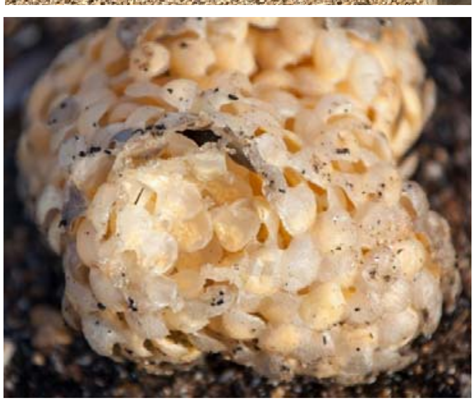

Management recommendations for English non-quota fisheries: Common whelk

Blue Marine Foundation

Final Report

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Submitted by

MRAG

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List of Abbreviations

CFP	Common Fisheries Policy
CPUE	Catch Per Unit of Effort
EMFF	European Maritime and Fisheries Fund
ETP	Endangered Threatened or Protected species
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FLAG	Fisheries Local Action Groups
ICES	International Council for the Exploration of the Sea
IFCA	Inshore Fisheries and Conservation Authorities
LPUE	Landings Per Unit of Effort
MLS	Minimum Landing Size
MMO	The Marine Management Organisation
MPA	Marine Protected Area
MSP	Maritime Spatial Planning
MSY	Maximum Sustainable Yield
NGO	Non-Government Organisation
RFMO	Regional Fisheries Management Organisation
SOM	Size at Onset of Maturity
TAC	Total Allowable Catch
TAG	Technical Advisory Group
TBT	Tributyltin
TCM	Technical Conservation Measure
TSL	Total Shell Length
UK	United Kingdom
VMS	Vessel Monitoring System

1 Introduction

The Blue Marine Foundation ('the Client') has requested the provision of recommendations for the future management of a non-quota fishery in England, namely the common whelk (*Buccinum undatum*). Recommendations are supported by a desk-based review of the current state of knowledge using available literature and insights from stakeholders, where possible.

1.1 Study Context

English non-quota fisheries are often characterised by diversity and dynamism - employing a range of fishing methods and gear types to target a variety of species, sometimes changing approach in response to seasonal abundances or demand. Many non-quota species are exploited inshore, and as such they can be of great significance for coastal communities and economies, with some ports being highly dependent on their continued productivity. Yet, despite socio-economic importance they appear less of a research priority, relative to quota species. Indeed, several important non-quota fisheries are controlled through relatively few regulations and decision making often based upon minimal stock assessment.

English inshore fisheries are currently managed using a range of policy measures, including those at the European level under the Common Fisheries Policy (CFP), the national-level, and on a regional basis through the Inshore Fisheries and Conservation Authorities (IFCAs).

The coast of England is divided into ten IFCA jurisdictions, which extend to six nautical miles from the coast. IFCAs are responsible for conservation and sustainable management of fisheries resources within their jurisdiction - balancing the social and economic benefits of exploitation with the need for environmental conservation. The IFCAs act as statutory regulators and manage marine resources according to European, national and local government legislation. As such, IFCAs have the authority to create and enforce local byelaws, drawing on expert knowledge and evidence. Alongside the Marine Management Organisation (MMO), IFCAs are important managers of many of England's non-quota fisheries, including the common whelk. This fishery has been identified due to its growing importance to regional economies, but also due to the relative dearth of information. Furthermore, due to the nature of many non-quota species, there is relatively little regulation in place to effectively manage their sustainable exploitation or limit entry to the fishery.

Whelk fishing has been increasing throughout England over the past few years - UK whelk landings have steadily increased from 8.4 to 22.7 thousand tonnes between 2003 and 2016 and were valued at over £22.9 million in 2016.[1] Within England, whelk catches are regularly recorded along its entire coastline, but are predominantly landed at ports in the Southern IFCA and Sussex IFCA districts. As commercial demand continues, it is critical to obtain baseline life history information to inform stock assessment and support fishery management. Further, the IFCAs are aiming to coordinate their approach to whelk research, and, potentially management.[2] Due to the recent increase in exploitation and sedentary life history characteristics, the whelk has been identified as potentially vulnerable to overfishing in England.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/653616/Underlying_dataset_-_August_2017.xlsx
[2] "*Whelk research, evidence and management*", 2018 TAG conference – whelk summary.

2 Review of the Fishery

Below, some of the key information necessary for supporting management decisions is reviewed and synthesised. Focus is given firstly to information from the UK, then expanded to cover international examples, where information is lacking. This information is then used to support recommended management responses.

2.1 Biology

The common whelk, or waved whelk, is a subtidal, carnivorous neogastropod mollusc that is distributed throughout most of the northern Atlantic and adjacent seas (Golikov, 1988). They are found between low-water and depths up to 1,000 metres, but are most commonly caught between about forty and sixty metres (Nielsen, 1975).

