Exe Estuary
Mussel Stock Assessment 2019

Oliver Thomas

Environment Officer
Devon and Severn Inshore Fisheries and Conservation Authority
December 2019

Contents

1. Introduction

1.1 The Exe Estuary

The Exe Estuary is the one of the most highly designated nature conservation sites in Devon; it is a Ramsar Site, a Special Protection Area (SPA), and a Site of Special Scientific Interest (SSSI). It encompasses over 3,000 hectares of diverse aquatic and terrestrial habitats (EEMP, 2014). The Exe Estuary SPA includes both marine areas (i.e. land covered continuously or intermittently by tidal waters) and land which is not subject to tidal influence (Figure *1*). Sub-features have been identified which describe the key habitats within the European Marine Site necessary to support the birds that qualify within the SPA. Bird usage of the site varies seasonally, with different areas being favoured over others at certain times of the year. The mussel beds are important in supporting the wintering wader and wildfowl assemblages to enable them to acquire sufficient energy reserves to ensure population survival (Natural England, 2015). Oystercatchers are the main bird species to use the mussel beds, along with Redshank, Curlew, Turnstone and Greenshank. Several thousand Oystercatchers overwinter on the Exe Estuary and predominantly feed on the mussels, a few will also feed on cockles, winkles and ragworms (Goss-Custard & Verboven, 1993).

