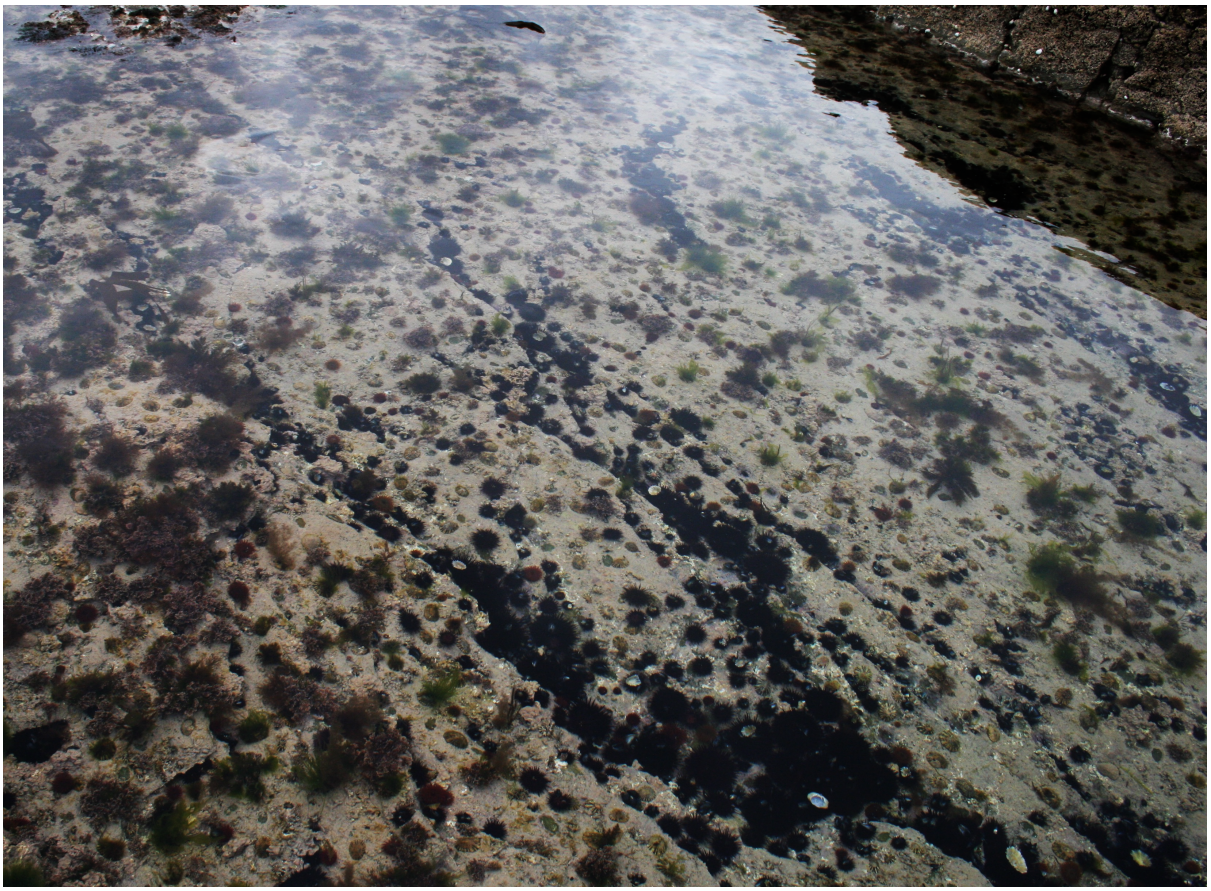
Restocking and ranching of the purple sea urchin *Paracentrotus lividus* on the west coast of Ireland



Deliverable T3.1.1 SME Report

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URCHIN
Utilising the Arctic Urchin Resource

Northern Periphery and Arctic Programme
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Introduction

The valuable European purple sea urchin *Paracentrotus lividus* (Lamarck, 1816) is gregarious by nature and inhabits intertidal rock pools or in aggregations in the sublittoral (Paredes and Bellas, 2013; Hefferenan, 1999; Moylan 1997). *P. lividus* has an extensive geographical range from Morocco to the eastern Mediterranean, French, Spanish, Portuguese and Irish west coasts and the outlying island of western Scotland (Lawrence and Lawrence, 2014).