European populations are reported to breed during autumn and winter (Kideys *et al.*, 1993). Although the literature is inconclusive as to specific timing, essentially, once ambient water temperatures fall below 9 ˚C females begin to lay their eggs – this usually occurs in November, but may continue until April (Lawler and Vause, 2009). Around England, whelks are close to their southern limit, as warmer temperatures are thought to be a limiting factor to reproduction (McIntyre *et al.*, 2015).The eggs are fertilised internally and subsequently laid on hard benthic substrata – at this stage there can be high natural mortality due to predation (Dumont *et al.*, 2008). High larval mortality from urchin predation has been posited to make the fishery vulnerable to overfishing (Fahy, 2001), but this is not corroborated in the literature. Larval stages occur within the egg and juveniles emerge after three to five months and therefore enter the benthic-phase directly i.e. with no pelagic phase (Kideys *et al.*, 1993; Martel *et al.*, 1986b), resulting in limited dispersal potential.

In addition to the lack of a planktonic phase, adult whelks have been shown to be relatively sedentary and only exhibit limited movements (Hancock, 1963; Himmelman and Hamel, 1993; Pálsson *et al.*, 2014). It has been suggested that these two life history traits could limit mixing between populations, reducing gene flow, and resulting in local variations and adaptations (Gendron, 1992; Shelmerdine *et al.*, 2007; Valentinsson *et al.*, 1999; Weetman *et al.*, 2006; Yamada, 1989). Reduced connectivity between populations of common whelk has implications both for the evolution of the species, but also for their management (Pálsson *et al.*, 2014). For example, it could mean that this species is particularly susceptible to localised depletion and may lead to protracted recovery times if overfishing does occur (Himmelman and Hamel, 1993; Weetman *et al.*, 2006), indicating that regionalisation of management would be most appropriate from a biological perspective (Borsetti *et al.*, 2018).

Furthermore, a significant aspect of the whelk's life history, in terms of its sustainable exploitation, is the regional variations in the size at onset of maturity (SOM). Indeed, SOM for this species is highly variable throughout much of its range. Borsetti *et al.*, (2018) compiled a wide range of SOM estimates from across the world, but importantly, showed that current EU-wide minimum landing size (MLS) regulation tends to fall below the estimated SOM (see section 2.4), potentially increasing the risk of recruitment overfishing. Removing juveniles (i.e. <SOM) before they can contribute to the spawning stock, in turn, is likely to provide lower future recruitment (de Vooys and van der Meer, 2010).

Variability in SOM has also been shown to occur on much finer scales. For example, whelks caught in shallow water have been found to mature at a smaller size than those from deeper waters (Haig *et al.*, 2015). Indeed, size at maturity in England has been found to be negatively correlated with depth and temperature (Bayse *et al.*, 2016; McIntyre *et al.*, 2015) - consistent with published literature from Canada (Gendron, 1992). Furthermore, it has been suggested that a fished whelk population may result in animals reaching SOM at a smaller size over time, when compared to an unfished population (Fahy *et al.*, 1995; Martel *et al.*, 1986b).

Once whelks become mature, there is evidence that growth subsequently slows (Brokordt *et al.*, 2003; Hancock, 1967; Jalbert *et al.*, 1989; Santarelli-Chaurand, 1985), likely as a result of the energetic requirements of reproduction (Jalbert *et al.*, 1989). In other gastropods, where size and fecundity are correlated, the slowing of growth at maturity implies that investment in current reproduction compromises future reproduction (Bell and Koufopanou, 1986). As a result, a compensatory strategy has been recorded in a significant proportion of female whelks in the Mingan Islands, in that they do not reproduce every year (Martel *et al.*, 1986a). In contrast, adult males reproduce annually probably because their reproductive costs are lower.

Significant differences for most measured parameters (e.g. size, growth, age, maturity), suggest that large-scale management measures, such as a single MLS, is not a practical solution for management with regards to biological sustainability (Shelmerdine *et al.*, 2007), and that small-scale management should be considered on a region-by-region basis to assess the practicality of each measure.

2.2 Stock Status

Across much of the common whelks range there is a lack of suitable data and therefore stock status is largely unknown in the UK and elsewhere (Woods and Jonasson, 2017). Minimum landing sizes and catch limits are commonly set across Europe, Canada and the US, but there are few data available to conduct detailed stock assessments or indeed estimate abundance. Instead, CPUE or LPUE is often used as a proxy for abundance, but this can be problematic. The lack of data and understanding of stock status across much of its distribution is seen by many as potentially exacerbating the risk of over-exploitation.