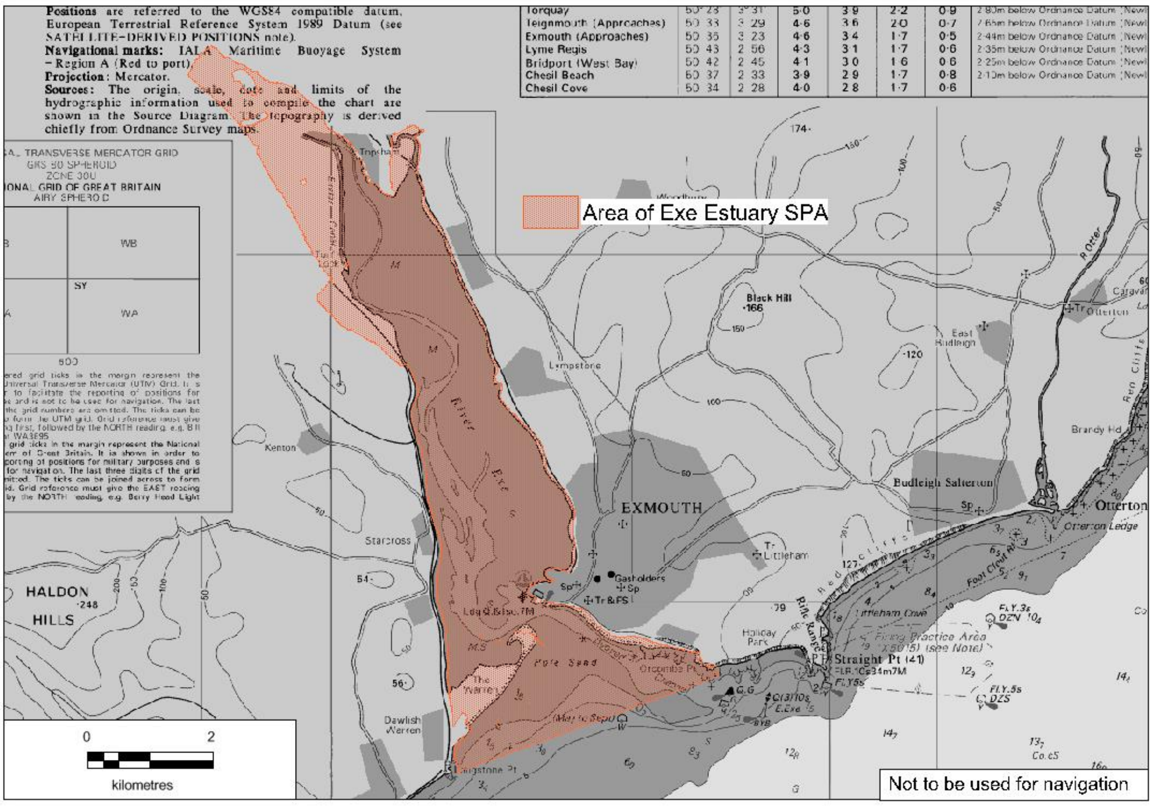

Figure 1 Area of the Exe Estuary SPA

The main commercial fishing activity occurring within the Exe Estuary SPA is the mussel fishery, worked by the Exmouth Mussels Limited. Exmouth Mussels Ltd. collect up to 2000 tonnes of mussel seed per year, from sites at the mouth of and outside the estuary. The seed mussel is then re-laid onto estuary fundus that Exmouth Mussels Ltd. leases, and therefore has rights to. Seed is re-laid at a ratio of 3:1, subtidal: intertidal. Once the seed has grown to marketable size, it is harvested using a “hydraulic jet elevator”, which uses water jets to dislodge the mussels from the bed onto a conveyor belt, which brings them up onto the fishing vessel for sorting. The main fishing activity occurs in the summer, when most wintering bird populations are absent, however some activity takes place all year round. Commercial mussel harvesting can only take place on classified beds (Figure 2) and is predominantly occurring sub-tidally. Devon & Severn(D&S) IFCA's stock assessments focus on the public fishery beds of Bull Hill and Starcross and the beds at Lympstone when access is possible. These areas are popular for recreational shellfish collection.

D&S IFCA introduced a temporary closure, from the 1st May 2019, on the public shellfish beds in the Exe Estuary due to the stocks being severely depleted.