The most northern limit to their geographic range seems to be determined by a minimum sea temperature of 8°C in February (Le Gall, 1989). *P. lividus* is fished, harvested and cultured for their high quality roe (Cook *et al*., 2007). *P. lividus* is algivorous by nature but has been known to utilise animal proteins (Cook et al., 2007). Sea urchins are dioecious and can be identified as male or female at spawning induction, however no external differences between the sexes can be seen (Hannon et al., 2015). Fertilisation is external and fertlisied eggs hatch into swimming veliger larvae during their planktonic stage and become settled post larvae during their benthic stage (Rahman *et al*., 2014), the benthic stage is brought along when the swimming larvae become competent, these competent larvae are sensitive to chemical signals in the water column and are induced to settle by these chemical signals or induction cues (Hannon *et al*., 2014; Ohshiro *et al*., 1999; Takahashi & Koganezawa, 1988).

Sea urchin fisheries have been in a state of flux since the mid 1990s following the collapse of several large-scale commercial fisheries (Johnson *et al*., 2012) and the entrance of new suppliers such as Chile and Russia (Gibson *et al*., 2016) partially filled the market and in some cases reduced the market price for some sea urchin species.
Declining fisheries and wild stocks due to not imposing fisheries controls and management in time (Gibson *et al*., 2016), the culture of some of the more valuable species of sea urchins has been investigated on a large to commercial scale in some regions (Lawrence & Lawrence, 2014).

Fishery

Extensive extractive fisheries have existed for *P. lividus* in most countries where the species is endemic, the fishery is primarily conducted by hand collection in the intertidal zone or by divers using self-contained underwater breathing apparatus (SCUBA) (Johnson *et al*., 2012, Heffernan, 1999). In some regions of France, it has been possible to harvest sea *P. lividus* by dredging which caused the near extinction of the species on the coasts of Brittany, where the only reported areas that *P. lividus* remain are on outlying exposed reefs (Guillou & Lumingas, 1998, Southward & Southward, 1976). Contrary to the experience with *P. lividus* dredging in Brittany the green sea urchin *Strongylocentrotus droebachiensis* is extensively fished in Iceland by means of dredging with limited impact to biomass in fished regions (James *et. al.*, 2016). For more information on fishing and harvesting techniques for sea urchins refer to James et. al., (2016)

Examples of urchin fishery protection in Europe

Since the establishment of a fishery in the 1960s for *P. lividus* in Ireland through the 30 years of the fishery there has been no government imposed regulation on catch or effort on the industry before, during or after the collapse of the fishery in the mid 1990s'(Gibson *et al*., 2003). The only regulation applied to the fishery in Ireland is applied by the market which dictates a minimum test diameter size of 50mm. There is no closed season, fishing activity ceases when the harvesters and buyers can no longer transport the sea urchins without risk of them spawning in transit to market.

The Mediterranean island of Sardinia imposes fisheries protection on its endemic population of *P. lividus*, fishing season is between 1st November until April 30th with a total allowable catch of 3000 sea urchins per day per fisherman with a minimum test size of 50mm. Harvesting is not allowed on Mondays and each fisherman must maintain personal log book for daily fishing records. In other Italian regions, there are similar rules in Sicily and Puglia (Pers. Comms. Dr Piero Addis). Examples like these could be applied to existing fisheries in Europe if the background stock assessment is carried out. Limited fisheries protection has been afforded to sea urchins and including other echinoderms which means uncontrolled and unmanaged fisheries has led to the near collapse of some regional stock of this species in Europe.

Market

In Europe, the main export market for *P. lividus* harvested in Ireland and continental Europe is in Paris, other regional local markets exist however, these local markets do not accept the same metric volume of sea urchins. The market demands a minimum test diameter of 50mm other than this there is limited control of catch sizes imposed by fisheries managers, for further information on the market for sea urchins in Europe refer to the URCHIN projects publication Stefánsson *et. al*., (2017)

Reseeding of over harvested sites

The culture of specific species of sea urchins is well documented from hatchery to on-growing (Lawrence, 2006). However, the use of ranching as a mean of aquaculture for the European purple sea urchin *P. lividus* has not been extensively investigated. The aim of this study along with fulfilling deliverable T3.1.1 (SME Report) is to investigate the possibility of using hatchery reared *P. lividus* as a means of restocking areas which have been overfished in the past.

