19/05/2019 | | 12.2 | 33.3 | 71 | 3-4 weeks | Sand, Copepods, Coscinodiscus, Phaeocystis bloom, Tubeworm, Barnacles, bad preservation |
| Week 20 | CH14 | 2 kts N | 10 kts NW | 15.3 | calm | 07:40 | 19/05/2019 | | 11.2 | 33.5 | 28 | 3-4 weeks | Tubeworm, Excessive Phaeocystis, organic material, Barnacles, low Copepods, Odontella, bad preservation. |
| | WW14 | slack(LW) | SE light | 6 (net) | calm | | 17/05/2019 | | 10.8 | 33.9 | 0 | na | Debris, Odontella, Coscinoscus, Tubeworm, Phaeocystis, Preservation issue |
| | ND14 | | | | | | | | | | | | |
| | CR15 | | | | | | | | | | | | |
| | WX15 | 1 kt S | 5 kts S | 14.3 | calm | 12:25 | 24/05/2019 | | 12.9 | 32.7 | 20 | 4-6 weeks | Sand, Low Copepods/Tubeworm, Excessive high Phaeocystis bloom, Preservation issue |
| Week 21 | CH15 | 1.5 kt S | 5 kts NW | 14.5 | calm | 07:20 | 24/05/2019 | | 12.3 | 32.9 | 0 | na | sand, Phaeocystis excessive bloom, Copepods,Coscinodiscus, Odontella, Tubeworm/Barnacles low, bad presentation |
| | WW15 | 1 kt N | light | 8 | calm | 08:00 | 23/05/2019 | | 11 | 30.6 | 0 | na | med debris,high Rhizosolenia,, Tubeworm, Ceratium, Copepods,Odontella, 1 "d" larvae not mussel, nice mix |
| | ND15 | 1 kt S | E 2 | 14.4 | calm | 07:00 | 25/05/2019 | | 12.3 | 31.5 | 263 | 202 4-6 weeks | 61 @ 6 weeks+, Noctiluca bloom, Rhizo bloom, Phaeocystis, high Copepods, Low second spp Echinoderms, excessive Iodine |
| | CR16 | | | | | | | | | | | | |
| | WX16 | | | | | | | | | | | | |
| Week 22 | CH16 | | | | | | | | | | | | |
| | WW16 | Slack (LW) | SW strong | 6 | choppy | 17:30 | 30/05/2019 | | 12.6 | 30.2 | 0 | na | High Rhizo, Copepods, high organic debris, high Tubeworm, bad preservation, Odontella low, 1 non mussel D larvae |
| | ND 16 | 1 kt N | Southerly 4 | 14.6 | choppy | 06:30 | 29/05/2019 | | 11.6 | 32.3 | 264 | 95% 4-6 weeks | 5% 6 weeks +. Rhizsolenia bloom, Phaeocystis bloom, Urchin/Starfish high,Excessive Iodine, Tubeworm high, Seamatting, Noctaluca. |
| | CR17 | | | | | | | | | | | | |
| | WX17 | | | 14.2 | | | | | 13.5 | 33.1 | 30 | 3-4 weeks | V high Copepods, high organic material, Barnacles, few Tubeworm,, V low Diatoms, Phaeocystis, bad preservation. |
| Week 23 | CH17 | | | 15.3 | | | 3/6/19-9/6/19 | | 13.4 | 33.6 | 66 | 3-5 weeks | Sand, Copepods, Coscinodiscus, Odontell |
| | WW17 | 1 kt N | Strong SW | 6 | choppy | 08:50 | 07/06/2019 | | 14 | 29.7 | 24 | 3-4 weeks | High Copepods,High Organic debris, low preservation,Rhizo, Odontella, mod Tubeworms |
| | ND17 | 2 kts S | calm | 13.7 | calm | 07:00 | 03/06/2019 | | 11.6 | 32.3 | 10 | 4-6 weeks | Excessive Rhizosolenia bloom,Low Noctaluca, excessive Iodine, Echinoderms |
| | CR18 | | | | | | | | | | | | |
