North Western IFCA
Inshore Fisheries and Conservation Authority

Razor Clams in the North Western IFCA District: is there potential for a sustainable fishery?

Alex Aitken and Mandy Knott

January 2018

1 Executive Summary

This report outlines the considerations that need to be taken before a commercial razor clam fishery can be permitted within the North Western Inshore Fisheries and Conservation Authority (NWIFCA) District. Under the Marine and Coastal Access Act 2009 NWIFCA have the duty to:

(a) seek to ensure that the exploitation of sea fisheries resources is carried out in a sustainable way,

(b) seek to balance the social and economic benefits of exploiting the sea fisheries resources of the district with the need to protect the marine environment from, or promote its recovery from, the effects of such exploitation, and

(c) seek to balance the different needs of persons engaged in the exploitation of sea fisheries resources in the district.

The purpose of this report is to review work that has previously been carried out in the District, gather information on potential commercially viable species, review fishing methods and the environmental impacts of those, and to investigate razor clam fisheries in other areas in terms of their management and sustainability.

In recent years NWIFCA has received multiple requests to fish for razor clams. In the past, research and trials have been carried out with the aim of assessing stocks in different areas including Liverpool Bay and north of Walney Island. Results yielded information about species present at the time of study; however no trial has extended further than this. Potential commercial species identified from these trials include *Ensis ensis, Ensis siliqua, Ensis arcuatus, Pharus legumen, Spisula solida* and *Tapes decussatus*. The target species for the fishery under review are *Ensis* spp., with other bivalve species comprising potentially marketable bycatch.

There are various methods of fishing *Ensis* spp. each of which has differing environmental impacts, efficiencies and constraints. In the past focus has been on subtidal dredging of *Ensis* spp., a highly efficient method with potentially adverse environmental impacts. This method is the main focus of this review. There has also been some minor interest in hand gathering *Ensis* spp. intertidally; this method is highly selective and less efficient with fewer environmental impacts.

Razor clam fisheries exist around Europe and fisheries in Ireland, Scotland and the Netherlands have been analysed in detail to understand how management measures are implemented and the effects of these. In Ireland, there is an open access razor clam fishery fished almost exclusively using dredges. Fishing activity is reported to have increased in the past 15 years with significant temporal population declines. In Scotland, razor clams are fished by suction dredge, hydraulic dredge and hand gathering by divers. There are no direct management measures in place apart from a requirement for a razor fish licence. The population size and structure, the amount of fishing activity, and therefore the sustainability of the Scottish *Ensis* fishery is unknown. The Dutch *Ensis* fishery is heavily regulated with annual stock assessment surveys and a list of stringent management and monitoring measures. This has led to the fishery achieving Marine Stewardship Council (MSC) accreditation. However the target species in this fishery is the non-native *Ensis directus,* although now fully established in Dutch coastal waters.

In an effort to progress possibilities for permitting a sustainable razor clam fishery(ies) in the NWIFCA District, this review has collated information on the management of past and existing razor fisheries throughout Europe. The emphasis of the review was to explore management implemented by other regulators to ensure sustainability of stock, and minimal impact on the ecosystems in which razors are found. Regrettably the review has not revealed many answers to the very real practical questions facing NWIFCA in its attempts to permit fishing of what could be seen as a ‘virgin’ fishery. It is interesting to note that there are no permitted razor clam fisheries in English waters, so perhaps the NWIFCA does not face this conundrum alone.

Extensive research is required to answer the outstanding questions to understand whether carefully managed dredging activity could be a viable and sustainable method for harvesting razors in the District. This has huge cost and time implications, which a publicly funded body is not able to fulfil. While previous work has identified potential species and areas for a fishery(ies), and elements of management from other fisheries can be adopted as good practice, at the present time there are too many gaps in knowledge and serious outstanding questions remaining to make much more progress.

To summarise these include:

- an understanding of the population structure of commercially viable species**;**
- an understanding of target and non-target species ecology and behaviours, recruitment, survivability and size at sexual maturity;
- an understanding of the effects and efficiency of gear / gear design on the target and non-target species and the surrounding ecosystem;
- an exploration of impacts of other gear types such as electrofishing;
- an understanding of the overall effects of fishing activity at different intensities on biological, physical and chemical features within the area of the fishery, and the risk to protected features;
- impacts of fisheries on prey availability for fish and bird species, and disturbance to protected SPA species.

NWIFCA encourages industry to seek to collaborate collectively, and to work with NWIFCA scientists, academic institutes and others to establish means of securing funding for in-depth research.

Contents

2 History of Interest in Razor Clam fishing in the NWIFCA District

Over the past 10-12 years there has been a variety of interest in harvesting sub-tidal razor clams in the NWIFCA District. Some trial fisheries have been authorised but have not gone ahead, the Authority objected to an application for a Several Order, and multiple organisations have attempted to investigate potential fisheries.

Market demand for razor clams mainly comes from overseas with a rapidly growing market in South East Asia, predominantly China (Murray et al., 2014). There is a limited market in the UK, mostly restaurants, and a shrinking market in Europe, which mainly supplies Spain and Portugal (Murray et al., 2014). Different species are priced in different ways, with the market preference for the larger *E. siliqua* which are priced by size (Muir and Moore, 2003). *E. arcuatus* are generally sold at the same price regardless of size and a lower value per kilo (Murray et al., 2014). Value of stock in England cannot be ascertained as no fishery exists; however in Scotland the value has increased from below £0.5 million in 2006 to £2.3 million in 2016 (Scottish Government, 2017a). A current example (5th Jan. 2018) of price for 6 medium size (320g) wild caught razors sold on the internet is £12.00 (https://www.thefishsociety.co.uk/shop/razorshell-clams.html).

2.1 CEFAS / Intershell 2006/07

Study: *Investigation of potential fisheries for razor fish and other bivalves in the Eastern Irish Sea*.

In 2006 CEFAS, as part of the DEFRA *ad hoc* fisheries research programme 2005/06, conducted a project with the overall objective to identify any potential future fishery for bivalves. This involved: 1. An Eastern Irish Sea bivalve survey to conduct a wide ranging grab survey of soft sediment areas of the north eastern Irish Sea and; 2. to examine an area of Liverpool Bay which industry had earmarked for a trial fishery.

The Eastern Irish Sea bivalve survey aimed to identify potential alternative bivalve fisheries resources, where 120 sites were sampled by grab and 14 species of bivalve observed. CEFAS stated that overall numbers recorded were low and the survey grid was too low a resolution to identify specific commercial beds. However, it did provide indications for future investigations.

CEFAS conducted sampling on a finer scale in the Southport area of Liverpool Bay after it was identified by the company Intershell as an area for a potential trial fishery. Intershell identified the razor clam, *E. siliqua* and the bean solen, *P. legumen* as potential candidates for a commercial fishery as the shells of each species were commonly found on the strandline at Southport. Twenty grab samples were carried out and six clam species of known or potential commercial value were identified and their density and distribution mapped (Figure 1). Three species: *E. siliqua, P. legumen* and *S. solida* were found in a number that they estimated to be "a fishable abundance". Three other species: *Chamelea galena, Mactra coralina* and *Dosinia lupinus* were each recorded only once. They recommended further sampling to clarify the distribution of species.

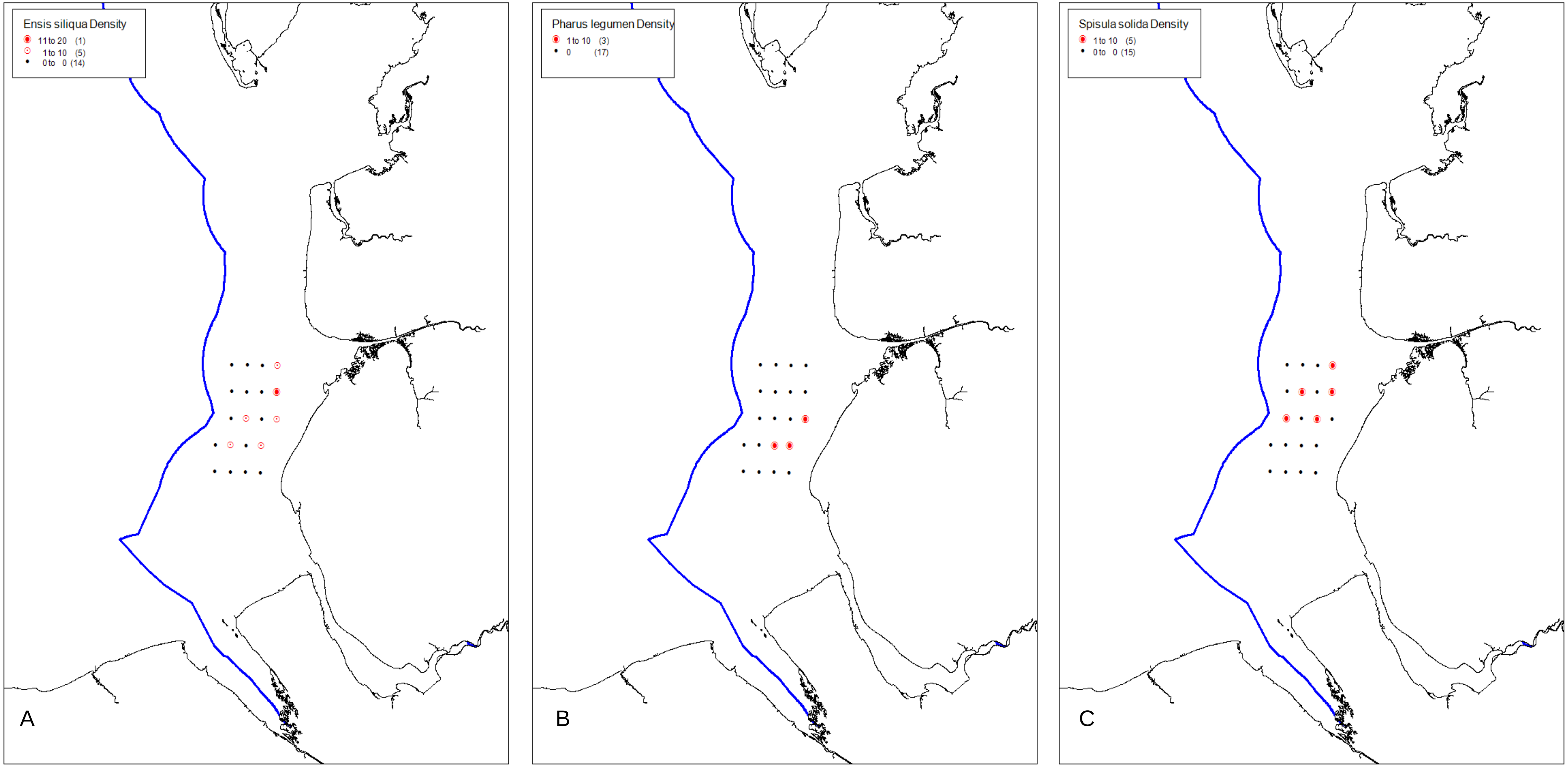

Figure 1. Densities of *E. siliqua* (A), *P. legumen* (B) and *S. solida* (C) per 0.1m ^{2} grab from the 2006 CEFAS survey at Southport. At each of the sites shown a mini Hamon grab was deployed. This grab samples 0.1m^2 of the seabed to a maximum depth of 200mm. Maximum densities - *E. siliqua* 17 per 0.1m^2, *P. legumen* 5 per 0.1m^2, *S. solida* 10 per 0.1m^2.

2.2 CMACS and AWJ Marine 2007

Study: *Liverpool Bay Razor Clam (Ensis spp.) Survey*

Stock assessments were conducted off Southport and the Wirral coasts using a hydraulic dredge to carry out 44 tows each of 50 m in length. *Ensis* species were separated from the rest of the catch and sorted to species level. Species other than *Ensis* were identified but not counted. Three species of razor clam were caught: *E. siliqua, E. arcuatus* and *E. ensis*. Variable abundances were recorded, the densities ranged from 0 to 9 individuals per m^2. The report identified the distribution (Figure 2) and the population age size structure of *E. siliqua* and *E. arcuatus* for both sites. At the Wirral site they recorded a broader range of shell lengths suggesting that several age cohorts were represented. Thirty benthic organisms were recorded as bycatch (Appendix 1), although abundances of each species are unknown, they stated the majority of bycatch came on to deck intact and was therefore returned to the sea alive. Naturally survivability of each would vary depending on species.

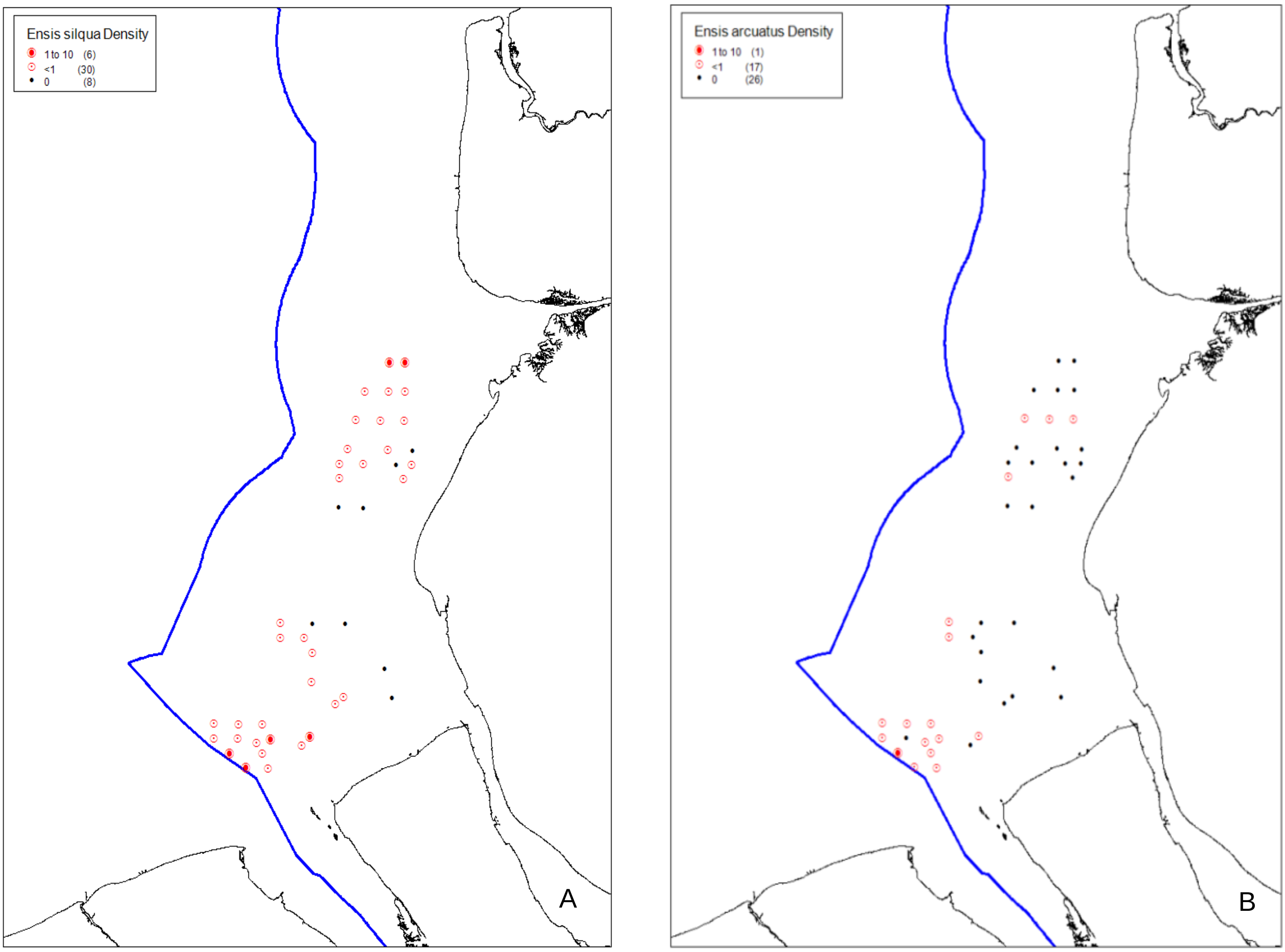

Figure 2. Densities per m^2 of *E. siliqua* (A) and *E. arcuatus* (B) in the 2007 stock assessments carried out by CMACS and AWJ Marine.

2.3 Seafish 2008

Study: *Developing a New Fishery: Guidelines for Environmental Good Practice (Gray, 2008)*

Seafish produced a report detailing guidelines on how to open a new razor clam fishery using populations off the Cumbrian Coast as a case study. The report includes: information about the target species, identifies key contacts in the area, examines potential markets, details potential harvest methods, reviews the physical environmental conditions and biological communities and habitats in the area, gives details of the protected areas and advises on legal information required. The document contains steps to producing a fishery management plan, but does not detail how to implement it to achieve a sustainable fishery. The study was commissioned by the Barrow in Furness Fishermen's Association with the aim to investigate the feasibility of them developing a new sustainable fishery in the area. Recommendations include sourcing funding to carry out an experimental fishery to gather data.

2.4 CEFAS 2010

Study: *Experimental dredging North Walney*

The study aimed to dredge 34 stations north of Walney Island in Cumbria, of which, 26 were successful. A hydraulic dredge was used to conduct tows of 10 minutes in length. The main catch was *E. siliqua* with an average of 68 individuals per tow and *P. legumen,* which were abundant in some areas (Figure 3). Bycatch included *Echincocardium cordatum* (Heart urchin) plus additional clam species. The study found a mixture of age classes of *E. siliqua* suggesting recruitment was a regular event, although was unable to age individuals precisely. Recommendations included making gear more selective to reduce shell damage and an increase to the minimum landing size.