Significant tonnage of sea urchins were harvested from the intertidal zone on the West and South-West coasts of Ireland between the 1970 and the mid 1990s' which in effect decimated the fishery and has never recovered (Lawrence and Lawrence, 2014). This can be linked directly with the collapse of the fishery in Brittany in the late 1960s when fishery began in Ireland shortly after.

Significant areas were overfished during this period and due to low recruitment, stocks in these areas never returned to what was once witnessed. With the decline of sea urchin harvests in Ireland the culture of the species was investigate in Ireland since the mid 1990s with the establishment of one of the worlds longest running sea urchin hatcheries Dunmanus Seafoods Ltd.

As part of the URCHIN Project Dunmanus Seafoods Ltd were contracted to produce juvenile sea urchins (*P. lividus*) between 15-20mm in test diameter for reseeding at two licensed sites on the west coast of Ireland. The two selected sites for reseeding were Purteen Harbour on Achill Island, Co. Mayo and Mullaghmore Co. Sligo. Both sites were re-seeded with project associated partners Treanbeg Shellfish Ltd and Mullaghmore Seafarm Ltd respectively.

Both sites were exposed, high energy sites with significant water movement. Previously both sites were completely harvested out by fishermen during the 1990s' with little or no recovery.

Site selection

Initially four proposed sites for re-seeding activities were identified in conjunction with associated partners In Co. Donegal, Co. Sligo, Co. Mayo and Co. Galway. The criteria for site selection was specific to the needs and nature of the sea urchin. Sites must have previously been recorded as optimal harvest sites by harvesters, must contain some adult sea urchins and have a ready supply of storm cast kelp and seaweeds. *P. lividus* primarily feeds on seaweed from outside of the rock pool which is carried into the pool by strong tides or storm cast weed.

Arranmore Island, Co. Donegal

Sites on the Island were surveyed in January 2016 with associated partner Mr Seamus Bonner of the Arranmore Development & Employment Co-Op. Site surveys were conducted at low water on spring tides however no sea urchins or sea urchin harvest sites were located on the intertidal surveys. No sites were selected on Arranmore for seeding due to a lack of endemic sea urchins or favorable condition.

Burtonport on the mainland opposite Arranmore Island had reported sea urchin harvesting taking place however no reports of sea urchins been harvest from Arranmore from either fish buyers or fishermen. Form all accounts *P. lividus* did not exist in numbers worth harvesting if they were there at all.

Figure 1. Section of the caost line on Arranmore Island, Co. Donegal where intertidal surveys for sea urchin reseeding sites.

Mullaghmore, Co. Sligo

Two sites were selected in Mullaghmore, Co. Sligo with associated partner Mr Philip Waters of Mullaghmore Seafarm Ltd who are sea urchins and shellfish buyers. Both sites extremely tidal and can be reached at low water tides during neaps and springs as the rock pools are located quite high on the inter-tidal zone. Outside of the rock pool system there are reef breaks which supply the pools with sufficient quantities of fresh seaweed. The rock pool systems are located on a low sloping exposed rocky shoreline.

Figure 2. One of the rock pools re-seeded at Mullaghmore, Co. Sligo. In the figure, wild sea urchins can be seen where they have pitted the limestone. Some of the rock pool system was covered with the invasive macroalgae *Sargassum* Spp.

Purteen Harbor, Achill Island, Co. Mayo

Site selection on Achill Island was located on the west side of the island located beside Purteen harbor. This site was selected in conjunction with associated partner Mr Fergal Guilfoyle of Treanbeg Shellfish Ltd. This is known commercially overharvested site on the island and contains one of the only standing stocks of harvestable sea urchins on the island.

The site is extremely exposed and very low on the inter-tidal zone very close to the level of the lowest astronomical tide (LAT). The rock pool systems are supplied with storm cast seaweed and are only uncovered by tide during low water springs. The rock pools are uncovered for only 1-2 hours during low water springs. This site was selected as part of the re-seeding program due to the ideal location with respect to the selection criteria.

Figure 3. the above figures are images of the re-seeding site at Purteen on Achill Island, Co. Mayo.

Figure 4. One of the rock pools at the Errislannan peninsula Connemara.

Errislannan, Ballyconneely, Connemara, Co. Galway

This is a known overharvested site on the Western edge of Connemara. The site is extremely exposed to rough sea conditions and weather. This site contains a large quantity of market sized wild sea urchins. This site was not selected as this site had been reseeded previously and currently doesn't have the space or carrying capacity for quantities of juvenile sea urchins.