Indeed, there are several reports of localised extinctions of whelk, due to multiple pressures. In particular, their high-profile disappearance from the western Dutch Wadden Sea (Cadee *et al.*, 1995; de Vooys and van der Meer, 2010). It reportedly began in the mid-1920s with a gradual decline due to overfishing and reportedly lethal shell damage by fishing gear. Contrary to in England and France where whelk fishing is almost exclusively conducted using traps, in the Wadden sea special dredges were used (de Vooys and van der Meer, 2010). This decline eventually led to the closure of the fishery in the early 1970s, but by this point tributyltin-based (TBT) antifouling paints had come into popular use. These paints were subsequently proved to cause imposex[3], and possibly, therefore, reproduction failure, thus leading to localised extinctions (Cadee *et al.*, 1995). Furthermore, localised reductions in density can depress reproductive activity in relatively sedentary animals – this has been previously recorded in several animals, including the queen conch (*Strombus gigas*) (Gascoigne and Lipcius, 2004).

[3] Imposex is a disorder in gastropods often caused by the toxic effects of certain marine pollutants that causes female marine gastropod molluscs to develop male sex organs.

This tangible threat to overexploitation is a key driver for the development of data-poor techniques for whelk fisheries.

Woods and Jonasson, 2017, considered that hierarchical Bayesian methods were suitable for estimating parameters and reference points for data-poor stocks (as they can borrow strength from stocks with more information) and proceeded to analyse the Icelandic whelk fishery. Importantly, they tested the importance of including spatial variation (in biological parameters and catches) in their population dynamics models, and demonstrated where more data were needed to improve assessment. Indeed, the best model included spatial variation in population dynamics, but more contrast in the data or additional abundance data were needed to be useful for true stock assessment. However, this study provides baseline information that could enable stock assessments for other data-poor whelk fisheries.

Availability of UK whelk fishery data is generally quite poor, and the absence of stock assessments has prevented the definition of Total Allowable Catch (TAC) limits (McIntyre *et al.*, 2015). The lack of comprehensive stock assessments has resulted in a level of uncertainty of the current status of English whelk populations. However, the Eastern IFCA (EFICA) has recently utilised National Marine Fisheries Statistics (MMO data) to provide a status on current stocks, using estimated CPUE based on number of active vessels, as a proxy (EIFCA, 2015). It was observed that during 2014 there was an overall reduction in CPUE within the district, raising concerns over the sustainability of current effort levels (EIFCA, 2015).

Between 2010 and 2013, Sea Fisheries Statistics indicated total whelk landings rose significantly, by 667%. However, the following year witnessed a plateau, despite an increase of 41% in the total number of vessels landing whelks per month. Observations of a reduced CPUE could be indicative of a fishery exceeding sustainable limits (EIFCA, 2015). Additionally, EIFCA (2015) highlights that estimates for CPUE only consider the quantity of vessels due to data limitations and therefore overlooks the number of pots per vessel and the relative soak time of each pot, while increases in quantities of pots per vessel have been observed by a number of IFCAs, suggesting the original CPUE assessment was underestimated.

2.3 Fishery

Small artisanal whelk fisheries have existed in the UK since the early 1900s; annual landings of 4,500 tonnes were reported for England and Wales in 1911 (Dakin, 1912). Increasing demand for whelks, particularly from overseas markets, has been a significant driver in the increased landings in more recent years (Fahy *et al.*, 2000), but the depletion of some stocks of Pacific species of whelk reportedly also played a part (Fahy *et al.*, 2005). This increasing demand has seen the value of whelks increase from approximately £500 per tonne in 2005[4] to £1,200 per tonne in 2018. Landings into England and Wales, from UK vessels, have increased in the last decade, from 8.4 thousand tonnes in 2003 (Lee, 2003) to 18.8 thousand tonnes in 2013 (Radford, 2014) - overall landings of whelks in England in 2016 (ca. 13, 000 tonnes) was almost double those in Wales (ca. 6,500 tonnes)[5]. The increased market demands and subsequent rise in landings has seen estimated values of English landings increase from £5.3 million in 2008 to £12.8 million in 2017 (Figure 1).[5]

[4] Southern Sea Fisheries Report (2005); https://www.dorsetforyou.gov.uk/media/pdf/i/4/SouthernSeaFisheriesNovember2005_1.pdf
[5]UK sea fisheries annual statistics; https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics

Clearly, there are a number of valuable whelk fisheries throughout the UK, some being of particular importance due to their localised nature and because they are often a seasonal alternative for fishers that predominantly target crab and lobster (McIntyre *et al.*, 2015). Whelk fisheries can therefore contribute important income locally in some regions. They are reportedly becoming a popular displacement fishery as vessels move from other, more regulated species, into the less regulated whelk fisheries (McIntyre *et al.*, 2015). For these reasons, whelks are among the most important shellfish fisheries for the UK, after Nephrops, scallop, crab and lobster (Haig *et al.*, 2015).