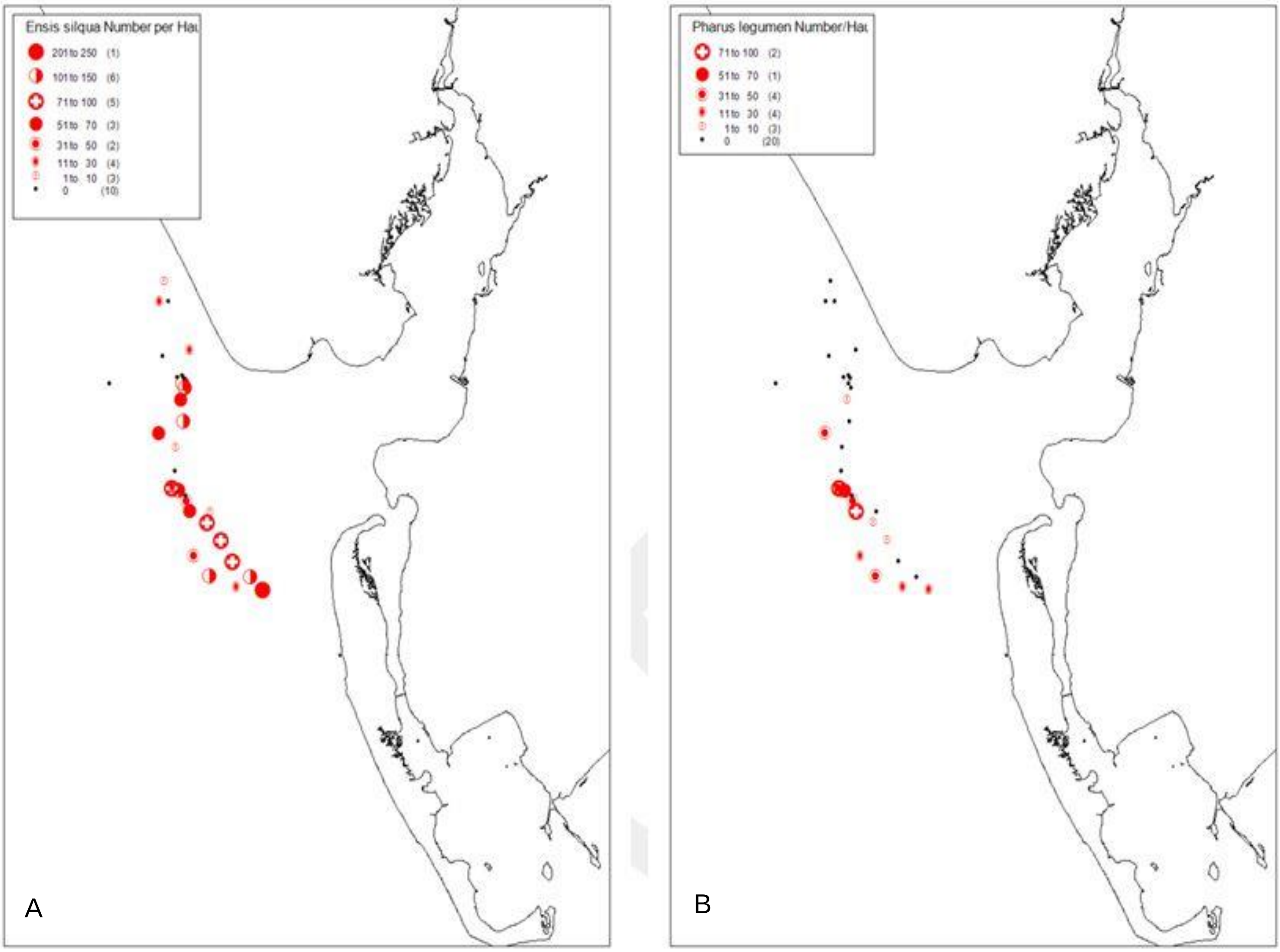

Figure 3. Number per haul of *E. siliqua* (A) and *P. legumen* (B) from experimental dredging (CEFAS) North of Walney Island in Cumbria in 2010.

2.5 NWIFCA and Liverpool University project proposal

In 2012 NWIFCA was approached by industry to further progress permitting fisheries in three areas in the North West (Figure 4). A group was set up consisting of NWIFCA officers and Members, and industry representatives. NWIFCA position was that the fishery should be classed as a 'virgin' fishery and with a no fishing starting point, to achieve sustainability fishing could only be permitted once clear and defined management measures had been established based on detailed scientific evidence.

A three year research plan was developed with academics from Liverpool University to assess sustainability potential of fishing by electro-dredge which included:

i. Sustainability/recoverability of the stock(s)
    a. Population size and structure
    b. Recruitment
    c. Mortality
    d. Damage
ii. Impacts on non-target species of bivalves
    a. Population size and structure
    b. Recruitment
    c. Mortality
    d. Damage

iii. Recoverability of ecosystem
   a. Changes in and recovery of benthic communities
   b. Changes in food availability for birds and fish
   c. Changes in sedimentary environment at harvested sites and adjacent regions
   d. Rate of removal of dredge tracks

The costs associated with the research were beyond the resources of NWIFCA, and industry were invited to explore funding opportunities. However no further progress was made and the group dissolved.

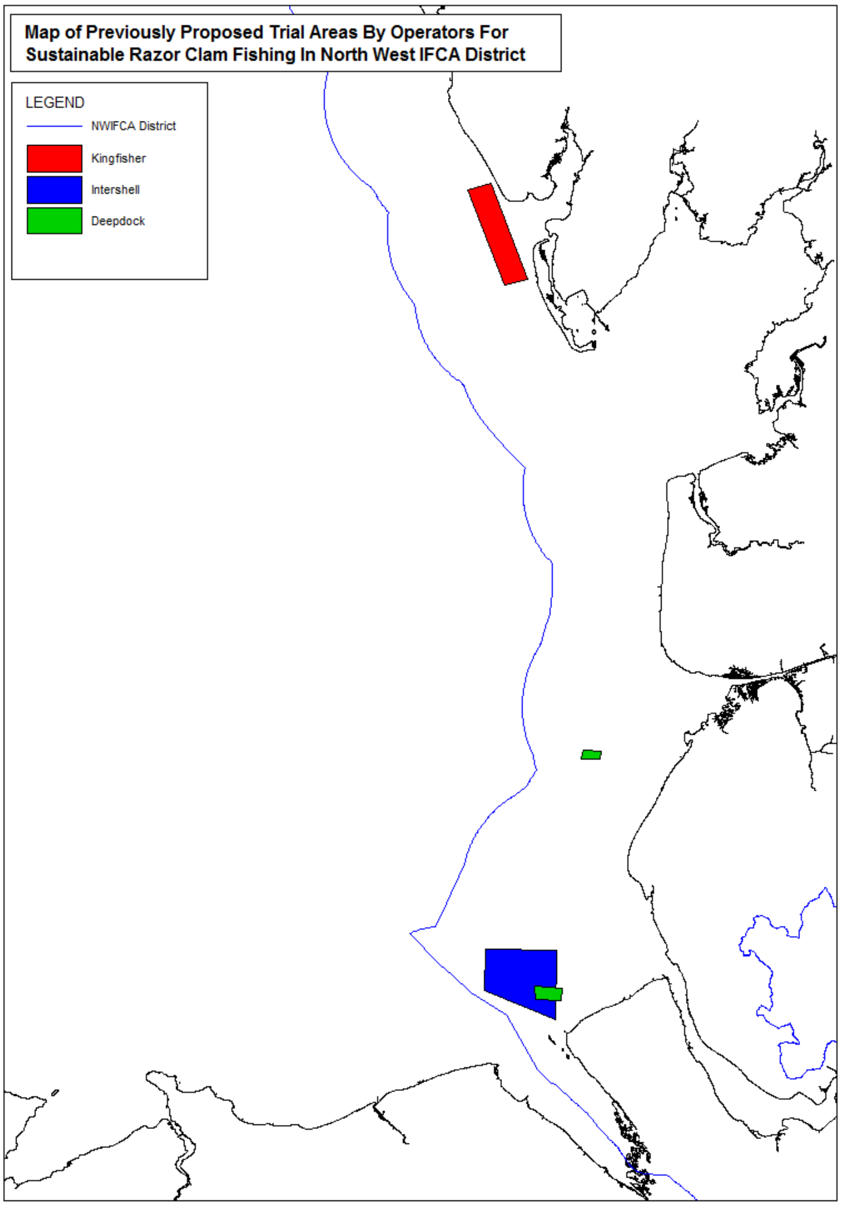

Figure 4. Map of Operator Interest Areas for Razor Clam Research 2012.

2.6 CEFAS and NFFO Project 2013-14

Study: *Sustainable Razor Clam Fishing: Limiting Ecosystem Impacts by the use of the 'electric dredge'*

This project was funded under the Defra Fisheries Science Partnership programme with the aims of developing a method of electro fishing for razor-clams that is commercially and environmentally acceptable. CEFAS proposed to assess the performance of a razor clam electro-fishing sledge in Liverpool Bay for a period of ten days between August and October 2013. The small-scale trial comprised two phases: the aim of the first phase was to develop a commercially viable electro-fishing sledge. Once the sledge had been optimised an assessment of the biological effects was to take place during the second phase.

The trial was to be undertaken by a fishing vessel fishing two 5-day trips which in total would cover approximately 14ha. This was to initially involve towing the electro sledge, equipped with underwater video, in order to develop the optimal design and method of deployment. If this proved successful then further survey work would be carried out to gather biological information on both the target species and the associated benthic community. This would include a maximum of sixty Day grab samples.

The electro-fishing gear was designed in collaboration with the vessel's skipper and Belgian manufacturers (who have experience of using electro gear for flatfish & shrimp). The gear design was based on the scallop gear that matched the vessel's current use and involved a 4m steel towing bar, trailing electrodes and two collection cages. Ten electrodes, each 2.4m in length, trailed from the bar (from which they were insulated) back to two collection cages which would be towed from the same bar. Each collection cage was 1.5m wide and had a narrow scraper bar attached to the front to prevent razor clams from escaping under the cages (see Figure 5). The floor of the collection cage comprised bars spaced to avoid capturing undersize razor clams (< 100mm in length).

The sledge was towed from the vessel's trawl winch while the electrical pulses were supplied through a separate cable. Pulsed DC was used at approximately 20 volts. Voltage was no higher than 40 volts due to Health & Safety considerations.

Razor clams respond to electrical pulses by vacating their burrows allowing them to be collected by the cage. It would be necessary to optimise the towing speed, voltage, amperage pulse frequency and the angle of the non-penetrating blade at the front of the collection cage. A camera was to be deployed on the sledge and it was hoped that visibility would be good enough to monitor the action of the sledge on the seabed and the reaction of benthic organisms to the electric pulses.

Once the sledge had been optimised and shown to be commercially viable, an area would be designated and divided into four. All four of these sub-areas would be sampled randomly by Day grab. Two sub-areas would then be fished with a series of parallel tows which would be carefully measured so as to calculate the proportion of the area affected by the gear. Another series of day grab samples would then be taken at random within all four areas. From this they were hoping to be able to make an assumption about the number of samples which come from fished parts of the seabed. Animals from these samples would be examined for any effects from the pulse gear. Un-fished areas would act as a control for environmental effects.

The size of the areas and the number of grab samples taken would depend on the findings from the development phase. Tows were expected to be short (<20min). Catches of razor clams would be quantified and samples measured and aged. By-catch species would be measured and recorded. A selection of animals would be kept in tanks to assess the survival of different species caught. At some tows a fine mesh liner would be used in the cage to retain any small animals which would otherwise pass through.

The area was to be within the two small sites in Liverpool Bay detailed in the map below (Figure 6) taking place on a muddy sand/sandy mud seabed substrate. These sites were identified from previous industry interest (see 2.5 above). Tow speed was to be approximately 0.2 knots. The minimum depth of water for the trial was to be in accordance with the vessel's 3.8m draft whilst the maximum depth of water was to be approximately 15m.

The action and efficacy of the gear was to be recorded using cameras mounted on the gear. Adjustments would be made to the angle of the scraper bar and other parameters to maximise efficiency. The effect of weather conditions on the use of the gear was also to be assessed.

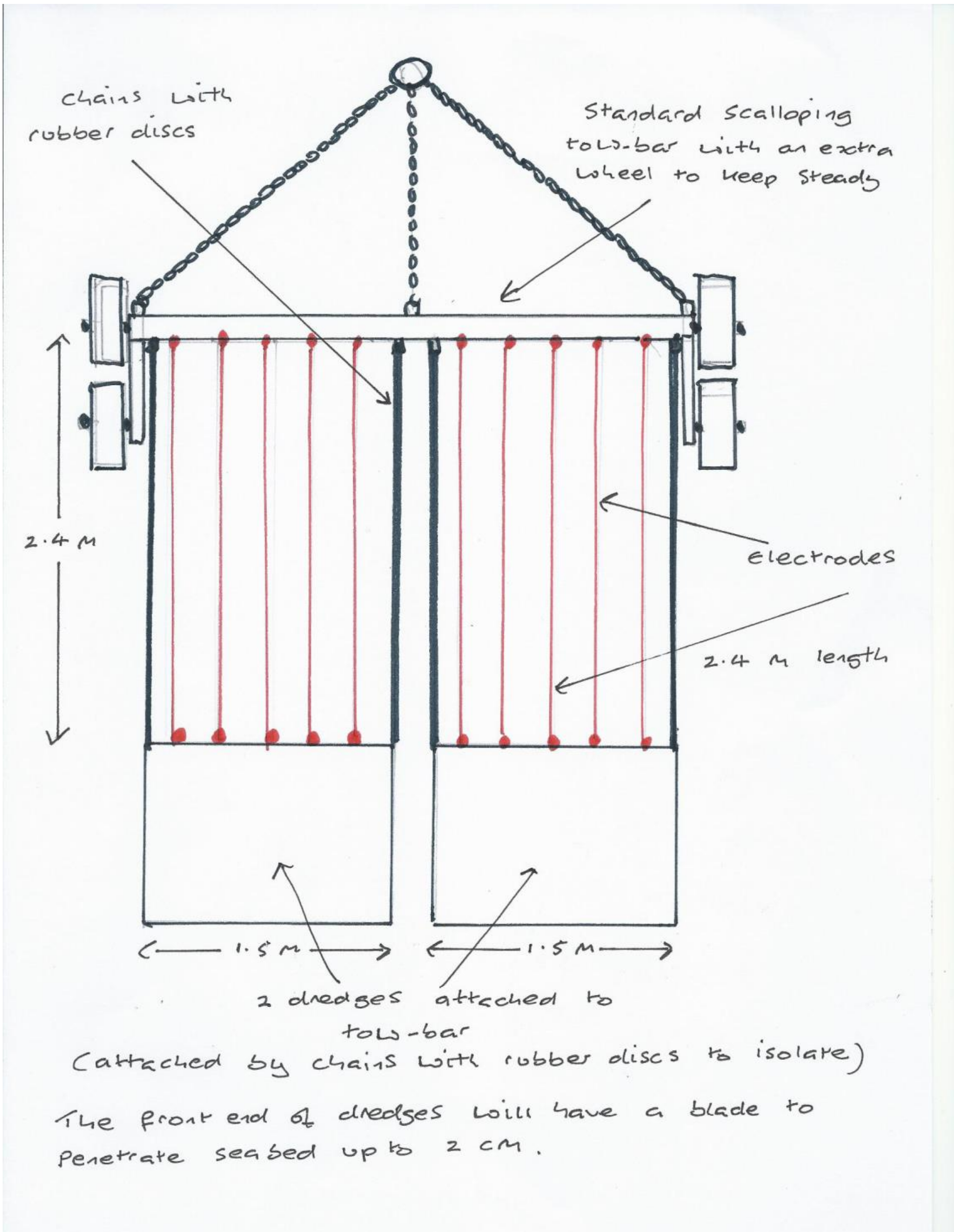

Figure 5. Configuration of the CEFAS trial electro-fishing sledge 2013-14.

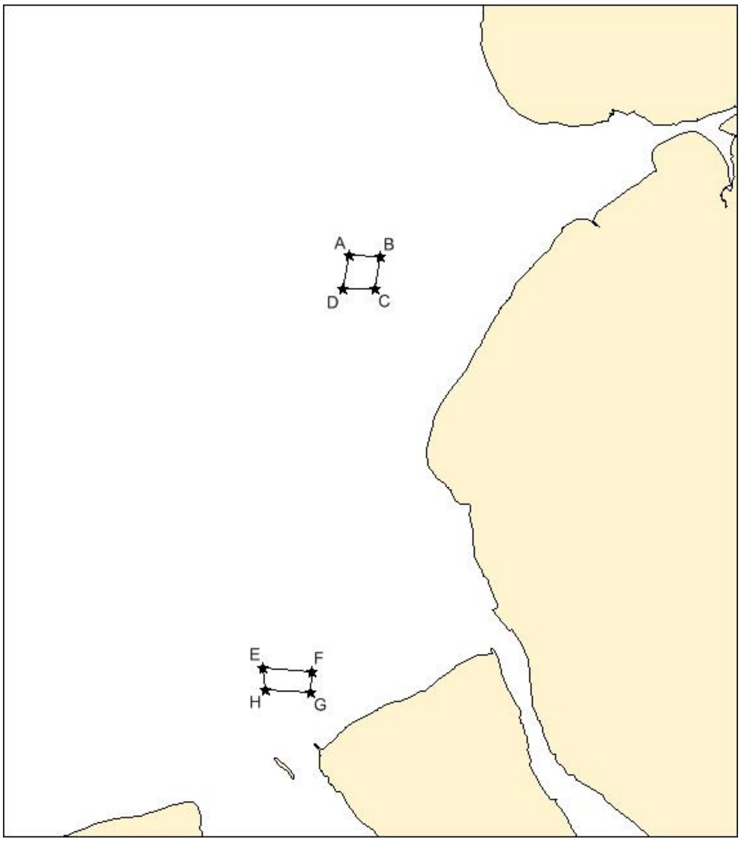

Figure 6. Two areas in Liverpool Bay proposed to be fished in the CEFAS trial of electro dredge 2013-14.