Juvenile Production & Methods

For reseeding efforts to begin juvenile sea urchins needed to be produced with a test diameter of 15-20mm before they could be placed out in the rock pool systems in the different locations. Previous reseeding efforts carried out By Mr John Chamberlain of Dunmanus Seafoods Ltd recommended they the juvenile sea urchins must be 15mm and over in test diameter before they can be seeded out due to predation (Pers Comms. Mr John Chamberlain).

Juvenile *P. lividus* were produced at the commercial sea urchin hatchery of Dunmanus Seafoods Ltd, West Cork, Ireland as part of the URCHIN project. Adult brood stock were selected and induced to spawn via injection of KCl into the celomic cavity as described in Hannon *et al*., (2015). Once male and female gametes have been collected fertilisation was then followed by hatched swimming larvae 24 hours later. Swimming, feeding larvae were reared through all larva stages up until competency prior to transfer to settlement tanks when the larvae are ready to settle and metamorphose into post larval sea urchins.

Figure 5. (Left) eggs been collected from female sea urchins, (Right) Male sea urchin releasing sperm

Figure 6. Post larval sea urchins settled on PVC settlement plate at Dunmanus Seafoods Ltd.

Post larval sea urchins were then reared in settlement tanks until a maximum of 7mm when their encrusting macroalgal diet (*Ulvella lens*) becomes growth limiting. Once weaned onto soft red, green and brown macroalgae the juvenile sea urchins are transferred into a cone tank system for on-growing prior to grading and transfer to sea.

Figure 7. Juvenile sea urchins transferred to the cone tank on-growing system at Dunmanus Seafoods Ltd.

Under advice from Dunmanus Seafoods grading of the juvenile sea urchins was carried out to remove all undersized sea urchins (<15mm in test diameter) as these animals would be predated upon this is based on direct experience (Pers. Comms. Mr John Chamberlain). The sea urchins would also be more capable of successfully attaching themselves to suitable substrates.

Figure 8. Juvenile sea urchins been hand graded at Dunmanus Seafoods. Plastic 15mm oyster mesh was used as a grading table to remove all smaller sized sea urchins. Sea urchins cannot be mechanically graded like other shellfish as they cling to each other and their surroundings.

Re-seeding

The total amount of sea urchins graded was approximately 20,000 with 10,000 to be transferred to each site. The transfer of juvenile sea urchins to the re-seeding sites calm sea and low water springs were required before the animals could be transferred from Dunmanus Seafoods in West Cork to the sites Purteen on Achill Island (424Km) and Mullaghmore in Co. Sligo (433Km) Respectively. This was carried out over different days due to the large distances involved. Sea urchins were packed in 10kg polystyrene boxes with fresh seaweed and gel ice blocks to keep the boxes cool on the transfer. Sea urchins were out of water for no more than 7 hours at the upmost and the sea urchins were directly transferred from the on-growing tanks to the rock pool sites with the least amount of handling as possible which can cause undue stress to the animals.

The seeded-out juveniles were measured periodically when both sea, weather and tidal conditions suited as both sites are exposed to rough unpredictable sea conditions at times. Weight (g) and test diameter (mm) measurements were taken on site along with abundance measurements for estimation of stocking density, survival and predation where possible. Considerable care was used when removing sea urchins from the rockpool trying not to damage the spines, test or tubefeet. This care was repeated when returning them to where they were removed from.

Results

Juvenile sea urchins were initially reseeded after grading in July 2016 to their designated ranching sites in Mullaghmore Co. Sligo and Purteen on Achill Island Co. Mayo. The mean initial test diameter of the juveniles seeded out at both sites was 18.7mm (±0.69) and the mean initial weight of 3.1g (±0.27) respectively. Positive increase in test diameter (mm) and weight (g) can be seen in all figures below.

Survival was measured by abundance which considers declining numbers due to predation and possible mechanical mortality form storms and the exposed nature of the sites. Due to the cryptic nature of juvenile sea urchins in particular, *P. lividus* accurate estimations of stocking density were difficult to measure as once the urchins were seeded out they began to move into new space and occupy crevices and the underneath of boulders in the rockpools. The estimation of known numbers of sea urchins for Achill Island was an estimated 65% survival and for Mullaghmore Co. Sligo which showed slightly lower survival of 60%. These survival estimations of the ranched sea urchins on both sites which correlate with previous studies based on the size or the juveniles seeded out (Britz, 2005, Brown & Eddy, 2015).