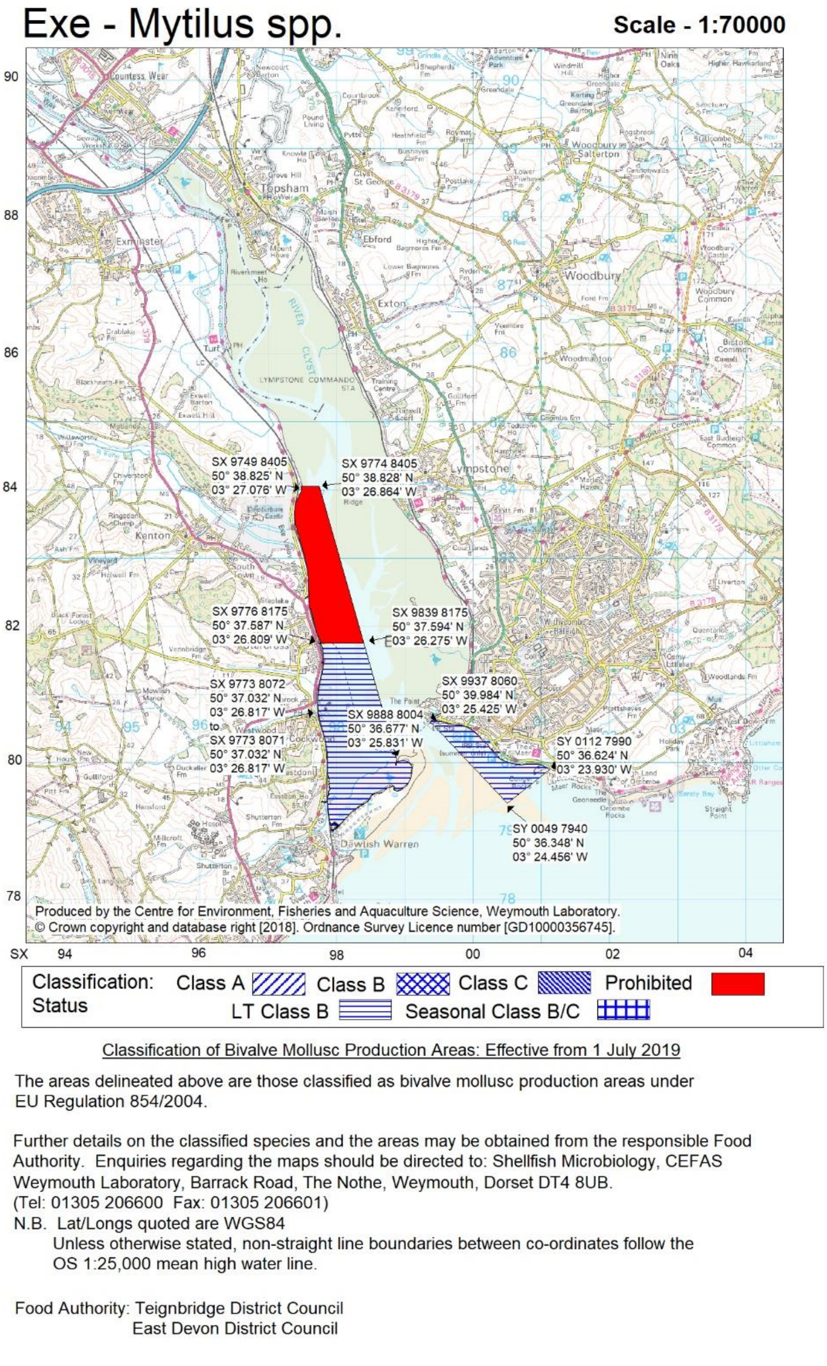

Figure 2 Classified mussel harvesting areas on the Exe Estuary (Cefas, 2019)

1.2 *Mytilus edulis*

Blue mussels, *Mytilus edulis*, are cold-water mussels which can occur in brackish water (Gardner, 1996). They are found on the north Atlantic and north Pacific coast of North America, Europe and in other temperate and polar waters. Blue mussels can occur intertidally and subtidally, and on a variety of substrates, from rocks to sediments, and in a range of conditions. “Blue mussel beds on sediment” are listed as a UK Biodiversity Action Plan (BAP) Priority Habitat (Maddock, 2008). This includes a range of sediments, such as sand, cobbles, pebbles, muddy sand and mud. *M. edulis* ability to occupy such a range of habitats results from its ability to withstand wide variation in salinity, desiccation, temperature and oxygen concentration (Bayne & Worrall 1980, Seed & Suchanek, 1992, Andrews et al., 2011).

M. edulis beds play an important role in the healthy functioning of marine ecosystems; having a role in coastal sediment dynamics, acting as a food source to wading birds, and providing an enhanced area of biodiversity in an otherwise sediment-dominated environment (Maddock, 2008). Mussel beds support their own diverse communities as the mussel matrix, composed of interconnected mussels and accumulated sediments and debris, provides numerous microhabitats and an organically enriched environment (Andrews et al., 2011, Seed & Suchanek, 1992). Blue mussels are filter feeders, feeding primarily on micro-algae, suspended debris and zooplankton, and play a vital role in estuaries by removing bacteria and toxins.

The reproductive strategy of *M. edulis* is to deploy a large number of gametes, approximately three million eggs, into the surrounding water where fertilisation takes place (Andrews et al., 2011). Following fertilisation, the zygotes, as planktonic larvae, undergo six stages of metamorphosis before settlement. Mussels can adapt their reproductive strategy depending on environmental conditions. For example, the release of gametes can be timed to complement favourable environmental conditions, and the planktonic phase can last between two and four weeks depending on temperature, food supply and availability of a suitable substrate to settle on (Andrews et al., 2011). Depending on temperature and nutrient levels, spawning may occur just once or several times per year (Bayne & Worrall 1980, Seed & Suchanek 1992, Handå at al., 2011).