It is understood that no report was produced from this trial due to an overall failure to find a stock of razors. A lengthy delay in the start of the project saw it begin in Liverpool Bay in spring 2014. When no stock was found there focus moved to the mouth of the Duddon Estuary (Fig. 7) in the summer. When again fishing failed to reveal a stock, the project put divers in the water at four stations off the Duddon coast in an attempt to visually identify sites for the vessel and gear to target. Depth ranges of dives were 3.4 – 6.6m on a 7.8m high tide. Razors were found at two out of the four sites, with estimated density at one site of 1 per 1.5m², and abundance from a straight swim at the other site of one razor every 2-3m.

Although unsuccessful in terms of its aims, this project provides very useful information on the difficulties of managing razor fisheries. Although vast swathes of dead shells get washed up on beaches at Leasowe (Wirral), along the Ribble Estuary and in the Duddon Estuary, actually finding the source of them proves to be an enigma.

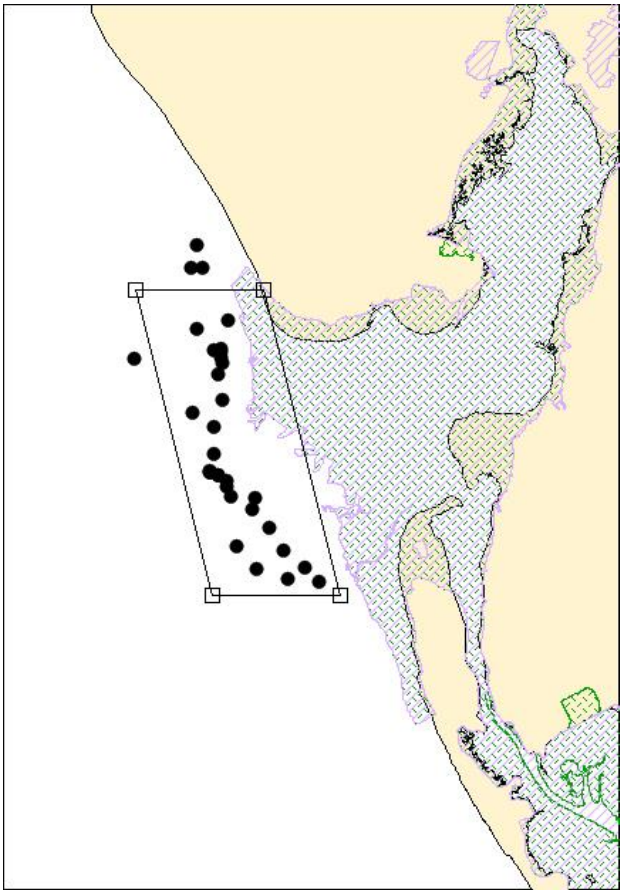

Figure 7. Sites at the mouth of the Duddon Estuary surveyed during CEFAS electro dredge trial 2014.

3 Species of interest to the fishery

Several bivalve species have been proposed as potential target species which are found burrowed in sandy substrate, a relatively common substrate in the District. Sea depth ranges for these species begin at extreme low water and continue to the shallow sublittoral. This means that, apart from at very low tides, these species are constantly submerged. Clams are filter feeders; collecting particles in the water column by passing water through their bodies via two siphons which protrude out of the sediment.

Knowledge of life history and biological information of a stock and its role in the wider eco-system is essential to inform sustainable management. Stock structures can vary from area to area, even over relatively small distances. Data such as age and size at maturity, timing of spawning and longevity is important. This information ensures that fisheries management measures based on robust evidence, such as minimum landing size and closed seasons to protect spawning stock, can be implemented in order to maintain a sustainable fishery. The main species of interest to a commercial clam fishery are described below, and a summary of their generic life history traits and habitat preferences for these species, plus additional species found in the District, can be found in Table 1.

3.1 *Ensis* spp. (Razor Clam)

Three native species of the genus *Ensis* are currently commercially exploited in Scotland and Eire: *E. ensis, E. siliqua* and *E. arcuatus* (Figure 7). These species are distinguished primarily by size and curvature of the elongate shell; however this can be difficult particularly when individuals are small (e.g. <100 mm). This is particularly true for *E. arcuatus* and this species is frequently mis-identified as *E. siliqua*.

All species are found in sandy sediments from the lower shore to shallow sublittoral to a depth of 60m. However, each has a more specific preference for sediment type with *E. arcuatus* found most commonly in finer sediments and *E. ensis* coarser (Henderson and Richardson 1994). Water depth and level of exposure may also play a role in determining species and individual distribution, with larger individuals more able to withstand greater disturbance (Henderson and Richardson 1994). The species are not found in exposed areas where sand is churned by wave action (Breen et al., 2011). This difference in habitat preference may mean that mixed populations are rare. Birds such as eider duck and scoters are the main predators of adults, and the larvae are eaten by crustacea and fish (Marine Stewardship Council, 2017).

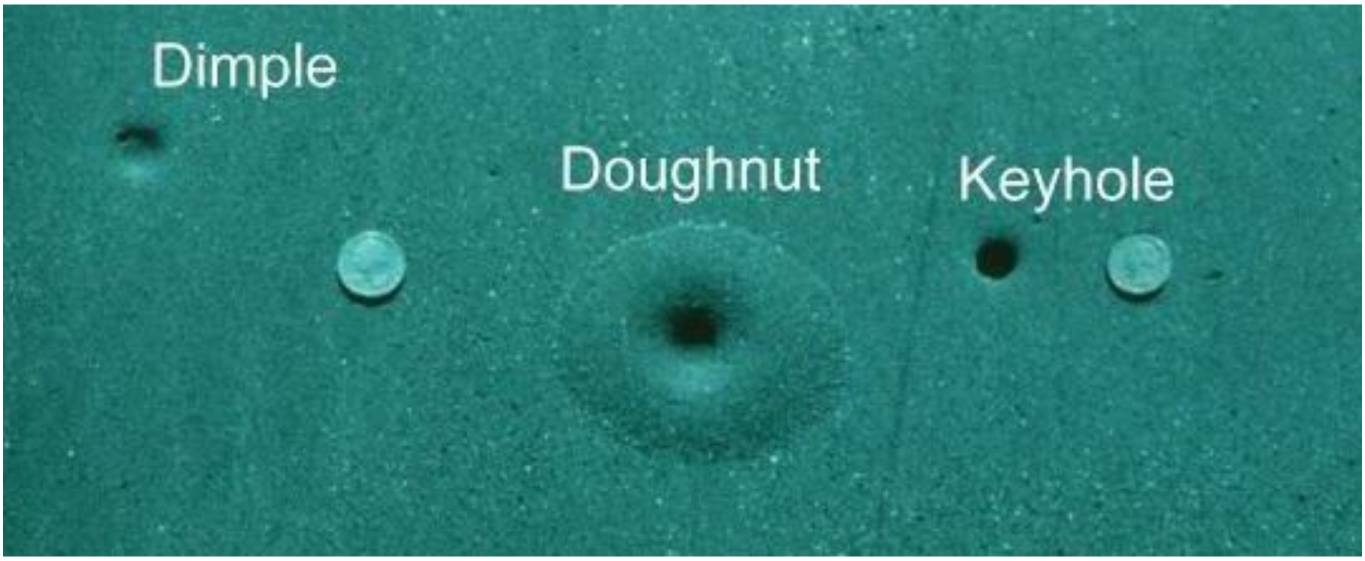

Figure 8. Different types of razor clam 'shows' on surface sediment. Coin used for scale is USA quarter. (Source: Fishing and Shellfishing).

Figure 9. *E. siliqua* in situ (Source: Paul Newlands Copyright: Paul Newlands)

Maximum size varies between species with *E. ensis* 130 mm, *E. siliqua* 200 mm and *E. arcuatus* 150 mm (Ryland and Hayward 1995). Size also differs between sexes and in *E. siliqua* males are larger than females (Fahy and Gaffney 2001). Maximum age is similar for all species with an age of 19 years recorded for an *E. siliqua* individual in Ireland (Fahy and Gaffney 2001).

Aging of individuals using annular rings has proved difficult in most cases as winter growth does not cause a definite ridge. However for *Ensis directus*, an invasive American species, isotopic analysis showed that banding did correspond with age in years. A more practical method of aging *Ensis* spp., particularly in the field or with limited resources, is to use a growth curve which relates size to age. These curves are best produced for specific areas as, for example, age/size relationships varied between Welsh and Irish populations, particularly when young (Henderson and Richardson 1994, Fahy and Gaffney 2001).

Sexing of individuals is also difficult using visual methods alone; instead histological specimens are used. However, even when using this method, individuals in early gametogenesis or after spawning cannot be sexed. Overall male:female ratios for *E. siliqua* are 1:1 but when separated into size classes females predominate smaller classes while males predominate the larger (Gaspar and Monteiro 1998).

In Portugal *E. siliqua* reach sexual maturity in their first year at sizes of 60 to 100 mm (Gaspar and Monteiro 1998). However, similar studies for Welsh and Irish populations estimate age of maturity to be at least three or even four years (Henderson and Richardson 1994, Fahy and Gaffney 2001). This corresponds to the current EU minimum landing size of 100 mm although there is a suggestion that maturity may not occur until greater lengths (i.e. 120 mm) (Fahy and Gaffney 2001). Spawning occurs annually in mid-summer with specimens spent by the end of August. Settlement of larvae may be inhibited by the presence of adult conspecifics and mixed sizes in the same area have been less commonly observed. However, migration of smaller individuals to areas opened up by fishing has been suggested (Fahy and Gaffney 2001).

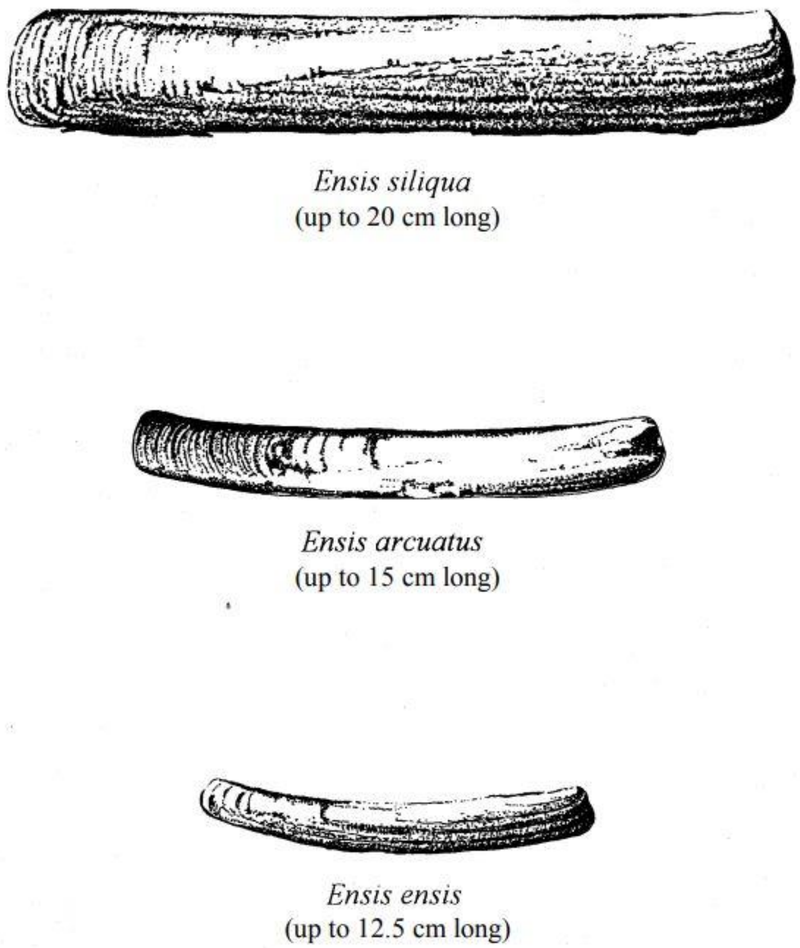

Figure 10. Commercial *Ensis* spp. in the UK. (Source: Pyke, 2012)

3.2 *Pharus legumen* (Bean Solen/ Egg Razor Shell)

This species may also be classed as a razor clam. Similar in shape and size to *Ensis* spp., *P. legumen* (Fig. 11A) can be distinguished by the position of the hinge (in the centre as opposed to anterior end) on the shell. *P. legumen* is found on the Western coasts of Britain; however little is known about the biology of this species.

P. legumen is found in clean sand from the lower shore to shallow sublittoral. This species reaches a maximum size of 130 mm. Lifespan is six years (Fish and Fish 2011) although it is unknown when sexual maturity is reached. EU minimum landing size for this species is 65 mm.

Time of spawning is unknown but probably occurs in summer as it is at this time that settlement of larvae occurs (Fish and Fish 2011). *P. legumen* have been observed living in mixed communities with small (< 60 mm) *E. siliqua* individuals (Fahy and Gaffney 2001).

3.3 *Spisula solida* (Surf clam)

Spisula solida (Fig. 11B) is widespread throughout the UK and is currently exploited for commercial fisheries in southern Europe. It was identified as a species of interest in previous bivalve dredging trials in the District. Most information available on this species comes from populations in Portugal.

S. solida occurs in sandy sediments from low water to depths of about 13 m (Gaspar et al. 1995). It has been suggested that individuals will move into deeper waters (e.g. from 3 to 7 m) in winter in order to avoid disturbance from storm activity (Dolbeth et al. 2006).

This species can reach a maximum size of 50 mm and growth is fastest in the first few years of life. An individual aged 13 years has been recorded, although average lifespan may range from three years in Portugal (Dolbeth et al. 2006) to ten years in Ireland (Fahy et al. 2003). Individuals can be aged reliably using annuli although darker rings can also be a result of disturbance events leading to overestimates of age (Gaspar et al. 1995).

Sexual maturity in Portuguese populations occurs during the first year (Dolbeth et al. 2006). However, as with species such as *E. siliqua* this may be much earlier than individuals in the UK. EU Minimum landing size for this species is 25 mm at an age of approximately 3 years in Irish populations (Fahy et al. 2003).

Spawning in Portugal occurs in early spring between February and May with all individuals spent by June. Cues for spawning are thought to be temperature related, relying on a general increase rather than a specific temperature value (Joaquim et al. 2008). Settlement of spat occurs in June and July with several age classes occurring in the same area (Dolbeth et al. 2006).

3.4 *Lutraria lutraria* (Common Otter Shell)

Lutraria lutraria (Fig. 11C) is distributed throughout the UK and has been identified as a target for commercial exploitation. However less is known about this species.

L. lutraria are found in varied sediments from muddy sand to gravel in depths from low water to about 100 m. Distribution has been seen to be patchy (Kerr 1981). Individuals have long siphons and are buried at depths of 30 cm in the sediment (Holme 1959). Little movement is seen after settlement apart from moving deeper into the sediment with growth. Poor ability to rebury when disturbed (Hauton and Atkinson 2003) means that stable habitats are preferred.

Individuals have been recorded to have a maximum size of 140 mm and individuals aged 18 years have been found in Scotland (Kerr 1981). Age at sexual maturity is unknown and there is no EU Minimum Landing Size for this species.

Spawning occurs during the summer with a peak in May. By August all specimens from Scotland were spent (Kerr 1981). In a Scottish population the majority of individuals in one area were in the same age class and thus from one settlement event (Kerr 1981).

3.5 *Tapes decussatus* (Palourdes or Checkered/Grooved Carpet Shell)

Tapes decussatus (Fig. 11D) (also known as *Ruditapes decussatus* or *Venerupis decussata*) is found on the southern and western coasts of the UK. This species is commonly farmed as well as fished in Europe, especially in the Mediterranean. Generally seed is harvested from the wild, re-laid and “farmed” in sheltered lagoons. Some attempts have been made to carry out similar activities in the UK (Walne 1976). However, fisheries activity for this species is rare in the UK and thus information about *T. decussatus* in this area is limited.

T. decussatus is found in a range of sediments including sand, muddy gravel and clay, buried approx. 15 - 20 cm deep (FAO 2012). It occurs further up the shore than other species investigated and range from the mid/low shore to a depth of a few metres (FAO 2012).

T. decussatus have a maximum length of 75 mm. However, field studies have found this value to be far lower (e.g. 50 mm in the Adriatic (Jurić and Bušelić 2012)). In this Adriatic study the majority of individuals were two to three years old with a maximum of six years.

This is another fast growing species which is thought to reach sexual maturity and commercial size at two years (Beninger and Lucas 1984, Jurić and Bušelić 2012). However, no data is available for the UK and thus these values could differ for local stocks. EU minimum landing size for *T. decussatus* is 40 mm.