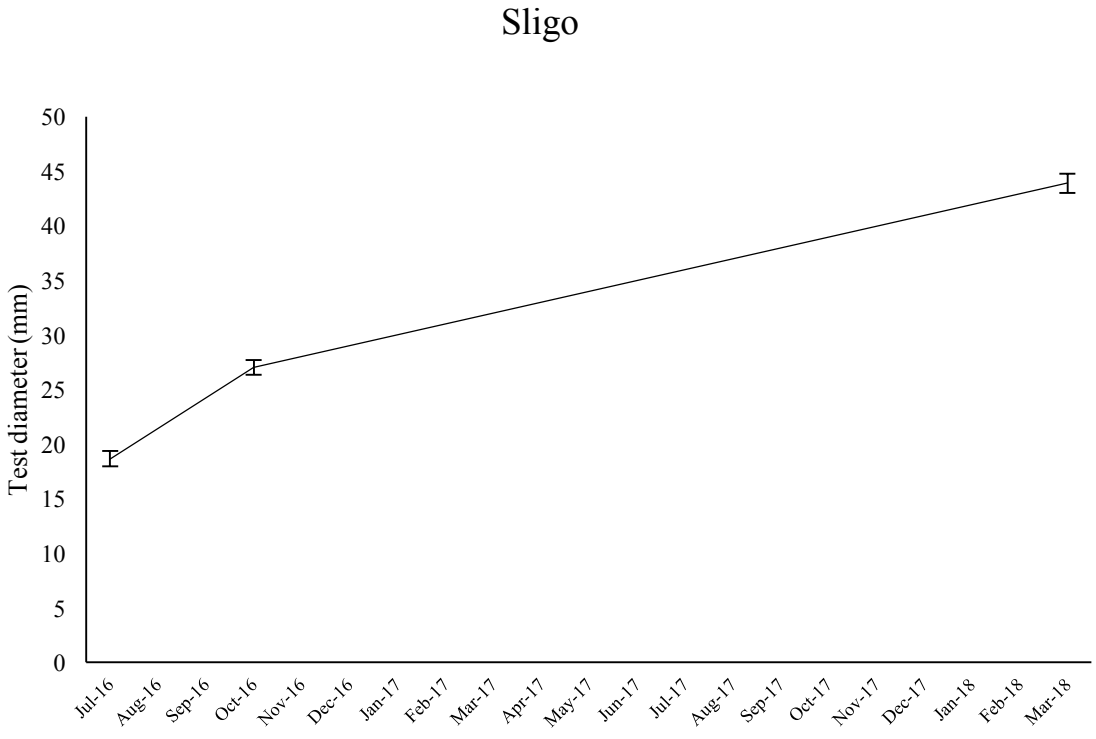

Figure 9. Juvenile sea urchins seeded out at Mullaghmore Co. Sligo showed a positive growth rate in both test diameter (figure 9) and weight (figure 11). The above graph describes the mean test dimeter (mm) from seed out to final measurements of 43.8 mm (±0.88). the overall mean difference in test diameter (mm) was 25.2mm.