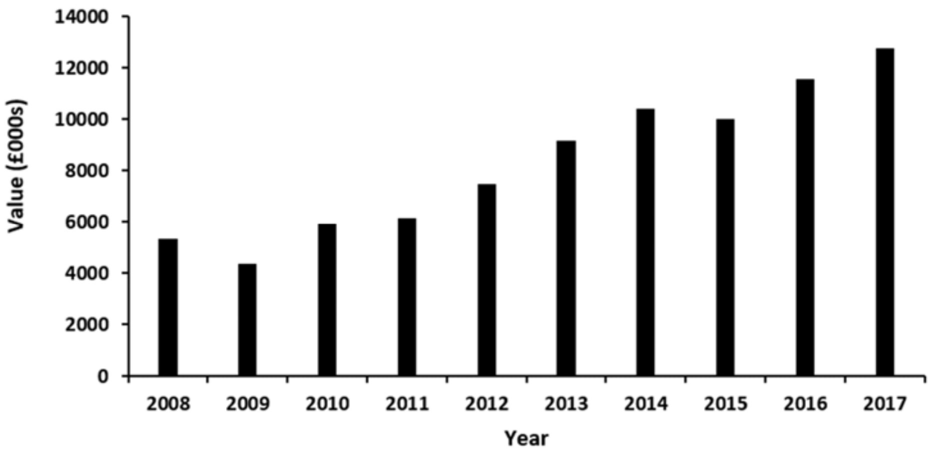

Figure 1: Annual value (£'000s) of landed *B. undatum* in England (MMO, 2008-2017). Data from 2017 does not include the value of landings by foreign vessels into UK ports.

Sea Fisheries Statistics[5] over the last decade indicate total English landings of *B. undatum* are highest at ports within the Southern, Sussex, and Devon & Severn IFCA districts (Figure 2). On the other hand, over the past 10 years, large increases in annual landings have been observed in districts along the east coast of England (Figure 2), regions previously landing lower quantities of whelks in comparison to the southern areas of the country.

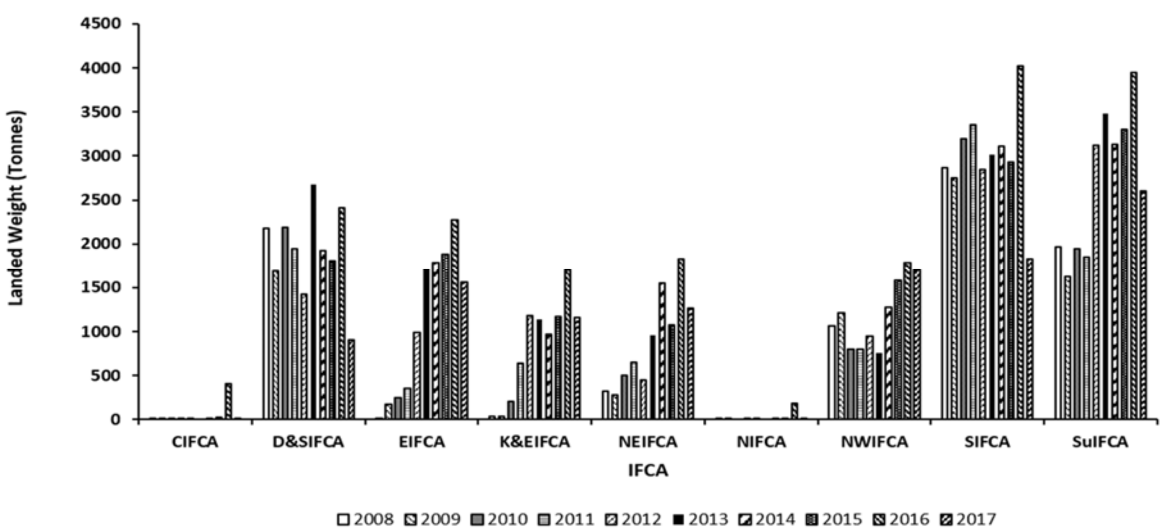

Figure 2: Total annual landings (tonnes) of *B. undatum* in each IFCA district (MMO, 2008-2017). Data from 2017 does not include landings from foreign vessels to UK ports.

Eastern IFCA represents one of the most significant increases, recorded landings of 2,274 tonnes in 2016 compared to 8 tonnes in 2008 - representing a ca. 30,000% increase over the last decade (Figure 2). In line with these observations, Eastern IFCA recently highlighted that 2014 saw the largest increase in the number of active vessels, with landings into ports within the district rising by 667% (weight) since 2010 (EIFCA, 2015). Similarly, total whelk landings in Kent and Essex IFCA have shown a substantial increase of ca. 4,600%, rising from 36 tonnes to 1,700 tonnes between 2008 and 2016.[5] The extent of these relatively rapid increases in whelk landings explains the decision to implement additional emergency byelaws within the Eastern and Kent & Essex IFCAs, as a management strategy to mitigate future exploitation to this fishery (see section 2.4).