Current threats to *M. edulis* beds include commercial fishing, water quality, coastal developments, anchoring, bait digging, and intensive recreational hand gathering (Maddock, 2008).

1.3 Objectives

The objective of this project is to carry out annual surveys of the public mussel beds on the Exe Estuary, to define where the mussel beds are and accurately map, using GIS, the overall extent of each of the mussel beds. D&S IFCA will undertake a stock assessment on each of the beds to estimate the density of mussels on the beds and the total stock of marketable mussels. Results of these surveys can be compared on an annual basis. This will help inform future management of the mussel beds on the Exe and the development of shellfisheries in this part of the D&S IFCA’s District.

2. Methodology

Due to the varying levels of patchiness and density the area surveyed cannot always be indicative of the size of a true mussel ’bed’ and is a representation of the area in which live mussels were located. The perimeter of this survey area was recorded by walking the extent of the live mussel habitat and marking coordinates with a handheld GPS. These were later plotted using QGIS software (Figure 3).Where live mussel was present but in density’s too low to be surveyed effectively, the perimeter of the survey area was mapped and a qualitative visual assessment within the perimeter was carried out (Figure 4).

To determine coverage and patch density transects were walked in a zig-zag pattern across the survey area, right up to the perimeter, providing optimum coverage across the transect. The start and end coordinates of each transect were recorded using a handheld GPS. A 4ft bamboo cane with an 11cm ring attached to the end, arranged so that the ring sits flat on the ground when held out to one side, was used to determine the mussel coverage for each transect. Every three paces along each transect the cane was flicked out to one side and it was recorded whether it was a “hit” if the ring contains live mussels, or a “miss” if the ring did not contain live mussels. The hit/miss data once pooled, were used to calculate the percentage cover of live mussels over the survey area. However, as no samples were collected the following methodology referring to measuring and weighing of samples does not apply to this survey and is included as reference material only. Ordinarily on every fifth hit the contents of the ring are taken as a sample, using an 11cm diameter corer. All mussel samples from the same transect are collected together in one bag and kept separate from those of other transects.

Once all transects are complete mussel samples are sieved and cleaned. For each transect the number of samples taken is recorded, all mussels are then measured and divided into the following size groups; 1-10mm, 11-20mm, 21-30mm, 31-40mm, 41-50mm, 51-60mm, 61-70mm, 70+mm. The data collected from both the transects and samples are then normally used to calculate the coverage, density and area of the survey area (Figure 5), which is then used to estimate the mussel tonnage on each site. Size distribution data are also normally obtained from the length measurements of mussels in the retained samples. The hit data can be used to work out average density of denser mussel patches across for the whole survey area, compensating for the possibility of some transects being longer than others.

Figure 3 Transects walked (black) and Starcross survey area (orange).

Figure 4 Lympstone and Bull Hill Survey areas (orange).

$$\%\ \text{cover} = \frac{\text{no. hits}}{\text{no. hits} + \text{no. misses}}$$

$$\text{Density across bed} = \frac{\text{total mussel weight/surface area sampled}}{\%\ \text{cover}}$$

Figure 5 Calculations used for mussel coverage on bed, and density of mussels across bed.

3. Results

Starcross was surveyed on 5th June 2019. 9 transects were conducted. Due to absence of live mussels no samples were taken. Since 2018 the tonnage total stock has decreased to <1 ton. 1.9 ha was surveyed with an estimated 1% of this area contained live mussels (Figure 7). High abundances of the pacific oyster *Magallana gigas* (previously known as *Crassostea gigas)* were noted towards the downstream extent of the survey area. The substrate was majoritively sandy/gravel.

Bull Hill was surveyed and on 6th June 2019. Densely packed live mussel spat <1 covered an 2,541m^2 area (Figure 6), which was mapped. The small survey area made surveying using the Dutch wand technique unfeasible and a semi-quantitative assessment of mussels within the bed was made instead. This population was surveyed again on the 27th of November 2019, dense mussel was again found within the survey area, this time on average >1cm. The substrate was predominantly sandy/gravel.