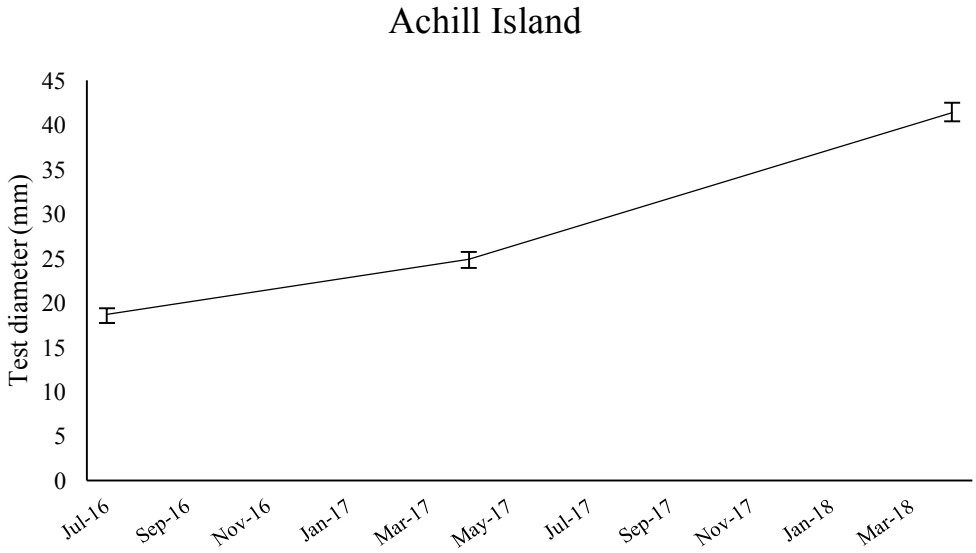

Figure 10. Purteen on Achill Island was the most exposed and active site which provided increased growth rates in test diameter (mm) attaining a mean of 41.3mm (±1.1). the overall mean difference in start and finishing measurements was 22.7mm respectively.

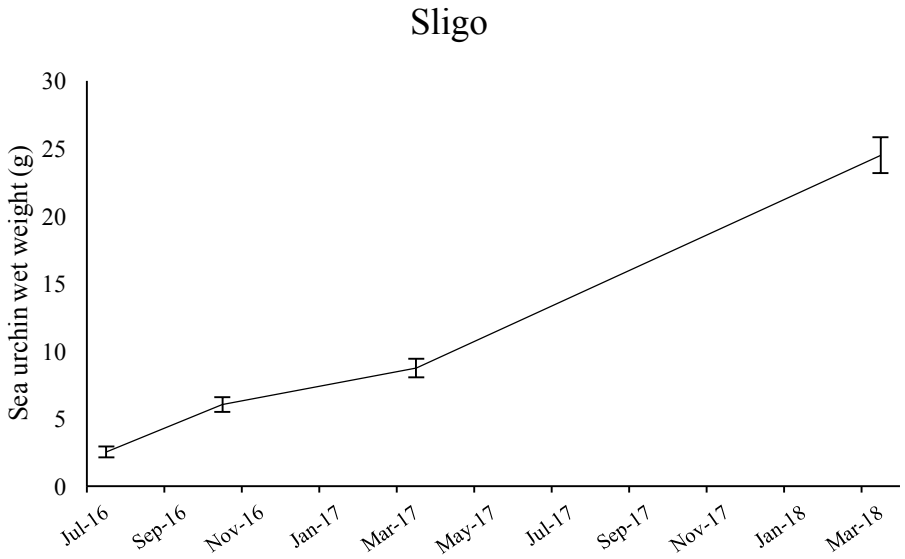

Figure 11. From the inisital mean starting weight of 2.54g (±0.4) the juvenile sea urchins seeded out at Mullaghmore Co. Sligo reached an overall mean weight of 24.5g (±1.3). the overall mean difference in weights was 21.9g.

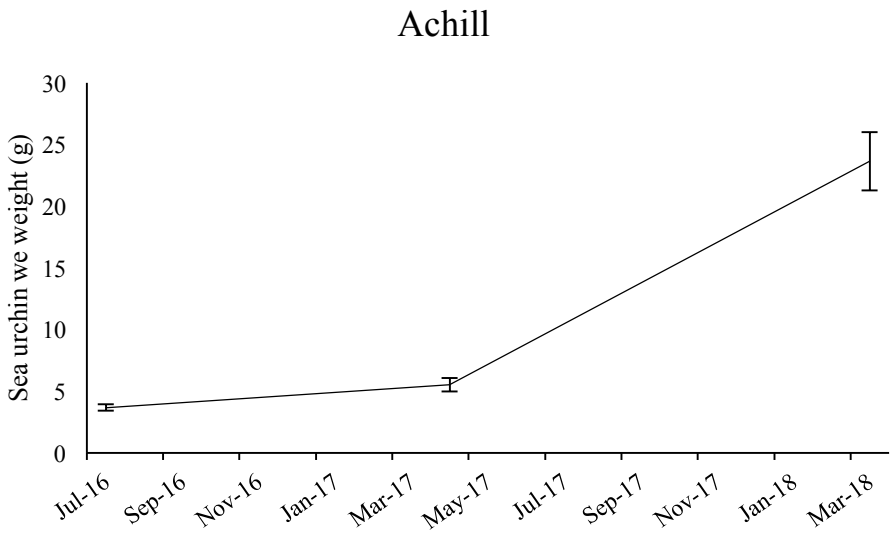

Figure 12. the initial weight of animals seeded out at Achill Island was 3.7g (±0.3). the final measurement of 23.6mm (±2.3). the mean overall difference in weight between start and finish was 19.9g.