| | WX18 | 0.5 S | 25 kts Southerly | 14.6 | choppy | 13:10 | 14/06/2019 | | 13.6 | 33 | 66 | 57 1-2 weeks | 9 @ 5-6 weeks, High debris, mod Seasquirts, v low Copepods, sand, tubeworm |
| Week 24 | CH18 | 0.5 N | 5 kts Southerly | 14.9 | calm | 07:45 | 14/06/2019 | | 12.6 | 33.3 | 273 | 2-4 weeks | Odontella low,Escessive Rhizo, high Debris, bad preservation, high Copepods, mod second species bivalve. |
| | WW18 | 1 N | Fresh SW | 6 | choppy | | 15/06/2019 | | 13.6 | 30 | 38 | 3-4 weeks | High organic debris, Rhizo and Pennate diatoms high, lowCoscinodiscus, high Copepods. |
| | ND18 | | | | | | | | | | | | |
| | CR19 | | | | | | | | | | | | |
| | WX19 | slack | 10 kts southerly | 14 | calm | 13:25 | 21/06/2019 | | 14.6 | 33 | 0 | na | V high scale/flake debris, Low Copepods, Low Tubeworm, some Barnacles + Crab larvae low to moderate. |
| Week 25 | CH19 | 1.5 N | calm | 15.1 | calm | 10:55 | 21/06/2019 | | 13.7 | 33 | 254 | 5-6 weeks | Sand, Copepods,Debris, V.high Rhizosolenia + Diatoms, Preservation issue |
| | WW19 | 1 N | light | 6 | calm | 20:20 | 20/06/2019 | | 16.3 | 28.7 | 523 | 2-4 weeks | Copepods, Rhizo bloom, Sand, Coscinodiscus, Underpreserved, 2nd bivalve species |
| | ND19 | 0.5 S | Southerly 3 | 13.7 | calm | 07:00 | 22/06/2019 | | 12.7 | 32.3 | 353 | 3-5 weeks | Noctaluca bloom, Preservation issue, sand, Rhizo bloom, Ceratium, Echinoderms, Protoperidinium. low second species "D" |
| | CR20 | | | | | | | | | | | | |
| | WX20 | 0.5 S | 10 kts southerly | 15 | calm | 13:40 | 29/06/2019 | | 15.8 | 32.6 | 19 | 2-3 weeks | Sand, high Copepods, low Plankton, high Zooplankton, Tubeworm, Bivalve other species |
| Week 26 | CH20 | slack | calm | 14.8 | calm | 07:55 | 29/06/2019 | | 14.6 | 32.8 | 679 | 2-4 weeks | Underpreserved,sea matting, Copepods, Rhizo,sand, Tubeworm |
| | WW20 | | SE light | 6 | calm | 09:00 | 29/06/2019 | | 16.2 | 29.2 | 0 | na | Sand, V high Rhizo, few Copepods, Coscinodiscus |
| | ND20 | slack | east 4 | 12.8 | choppy | 12:15 | 27/06/2019 | | 14.8 | 30.8 | 76 | 3 - 4 weeks | 33 @ 5-6 Weeks.Too much Iodine, Low Tubeworm, Noctaluca Bloom,low Copepods, Ceratium low, Rhizo bloom, Protoperidium |
| | CR21 | | | | | | | | | | | | |
| | WX21 | 0.5 N | calm | 14.9 | calm | 12:35 | 06/07/2019 | | 16.1 | 32.9 | 57 | | Sand, Copepods, Protoperidinium,Tubeworm, Rhizo. Not enough preservative. |
| week 27 | CH21 | 0.5 S | 10 kts W | 14.6 | cal, | 07:10 | 06/07/2019 | | 15.9 | 32.7 | 53 | 2-3 weeks | 53 4-6 Weeks, Sand, Copepods, Rhizo,high Tubeworm, Protoperidinium,Coscinodiscus, Echinoderm |
| | WW21 | slack (ebb) | calm | 6 | calm | 16:00 | 04/07/2019 | | 16.6 | 29 | 71 | 3-4 weeks | Sand, Rhizo bloom, med debris,Copepods, Cosinodiscus,Tubeworm, insuffficient preservative |