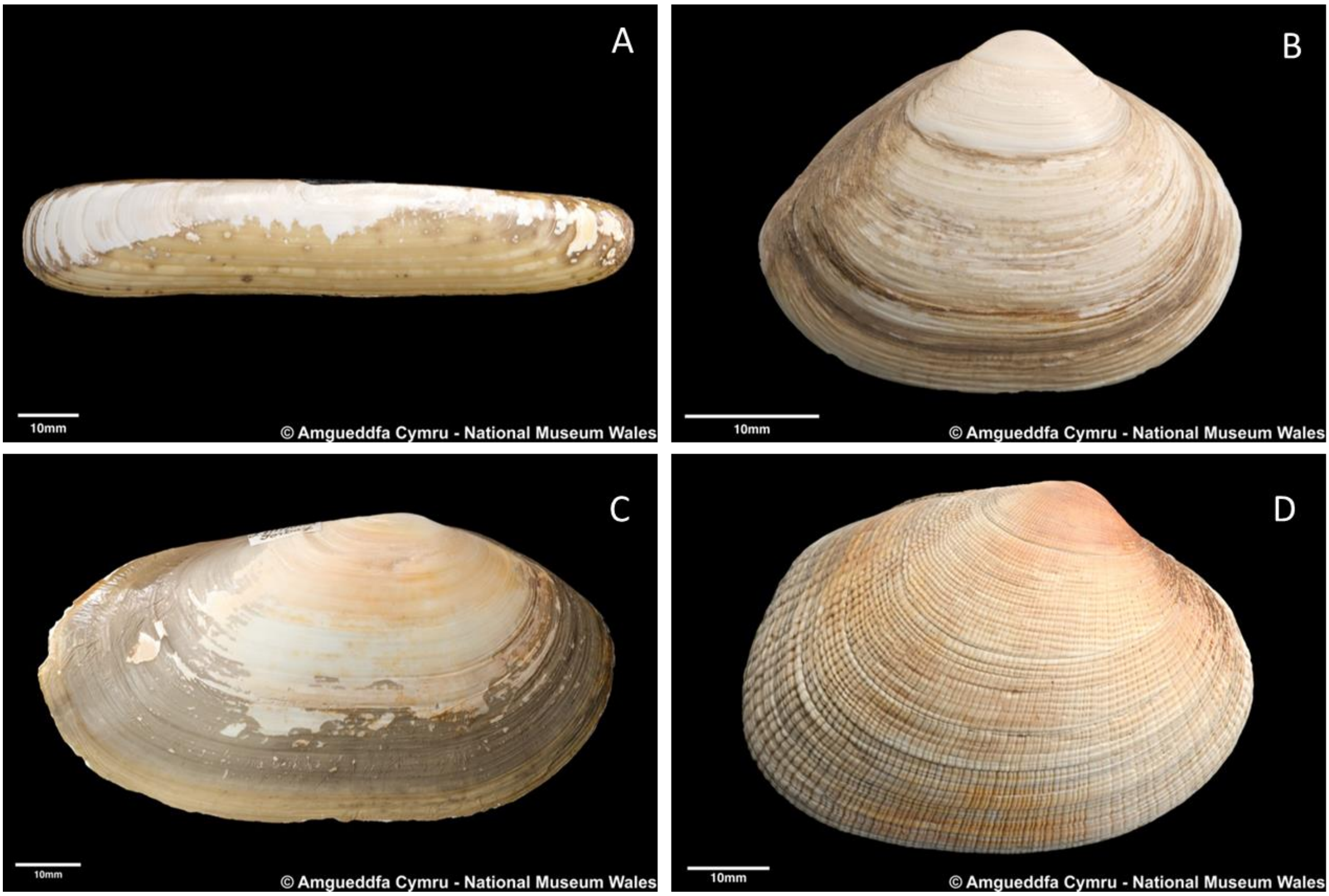

Figure 11. Potential commercial bivalve species in the UK (A) *Pharus legumen* (B) *Spisula solida* (C) *Lutraria lutraria* (D) *Tapes decussatus* (Source: Natural History Museum Wales, 2017).

Table 1. A summary of the ecology and life cycle of the species of commercial importance present in the NWIFCA District. NB. Data may be taken from areas outside of NWIFCA District and may differ from District populations.

Species	Common Name	Max length	Age at maturity	EU Minimum Landing Size	Spawning Season	Habitat	Water Depth
Ensis ensis	Common Razor Shell	130 mm	3 / 4 years	100 mm	June - August	Muddy sand & sand	Low water to 60 m
Ensis siliqua	Pod Razor Shell	200 mm	3 / 4 years	100 mm	June - August	Clean sand	Low water to 60 m
Ensis arcuatus	Razor Shell	150 mm	3 / 4 years	100 mm	June - August	Coarse sand & fine gravel	Low water to 60 m
Pharus legumen	Bean Solen/ Egg Razor Shell	130 mm	Unknown	65 mm	Unknown for UK (Portugal: Summer)	Clean sand	Low water to 25 m
Spisula solida	Surf Clam /Thick Trough Shell	50 mm	Unknown for UK (Portugal: First year)	25 mm	Unknown for UK (Portugal: February – May)	Sand	Low water to 15 m
Lutraria lutraria	Common Otter Shell	140 mm	Unknown	None	April - May	Muddy sand to gravel	Low water to 100 m
Tapes decussatus	Palourdes /Carpet Shell	75 mm	Unknown for UK (Egypt: 1-2 years)	40 mm	Unknown for UK (Spain: May – September)	Sand, muddy gravel & clay	Low water to 5 m

4 Issues for Sustainable Management

For the success of any fishery the sustainability of the target species is imperative. Conflicting pressures exist in razor clam fisheries: extremely efficient gear coupled with the slow growth of the target species (Hauton et al., 2007) could result in a stock being overfished and left in a non-recoverable state in a short period of time. It is important to ensure that not only is the target stock fished sustainably, requiring understanding of the ecology, population structures, recruitment and distribution of the species, but that the wider impacts on other species, communities and habitats are also considered. Market demand and the value of the stock available may affect fishing intensity. Demand is reported to have decreased in Spanish and Portuguese markets but increased in South East Asian markets (Murray et al., 2014). This has caused an increase in Scottish landings over the past ten years (Scottish Government, 2017a). The level of impact depends upon the nature of the substrate, the species targeted and the design of the gear used (Addison et al., 2006). A summary of potential gear used can be found in Table 2.

Table 2. A summary of potential harvesting methods and review of constraints and impacts (adapted from Gray, 2008 and Woolmer, 2011).

Harvest Method	Operating Procedure	Limiting Factors	Catch Quality	Catch Rate	Environmental impacts	Potential for sustainable fishery
Intertidal Hand Gathering	Foot access to lower shore, extraction by hand/tool.	Limited to lower shore and by tides.	Variable depending on method. High quality product achievable.	Low <100 per hour.	Low - no physical impacts. Possible bird disturbance.	Likely to be sustainable at very low effort.
Intertidal Hand Gathering with Salt	As Intertidal Hand Gathering, with broadcast spreading of salt.	Large scale means likely to be a 'one time' harvest. May be a legal issue with the use of chemicals in the sea.	High quality product achievable.	Medium potentially 1000+ per tide.	No direct evidence but indications of some effects – likely to be limited by exposure of site.	Not sustainable due to the potential for the removal of stock from whole sections of bed.
Gathering by Divers	Diving from shore or vessel, extraction by hand or tool.	Weather and visibility dependant. Limited by diver bottom time.	High quality live product.	Low <100 per hour.	Low - no physical impacts.	Sustainable but viability questionable due to catch rate. Visibility an issue in turbid waters.
Gathering by Divers with Salt	As Gathering with Divers, with spread of saline solution.	May be a legal issue with the use of chemicals in the sea.	High quality live product.	Medium potentially 3000+ per tide.	No direct evidence but indications of some short and medium term effects of salt on fauna.	Unable to assess sustainability without more information on the environmental effects.
Divers using Electro Gear	Diving from vessel, with towed electrodes.	Currently illegal to use electricity for fishing due to health and safety risks posed from electrical contact with water.	High quality live product.	High 5000+ per day.	Limited information but initial studies report minor impacts.	Reported as potentially sustainable if stock sensitively managed and if environmental impacts can be demonstrated to be acceptable. Unsustainable without sensitive management.

Hydraulic Dredge	Dredge towed or fly-dragged from vessel	Limited to water less than 10 m in depth.	Lower quality product which requires de-gritting.	High 5000+ per day.	Significant seabed impacts due to disturbance in stable sediments. May be acceptable in mobile sediment habitats. Damage to target and non-target species widely reported in the literature.	Reported as potentially sustainable if stock sensitively managed and suitable habitats selected. Unsustainable without sensitive management.
Electro Dredge (experimental)	Electrode and dredge towed or fly-dragged from vessel.	Currently illegal to use electricity for fishing.	Likely to be high quality live product.	Likely to be high 5000+ per day.	Limited information but initial experimental studies report minor impacts.	Reported as potentially sustainable if stock sensitively managed and if environmental impacts can be demonstrated to be acceptable. Unsustainable without sensitive management.

4.1 Sustainability – Fishing impacts on target species

Ensis spp. are a relatively slow growing and long lived species, they reach sexual maturity at around four to five years (Murray et al., 2014). This combined with intermittent recruitment means that they are particularly susceptible to the impacts of fishing. Fishing activity affects both population density and size/age structure. Density decreases at the onset of fishing as established, larger individuals are removed from the population. In Scotland density between fished and un-fished sites differed by over 40% (7 m^{-2} vs. 4 m^{-2}) (Robinson and Richardson 1998). However, long term effects in Ireland varied between sites, suggesting that other environmental factors play a part in the response of fished stocks while economics can also have a role in determining fishing pressure (Clarke and Tully 2011).

More marked effects of fishing on *Ensis* sp. relate to the size/age structure of populations. Fished areas have populations with a smaller average size. Fishing removes older and larger individuals, with 33% of the total population >150 mm in length pre fishing and 15% >150 mm post fishing, in the Bay of Ireland (Robinson and Richardson 1998). This fished area also lacked a "medium" (50 – 90 mm) size class. However, smaller, juvenile individuals were observed only in the fished areas. This may be because there is intraspecific competition between larger and smaller clams and thus removal of these larger clams allows for the migration of smaller individuals or settlement of larvae in this area (Murray et al., 2014).

Ensis that have been left behind by a dredge either re-bury or move outside of the dredge track (Bailey et al., 1998). The majority of individuals (85 – 90%) begin to re-bury soon after being exposed and it has been suggested the fluidisation of sand aids in faster reburial (Hauton et al., 2003).

4.1.1 Hydraulic dredging

The efficiency of the hydraulic dredge (Fig. 12) to remove razor clams has been measured at 90% with the potential capacity to remove undersized immature individuals (Marine Institute & Bord Iascaigh Mhara, 2015) compared to non-hydraulic dredges fishing for clams, scallops and oysters where efficiency has been recorded at 10-35% (Hauton et al., 2007). The design of the dredges used in Ireland has been tested in the Wash (Addison et al., 2006). The speed and direction of the dredge was varied and they found slower towing speeds reduced damage rates to the target species, non-native *Ensis directus*, from 35% to 15% (Addison et al., 2006).

4.1.2 Electro fishing

Electro fishing is currently illegal in European waters (EU Regulation 850/98, Article 31) for health and safety reasons and limited knowledge of its effects (Breen et al., 2011). Electrofishing stimulates *Ensis* spp. escape response of leaving their burrows when exposed to the electric field (Woolmer et al., 2011). As they leave their burrows they are collected by divers or, in fewer cases, a dredge. Woolmer et al. (2011), conducted a Before and After Control (BACI) experiment to record the response of species to electric stimuli. *Ensis* spp. were reported to exhibit an escape response, some actively swimming away from the gear, and others remaining stationary on the surface. Recovery times of 3-10 minutes were observed. Murray et al. (2014) measured the response rate of razor clams to electric stimuli; they found that some individuals had reburied before quadrats could be placed. Some clams had reburied to the extent that less than 1 cm was showing above the surface. All clams had recovered within 30 minutes of exposure at one site and 93% had recovered at another site.

Both studies concluded that the use of electric stimuli elicits escape responses in *Ensis* spp. which could then be hand-picked by divers. Breakage rates and mortality were significantly lower than for other removal methods i.e. dredging (Breen et al., 2011) and hand caught by divers can result in minimal undersized *Ensis* and bycatch. Results from these electrofishing trials for razor clams in the UK have reported the high efficiency of this method compared with hand pulling or salting (Woolmer et al., 2011; Murray et al., 2014). It also yields a higher quality and more valuable product (Murray et al., 2014).

Figure 12. Example of a hydraulic dredge used to fish for razor clams (Source: Hervas et al., 2012)

4.2 Discards and mortalities/impacts on non-target species

Removal of a target species can affect other species within an ecosystem through both direct removal as bycatch (Tuck et al., 2000) and through changes to species composition which affects community interactions.

4.2.1 Removal of prey species

Many fish are known to make use of bivalve and other benthic fauna during one or more stages of their life cycle. Flatfish species are known to consume bivalves, but are opportunistic feeders and will utilise a wide range of benthic fauna dependent upon availability and competition. Plaice (*Pleuronectes platessa*) juveniles eat a high proportion of bivalves or bivalve siphons (Raedemaecker et al. 2011) and it is important for growth and condition of juvenile flatfish as well as habitat quality. The effects of fishing activity on the vulnerable life history stages of such species must be taken into account considering spawning area and location of fish species.

Birds such as diving sea ducks utilise intertidal and subtidal bivalves as a prey source. The Common Scoter (*Melanitta nigra*) is known to feed on a variety of bivalve species, including *Ensis* spp. (Kaiser, 2002). The birds are not species specific in their prey selectivity, but are size selective to optimise energetic returns. The foraging pattern employed is thought to rely upon touch and the ability to reach the areas where prey is abundant through diving (Kaiser et al., 2006). Common Scoter is present within Liverpool Bay from August to May, with most significant numbers present during August to March (Lawson et al, 2016). Physical disturbance to sediment by fishing gear could alter the bivalve composition and in general the faunal communities within benthic habitats. This may have a negative effect on diving sea ducks feeding on the bivalves such as the Common Scoter.

The Red Throated Diver (*Gavia stellata*) is a piscivorous bird that is obligated to dive for their prey. They are not known to be particularly selective in choice of prey, reportedly taking whatever small fish are most abundant in a particular area (Guse et al., 2009). Red Throated Diver is thought to have a strong association with shoals of sprat. They also eat herring, gobies, sand eels, and various flatfish such as plaice and sole. They are predominantly found in areas 0-20m in depth with sandy substrate which is suitable for their prey type. This species may not be directly affected by removal of prey but could be affected by a change in food web interactions as the food resource of its common prey is depleted. Further, normal behaviour may be disturbed by an increase in fishing activity at foraging and loafing sites.

Both of these bird species are designated as protected features of the Liverpool Bay SPA and Solway Firth pSPA, both areas identified as potential razor clam fisheries.

4.2.2 Hydraulic dredging

Dredging for razor clams can negatively affect non-target species by direct removal as bycatch which may result in physical damage or mortality. Studies have recorded the damage hydraulic dredging has on individuals of non-target species (Gaspar and Monteiro, 1998, Rambaldi et al., 2001, Moschino et al., 2002, Gaspar et al., 2003, Hauton et al., 2003). Bycatch levels recorded in literature are variable; levels of less than 30% of total catch were recorded in the Clyde Sea (Hauton et al., 2003) compared to a Scottish sea loch where landings of bycatch were reported in the range of over 70% of total catch (Tuck et al., 2000). In this experimental fishing trial, bycatch composition was 52% polychaetes, 23% crustaceans, 18% molluscs and 7% other phyla. Damage to bycatch ranged from 10 to 28% of individuals with the heart urchin *Echinocardium cordatum* most prone to damage. Smaller bodied individuals were less likely to be damaged and of all crustacean species retained in the dredge none showed signs of physical damage (Tuck et al., 2000).

For species which are more mobile in normal circumstances this disturbance has less of an impact. Hydraulic dredging in the Adriatic Sea found little or no damage to polychaetes and crustaceans, but molluscs including other bivalves were adversely affected (Morello et al., 2005). There was also a short term impact to scavengers and predators (Morello et al., 2005). Dredging can change community composition. Tuck et al (2000) report that within a day of fishing the proportion of polychaetes in the sediment had reduced and the proportion of amphipods had increased. However after eleven weeks proportions were similar to pre fishing levels.

4.2.3 Electro fishing

In Murray et al's. (2014) study of electro-fishing over half of non-target species, most of which were crustaceans or echinoderms, had either recovered before positioning of the quadrat could take place or were not affected by the electric field. All fish and common starfish (*Asterias rubens*) were unaffected; crustacean, ophuroid and polychaete species observed took several minutes to recover. The effects on benthic invertebrates are described as low but with subsequent effects to food intake and survival in some species (van Marlen et al., 2009). However in scientific studies exposure time to electricity tends to be lower than it would be in long term fishing events which is likely increase impacts (Murray et al., 2014). The effect of increased intensity over greater periods of time more akin to fishing effort must be analysed.

In Woolmer et al's BACI study burrowing bivalves exhibited escape responses with recovery times of less than three minutes; crustacea and echinoderms mainly exhibited disorientation with recovery times of less than five minutes, and fish exhibited escape response or disorientation with a recovery of less than two minutes. However disorientation in the recovery time may lead to increased predation. Behaviour of diving seabirds was also observed during trials with no obvious response to the electric charge. They found no change in species composition after 24 hours and when surveyed again after 28 days.

4.2.4 Hand gathering

Bycatch is not an issue as collection is highly targeted and selective. Undersize individuals are also easily identified and left to remain in their original habitat.

4.3 Impacts on surrounding habitat

The impacts of the methods most used around the UK, have been assessed for their impact below. The impact of dredging on sandy habitat (Tuck et al., 2000; Gilkinson et al., 2003; Clarke and Tully 2014) and on benthic communities (Hall et al., 1990; Tuck et al. 2000) has been well explored and documented.

4.3.1 Hydraulic dredging

Studies around the world have explored the changes in sediment involved in benthic fishing activity. Effects include the resettlement of suspended sediment and the persistence of tracks in different sediment types (Gaspar et al., 2003), effects on sediment morphology and texture (Constantino et al., 2009), an increase in grain size post fishing (Fahy and Carroll, 2007), and changes from sandy gravel to gravelly sand (Hauton et al., 2003). Benthic faunal communities with specific habitat niches will be impacted by these changes.

The effects of hydraulic dredging on sandy sediment have been assessed by monitoring the effects of single fishing events. In deep sandy habitat immediate impacts of hydraulic dredging caused furrows which created a dramatic change to seabed topography (Gilkinson et al., 2003). After one year furrows were still detectable in side scan sonar. The density of bivalve burrows were reduced by up to 90% post dredging and did not recover to that level in the three years of monitoring (Gilkinson et al., 2003).