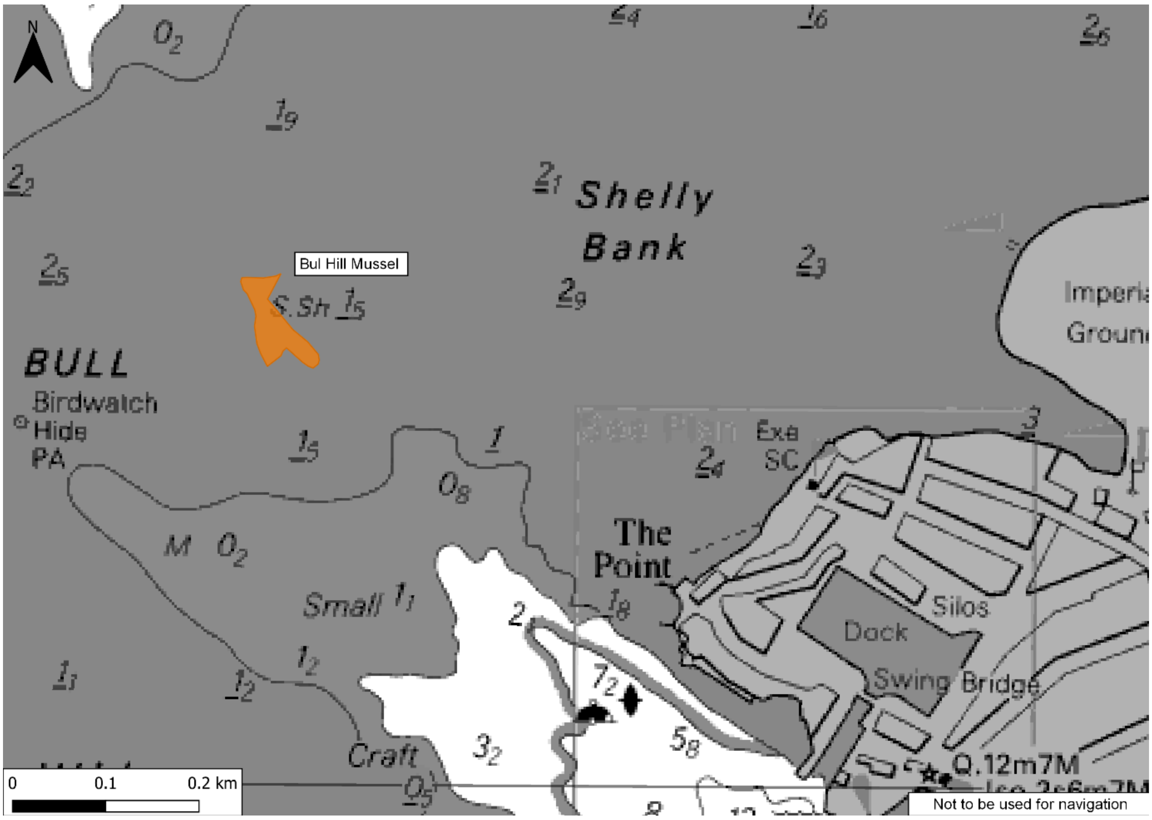

Figure 6 Location of dense mussel on Bull Hill (orange).

Lympstone was surveyed on 18th May 2018 (Figure 4). Mussel was largely absent, with only irregular sparse single instances of large (>50mm) live individuals found attached to live oyster and mussels shell detritus, the substrate was comprised of thick intertidal mud. Large intertidal seagrass beds were observed towards the shoreward extents and oysters towards the low intertidal.