| | ND21 | 1 kt s | westerly 4 | 13.7 | calm | 07:00 | 06/07/2019 | | 15.9 | 30.9 | | | Too much Iodine to see anything properly,Sand,Echinoderms, excessive Rhizo bloom, Tubeworm |
| | CR22 | | | | | | | | | | | | |
| | WX22 | slack | 10 kts NW | 15.2 | calm | 12:35 | 12/07/2019 | | 16.2 | 32.7 | 226 | 2-3 weeks | 57 4-6weeks, Sand, Copepods, Tubeworm, high Diatoms, good sample of mix. |
| week 28 | CH22 | 0.5 kt S | 20 kts NW | 15 | choppy | 07:30 | 12/07/2019 | | 15.3 | 32.5 | 90 | 3-4 weeks | 23 5-6 weeks, Copepods, Rhizo bloom,Tubeworm, Protoperidinium,Needs more Iodine |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WW22 | 1 kt N | calm | 6 | calm | 17:00 | 12/07/2019 | | 16.6 | 29.2 | 416 | 2-4 weeks | Tubeworm, Copepods, Coscinodiscus, Rhizo bloom,Ceratium, Sand, mod Zooplankton, V bad Preservation. |
| | ND22 | | | | | | | | | | | | |
| | CR23 | | | | | | | | | | | | |
| | WX23 | 0.5 kt S | 5 kts W | 14.5 | calm | 14:50 | 20/07/2019 | | 16.8 | 32.6 | 179 | 3-4 weeks | Sand Copepods, Rhizo, Tubeworm, bad preservation |
| Week 29 | CH23 | slack | 10 kts W | 14.5 | calm | 13:15 | 20/07/2019 | | 16.5 | 32.4 | 604 | 2-4 weeks | Copepods, Sand, excessive Rhizo, Tubeworm, Coscinodiscus, Protoperidinium, bad Preservation |
| | WW23 | slack | calm | 9 | calm | 18:30 | 18/07/2019 | | 16.8 | 29.9 | 396 | | Copepods, sand, Tubeworm, Coscinodiscus, Protoperidinium. Half full sample. |
| | ND23 | | | | | | | | | | | | |
| | CR24 | | | | | | | | | | | | |
| | WX24 | 0.5 N | 10 kts S | 14.5 | calm | 13:35 | 27/07/2019 | | 17.9 | 32.7 | 47 | 1-3 weeks | Copepods, Tubeworm, Echinoderms, Rhizo, low to moderate content |
| Week 30 | CH24 | slack | calm | 14.5 | calm | 12:00 | 27/07/2019 | | 16.6 | 32.8 | 896 | | Tubeworm, Copepods, Protoperidinium, Ceratium, sand, second specied "d" larvae |
| | WW24 | 1 kt S | SE moderate | 10 | calm | 20:00 | 24/07/2019 | | 16.8 | 29.8 | 91 | | Sand, debris, Copepods, Coscinodiscus, Tubeworm (17M on bottle) |
| | ND24 | 0.5 N | W 3 | 12.8 | calm | 07:00 | 27/07/2019 | | 15.3 | 32.2 | 130 | | Sand, too much Iodine, Prtotoperidinium,Ceratium, Noctaluca, Copepods, Tubeworm, Coscinodiscus, Echinoderms |
| | CR25 | | | | | | | | | | | | |
| | WX25 | 1.5 kt E | 5 kts E | 14.5 | calm | 13:50 | 01/08/2019 | | 17.5 | 32.8 | 60 | | Sand, Copepods, Tubeworm, Protoperidium, Ceratium |
| Week 31 | CH25 | 0.5 S | 5 kts NE | 14.5 | calm | 11:35 | 01/08/2019 | | 16.8 | 32.9 | 519 | | Copepods, Tubeworm, Sand, Protoperidinium, Ceratium |
| | WW25 | | SW light | 9 | calm | 12:00 | 31/07/2019 | | 17.5 | 30.5 | 63 | 2-4 weeks | No Preservation, Sand, Copepods, Debris, Coscinodiscus, |