Tuck et al. (2000) examined the effect of hydraulic water jet dredging in an exposed shallow sandy subtidal environment. Immediate effects were visible, with trenches left on the seabed which started to fill after five weeks and were no longer visible after eleven. Sediment remained more fluidised in fished areas than in surrounding non-fished areas after eleven weeks. Clarke and Tully (2014) monitored the effects of hydraulic dredging on bivalves in the intertidal zone and did not detect any significant effects on benthic sediments.

Dredging activity can change community composition; gears re-suspend and fluidise sediment, move and bury boulders and may leave long lasting trenches (Mayer et al., 1991) all of which can impact benthic communities. Hall et al. (1990) observes infaunal community response to hydraulic dredging in 7 m depths of a Scottish sea loch 40 days after fishing. They recorded an initial reduction in the abundance of a significant proportion of species; however after 40 days no effects of fishing could be detected both in species abundance and through visible signs on the sea floor. In areas where *Ensis* spp. are heavily fished, such as the north-west Irish Sea off the coast of Ireland, penetration of the fine sandy mud habitat resulted in two bivalve species: *P. legumen* and *L. lutraria* increasing in number within fished areas. The abundance of opportunistic species such as *L. lutraria* increases with the removal of slow growing *Ensis* spp. (Fahy and Carroll, 2007).

Studies of the effects of experimental single fishing events are useful but do not reflect fishing operations, when the effect of multiple tows in any area would be more profound (Tuck et al., 2000). Recovery rates from fishing are more rapid in less stable habitats and defined areas that are fished more than three times per year are likely to be permanently altered (Collie et al., 2000). The persistence of the effect of the gear on habitat depends on the amount of activity taking place as well as the sediment structure, level of exposure and tidal regime.

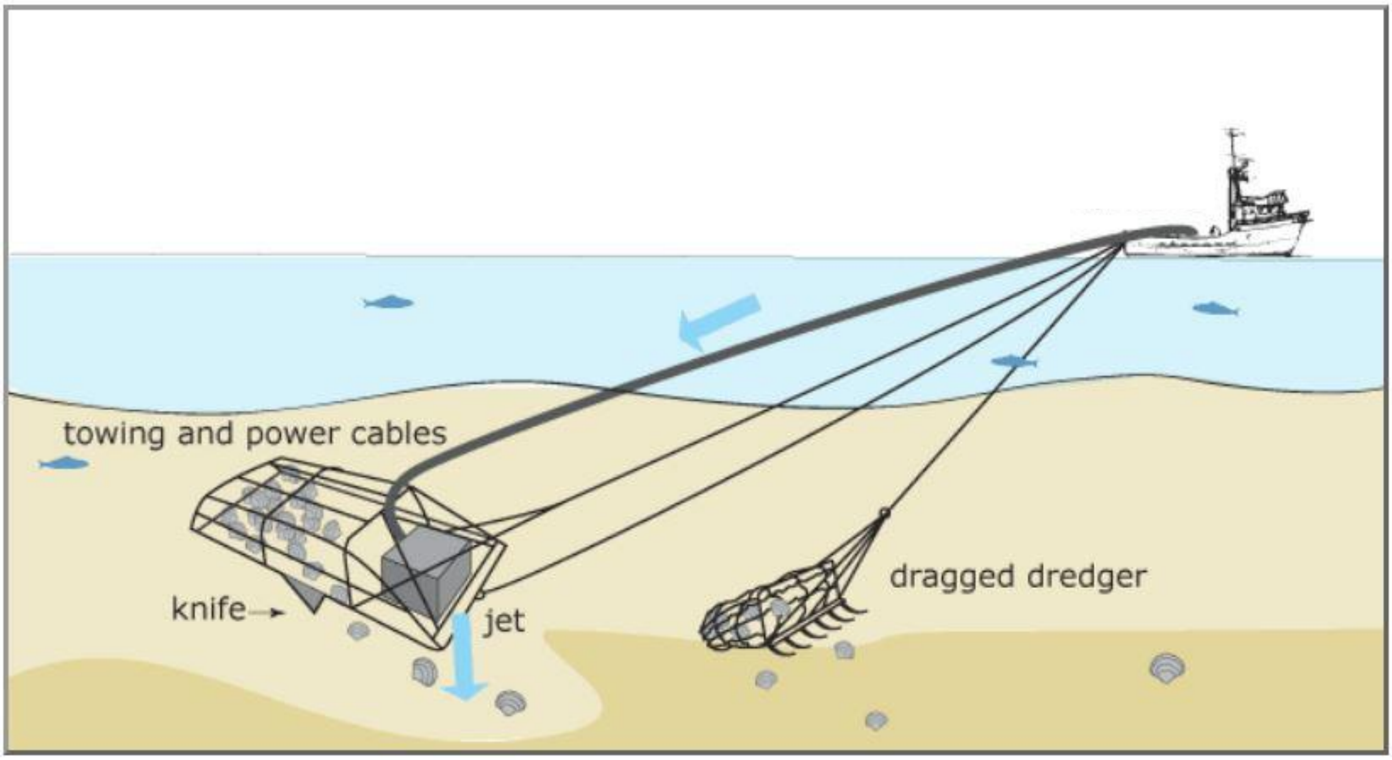

Figure 13. Diagram showing hydraulic dredging versus non-hydraulic dredging from a vessel (Source: Monterey Fish Market, 2011)

4.3.2 Electro fishing

Electrofishing involves electrodes being pulled over the sediment. When divers hand gather target species the sediment is not penetrated and little impact to the sea bed has been reported in previous studies (Breen et al., 2011). Murray et al. (2014) reported minimal impact to the sea bed of shallow sandy inshore waters (<10 m depth), compared to the impacts caused by bad weather. Woolmer et al. (2011) found that electric field treatment did not change the properties of the sediment. Use of an electro-dredge may have a greater impact on sediment, when electrodes pass electrical currents into the sediment immediately ahead of a dredge blade (Sheehan et al., 2015) which penetrates the sediment and may have similar impacts to that of other dredges (Section 4.3.1). However further research is required for both methods to determine immediate, short term and long term effects, and the effects at differing fishing intensities. Electro-fishing may release copper and metal ions into the marine environment which have been reported to have adverse effects on marine organisms in the past (Morrisey et al., 1996). However there is insufficient information to draw conclusions about the levels of chemicals released through this method and their effects (Breen et al., 2011).

Electro-fishing is a method that is documented to have positive results in terms of catchability of target species, and effects on non-target species and the surrounding environment. However much further research is required to be confident in these results and to understand how to manage such a fishery in a sustainable way.

4.3.3 Hand gathering

The presence of hand gatherers on the shore may disturb local wildlife and in particular birds. This is also true for the use of boats to transport divers. Any digging activity may also alter the immediate habitat. This activity has only a minor, temporary environmental impact as long as the type of gathering is on a small scale and low on the shore so can only occur on specific tides. Undersize individuals are also easily identified and left to remain in their original habitat.

The use of salt, particularly on a large scale may have some wider reaching environmental effects. When using salt to induce osmotic shock in invasive algae, for example, affected infauna took six months to recover (Creese et al., 2004).

5 How Other Regulators Manage Razor Clam Fisheries

A summary of review of commercial razor clam fisheries and management measures is given in Table 4. Only management measures from governing bodies are included.

5.1 Ireland

5.1.1 Background and Information

Commercial SCUBA diving for shellfish is illegal in Ireland so Irish razor clam stocks have been exploited almost exclusively using dredges (Murray et al., 2014), and fishing began in 1998 (Fahy, 2011). Razor clams occur along the east coast of Ireland in mud and muddy sand habitats from Dundalk to Dublin, and Cahore to Rosslare (Marine Institute & Bord Iascaigh Mhara, 2015) (Figure 14). The actual stock structure of the fisheries in Ireland is unknown; however it is thought that it is relatively open along the east coast in the north Irish Sea with separate stocks in the south Irish Sea (Marine Institute & Bord Iascaigh Mhara, 2015).

The fisheries in Ireland are split into north Irish Sea stocks, south Irish Sea stocks and west coast stocks. Other isolated stocks occur along the south and east coast. The north Irish Sea stocks are the most exploited with sixty vessels recorded fishing in the area in 2015; ten vessels fish in the south Irish Sea, and on the west coast two too three vessels were recorded fishing in 2015 (Tully, 2017).

The Irish Sea fishery targets *E. siliqua*, the west coast fishery targets both *E. siliqua* and *E. arcuatus*. Target species are fished sub-tidally using hydraulic water jet dredges or non-hydraulic propeller dredges to penetrate the sediment up to 25 cm depth (Marine Institute & Bord Iascaigh Mhara, 2015).

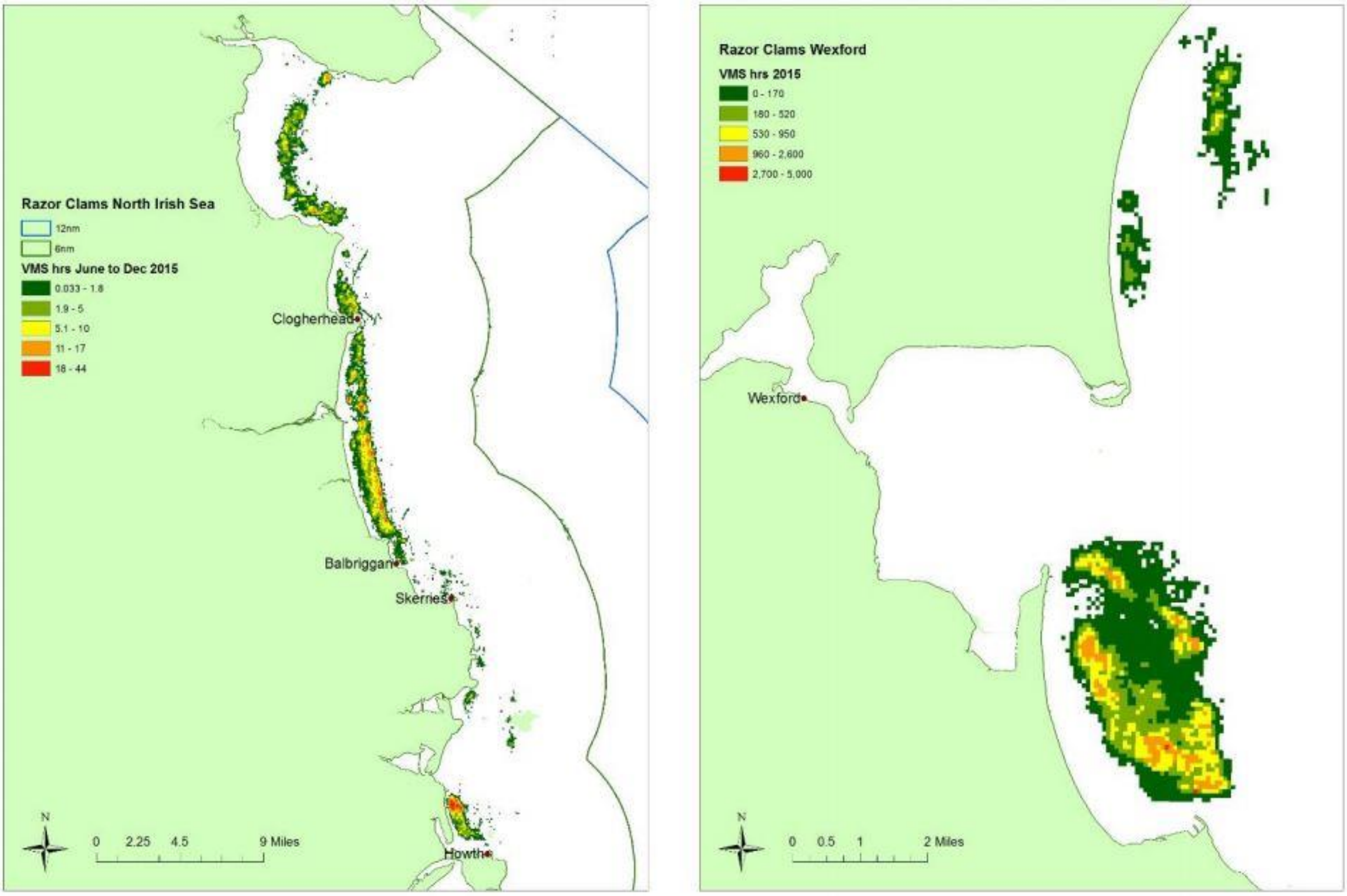

Figure 14. Distribution of fishing activity, from iVMS data, in the north and south Irish Sea fisheries. Note different map scales. (Source: Marine Institute & Bord Iascaigh Mhara, 2015).

5.1.2 Management

Irish razor fisheries are open access. The Irish fleet is split into sectors for which licences can be bought, and the razor clam fishery is open to any vessel with a “polyvalent general or specific” licence. There is currently no restriction on the number of vessels (BIM, pers. comms. 2017). Across all fisheries in Ireland the minimum landing size is 100 mm (further management measure in the south Irish Sea fishery have increased this to 130 mm) and all vessels of any length fishing for razor clams in the area are required to report their position using inshore VMS (iVMS) since 2015. In addition, each razor clam fishery around Ireland has slightly different management measures.

North Irish Sea: Up to 2013, a number of issues arose in the fishery including the proximity of the fishery to features of an SPA, declining catch rates in recent years and increasing market demand and fishing effort. In 2014, the North Irish Sea Razor Fishermen’s Organisation put together a proposal to manage the fishery and address such concerns. This comprises individual vessel weekly quotas, closure of the fishery for four weeks in June to protect spawning stocks, closed areas if catch rates decline past a threshold, and increased monitoring of catch through recording landings and effort. In 2016, a statutory instrument (SI) was introduced setting a weekly vessel TAC of 600 kg and prohibition of landing on Sundays (SI 588/2015). The fishery overlaps Dundalk Bay SPA and occurs close to a number of intertidal mud and sand flat SAC designations.

This fishery has expanded significantly from 2011-2015 with indicators (landings per vessel and catch per hour) showing significant temporal declines (Marine Institute & Bord Iascaigh Mhara, 2015).

South Irish Sea: Management measures include limits to the daily time to fish (07:00-19:00), a catch limit (2.5 tonne quota per vessel per week), boats must carry iVMS which transmits GPS position on a one minute frequency to minimise overlap with Natura 2000 sites, dredge number and size restrictions (one dredge per vessel not to exceed 122 cm width and bar spacing greater than 10 mm), and increased MLS from 100 to 130 mm. Fishers are also required to give prior notice of intention to fish, and must submit fishing docket information on landings and date and location of fishing. The fishery occurs close to or overlaps SACs and SPAs.

This fishery opened in 2010 and expanded to 2013. Catch rates in 2015 were significantly lower than in previous years causing a change in fishing effort to a less exploited area (Marine Institute & Bord Iascaigh Mhara, 2015).

West Coast: Annual voluntary TAC agreement on individual stocks.

Studies have been conducted to understand the effects of the unregulated use of hydraulic dredges on razor clam populations in the Irish Sea (Fahy and Gaffney, 2001; Fahy and Carroll, 2007). The effect that unregulated exploitation can have on razor clam fisheries is illustrated on the Gormanstown bed in the north Irish Sea. Two thirds of the estimated biomass was removed over two years. The effect of this heavy exploitation between 1997 and 2005 was described by Fahy (2011). The study describes a change in species composition with an increase in scavengers and opportunistic deposit feeders, *E. siliqua* stocks had not recovered to pre-1997 levels and had been replaced by *L. lutraria*, another suspension feeding bivalve.

Landings per unit effort (LPUE) are estimated for the fishery using data from consignments to buyers, logbooks and data from sentinel vessels (Tully, 2017).

5.2 The Netherlands

5.2.1 Background and Information

The *razor clam* fishery takes place entirely within Dutch coastal waters, where only Dutch registered fishing vessels are licensed to fish for *Ensis* spp. (Food Certification International, 2014). The fishery targets *E. directus,* a non-native species from the western Atlantic. The species was introduced to the German North Sea coast in the 1970s and has since spread throughout the North Sea (Hervas et al., 2012). It occupies poorly populated niche environments forming 'beds' in muddy, fine sand with small amounts of silt in intertidal and subtidal zones of bays and estuaries (Hervas et al., 2012).

A hydraulic dredge fishery for *E. directus* started in 1990, at which time the fishery was open to any vessel that was suitably registered and licenced. A change in management occurred when in 2004, five permits were issued to those who had a track record of fishing between 1993 and 2003. A further three permits were issued in 2006 in exchange for twelve licences leaving the *Spisula subtruncata* fishery (Nederlandse Visserbond pers. comms, 2017). Landings have been recorded since 2006 and have increased each year up to 2011. Razor clams are fished almost exclusively for the live market; therefore fishing is carried out to meet orders so activity stops once the required amount of razors are caught (Agonus, 2013).

Figure 15. Dutch razor clam hydraulic dredger (Source: Damen Shipyards)

The gear type used in this fishery is a hydraulic dredge (Fig. 15) which fluidises the sediment by pumping water into the seabed. The dredge penetrates the sediment up to 22 cm, the sediment and its contents collect into a steel basket at the rear of the dredge with a minimum spacing of 11 mm. Catch is then transported via a pipe with a pump on to the deck of the vessel (Hervas et al., 2012).

There are two Natura 2000 sites close to the southern fishery, and Habitats Regulations Assessments have been carried out on the *Ensis* fishery to ensure that the conservation status of both sites is met (Addison et al., 2015). The fishery is owned by the Producer Organisation CPO Nederlandse Visserbond, who are responsible for the management of the fishery (Nederlandse Visserbond pers. comms, 2017). In 2012 the fishery became Marine Stewardship Council (MSC) accredited as a sustainable fishery. National legislation exists to regulate fisheries from which management measures are implemented (Table 3) as well as a range of EU regulations relating to transfer and amalgamation of permits, MLS compliance, monitoring of landings, logbook and VMS data (Addison et al., 2015).