Discussion & Conclusion

The overall output of the reseeding and restocking as part of the URCHIN project (Deliverable T3.1.1 SME Report) has been successful as both the test diameter and weight showed positive increase on a continually basis over the duration of the trial. This reseeding trial was conducted in the exposed environment of the west coast of Ireland the results are promising as the first specific trail of restocking of *P. lividus* species in Ireland.

With little or no input or interaction the farm reared sea urchins had to forage once seeded out therefore utilising available storm cast seaweed which was thrown into the rockpool by the rough seas or what available food they could catch with their tube feet. *P. lividus* can utilise animal proteins which was identified by Cook *et. al.* (2007) however by nature sea urchins are typically algivorous.

The overall survivability and growth rates of the sea urchins at both reseeded sites (65% – 60%) had positive increases in overall wet weight and test diameter (TD). The sea urchins seeded out at Mullaghmore Co. Sligo achieved the highest mean weight and test diameter of 24.5g and 48.3mm, where the sea urchins seeded out at Achill Island Co. Mayo achieved a mean test diameter of 41.3mm and a mean weight of 23.6g which is slightly less than the growth (weight and TD) of the sea urchins seeded out at Mullaghmore Co. Sligo. The results are promising however the cryptic behavior and foraging activity of smaller sea urchins (<15mm TD) are more susceptible to predation from green shore crabs, which can be greatly affected by where on the intertidal zone the rockpools are situated (Pers. Comms. Mr John Chamberlain, Dunmanus Seafoods Ltd). Therefore, it is recommended that the *P. lividus* spat are greater than 18mm in test diameter prior to restocking on the sea shore.

If the overall production price of juvenile sea urchin spat could be reduced and the bottlenecks in commercial spat production could be overcome, then ranching and restocking of sea urchins on the west coast of Ireland could be a viable possibility for aquaculture licenses holders to increase and diversify their production.

Looking at sea urchin stock enhancement on a larger scale, Japan heavily subsidised their restocking efforts over a 30 year period which they were able to attain a greater than 60% survival depending on the size at which the sea urchin spat were seeded out (Britz, 2005, Brown

& Eddy, 2015). For this situation to happen in Europe legislation regarding the fishing and harvesting of echinoderms must be implemented to protect the investment by enterprises.

Due to the lack of legislation around echinoderms in Ireland sites for reseeding must be licensed to afford protection to the owner of the sea urchins from harvesting by individuals or groups. As reseeding is deemed as an aquaculture activity interested parties in seeding out sea urchin spat must be a holder of a foreshore licenses for aquaculture which under current time-lines may take up to and including seven years before activities can start.

With Ireland only having one commercial sea urchin hatchery and one other in operation on a smaller scale the production of sea urchins from aquaculture is at an all-time low. With the possibilities of reseeding over fished areas in Ireland and investigating long-term stock enhancement this may be a possibility for cooperatives in regional and peripheral areas to diversify form commercial fishing and harvesting of shellfish.

This trial was carried out in conjunction with two project associated partners (Mullaghmore Seafarm & Treanbeg Shellfish) who are active in both aquaculture and fisheries, with these two licensed sites there may be the possibilities to continue and increase numbers of sea urchins seeded out however, the overall cost and length of production for juvenile sea urchins is still an industry barrier both here in Europe and internationally (Hannon *et. al.* 2015).

The results are promising from this study however further research and in-depth investigation is required into restocking sea urchins as a means of aquaculture production due to the cryptic behavior of the different size classes of juvenile sea urchins and their interaction with the exposed high energy rockpool environment.

Acknowledgements

The URCHIN project would like to acknowledge both assicated partners involved in this study Mr Philip Waters of Mullaghmore Seafarm Ltd and Mr Fergal Guilfoyle of Treanbeg Shellfish Ltd for all their help from the beginning of this study right up to the end. We would also like to thank Mr John Chamberlain of Dunmanus Seafoods Ltd for all his in-depth and practical production knowledge of producing sea urchins and the pitfall and dangers of restocking efforts on the west coast of Ireland.

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