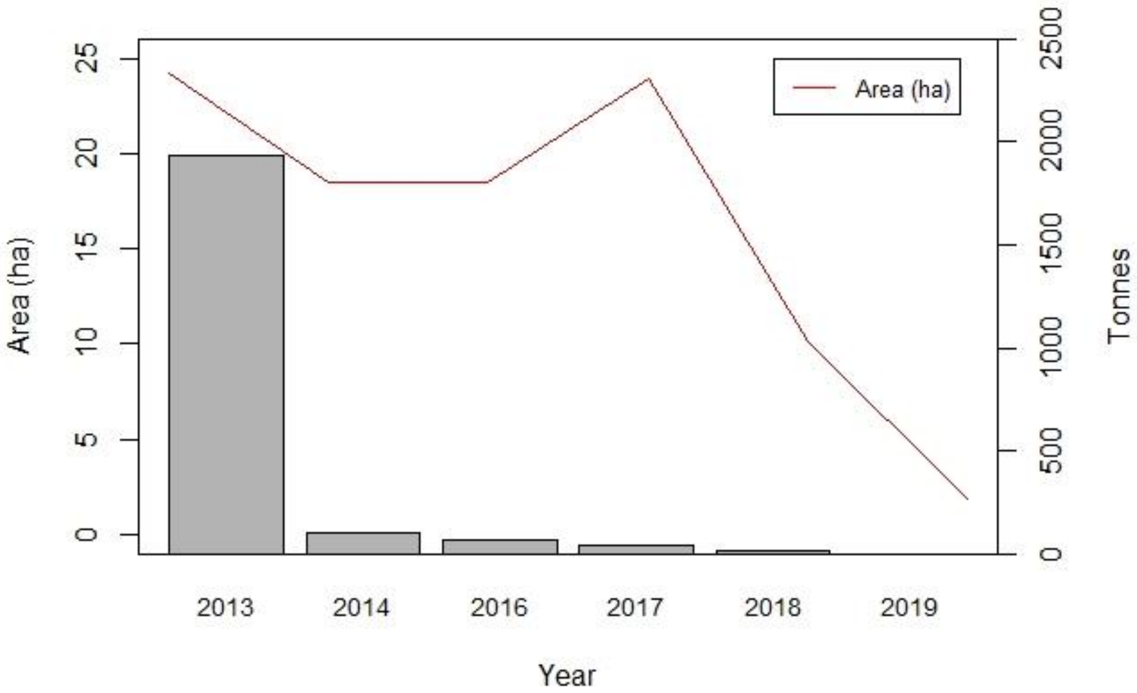

Figure 7 Total survey area found to contain live mussels plotted over total stock 2012-2019.

4. Discussion

In 2014 large storms scoured away once previously stable beds, which reshaped the local hydrology. This was later followed by several Harmful algal Blooms (HABs) incidents which reduced populations further. Mussel populations, since these events, have been unable to recover to anywhere near their previous population estimates, and are currently absent in anything that could be described as a dense, homogeneous, and stable population within the estuary.

Live populations of *Mytilus edulis* within the surveyed intertidal zone at Starcross (Figure 3) show no indication of recovery since 2014. Their presence is effectively negligible at the survey site with no live mussels being observed in the surrounding areas. In their place large numbers of pacific oysters *Magallana gigas* have established since 2018 and now seem to be the dominant filter feeding bivalves on the intertidal, particularly on the shoreline adjacent to Starcross.

A small dense and stable mussel population has established on Bull Hill since 2018 (Figure 6), with the dense <1cm spat discovered in June of this year growing to observable levels >1cm at the end of November. This bed, although small, has potential to grow in both density and spatial distribution. Recovery from a bed this size to Bull Hill's previous population levels, even without disturbance, could still take decades (Robins et al., 2016). Further annual monitoring should, however, provide data pertaining to the rate and scale of recovery.