With that being said, ports located on the south coast of England represent 50% of the top ten landing sites for *B. undatum* in the country; in 2016 Shoreham and Eastbourne in Sussex IFCA recorded landings of 1,345 and 1,110 tonnes of whelks, respectively, representing catch values of £306,812 and £457,143. Thus, making whelk fishing a significant sector within these two ports (Table 1).

Table 1: Top 10 English ports for total *B. undatum* landings (tonnes) in 2016 (MMO, 2017).

Rank	Port	District	Total Landings (Tonnes)		
			2014	2015	2016
1	Shoreham	Sussex IFCA	447.7	867.1	1,344.6
2	Eastbourne	Sussex IFCA	1,238.9	1,100.9	1,109.9
3	Whitehaven	North Western IFCA	655.0	789.2	931.0
4	Portsmouth	Southern IFCA	977.4	1,010.9	882.4
5	Wells	Eastern IFCA	964.7	680.9	770.5
6	Grimsby	North Eastern IFCA	615.2	461.6	737.3
7	Weymouth	Southern IFCA	839.9	695.1	679.2
8	Bridlington	North Eastern IFCA	934.1	609.7	592.8
9	Ilfracombe	Devon &Severn IFCA	716.9	874.5	533.4
10	Lowestoft	Eastern IFCA	279.3	539.3	526.7

2.3.1 Fishing Methods

Whelks in the UK are almost exclusively caught using baited traps, set for approximately 24 hours - as bait attractiveness reduces dramatically beyond this point (Bennet, 1974). Some of the largest whelk fishing vessels may set up to 1,000 traps each day (Fahy, 2001) – but usually numbers set are below 200. There is a clear distinction between different segments of the fleet that target whelks, from the '*super-potters*'[6] that target whelks exclusively, and are capable of fishing outside of IFCA jurisdictions, to the small-scale fleet, and in particular those fishers who target whelks only periodically, as a 'top-up' to their primary target. UK Sea Fisheries Statistics[7] indicated that in 2016, whelks landed in England from vessels under 10m constituted 47.7% of the total landings, compared to an average of 53.7% between 2008 and 2015 (Figure 3); indicating a potential increase in recent activity of vessels over 10m.

[6] Jerry Percy, Pers. Comms.
[7] https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics

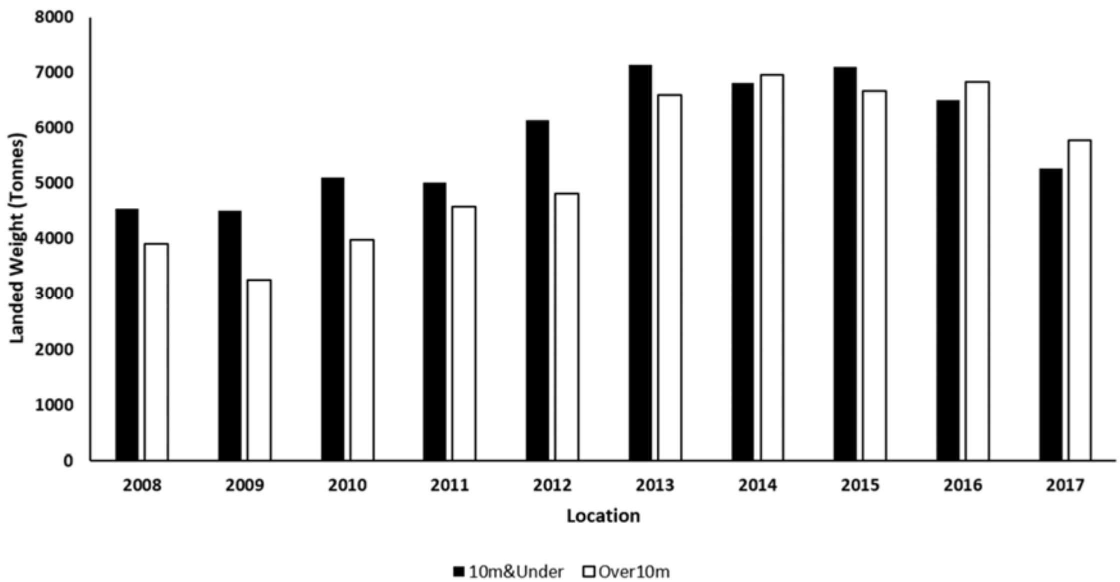

Figure 3: Total annual *B. undatum* landings (tonnes) by vessels under 10m and over 10m in England, between 2008 and 2017 (MMO, 2008-2017). Data from 2017 does not include landings from foreign vessels to UK ports.