Table 3. Dutch national legislative instruments

Legislation	Description
Fisheries Act (Visserijwet 1963)	Establishes powers and responsibilities to regulate fisheries.
Royal Act (Koninklijk Besluit)	The Minister of Economic Affairs is empowered to regulate fisheries through licensing and technical measures.
Netherlands Fishing Act	All commercial fishing vessels are obliged to carry a permit issued by the Ministry.
Nature Conservation Act	Protects nature areas, wild animals and plants. Stipulates maximum catch rates on some fished species.

5.2.2 Management

There are eight licences issued for the fishery, with only six currently active. Although this is not limited it is unlikely to increase (Nederlandse Visserbond pers. comms. 2017). There is a maximum catch rate of 8000 tonnes per year across both North and South fisheries. Dutch MLS follows EU regulations at 100 mm. Licences are subject to conditions: one dredge per vessel, gear restrictions (a minimum grill spacing of 11 mm and a maximum knife width of 1.25 m), speed limits while gear is active, and requirement for VMS to record speed and location. However licences are not assigned individual quotas, and licences can be transferred or sold. Permits are also issued under the condition of an emergency closure if negative impacts to the habitats associated with the fishery are demonstrated or if high levels of *Spisula* bycatch occur.

Razor clam stock biomass and distribution are estimated annually through independent research surveys carried out by the Dutch state scientific advisors Wageningen Marine Research (WMR). Surveys have been carried out since 1995 to assess stocks of razor clams and record other species in the catch. Sampling follows a grid of stations stretching the entire Dutch coastline (Appendix 2); however sampling effort is concentrated on areas previously found to have high numbers of razors (Hervas et al., 2012). Stock estimates are calculated for sized and undersized razors. The survey gear used takes only the upper part of the animal so the width is measured and converted into length. Stock biomass is also estimated by shell width using width-weight conversion calculations. As this is an annual survey a time series can be produced showing the total stock size, the percentage sized and undersized, alongside the current exploitation rate of the fishery over time (Appendix 3). This allows the proportion of razors that could be landed from the adult population to be calculated as the maximum exploitation rate. Bycatch of undersized individuals and non-target species is monitored across all areas on all fishing vessels by taking samples from each vessel at regular intervals and recording the catch composition.

Monitoring of landings data is conducted by the Algemane Inspectie Dienst (AID). All vessels are required to fill in EU logbooks which are submitted to the AID. Sales notes from factories must also be submitted and vessels over 15 m must be fitted with VMS which signals position, course and speed every 2 hours at sea. Cross checking of these three data sources plus sightings from patrols allows infringements to be detected.

E. directus can exhibit significant fluctuations in overall biomass with the highest measurement at 135,530 million individuals in 2010 and lowest at 3,862 million individuals (Agonus, 2013). It is speculated that exploitation rates of the fishery are so low (max. 8000 tonnes) that fluctuations have little to do with fishing and are heavily dependent on natural growth and recruitment (Agonus, 2013). In 2015 low stock numbers recorded may be partially attributed to a major die-off of small *E. directus* found washed up on beaches (Cappell et al., 2017).

5.3 Scotland

5.3.1 Background and Information

The commercial razor clam fishery in Scotland began during the 1990s with landings first recorded in 1994 totalling around 40 tonnes (Hauton et al., 2011). From 1995 to 2006 landings ranged between 40 – 220 tonnes, and increased to 718 tonnes in 2009 with a value of £1,754,000 (Breen et al., 2011). There were a number of key areas carrying out this fishing operation including Shetland, Orkney, the Western Isles and South-West Scotland. In more recent years the fisheries in the southwest have expanded but landings in the northern and eastern areas have declined substantially. The two species of commercial importance in Scotland are *E. siliqua* and *E. arcuatus* (Muir, 2003).

The number of vessels in the fleet are estimates only; there have been between 14 and 27 vessels per year involved in the Scottish razor fishery since 1997, the majority of which are in the <10 m sector (Breen et al., 2011). The main fishing method from 1997-2005 was hand gathering by divers, with dredging (both suction and hydraulic) making up a small component (Murray et al., 2014), although increased demand from Europe and the Far East has led to a growth of interest in the fishery (Hauton et al., 2003). The diversity of gear used increased in 2005 with vessels employing more than one method. It has been noted by Breen et al. (2011) that the increase in landings could be due to the increase in the use of dredges as it is more efficient than diver caught. Since 2004 there has also been an increase in 'suspect' vessels using unknown or unsuitable gear (Breen et al., 2011).

The size of the population of *E. siliqua* and *E. arcuatus* requires more up to date information. Suction dredge surveys (McKay, 1992), and hydraulic water jet dredge surveys (Anon., 1998) have been carried out in the past identifying areas where the species are present (from Breen et al., 2011). However they occurred in the 1990s and early 2000s since which the fishery has expanded.

5.3.2 Management

Since 18 August 2014 it has been strictly prohibited to fish for, carry and land razor clams (*Ensis* spp.) with a domestic licence. Authorisation to fish for, carry or land razors is only given in the form of a separate 'Razor Fish Licence' (Marine Scotland, 2014). The EU minimum landing size (MLS) of 100 m applies. There are no other direct management measures in place for this fishery. There are broader management measures which can affect fishing for *Ensis* including spatial restrictions on the use of mobile gear. The use of dredges is restricted in some sheltered areas protecting sensitive habitats under the Inshore Fishing (Scotland) Act 1984 (Murray et al., 2014). There is also a requirement for all commercial vessels, including those fishing for razors, to record the weight of the landed catch and the ICES rectangle fished. At present there is no catch or effort limit for the Scottish razor clam fishery which has raised concerns about sustainability, especially after the increase in landings recorded in recent years.

5.3.3 Electrofishing for razors

This fishing technique is currently illegal in European waters (EU Regulation 850/98, Article 31); however there are reports that this method has been employed in Scotland since 2004 (Breen at el., 2011). Electrodes are pulled across the sea bed inducing an electric charge which stimulates razors within the sediment to emerge from their burrows. Divers follow the electrodes and collect the razor clams left in their wake (Murray et al., 2014). It is more efficient than hand gathering by diving and results in a better quality product than dredging methods.

Marine Scotland carried out a study on electrofishing to investigate the immediate behavioural and short term survival effects of electrofishing on *Ensis* spp. (Murray et al., 2014). To do so they conducted boat trials to monitor the recovery rates of *Ensis* and of non-target species after electrode stimulation and to video the effects on sea bed habitat. They reported that this method was a low impact way to harvest razor clams, the effects on target and non-target species is non-lethal and the impact on the sea bed minimal. Due to its efficiency, regulations must be in place to ensure sustainability.

Following a public consultation in 2016 a limited trial fishery has been authorised by Scottish Government in order to gather further information about the sustainability of the method. The trial is set to take place in a restricted number of areas in early 2018 following stock assessment surveys (methods of which were not available at the time of writing). During the trial a limited number of vessels will be authorised to electro-fish for razor clams in selected areas, data from which will be gathered with the aim of monitoring stocks and population structure (Marine Scotland, 2017).

5.4 Electrofishing trials in Wales

There has been interest in fishing razors in Wales over the past 20 years, and trials have taken place in areas such as Carmarthen Bay to look at the effects of both hydraulic dredging and electrofishing. However the trials did not go any further due to management and monitoring constraints (Woolmer, pers. comms. 2017).

Electrofishing trials have also been carried out in Carmarthen Bay, South Wales to assess the effects of electrofishing on non-target invertebrate macrofauna and epifauna using a BACI experiment (Woolmer et al., 2011). They described no significant short term or long term (28 days post-fishing) effects in the community or relative species abundance of macrofauna. Epifauna and fish were observed exhibiting disorientation after the initial shock event with no significant changes after 28 days. Only *E. siliqua* were observed to take more than five minutes to recover. They reported that electrofishing can harvest *Ensis* spp. without negative effects on epifauna and macro faunal communities (Woolmer et al., 2011).

Table 4. Review of commercial razor clam fisheries and management measures. Only management measures from governing bodies are included.

Fishery	No. of vessels	Gear	Target species	Management measures
Ireland				
North Irish Sea	60	Hydraulic dredge	*E. siliqua*	600 kg weekly vessel TAC. Prohibition of landing on Sundays. Vessel must carry iVMS.
South Irish Sea	10	Hydraulic dredge	*E. siliqua*	Fishing hours limited to 07:00 -19:00. Catch limit of 2.5 tonnes per vessel per week. One dredge per vessel. Bar spacing greater than 10 mm and dredge must not exceed 122 cm width. Fishers must give prior notice of fishing and submit gatherers documents no later than 48 hours after landing. Vessel must carry iVMS.
West Coast	2-3	Hydraulic dredge	*E. siliqua, E. arcuatus*	Vessel must carry iVMS.
Holland	6[a]	Hydraulic dredge	*E. directus*	Limit on the number of vessel licences. Maximum TAC of 8000 tonnes per year. One dredge per vessel. Bar spacing greater than 11 mm and maximum dredge width 1.25 m. Restricted speed limits while towing. All vessels are required to fill in EU logbooks. Closure of the fishery if negative impacts to habitats/high levels of bycatch occur. Vessel must carry iVMS.
Scotland	27[b]	Hand gathered (divers), suction dredge, hydraulic dredge	*E. siliqua, E. arcuatus*	Must have a razor fish licence.

[a] 6 out of 8 licences are currently active.

[b] Maximum number of vessels, fluctuates year on year.

6 Barriers to Progress

It is the duty of the NWIFCA to ensure healthy seas, sustainable fisheries and a viable industry. While the NWIFCA supports diversification of fishing effort, it is imperative that fishing activity is managed effectively to ensure sustainability of the target stock, other species and habitats potentially affected by the fishery. This section explores outstanding questions that must be addressed before moving towards a dredge or hand gathered razor clam fishery within the NWIFCA District.

6.1 Impact of removal on target species

6.1.1 Population size and structure

High efficiency of dredge gear, irregular recruitment and changes in benthic communities suggest there is significant potential for overexploitation of razor clam beds (Marine Institute, 2009). Knowledge and monitoring of population size and structure is imperative for the sustainability and recoverability of the stock whatever fishing method is employed. Stock assessments are an integral part of managing a fishery sustainably.

Previous studies into fisheries in the NWIFCA district have identified at least six commercially valuable species (see section 2). While they may not be target species, all species affected by commercial gathering must be included in the stock assessments. Such assessments should inform whether target species are present in commercially fishable numbers, and for both target and non-target species the spawning stock biomass and biomass of overall populations. Stock assessments should cover the geographical area of commercially targeted species and should be carried out regularly.

Thorough stock assessments are an integral part of the MSC sustainability accreditation awarded to the Dutch *Ensis* fishery. Here, independent bivalve surveys are carried out by the scientific state advisors Wageningen Marine Research (WMR). Surveys assess the population of eleven species of bivalve mollusc across the entire Dutch coastline (Hervas et al, 2012). They are requested and funded by Dutch government and have been carried out since 1995. Results from this annual survey are used to assess the population size and structure of *E. directus.* These results are combined with the landings data (plus an additional discard rate) to estimate the proportion of the population affected by the fishery.

One difficulty faced when assessing razor clam stocks is finding the beds. Finding *E. directus* beds in Dutch stock assessments is slightly easier as the longevity of surveys has allowed for knowledge of the location of *E. directus* beds, and the whole of the coastline is covered in the programme. These are areas surveyed at a finer scale using densities from the previous year's results. Furthermore, *E. directus* is reported to occupy distinct habitat from other species: generally exposed poorly populated areas of muddy, fine sand with small amounts of silt (Hervas et al., 2012). This differs for species found in the NWIFCA District where populations of different species inhabit similar locations and have been reported to move around. Previous work by CEFAS in 2013 - 14 to carry out experimental electro-fishing for razor clams in the District was abandoned, after two attempts resulted in no catch from areas where *Ensis* spp. were previously reported (CEFAS, 2015). This presents difficulties in conducting sub-tidal stock assessments that would have to be addressed. Historic data gathered from previous work carried out in the District could be employed here as a starting point; however a previous study conducted by Intershell and CEFAS in 2007 recommended that further sampling was required to clarify the distribution of species.

Outstanding questions that must be addressed:

- Who would fund and carry out assessments?
- What species would be recorded?
- Where and how large is the survey area?
- What gear should be used to survey?
- How often should surveys be carried out?

6.1.2 Size at sexual maturity and spawning behaviour

Information is required about the size at sexual maturity for each species exploited. *Ensis* spp. has an EU minimum conservation reference size of 100 mm. This EU MCRS was incorporated in the legacy North West Fisheries Committee (NWSFC) Byelaw 19. Some individuals may reach sexual maturity at greater lengths than the MCRS. Studies have found size at sexual maturity of *Ensis* spp. differs geographically; in Portugal *E. siliqua* reach sexual maturity from 60-100 mm, whereas in the west of Ireland maturity may not occur until 120 mm (Fahy and Gaffney, 2001). To have confidence that the MCRS would protect juvenile stock, further study on each potentially commercial species in each area would have to be carried out or a precautionary MCRS applied.

While some information on life history and biology can be found in Section 2, further information through primary and secondary research would yield additional important information on spawning seasons and ecology. This would highlight whether it would be necessary to implement a closed season for the protection of spawning stock.

Outstanding questions that must be addressed:

- What is the size at sexual maturity for all *Ensis* species in different areas in the NWIFCA District?
- What MCRS should be used?
- Is there a regular spawning season and if so when?

6.1.3 Discards, damage and mortality

Accidental removal of undersize target species is common in many fisheries, and gear restrictions are required to ensure this is minimal (see section 6.3). A precautionary approach is taken in the Dutch *Ensis* fishery where the rate of undersize individuals caught and subsequently discarded has been estimated through surveys. This discard rate (40%) is then added to each catch to predict the amount of *Ensis* removed overall for both sized and undersized (Hervas, et al 2012). This method is effective in a fishery with one target species where there is little bycatch of other non-target species (Nederlandse Visserbonde pers. comms. 2017), but would be problematic to apply to a mixed fishery as each species may require different gear specifications, have different discard rates and each fisher may have different target species.

Damage and disturbance to target species must be taken into account when looking at the efficacy of fishing methods. Damage can be detrimental by rendering caught individuals unmarketable or harming undersize individuals and those not retained by fishing gear. Damage rates can be between 20% and 100% (Section 4.1.1). Changes in the setup of hydraulic dredges can be made in order to minimise damage, for example using a slower towing speed and positioning water jets to maximise fluidisation of the sediment (Addison et al., 2006). In the Dutch fishery, one management measure restricts the towing speed of vessels, which restricts the area a vessel can fish in a set period of time and results in less overall damage to shells (Hervas et al, 2012). Fishermen describe fishing around a 1 m strip and then leaving that area alone allowing for *E. directus* to relocate into the empty space left by the dredge (Nederlandse Visserbond, pers. comms. 2017). The damage / mortality of such individuals must be recorded as it could affect overall populations.

While exposed, individuals that are either discarded or left in the dredge track are susceptible to predation by scavenging fauna such as crabs. The ability and time taken to rebury are therefore important factors in determining survival after disturbance by dredging (Section 4.1.1) and would need to be further researched. Disturbance by dredging can also have a more long term effect on the health of target species. Large clefts or disturbances in shell growth of *E. arcuatus* have been reported as common in fished areas (Robinson and Richardson, 1998). Energy required for repair of minor damage may therefore reduce overall fitness of an individual. To understand how disturbance affects the growth rate of target species further, in-depth research is required.

<u>Outstanding questions that must be addressed</u>:

- What is the survival rate of discards?
- How does damage through fishing activity affect growth and survivability?
- How can the damage rates of *Ensis* spp. be minimised?
- What is the reburial time of disturbed individuals?
- How does disturbance affect growth and survivability of individuals?
- How can this be incorporated into management?

6.2 Impact of removal on non-target species

6.2.1 Population and size structure

While *Ensis* species are the primary target for this fishery, the habitats of *Ensis* spp. and other bivalve species are not discrete, therefore the catch may yield other bivalve species of commercial value (Section 2). It is important that the effects of the fishery on these species are considered in the same way as they are for *Ensis* spp. Therefore the population size and structure of these species should also be assessed (Section 6.1.1).

<u>Outstanding questions that must be addressed</u>:

- Who would fund and carry out assessments?
- What species would be recorded?
- Where and how large is the survey area?
- What gear should be used to survey
- How often should surveys be carried out?

6.2.2 Size at sexual maturity and spawning behaviour

Of the three other potential commercial species *P. legumen* has an EU MCRS of 65 mm, *S. solida* of 25 mm and *T. decussatus* of 40 mm; *L. lutraria* has no minimum conservation reference size. These sizes were incorporated in the legacy North West Sea Fisheries Committee (NWSFC) Byelaw 19. Some individuals may reach sexual maturity at greater lengths than the MCRS. For example the lifespan of *P. legumen* is 6 years but its size at sexual maturity is unknown (Fish and Fish, 2011). To have confidence that the MCRS is above size at sexual maturity, further study on each potentially commercial species in the District would have to be carried out or a precautionary MCRS applied.

Outstanding questions that must be addressed:

- What is the size at sexual maturity for all potentially commercial bycatch species in different areas in the NWIFCA District?
- What MCRS should be used?
- Is there a regular spawning season and if so when?

6.2.3 Discards, damage and mortality

Dredging activity has been reported as having adverse effects on non-target species (Section 4.2.2). Within the Dutch *Ensis* fishery one of the conditions in the MSC accreditation was to implement a comprehensive and routine bycatch monitoring plan. The Producer Organisation commissioned an external consultancy to carry out bycatch sampling in 2016. Sampling took place over 13 trips on 5 vessels in different locations across the fishing area. None of the species recorded are listed as a species of concern and the proportion of bycatch was low and there is no need for specific additional management measures to address excessive or sensitive bycatch (Cappell et al., 2017). However, within the NWIFCA District research should be undertaken to explore the extent to which target species habitat overlaps with non-target species and therefore the likelihood of bycatch in a fishery.