No presence of any dense population structures was observed at Lympstone (Figure 4). The sparse mussels found were comprised solely of large individuals, whose presence is more likely due to survival of a few resilient individuals, rather than recent spat settlement. The absence of new sprat providing some evidence for this hypothesis. Pacific oysters dominated this habitat, however unlike the newly forming 'reefs' at the mouth of the estuary these oyster beds are older and well established. Mussels could be found amongst the oyster attracted to live and dead shells by byssus.

Although the decline of the mussel and the rise of the oyster within the Exe, particularly that observed at Lympstone and Starcross may seem to be in correlation, the literature indicates that the relationship is not causative and more possibly as a result of physical environmental change rather than due to direct competition. The introduction of a non-native species occupying a similar niche within the same habitat is likely to cause concerns of population displacement. This applies to many of the estuary's in Northern Europe where mussels are now cohabiting with Pacific oysters. This concern is however largely unfounded. Biogenic pacific oyster reefs and mussel beds, although ecologically and morphologically different are not exclusive habitats to their respective creators. Both habitats play host to a variety of differing species including mussels on oyster reefs and oysters on mussel beds. The growth of one species population is not necessarily inhibited by the other, their nature as filter-feeding bivalves limits their interaction as direct competitors unless in a situation where stocking densities are unnaturally high (Shatkin et al. 1997, Ventilla 1982, Nehls et al., 2006). This may be the case when observed in the context of a dynamic open system estuary, such as the Exe, where nutrient availability is subject to a variety of differing pressures and toxic build up from faeces is incredibly unlikely. In this kind of system physical pressures like increased water flow will have a greater impact on mussel population size than nutrient deficiency from competition with pacific oysters.

Perhaps more worrying than the rise of the pacific oysters to mussel populations in the Exe Estuary may be the long-term impacts of ocean warming. The Exe Estuary, like many western European estuary's and coastal waters, has been subject to gradual warming since the industrial revolution, with the UK seeing increases in sea surface temperature of 0.7°c between 1971-2010 with temperatures projected to rising 1.5°c - 4°c within the 21st Century (Robins et al., 2016, IPCC 2014, Lowe et al., 2009). *Mytilus edulis* typically occupies a temperature range from 5-20° c (Bayne et al., 1976. Bayen and Worrall 1980), with tolerances of higher and lower temperature extending to 29°c and -30°c degrees respectively (Seed & Suchanek, 1992, Read & Cumming, 1967). Although estuarine temperatures are survivable by both juvenile and adult mussels, mussel larvae are significantly more susceptible to raised temperature and salinity pressures than mussels' post larval stages (Rayssac et al., 2010, Qiu et al., 2002). With increasing temperatures, the larvae suffer not only higher mortalities but also over 18°c slower growth rates (Rayssac et al., 2010). Milder winters have been shown in some populations in the Wadden sea to delay spawning, this has the compounded effect of larvae and juvenile mussel being subject to much higher levels of predation than previously subjected to. Decreased settlement in turn can limit successful recruitment, inhibiting rejuvenation of mussel populations (Nehls et al., 2006). Whilst climatic implications are currently unlikely to have a significant effect on the fecundity of mussel populations within the estuary, the long-term implications of increased estuarine warming may impact mussel populations in the Exe and other UK estuaries.

It is most likely to conclude, based on the results seen in these annual monitoring reports, that the mussel populations previously found within the survey sites of Starcross and Lympstone will see little to no recovery at all over the coming years. This is based on the near total absence of any established populations across the sites, and the current oceanographic dynamics of the estuary which inhibit successful high density spat settlement. The establishment of a small stable mussel population on Bull Hill is certainly a positive development and will need continued monitoring.

4.4 Recommendations

It is recommended that the stock assessments continue to be carried out on an annual basis, to monitor any future changes and to detect any signs of recovery. Additional metrics on annual temperatures within the exe could be obtained from external organisations within the exe for the Authority’s own records in order to account for long-term change. This will help to inform any future management measures that D&S IFCA may consider for the collection of mussels, as part of their review of existing byelaws and permit conditions.