| | ND25 | 0.5 S | E 2 | 12 | calm | 07:00 | 03/08/2019 | | 15.7 | 31.5 | 38 | | Excessive Iodine, Noctaluca, Echinoderms, Copepods, Odontella,Rhizo, sand, debris, Ceratium |
| | CR26 | | | | | | | | | | | | |
| | WX26 | 1 N | 10 KTS e | 14.5 | choppy | 13:35 | 08/08/2019 | | 17.3 | 32.7 | | | |
| Week32 | CH26 | 1 S | 5 kts E | 14.5 | calm | 07:30 | 08/08/2019 | | 16.8 | 32.8 | 169 | | Sand, Tubeworm, Coscinodiscus, Copepods |
| | WW26 | slack | SW light | 9 | calm | 14:00 | 10/08/2019 | | 17.6 | 30.5 | | | |
| | ND26 | | | | | | | | | | | | |
| | CR27 | | | | | | | | | | | | |
| | WX27 | 1 S | 10 kts NW | 14.5 | calm | 13:40 | 15/08/2019 | | 17.2 | 32.6 | 20 | 3-5 weeks | V high sand, no Preservative,V. low phyto, barnacle larvae low, difficult to analyse. |
| week33 | CH27 | | | | | | | | | | | | |
| | WW27 | 1 N | Southerly 4 | 7 | choppy | 14:00 | 14/08/2019 | | 17.3 | 30.3 | 0 | na | debris, V.High Copepods, |
| | ND27 | 0.5 N | Southerly 4 | 12.8 | choppy | 07:15 | 14/08/2019 | | 15.5 | 32 | 87 | 5-6 weeks + | Too much preservative, Odontella, Noctaluca, Copopods, Sand, Tubeworm, Cervatium. Low all - more like straight Phyto and not net sample. |
| | CR28 | | | | | | | | | | | | |
| | WX28 | 0.5 N | calm | 14.5 | calm | 12:00 | 25/08/2019 | | 17.2 | 32.4 | 30 | | High Copepods, Ceratium, sand, HighTubeworm, med debris, Protoperidinium, Mod Rhizo, pollen, Crab and Barnacle larvae low. No preservative |
| week34 | CH28 | 1 S | calm | 14.5 | calm | 07:20 | 25/08/2019 | | 16.6 | 32.5 | 182 | 2-3 weeks 80% | 2nd species moderate. Sand, Copepods no preservative, Tubeworm, high Odontella, Coscinodiscus |
| | WW28 | Slack (ebb) | calm | 6 | calm | 16:00 | 23/08/2019 | | 17.1 | 30.5 | 53 | 1-3 weeks | Sand, excessive Copepods, no preservative,, excess debris, Coscinodiscus, Odontella. |
| | ND28 | 0.5 S | SW 4 | 13 | choppy | 07:30 | 19/08/2019 | | 14.7 | 32.8 | 660 | | Noctaluca, Coscinodiscus, too much Iodine, Copepods, Ceratium, Odontella, Sand, Echinoderms, Tubeworm, Eucampia |
| | CR29 | | | | | | | | | | | | |
| | WX29 | | | | | | | | | | | | |
| Week35 | CH29 | | | | | | | | | | | | |
| | WW29 | Slack (ebb) | light W | 10 | calm | 17:30 | 28/08/2019 | | 17.2 | 30.3 | 0 | na | Sand, high Copepods, Tubeworm, med debris, Coscinodiscus, no Preservative, high Pollen, low Odontella |
| | ND29 | | | | | | | | | | | | |
| | CR30 | | | | | | | | | | | | |
| | WX30 | slack | 20 kts SW | 14.5 | choppy | 13:25 | 02/09/2019 | | 16.7 | 32.7 | 180 | | No preservative, Copepods, sand, Ceratium |
| Week36 | CH30 | 2 N | 10 kts W | 14.5 | calm | 09:00 | 02/09/2019 | | 16.1 | 32.8 | 0 | na | no Preservative, excessive debris, sand, organic debris, rejected |