As the UK fishery exclusively uses baited traps, landings and catches are inherently inked ot whelk ecology. Feeding behaviour of whelks has been recorded to vary annually depending upon the reproductive behaviours of local *B. undatum* population (Martel *et al.*, 1986a). Indeed, seasonal variations in LPUE for the Irish Sea whelk fishery have been attributed to this change in feeding activity (Fahy *et al.*, 1995). Understanding the abundance of a stock is paramount in order to understand how (or whether) to control the fishery. Fahy (2008), showed that the performance of the Irish whelk fishing fleet was largely driven by stock abundance; as abundance increased so too did effort from casual fleet (i.e. those not exploiting whelks exclusively) – considering the fishery to be unstable in this regard, potentially leading to "*boom and bust*" fishing – the fishery being open-access and lightly regulated. Lack of regulation, it is argued, may encourage a short term, opportunistic harvesting regime, which is not conducive to maintain biologically sustainable fisheries (Fahy, 2008). However, the whelk fishery provides a valuable seasonal alternative for fishers targeting other shellfish (e.g. crabs and lobsters), and it is expected, as other fisheries decline or undergo increased restrictions, further pressure could be exerted on the whelk fishery following fisher effort displacement (Haig *et al.*, 2015); hence, potentially leading to further unsustainable exploitation.

The common whelk is also regularly caught as by-catch following the use of beam trawls in dredging activities, however due to the presence of a hard exterior shell, it has been shown that almost 98% whelks survive after being caught (Kaiser and Spencer, 1996). Contrary to this, field observations by Ramsay and Kaiser (1998) indicated higher levels of predation of *B. undatum* by starfish (*Asteria rubens*) occurred in areas impacted by scallop dredging activities. In this study, whelks that were 'rolled', ensuing contact with bottom fishing gear, took significantly longer to perform their natural escape response; thus suggesting demersal fishing could indirectly increase whelk mortality (Ramsay and Kaiser, 1998). In contrast, Evans (1996) suggested, although with limited evidence, that areas disturbed by dredging activities may provide a competitive advantage to whelks. Positing that the availability of discarded dead or damaged animals may provide a food source for local whelks populations, thus leading to increases in abundance.

2.4 Current Management

European whelk fisheries are subject to measures defined under the CFP and hence are subject to a number of overarching technical measures that aim to safeguard from overfishing. The EU-wide MLS of 45 mm, for example - defined under EC regulation No 850/98[8] - is the only current management regulation transposed into UK fisheries legislation for the protection of *B. undatum* (Lawler, 2013). Recent changes in fishing effort following displacement from other fisheries has forced several fishery authorities in the UK to introduce further regulations and re-assess their whelk management (Lawler, 2013). In England, the IFCAs are responsible for the sustainable management of fisheries within their districts and under the Marine and Coastal Access Act (2009) have the jurisdiction to implement byelaws to mitigate against unforeseen overexploitation[9]. A byelaw does not come into full effect until it is confirmed by the Secretary of State, following stringent quality assurance by the MMO and local consultations, after which the byelaw may be passed with or without modifications[10]. In emergencies, IFCA byelaws may be made pursuant of the 2009 Marine and Coastal Access Act and have immediate effect without confirmation[10]; after a grace period, emergency byelaws go through the same process before being passed into local legislation.

Concerns regarding the status of whelk stocks have risen following recent increases in fishing effort, however, there are currently limited management measures protecting the fishery (McIntyre *et al.*, 2015). Generally, English whelk fisheries are unrestricted, lightly regulated, and require minimal capital investment to cover entry costs (i.e. pots and bait) (Haig *et al.*, 2015). In the past, this unmanaged approach to inshore fisheries has seen the SOM of other commercially exploited gastropods decrease, and although current research has not been able to provide supporting evidence for this in *B. undatum*, a number of concerns have been raised over the sustainability and status of both Atlantic and North Sea whelk fisheries (Haig *et al.*, 2015; McIntyre *et al.*, 2015; Nicholson and Evans, 1997; Shrives *et al.*, 2015). In spite of these concerns and evidence of increased fishing effort (Radford, 2014), there has been limited management measures implemented within the UK beyond the introduction of the EU-MLS of 45 mm shell height (Figure 4), which is often considered an inadequate strategy to conserve local stocks (McIntyre *et al.*, 2015).