References

Andrews, J.W., Brand, A.R., and Maar, M. (2011) MSC Assessment Report for Isefjord and East Jutland Danish Blue Shell Mussel Fishery [online: msc.org] Moody Marine Ltd. Derby UK.

Bayne, B.L.(1976). The biology of mussel larvae. In Marine mussels: their ecology and physiology (ed. B.L. Bayne), Cambridge: Cambridge University Press, pp. 81-120.

Bayne, B. L., and Worrall, C. M. (1980) Growth and production of Mytilus edulis from two populations. Marine Ecology Progress Series, 1: 317-328.

Cefas (2019) Shellfish harvesting classification zone maps www.cefas.co.uk/cefas-data-hub/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/classification-zone-maps/

Gardner, J.P.A. (1996) The Mytilus edulis species complex in southwest England: effects of hybridization and introgression upon interlocus associations and morphometric variation. Marine Biology, 125: 385-399.

Goss-Custard, J. D. and Verboven, N. (1993) Disturbance and feeding shorebirds on the Exe estuary. Wader Study Group Bulletin, 68: 59-66

Handå, A., Alver, M., Edvardsen, V. C., Halstensen, S., Olsen, A. J., Øie, G., Reitan, K. I., Olsen, Y., Reinertsen, H. (2011) Growth of farmed blue mussels (Mytilus edulis L.) in a Norwegian coastal area; comparison of food proxies by DEB modelling. Journal of Sea Research, 66(4): 297-307.

IPCC. (2014). In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D.,Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B.,Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.),Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Globaland Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1: 1132.

Maddock, A. (2008) UK Biodiversity Action Plan; Priority Habitat Descriptions. BRIG.

McGrorty, S., Clarke, R. T., Reading, C. J., & Goss-Custard, J. D. (1990) Population dynamics of the mussel Mytilus edulis: density changes and regulation of the population in the Exe estuary, Devon. Marine ecology progress series. Oldendorf, 6(2): 157-169.

Nehls, G., Diederich, S,. Thieltges, D.W., Strasser, M. (2006) Wadden Sea mussel beds invaded by oysters and slipper limpets: competition or climate control? Helgoland Marine Research, 60: 135-143.

Read, K.R.H. & Cumming, K.B. (1967) Thermal tolerance of the bivalve mollusc Modiolus modiolus (L.), Mytilus edulis (L.) and Brachiodontes demissus (Dillwyn). Comparative Biochemistry and Physiology, 22: 149-155.

Rayssac N, Pernet F, Lacasse O, Tremblay R (2010) Temperature effect on survival, growth, and triacylglycerol content during the early ontogeny of Mytilus edulis and M. trossulus. Marine Biology Progress Series, 417: 183– 191.

Robins, P. E., Skov, M. W., Lewis, M. J., Giménez, L., Davies, A. G., Malham, S. K., Jago, C. F. (2016). Impact of climate change on UK estuaries: A review of past trends and potential projections. Estuarine, Coastal and Shelf Science, 169: 119–135.

Seed, R. Suchanek, T.H. (1992) Population and community ecology of Mytilus. In The mussel Mytilus: ecology, physiology, genetics and culture (ed. Gosling, E.M.), Amsterdam: Elsevier Science Publ. Developments in Aquaculture and Fisheries Science, 25: 87-169.

Shatkin G, Shumway SE, Hawes R (1997) Considerations regarding the possible introduction of the Pacific oyster (Crassostrea gigas) to the Gulf of Maine: A Page 11 11 review of global experience. J Shellfish Res 16:463-77.

Ventilla, R.F. (1982) The Scallop Industry in Japan, Editor(s): J.H.S. Blaxter, Frederick S. Russell, Maurice Yonge, Advances in Marine Biology, Academic Press, 20: 309-382.