| | WW30 | Slack (ebb) | Fresh West | 16 | choppy | 14:00 | 05/09/2019 | | 16.9 | 30.6 | 0 | na | Sand, no preservative, Copepods, Coscinodiscus, Odonatella,tubeworm |
| | ND30 | 1.5 kt S | | 14.2 | | 15:30 | 07/09/2019 | | 15.3 | 31 | | | |
| | CR31 | | | | | | | | | | | | |
| | WX31 | | | | | | | | | | | | |
| Week37 | CH31 | | | | | | | | | | | | |
| | WW31 | 1 kt N | Strong SW | 8 | choppy | 14:00 | 12/09/2019 | | 16.3 | 20.9 | | | |
| | ND31 | | calm | 12.8 | calm | 06:45 | 14/09/2019 | | | | 76 | 3 - weeks | Noctaluca, mixed Odontella bloom, high biomass, too much Iodine Copepods, sand |
| | CR32 | | | | | | | | | | | | |
| | WX32 | slack | 20 kts SW | 14.5 | choppy | 13:25 | 19/09/2019 | | 16.7 | 32.7 | 19 | 3 - 5 weeks | Copepods, high Tubeworm, Ceratium,sand, no preservative, low Phyto, Mod Zooplankton |
| Week38 | CH32 | 2 kts N | 10 kts W | 14.5 | calm | 09:00 | 19/09/2019 | | 16.1 | 32.8 | | | |
| | WW32 | 1 kt S | light variable | 6 | calm | 17:00 | 18/09/2019 | | 16 | 30.5 | | | |
| | ND32 | | | | | | | | | | | | |
| | CR33 | | | | | | | | | | | | |
| | WX33 | 1 S | 10 kts SW | 14.5 | choppy | 13:15 | 25/09/2019 | | 16.2 | 32.8 | 104 | 3 - 4 weeks 85% | 15% 5 - 6 weeks, sand v.high tubeworm,Copepods, Odontella v.low Phyto |
| Week39 | CH33 | 0.5 S | 10 kts W | 14.5 | calm | 07:25 | 25/09/2019 | | 16 | 33 | 95 | 4 - 6 weeks | Guinardia,high zooplankton, sand copepods, high Odontella, Coscinodiscus |
| | WW33 | 1 kt N | light SW | 6 | calm | 11:30 | 26/09/2019 | | 16 | 30.5 | 94 | 3 -4 weeks | No preservative, sand,copepods, heavy debris, Coscinodiscus,Odontella. Sample is Rejectable |
| | ND33 | 1 kt N | light SW | 14.8 | calm | 06:30 | 25/09/2019 | | | | 28 | 3 - 4 weeks | Too much Iodine,Odontella bloom, Copepods, Ceratium, Sand, Tubeworm, Coscinodiscus, Heavy debris |
| | CR34 | | | | | | | | | | | | |
| | WX34 | | | | | | | | | | | | |
| Week40 | CH34 | | | | | | | | | | | | |
| | WW34 | Slack (ebb) | light SW | 6 | calm | 12:00 | 5/10/2019 | | 15 | 30.7 | | | |
| | ND34 | | | | | | | | | | | | |
| | CR35 | | | | | | | | | | | | |
| | WX35 | 1.5 S | 10 kts SW | 14.5 | choppy | 14:10 | 12/10/2019 | | 14.3 | 32.4 | 38 | 4 - 6 weeks | V heavy sand, Tubeworm, Copepods, excessive debris |
| Week41 | CH35 | 1 N | 10 kts SW | 14.5 | calm | 08:40 | 12/10/2019 | | 14.6 | 33 | 66 | 3 - 5 weeks | Low second species, sand copepods, pollen, barnacles. |
| | WW35 | | SW fresh to strong | 6 | choppy | 16:00 | 9/10/2019 | | 14.8 | 30.6 | 47 | 3 - 4 weeks | med debris, sand, copepods, Tubeworm, Coscinodiscus, excessive Odonatella spp |
| | ND35 | | | | | | | | | | | | |

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