However, whelk permitting byelaws have been introduced in the Kent & Essex, Eastern, and Sussex IFCAs, which, as part of their conditions include; pot limitations, escape holes, minimum riddle sizes, and increased MLS.[11] Indeed, several viable management strategies have also been suggested to protect and rebuild overexploited stocks, including compulsory sorting based on defined length-width relationships, gear and effort constraints (e.g. limits on pot size and quantity), and closed seasons during important reproductive periods (Haig *et al.*, 2015). An increase to the current MLS has been suggested as another feasible management measure in numerous studies (Heude-Berthelin *et al.*, 2011; McIntyre *et al.*, 2015;

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01998R0850-20140101&from=EN
[9] https://www.gov.uk/government/publications/ifca-byelaw-guidance
[10] http://www.association-ifca.org.uk/Upload/About/ifca-byelaw-guidance.pdf
[11] https://www.kentandessex-ifca.gov.uk/wp-content/uploads/2016/01/review-of-whelk-permit-byelaw-appendix-1.pdf

Shelmerdine *et al.*, 2007), prompting several regions and fisheries agencies to implement additional byelaws in fisheries under their control.

Currently, however, the only consistently enforced management measure is the MLS (McIntyre *et al.*, 2015). This method of management has been used across a number of crustacean species and intends to prevent the capture of the immature proportion of the stock, thus allowing them to spawn and effectively recruit new individuals (Jennings *et al.*, 2001). MLS must therefore be determined following assessment of a population to establish the true size of SOM, at which half of the population exhibits mature gonads (Lm_{50}) and are able to reproduce (Heude-Berthelin *et al.*, 2011). The MLS of 45 mm currently being enforced throughout the UK and EU has been shown to be insufficient in protecting the immature proportion of the whelk population (Fahy *et al.*, 2000; Heude-Berthelin *et al.*, 2011; McIntyre *et al.*, 2015; Shelmerdine *et al.*, 2007). Whelks collected by McIntyre *et al.*, (2015) from twelve sites around the English coast indicted that the SOM was higher than the current MLS, hence providing limited protection to the English spawning stock. Based on these findings, McIntyre *et al.,* (2015) indicated that MLS would need to be set higher in order to attain management objectives if it remained as the only whelk fishery management tool.

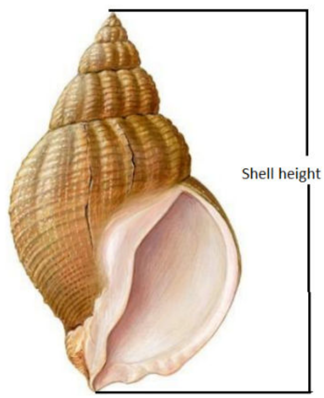

Figure 4: Shell height of *B. undatum*, the basis for MLS definition.[12]

Additional research has indicated that distinct populations of *B. undatum* may occur over small scales within the Northern Atlantic (Haig *et al.*, 2015; McIntyre *et al.*, 2015). It is now well documented that length frequencies, genetic structure, and SOM vary greatly between populations of *B. undatum* (Table 2) (Haig *et al.*, 2015) and therefore there is little support for the blanket approach of a 45 mm MLS to be implemented on a national scale (McIntyre *et al.*, 2015; Pálsson *et al.*, 2014; Shelmerdine *et al.*, 2007; Weetman *et al.*, 2006). As a result of these findings, there have been a number of regional changes to the current EU-MLS size, including increases to 55 mm in Wales, 70 mm in the Isle of Man and 75 mm in the Shetland Islands (McIntyre *et al.*, 2015). It has been recommended in several studies that future management strategies for whelk fisheries are based on a region-by-region basis, rather than nationally (McIntyre *et al.*, 2015).

However, significant increases to MLS often prove an unpopular management measure amongst fishers (McIntyre *et al.*, 2015). The negative short-term economic impacts to fishers targeting populations of *B. undatum* often outweighs the subsequent gains in yield and stock security, as these changes are slow and less apparent (Haig *et al.*, 2015; McIntyre *et al.*,

[12] http://www.seafish.org/rass/do_pdf.php?id=5247&section=all

2015). Hence, a gradual approach to this measure is advisable - a stepped alteration to the MLS could ease the short-term economic losses following reductions in fisher's yields (Haig *et al.*, 2015). Haig *et al.*, (2015) suggested a detailed monitoring plan should also ensue any increases in MLS to monitor changes in the population size structure.

Table 2: MLS and SOM for *B. undatum* cited in various studies (source: Haig *et al.*, 2015).

Location	Lm_{50} Male (mm)	Lm_{50} Female (mm)	Method*	Study Period	MLS (mm)	Reference
England	46 - 76	45 - 78	Visual	Jan - Mar	45	Hancock & Urquhart (1959); McIntyre *et al.* (2015);
Ireland	63 - 83	-	PL	-	50	Fahy *et al.* (2000)
Shetland	86	101	-	-	75	Shelmerdine *et al.* (2007)
France	49	52	Histology	-	45	Heude-Berthelin *et al.* (2011)
Canada	49 - 76	60 - 81	Pl/ GSI	Apr and May	70	Gendron (1992); Santarelli (1985)
Iceland	45 - 75	-	PL	May and Sep	45	Gunnarsson & Einarsson (1995)
Sweden	54 - 72	52 - 72	Microscopy	Oct - Nov	45	Valentinsson *et al.* (1999)

*Methods include; Visual, an assessment of the differentiation of the digestive whorl; PL, measuring the penis length to indicate male maturity; Histology, a complete histological assessment of the gonad; GSI, using the weight of the gonad as an index; Microscopy, examination of sperm or oocyte presence.