Some species which are not as mobile in adult life, such as *L. lutraria*, do not have a large, strong foot and so are less able to successfully survive exposure to damaging activity. However on the Gormanstown beds in Ireland, areas of fished *E. arcuatus* beds were then colonised by *L. lutraria* (Fahy and Carroll, 2007). Dredging benthic habitats also impacts on other non-bivalve species (Section 4.2.2). Extensive research and monitoring would be required to explore the rate of damage and the effects of disturbance on non-target species due to fishing activity and the effect this has on populations and community structure, and the functioning of the system.

Outstanding questions that must be addressed:

- What is the survival rate of non-target species discards?
- How does damage through fishing activity affect growth and survivability?
- How can the damage rates of non-target species be minimised?
- What is the reburial time / time taken to return to normal activity of disturbed individuals?
- How does disturbance affect growth and survivability?

6.3 Gear design

Gear features and design result on differing impacts on the environment. The Dutch *Ensis* fishery includes both gear restrictions and modifications in management measures. Restrictions aim to limit the amount of effort applied to the fishery such as one dredge per vessel and a maximum dredge width of 1.25 m (Hervas et al., 2012). They also enforce a minimum bar spacing of 11 mm to allow undersize individuals to escape. It is not clear what influenced the incorporation of these measures, but gear restrictions and modifications aim to reduce fishing impacts on the environment.

The sampling undertaken by CEFAS in 2010 in Liverpool Bay recommended further study into more selective gears to reduce shell damage. Further work is required to understand the effect of gear on the environment and whether modifications can be made to reduce environmentally damaging impacts while keeping catch rates efficient in the NWIFCA District.

A trial in Scotland for electrofishing razors is in the planning stage at the time of writing and is due to commence in February 2018. The trial aims to assess the sustainability of electrofishing for razors at specific sites around the Scottish coast (Scottish Government, 2017b). Results of this trial could inform the NWIFCA of the potential effects of such a fishery at a commercial scale.

Outstanding questions that must be addressed:

- What is the best dredge design for minimising breakage rates and retention of smaller individuals?
- What are the environmental and feasibility effects of different dredge types and sizes?
- What are the impacts of electro dredges compared with hydraulic dredges?

6.4 Recoverability of ecosystem

6.4.1 Benthic communities

Burrowing bivalves occupy similar habitats to other benthic invertebrates; any razor fishery will have an effect on these species and communities. Effects of dredging on non-target species have been documented with increase in scavenging species but a reduction in total number of macrofaunal species (Section 4.2.2). In Ireland, the high intensity of dredging activity led to a reduction in dominant (target) species and an increase in infaunal community diversity with an increase in scavengers and predators. Some species such as the tube worm *Lanice conchilega*, were completely eliminated from the fished area (Fahy and Carroll, 2007). The extent of effects on benthic communities can depend on fishing intensity with decreased species numbers related to increasing intensity (Morello et al., 2006). Effects on these organisms and the community structure as a whole must be researched in terms of varying fishing intensity to fully understand the effects of this fishery.

The effects on communities is dependent on a number of factors including dredging area, dredge design, frequency of activity, depth and other physical characteristics of the habitat. The effects of dredging activity are highly variable in different locations and at present have not been fully explored within the NWIFCA District. Extensive research and monitoring would be required to ensure protection of biodiversity and community structures against fishing activity.

Outstanding questions that must be addressed:

- What are the effects of hydraulic dredging activity on non-commercial bivalves and other invertebrate species?
- How do effects vary with gear used, habitat type, site exposure, depth?

6.4.2 Changes in sediment

Benthic fishing activity can have profound effects on sediment substrates (Section 4.3). Sediment resuspension occurs from direct contact from fishing gear (Kaiser et al., 2002), the effects of which can be widespread and include burial of benthic organisms, reduction of light for photosynthesis, smothering of spawning areas, releasing contaminants, exposing anoxic layers and affecting the metabolism of organisms (Duplisea et al., 2001; Johnson, 2002). The Irish Sea is characterised by large areas of sand and mud of differing consistencies. It is naturally a highly dynamic area and effects may be low. However they need to be explored in different areas.

Outstanding questions that must be addressed:

- What are the impacts on sediments including changes in particle size, sediment composition and recoverability of community structure?
- How does fishing intensity affect this?

6.4.3 Rate of removal of dredge tracks

The rate of removal of a dredge track is largely dependent on both biotic and abiotic factors including the type of sediment, site exposure, depth and levels of bioturbators present (Tuck et al 2000). The intensity of any fishing disturbance varies among habitat types; coarse sediments are less likely to be affected than fine sand or mud habitats which are more physically stable (Collie et al., 2000). Persistence of marks depends on current and wave action; in high energy environments recovery can occur within days, in lower energy environments recovery could take months or years (Lokkeborg, 2005). The Irish Sea consists of dynamic and sheltered areas, and persistence of dredge tracks in each should be explored.

Outstanding questions that must be addressed:

- What is the rate of removal of dredge tracks in different areas?
- What are the effects of persistent tracks?
- How does fishing intensity affect this?

6.4.4 Prey availability and disturbance

6.4.4.1 Fish

The North Eastern Irish Sea holds important nursery and spawning areas for commercial fish stocks. Knowledge of the reliance of these species on target bivalves within this fishery is limited; however there have been reports of *Ensis* spp. in the diets of dab and plaice within ICES area VIIa in the Irish Sea between 2005 and 2011 (CEFAS, 2017). While diets of these species are varied the effects of a dredge fishery for razors on them is unknown.

6.4.4.2 Birds

A large number of birds utilise the north east Irish Sea, both on migration and seasonally for breeding or wintering periods. Birds such as razorbills and guillemots as well as large numbers of Manx Shearwaters are found in central offshore areas. In inshore waters Common Scoter, terns and eider ducks utilise our inshore waters, and the estuaries and bays of the North West are host to a wide range of waders and other marine birds (Section 4.2.1).

Within the District there are Special Protection Areas (SPA) designated for the protection of birds. In 2010, a large area of Liverpool Bay was designated an SPA for the protection of species including Common Scoter and Red Throated Diver. In 2017, this SPA was extended to cover a larger geographical area and to additionally protect red-breasted merganser and cormorant. The Solway Firth pSPA affords protection to a number of birds in the Solway Firth, also including the Common Scoter. Common Scoter is known to feed on a variety of bivalve species, including razor clams (Kaiser, 2002) (Section 4.2.1). A number of scoter utilise Liverpool Bay and the Solway Firth and the areas further offshore. Shell Flat Special Area of Conservation (SAC) protects supporting habitat for Common Scoter. Its sandbanks provide important feeding ground for diving seaducks.

Additional to removal of prey, fishing activity may adversely affect bird species through disturbance. Common Scoter have been recorded as having a flushing distance of 2km from a 35m vessel, though small flocks have been witnessed to have a shorter flushing distance (Kaiser et al, 2006). Red Throated Diver (*Gavia stellata*) also dive for their prey. Although their main prey source are small fish, fishing activity could cause disturbance on their feeding and loafing grounds.

Under the Conservation of Habitats and Species Regulation 2010 (SI490, 2010) Article 6, before permitting an activity to go ahead within a European Marine Site (EMS) the competent authority must carry out a Habitats Regulations Assessment. The activity can only be allowed if it can be shown that it will have no adverse effect on the integrity of the EMS. Management measures can be incorporated to provide the assurance that the activity will comply with EU law.

As competent authority for inshore fisheries the NWIFCA is required to conduct the HRA. In order to carry this out with confidence evidence must be obtained to provide some answers to the questions above, along with the following relating specifically to SPA birds:

- What is the effect of removal of *Ensis* and associated bycatch / effect on community composition on SPA birds and their feeding requirements?
- What is the magnitude of bird disturbance and its effect on protected species?

6.5 Intertidal Hand gathering

Hand gathering is a less destructive method of fishing (Table 2) and mortality and damage is likely to only affect individuals that are fished directly with negligible impacts to non-fished individuals. Bycatch is extremely low as is damage to both target and non-target species. The speed at which razors can be harvested using this method would also limit the effort that could be put into the fishery. If this activity were to be carried out on a large scale intertidally, stock assessments should be carried out to understand the intertidal population size, structure and distribution. Effort would be limited as beds can only be accessed at low water and in some cases only on spring tides. Consideration may have to be given to the number of individuals wishing to prosecute the fishery, with controls implemented should high numbers be anticipated.

If excessive salt is used this may impact surrounding species however the extent to which this occurs is unknown. Removal of prey may impact other species and bird disturbance may be an issue (Section 6.4.4). An HRA must be carried out if this activity occurs within an EMS.

<u>Outstanding questions that must be addressed:</u>

- What are the specific locations of intertidal beds and how much do they move around?
- Which species would be targeted?
- What method of collection would be used?
- How does the use of salt to extract razors affect other species?

6.6 Other considerations

6.6.1 Classification

In order to protect public health from dangerous levels of toxins in shellfish entering the human food chain, all commercially fished bivalve mollusc shellfish beds have to be classified. Any new shellfish bed, whether subtidal or intertidal, follows the same procedure as classifying any other bivalve species (excluding scallops which are specifically mentioned in the legislation) (CEFAS, 2017). Any new harvesting areas are required to have a full sanitary survey and the provisional representative monitoring point (PRMP) assessment (CEFAS, 2017). The first step is to make an application to the Food Standards Agency (FSA). This application should be completed by the local food authority and industry. The local authority is responsible for classification and any sampling is to be done in conjunction with them.

There are very real practical difficulties facing local authorities in sampling a subtidal area. The local authority is advised to follow similar methods to harvesting which would mean dredging a monthly sample from a specific sampling point recommended in the Sanitary Survey report. This in many cases is simply not feasible. Alternatively sampling can be carried out by industry but must be overseen in person by an individual appointed by the local authority. This means in practice having someone out on a vessel sampling once a month for each commercial bed. Local authorities are unlikely to have the resources to carry out this work.

7 Conclusions

In an effort to progress possibilities for permitting a sustainable razor clam fishery(ies) in the NWIFCA District, this review has collated information on the management of past and existing razor fisheries throughout Europe. The emphasis of the review was to explore management implemented by other regulators to ensure sustainability of stock, and minimal impact on the ecosystems in which razors are found. Regrettably the review has not revealed many answers to the very real practical questions facing NWIFCA in its attempts to permit fishing of what could be seen as a ‘virgin’ fishery. It is interesting to note that there are no permitted razor clam fisheries in English waters, so perhaps the NWIFCA does not face this conundrum alone.

Extensive research is required to answer the outstanding questions to understand whether carefully managed dredging activity could be a viable and sustainable method for harvesting razors in the District. This has huge cost and time implications, which a publicly funded body is not able to fulfil. While previous work has identified potential species and areas for a fishery(ies), and elements of management from other fisheries can be adopted as good practice, at the present time there are too many gaps in knowledge and serious outstanding questions remaining to make much progress.

To summarise these include:

- an understanding of the population structure of commercially viable species;
- an understanding of target and non-target species ecology and behaviours, recruitment, survivability and size at sexual maturity;
- an understanding of the effects and efficiency of gear / gear design on the target and non-target species and the surrounding ecosystem;
- exploration of impacts of other gear types such as electrofishing;
- an understanding of the overall effect of fishing activity at different intensities on biological, physical and chemical features within the area of the fishery, and the risk to protected features;
- impact of fishery on prey availability for fish and bird species, and disturbance to protected SPA species.

NWIFCA encourages industry to seek to collaborate collectively and with NWIFCA scientists, academic institutes and others to establish means of securing funding for in-depth research to begin to unpick some of these questions. This will require commitment and investment from industry and the Authority alike.

8 References

Addison, J., D. Palmer, W. Lart, T. Misson and J. Swarbick (2006). Development of a suitable dredge for exploitation of razorfish (Ensis directus) in The Wash, Cefas & Seafish.

Addison, J., J. Hambrey, R. Cappell (2013). 3rd Annual Surveillance DFA Dutch North Sea Ensis Fishery. Acoura Marine. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 19/10/17.

Agonus (2013). Appropriate assessment Ensis fisheries Natura 2000 sites for Delta Plain of Raan and Noordzeekustzone. Agonus Fisheries Consultancy.

Anon. (1998) A study of the effects of water jet dredging for razor clams and a stock survey of the target species in some Western Isles populations. Marine Laboratory, Aberdeen Report Number: 8/98.

Beninger, P. G. and A. Lucas (1984). Seasonal variations in condition, reproductive activity, and gross biochemical composition of two species of adult clam reared in a common habitat: Tapes decussatus L. (Jeffreys) and Tapes philippinarum. Adams & Reeve. 79(1), pp 19–37.

Bailey, N., M. Breen, N. Graham, T. Howell, G. Sangste, I. Tuck, S. Davis, J. Donald, M. Harding, F. Kennedy and P. Wright (1998). A study of the effects of waterjet dredging for razor clams and a stock survey of the target species in some western isles populations. Marine Laboratory, Aberdeen.

Breen, M., Howell, T. and Copland, P. (2011). A report on electrical fishing for razor clams (Ensis sp.) and its likely effects on the marine environment. Marine Scotland Science Report, 2, 3.

Cappell, R., J. Hambrey, J. Addison (2016). 4th Annual Surveillance DFA Dutch North Sea Ensis Fishery. Acoura Marine. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 19/10/17.

Cappell, R., J. Hambrey, J. Addison (2017). DFA Dutch North Sea Ensis Public Comment Draft Report. Acoura Marine. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 20/11/17.

CEFAS 2015. Sustainable razor clam fishery 2013/14 – Fisheries Science Partnership. Accessed at: https://data.gov.uk/dataset/2014-2015-centre-for-environment-fisheries-aquaculture-science-cefas-sustainable-razor-clam-fis Accessed on: 1/12/17.

CEFAS 2017. England and Wales: Classification and Monitoring. Accessed at: https://www.cefas.co.uk/cefas-data-hub/food-safety/classification-and-microbiological-monitoring/england-and-wales-classification-and-monitoring/ Accessed on: 25/10/2017.

CEFAS, 2017. Fish Stomach Records. Predators of specified prey. Accessed at: https://www.cefas.co.uk/cefas-data-hub/fish-stomach-records/predators-of-specified-prey/ Accessed on: 11/12/2017.

Clarke, S. and O. Tully (2011). Long-term effects of hydraulic dredging for Razor Clam (Ensis siliqua) on benthic invertebrate communities in the North West Irish Sea. Irish Marine Institute.

Clarke, S. and O. Tully (2014). BACI monitoring of effects of hydraulic dredging for cockles on intertidal benthic habitats of Dundalk Bay, Ireland. Journal of the Marine Biological Association of the United Kingdom, 94(7), pp 1451-1464.

Creese, R. G., A. R. Davis and T. M. Glasby (2004). Eradicating and preventing the spread of the invasive alga *Caulerpa taxifolia* in NSW. NSW Fisheries Final Report Series (64).

Collie J.S., S. J. Hall, M.J. Kaiser, I.R Poiner, (2000). A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of Animal Ecology, 69, pp 785–798.

Constantino, R., M. B. Gaspar, J. Tata-Regala, S. Carvalho, J. Cúrdia, T. Drago, R. Taborda, C. C. Monteiro. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. Marine environmental research 67(2) pp 89-99.

De Raedemaecker, F., I. O'Connor, D. Brophy, A. Black (2011). Macrobenthic prey availability and the potential for food competition between 0 year group *Pleuronectes platessa* and *Limanda limanda*. Journal of Fish Biology, 79, pp 1918–1939.

Dolbeth, M., I. Viegas, F. Martinho, J. Marques, M. Pardal, M. Dolbeth, I. Viegas, F. Martinho, J. Marques and M. Pardal (2006). Population structure and species dynamics of *Spisula solida*, *Diogenes pugilator* and *Branchiostoma lanceolatum* along a temporal spatial gradient in the south coast of Portugal. Estuarine Coastal and Shelf Science, 66: 168-176.

Duplisea D.E., S. Jennings, S. J. Malcolm, R. Parker, D. B. Sivyer, (2001). Modelling potential impacts of bottom trawl fisheries on soft sediment biogeochemistry in the North Sea. Geochem. Trans. **2**, 112.

Fahy, E. and J. Gaffney (2001). Growth statistics of an exploited razor clam (*Ensis siliqua*) bed at Gormanstown, Co Meath, Ireland. Hydrobiologia 465: pp 139-151.

Fahy, E., J. Carroll, M. O'Toole, J. Hickey, E. Fahy, J. Carroll, M. O'Toole and J. Hickey (2003). A preliminary account of fisheries for the surf clam *Spisula solida* (L) (Mactracea) in Ireland. Irish Fisheries Bulletin 21.

Fahy, E., and J. Carroll (2007). Consequences of hydraulic dredging for a razor clam *Ensis siliqua* bed in the North West Irish Sea. Biology and Environment: Proceedings of the Royal Irish Academy, 107B (3), pp 115-128.

Fahy, E. (2011). Biology and commercial exploitation of razor clams in Ireland. In Díaz, A. G., Seijo, C. L., Gaspar, M. B. and da Costa González, F. (Eds.). Razorclams: biology, aquaculture and fisheries. Xunta de Galicia, Consellería do Mar, 297 – 304.

FAO. (2012). "*Ruditapes decussatus*." Cultured Aquatic Species Information. Accessed online at: http://www.fao.org/fishery/culturedspecies/Ruditapes_decussatus/en Accessed on: 30/07/12.

Fish, J. D. and S. Fish (2011). A student's guide to the seashore. Cambridge, Cambridge University Press.

Food Certification International (2013). 1st Annual Surveillance DFA Dutch North Sea Ensis Fishery. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 19/10/17.

Food Certification International (2014). 2st Annual Surveillance DFA Dutch North Sea Ensis Fishery. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 19/10/17.

Gaspar, M. B., M. Castro, C. C. Monteiro, M. B. Gaspar, M. Castro and C. C. Monteiro (1995). Age and growth rate of the clam, *Spisula solida* L., from a site off Vilamoura, south Portugal, determined from acetate replicas of shell sections. Scientia Marina, 59(1), pp 87-93.

Gaspar, M. B. and C. C. Monteiro (1998). Reproductive Cycles of the Razor Clam *Ensis Siliqua* and the Clam Venus Striatula off Vilamoura, Southern Portugal. Journal of the Marine Biological Association of the United Kingdom 78(04), pp 1247-1258.

Gaspar, M. B., M. N. Santos, F. Leitão, Luís Chícharo, Alexandra Chícharo, C. C. Monteiro (2003). Recovery of substrates and macro-benthos after fishing trials with a new Portuguese clam dredge. Journal of the Marine Biological Association of the United Kingdom 83(4) pp 713-717.

Gilkinson, K. D., Fader, G. B. J., Gordon Jr, D. C., Charron, R., McKeown, D., Roddick, D., Kenchington, E. L. R., MacIsaac, K., Bourbonnais, C., Vass, P. and Liu, Q. (2003). Immediate and longer-term impacts of hydraulic clam dredging on an offshore sandy seabed: effects on physical habitat and processes of recovery. Continental Shelf Research, 23(14), pp 1315-1336.

Gray, M (2008). Developing a New Fishery: Guidelines for Environmental Good Practice. Based on a Case Study Feasibility study of a new Razorfish (Ensis spp.) fishery off the Duddon Estuary and Cumbrian Coast, Lancashire. Seafish.

Guse, N., S. Garthe, and B. Schirmeister (2009). Diet of red-throated divers *Gavia stellata* reflects the seasonal availability of Atlantic herring *Clupea harengus* in the southwestern Baltic Sea. Journal of Sea Research, 62(4), pp.268-275.

Hall S. J., D. J. Basford, M.R. Robertson (1990). The impacts of hydraulic dredging for razor clams *Ensis* sp. on an infaunal community. Netherlands Journal of Sea Research, 27 (119) pp 25.

Hauton, C., R. J. A. Atkinson and P. G. Moore (2003). The impact of hydraulic blade dredging on a benthic megafaunal community in the Clyde Sea area, Scotland. 50(1), pp 45–56.

Hauton, C., T. R. W. Howell, R. J. A. Atkinson, and P. G. Moore (2007). Measures of hydraulic dredge efficiency and razor clam production, two aspects governing sustainability within the Scottish commercial fishery. Journal of the Marine Biological Association of the United Kingdom, 87(04), pp 869-877.

Hauton, C., T. Howell, A. Boyd (2011). Razor clam fisheries in the United Kingdom of Great Britain and Northern Ireland. In Díaz, A. G., Seijo, C. L., Gaspar, M. B. and da Costa González, F. (Eds.). *Razorclams: biology, aquaculture and fisheries*. Xunta de Galicia, Consellería do Mar, 273 - 296.

Henderson, S. M. and C. A. Richardson (1994). A comparison of the age, growth rate and burrowing behaviour of the razor clams, *Ensis siliqua* and *E. ensis*. Journal of the Marine Biological Association of the United Kingdom, 74(04), pp 939-954.

Hervas, A., F. Nimmo, A. Read (2012). Public Certification Report DFA Dutch North Sea Ensis Fishery. Food Certification International. MSC Sustainable Fisheries Certification. Accessed online at: https://fisheries.msc.org/en/fisheries/dfa-dutch-north-sea-ensis/@@assessments Accessed on: 19/10/17.

Holme, N. A. (1959). The British species of Lutraria (Lamellibranchia), with a description of *L. angustior Philipp*i. Journal of the Marine Biological Association of the United Kingdom, 38(03), pp 557-568.

Joaquim, S., D. Matias, B. Lopes, W. S. Arnold and M. B. Gaspar (2008). The reproductive cycle of white clam *Spisula solida* (L.) (Mollusca: Bivalvia): Implications for aquaculture and wild stock management. 281(Issues 1–4), pp 43–48.

Johnson K.A., (2002). A Review of National and International Literature on the Effects of Fishing on Benthic Habitats. NOAA. Tech. Memo., 77.

Jurić, I., I. Bušelić, D. Ezgeta-Balić, N. Vrgoč and M. Peharda (2012). Age, Growth and Condition Index of *Venerupis decussata* (Linnaeus, 1758) in the Eastern Adriatic Sea. Turkish Journal of Fisheries and Aquatic Sciences, 12, pp 431-436.

Kaiser, M.J. (2002). Predicting the displacement of common scoter *Melanitta nigra* from benthic feeding areas due to offshore windfarms. COWRIE-BEN-03-2002. School of Ocean Sciences, University of Wales Bangor.

Kaiser M. J., J. S. Collie, S.J. Hall, S. Jennings, I. R. Poiner (2002). Modification of marine habitats by trawling activities: prognosis and solutions. Fish Fish. **3**, 114–136.

Kaiser, M.J., M. Galanidi, D. A. Showler, A. J. Elliott, R. W. G. Caldow, E. I. S. Rees, R. A. Stillman, W. J. Sutherland (2006). Distribution and behaviour of common scoter *Melinitta nigra* relative to prey resources and environmental parameters. International Journal on Avian Science, 148, pp 110-148.

Kerr, A. K. (1981). Aspects of the biology of *Lutraria lutraria* (L.) (bivalia : Macteacea). PhD, University of Glasgow.

Lawson, J., Kober, K., Win, I., Allcock, Z., Black, J. Reid, J.B., Way, L. & O'Brien, S.H. 2016. An assessment of the numbers and distribution of wintering waterbirds and seabirds in Liverpool Bay/Bae Lerpwl area of search. JNCC Report No 576. JNCC, Peterborough.

Lokkeborg S. (2005) Impacts of trawling and scallop dredging on benthic habitats and communities. FAO Fisheries Technical Paper 472.

Marine Institute & Bord Iascaigh Mhara (2009). Shellfish Stocks and Fisheries Review 2009: An overview of Shellfisheries legislation, management and economic value in Ireland and assessment of selected stocks. Marine Institute and Bord Iascaigh Mhara.

Marine Institute & Bord Iascaigh Mhara (2015). Shellfish Stocks and Fisheries Review 2015: An assessment of selected stocks. Marine Institute and Bord Iascaigh Mhara.

Marine Scotland (2014). Razor Fishing Licensing Arrangements. Accessed online at: http://www.gov.scot/Topics/marine/Licensing/FVLS/razorlicence. Accessed on: 17/10/2017.

Marine Scotland (2017). Electrofishing for Razor Clams. Accessed online at: http://www.gov.scot/Topics/marine/Sea-Fisheries/management/razors. Accessed on: 17/10/2017.

Mayer, L. M., D. F. Schick, R. H. Findlay, and D. L. Rice (1991). Effects of commercial dragging on sedimentary organic matter. Marine Environmental Research 31, pp249–261.

McKay, D.W. (1992) Report on a survey around Scotland of potentially exploitable burrowing bivalve molluscs. Marine Laboratory, Aberdeen Report Number: 1/92 9pp.

Monterey Fish Market (2011). Fishing methods: Dredging. Accessed at: https://www.montereyfish.com/pages/methods/dredge.html. Accessed on: 21/12/2017.

Morello, E. B., C. Froglia, R. J. Atkinson, P. G. Moore. Impacts of hydraulic dredging on a macrobenthic community of the Adriatic Sea, Italy. Canadian Journal of Fisheries and Aquatic Sciences 62(9) pp 2076-2087.

Morello, Elisabetta B., Carlo Froglia, R. James A. Atkinson, P. Geoffrey Moore (2006) Medium-term impacts of hydraulic clam dredgers on a macrobenthic community of the Adriatic Sea (Italy). Marine Biology 149(2), pp 401.

Morrisey, D. J., Underwood, A. J. and Howitt L. (1996) Effects of copper on the faunas of marine soft-sediments: An experimental field study. Marine Biology, 125(1), 199-213

Moschino, V., M. Deppieri, M. G. Marin (2003). Evaluation of shell damage to the clam *Chamelea gallina*captured by hydraulic dredging in the Northern Adriatic Sea, ICES Journal of Marine Science, 60(2), pp 393–401.

Muir, S.D. (2003). The biology of razor clams (*Ensis* spp.) (L.) and their emergent fishery on the west coast of Scotland. PhD Thesis, University of London.

Murray, F., P. Copeland, P. Boulcott, M. Robertson, N. Bailey (2014). Electrofishing for Razor Clams (Ensis siliqua and E. arquatus): Effects on Survival and Recovery of Target and Non-Target Species. Scottish Marine and Freshwater Science 5 (14).

KJ Perdon, K. Troost, M. and J. van Asch Jol (2016) WOT shellfish monitoring in the Dutch coastal zone in 2016. Wageningen Marine Research, Report C093 / 16.

Pyke, M. 2002. Evaluation of Good Handling Practice for Razor Clams. Seafish Report No. SR548. Seafish.

Rambaldi, E., M. L. Bianchini, G. Priore, G. Prioli, N. Mietti, T. Pagliani (2001). Preliminary appraisal of an innovative hydraulic dredge with vibrating and sorting bottom on clam beds (*Chamelea gallina*). Hydrobiologia, 465(1-3), pp 169-173.

Robinson, R. F. and C. A. Richardson (1998). The direct and indirect effects of suction dredging on a razor clam (*Ensis arcuatus*) population. ICES Journal of Marine Science, 55(5). pp 970-977.

Ryland, J. S. and P. J. Hayward (1995). Handbook of the marine fauna of north-west Europe. Oxford, Oxford University Press.

Sala, A., Brčić, J., Herrmann, B., Lucchetti, A., Virgili, M. (2017). Assessment of size selectivity in hydraulic clam dredge fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 74, pp 339-348.

Scottish Government, 2017a. Scottish Sea Fisheries Statistics 2016. Accessed at: http://www.gov.scot/Publications/2017/09/4462/48. Accessed on: 05/01/2018.

Scottish Government, 2017b. Trial Electrofishery for Razor Clams. Accessed at: http://www.gov.scot/Topics/marine/Sea-Fisheries/management/razors/trial. Accessed on: 14/12/2017.

Sheehan, R., Caffrey, J.M., Millane, M., McLoone, P., Moran, H. and Lucy, F., 2014. An investigation into the effectiveness of mechanical dredging to remove Corbicula fluminea (Müller, 1774) from test plots in an Irish river system. Management of Biological Invasions, 5(4), pp.407-418.

Tuck, I. D., N. Bailey ,M. Harding, G. Sangster, T. Howell , N. Graham and M. Breen. 2000. The impact of water jet dredging for razor clams, Ensis spp., in a shallow sandy subtidal environment. Journal of Sea Research, 43, pp 65–81.

Tully, O. 2017. Atlas of commercial fisheries for shellfish around Ireland, Marine Institute, March 2017. ISBN 9781902895611 pp 58.

van Marlen, B., de Haan, D., van Gool, A. and Burggraaf, D. (2009). The effect of pulse stimulation on marine biota: Research in relation to ICES advice, progress report on the effects on benthic invertebrates. IMARES Report C103/09,49.

Walne, P. R. (1976). Experiments on the culture in the sea of the butterfish Venerupis decussata L. Aquaculture, 8(4), pp 371–381.

Woolmer , A., E. Maxwell, W. Lart. (2011) Effects of electrofishing for Ensis spp. on benthic macrofauna, epifauna and fish species Prepared for the South and West Wales Fishing Communities Ltd as part of Electrofishing for Razorfish (Ensis spp.) Project (FIFG 57437).

Appendix 1

Table 5 The list of species recorded in bivalves sampling conducted by CMACS and AWJ Marine in 2007 in Liverpool Bay.

Taxonomic name	Vernacular name
Acanthocardia sp.	Prickly/rough/spiny cockle
Aphrodita aculeata	Sea mouse
Arctica islandica	Icelandic cyprine
Arenicola marina	Lugworm
Asterias rubens	Common starfish
Astropecten irregularis	Sand star
Buccinum undatum	Common whelk
Chamelea gallina	Striped venus
Corystes cassivelaunus	Masked crab
Dosinia lupinus	Smooth artemis
Echiichthys vipera	Lesser weaver fish
Echinocardium cordatum	Sea potato
Hyperoplus lanceolatus	Sand eel
Laevicardium crassum	Norway cockle
Lanice conchilega	Sand mason
Limanda limanda	Dab
Liocarcinus sp.	Swimming crab
Lutraria lutraria	Otter shell ('black clam')
Mactra sp.	Trough shell
Mactridae	Trough shells
Metridium senile	Plumose anemone
Nephtys sp.	Catworm
Ophiua ophiura	Brittlestar
Ophiuroidea	Brittlestars
Pagurus sp.	Hermit crab
Pharus legumen	Blood razor
Polinices pulchellus	Alder's necklace shell
Psammechinus miliaris	Green sea urchin
Spisula sp.	Surf clam
Thia scutellata	Thumbnail crab

Appendix 2

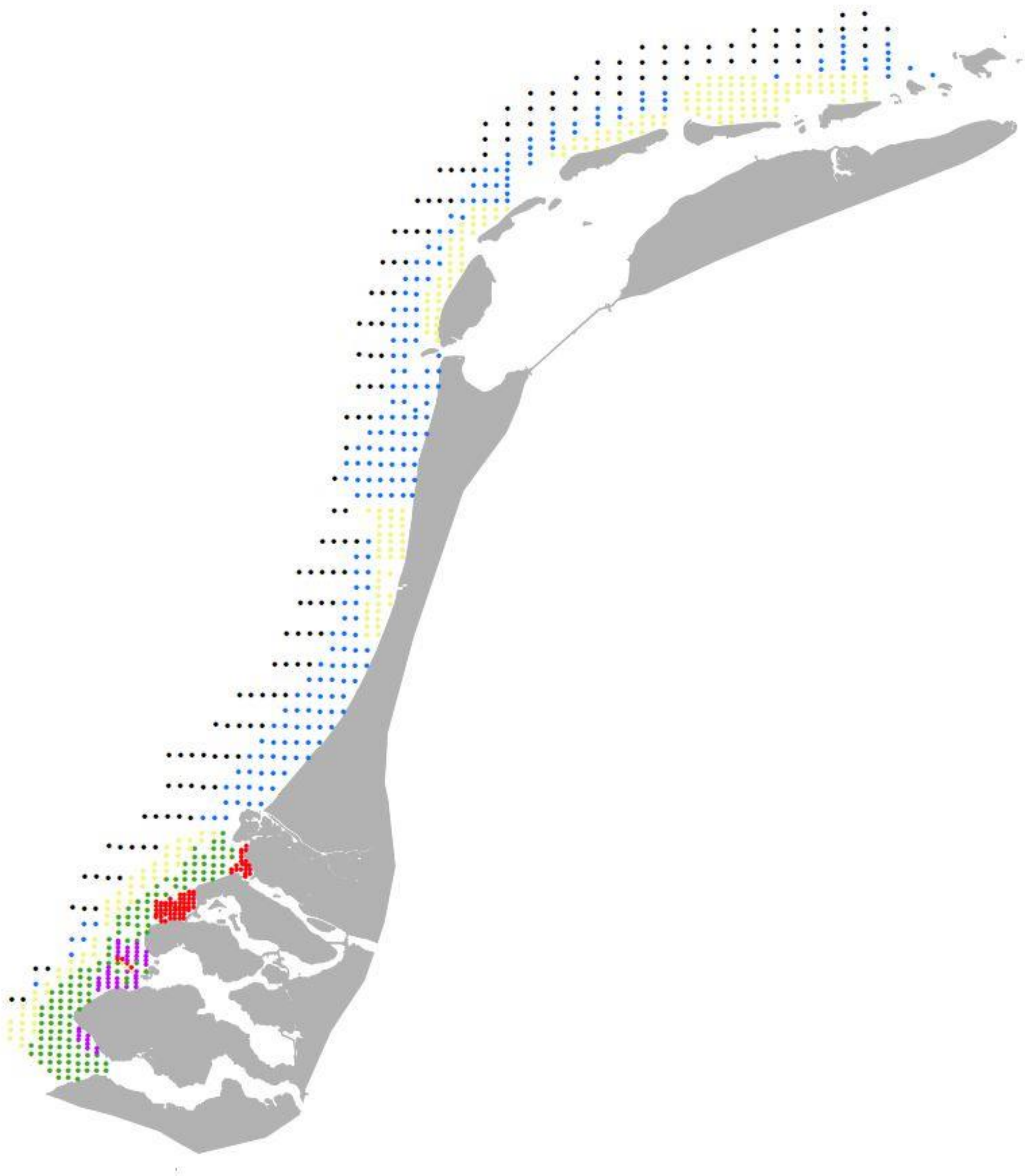

Figure 16 Dutch scientific state advisors (WMR) stock survey 2016. The location of the 855 sampling points along the Dutch coast. The different colours represent different strata (Source: Person et al., 2016).

Appendix 3

Table 6 The Dutch *Ensis* fishery total stock size (in millions) from 2006 - 2016, proportion of large and small razor clams and maximum and current exploitation rates of adult (>10 cm) stock. Proportions are calculated on the assumption that the average weight per animal landed is 25g. (Source: Perdon et al., 2016).

Year	Total stock size (millions)	Proportion <10 cm	Proportion >10 cm	Maximum exploitation rate (%)	Current exploitation rate (%)
2006	37,358	0.82	0.18	4.87	1.17
2007	70,075	0.89	0.11	4.27	1.2
2008	65,756	0.85	0.15	3.35	0.98
2009	26,571	0.74	0.26	4.61	1.61
2010	135,530	0.89	0.11	2.23	1.00
2011	96,410	0.84	0.16	2.12	0.99
2012	97,488	0.88	0.12	2.83	1.20
2013	72,447	0.83	0.17	2.65	1.28
2014	137,233	0.92	0.08	2.79	1.74
2015	53,653	0.87	0.13	4.53	3.17
2016	27,102	0.70	0.30	N/A	N/A