As mentioned, there are additional management strategies that have been proposed that aim to improve the success of management policy objectives. The implementation of a closed season during spawning periods could provide added protection to the spawning stocks, maximising the ability of mature individuals to successfully recruit (McIntyre *et al.*, 2015); although due to limited data on the precise timings of whelk spawning, further research would be required to understand the most appropriate period for this closure. Secondly, in most commercially exploited fisheries, TACs are annually defined to provide a limit on the amount of biomass removed from a fishery. These values are set as numbers of individuals or tonnes based on accurate stock assessment evaluations. The absence of such assessments for whelk fisheries contributes to the dearth of data from which TACs can be set (McIntyre *et al.*, 2015), therefore these data shortages need to be addressed in the future before this strategy can be adopted. Finally, limitations on the allowable number of pots and permit schemes are an effective, enforceable way of controlling fishing effort, and has been adopted in a number of other shellfish fisheries to date (e.g. crab and lobster). Such regulations have already been implemented as byelaws by a number of IFCAs. Introducing additional regulations to the whelk fishery would potentially have large economic impacts to fishers in the short term, however it is anticipated that these changes would result in higher yields in the long term.

A final overarching issue that is not clearly defined, which is paramount for any fisheries management decision, is having a defined target to which the fishery should be managed- this is often MSY, but can also be based on spawning stock biomass. Below, we provide a summary of some of the regional approaches to whelk management currently in place.

2.4.1 Regional Management Approaches

Several IFCAs have updated their whelk management regimes and implemented a number of statutory and emergency byelaws. The significant and rapid rise in whelk landings within Kent & Essex and Eastern IFCAs has been closely followed by comprehensive emergency byelaws (Lawler, 2013), which have since been passed by the Secretary of State and confirmed as full byelaws. In addition, other IFCAs have followed suit, implementing similar byelaws through permitting schemes that include pot limitations and gear adaptations as part of the conditions (Table 3). Although several IFCA byelaws have been introduced, in contrast to regulatory change in the Isle of Man and Shetland Islands, for example, alterations to the MLS have not been implemented, discounting research indicating this would be an effective strategy.

Of particular note are the introduction of whelk permitting byelaws by KEIFCA[13] and EIFCA. Permitting byelaws, are powers provided to the IFCAs and devolved ministers under sections 155 and 156 of the Marine and Coastal Access Act 2009, to create permits that have flexible conditions – allowing the possibility of reactive management - that is responding to new findings or threats to sustainability within approximately three months[14]. This approximate timeline is much shorter than the potential lead time when implementing standard bylaw procedures – and as such, this approach to management, particularly for a fishery that is rapidly growing, is an attractive method. The key drawback of permitting byelaws is that they do not represent the most significant deterrent, as they are the lowest tier of financial administrative penalty that is available to the English IFCAs.

KEIFCA Whelk Fishery Permit Byelaw

In 2013, KEIFCA Members met and approved the content of a Whelk Fishery Permit Byelaw, which has now become law. This process sees the introduction of two types of permit, which are required in order to set a whelk pot in their district:

- **Category 1** (commercial) permits allow the setting of a maximum of 300 pots, for an annual fee of £100 and £0.30 for each of the gear-tags;
- **Category 2** (recreational) permits allow the setting of maximum of 10 pots, for an annual fee of £30 and £0.30 for each of the gear-tags.

The Byelaw contains a number of conditions, including the requirement to submit monthly data and the following fishing gear adaptations:

- Whelks must be size graded using a riddle, constructed of parallel bars with a minimum spacing between bars of 22 mm.
- Two escape holes, of 22 mm diameter are required on each pot - positioned at least 150 mm from the base of the pot, or no more than 50 mm from the top of the pot;
- Each string of pots must be marked by a floating marker, of at least 30 cm diameter, at each end – marked with the PLN number of the vessel and the whelk permit number.

The KEIFCA considers whether it is necessary to review the permit conditions at least every three years. When a review of the conditions is taken, it consists of a consultation with current permit holders, which is usually supported by an impact assessment.

[13] *Whelk Fishery Permit Byelaw*, KEIFCA; https://www.kentandessex-ifca.gov.uk/wp-content/uploads/2014/03/whelk-byelaw.pdf
[14] IFCA Officer personal comments

Table 3: Current Inshore Fisheries and Conservation Authority byelaws and permit requirements[15],[16],[17],[18].

Management measure	Kent & Essex	Eastern	Southern	Devon & Severn	Sussex	North West
Current MLS	45mm	55mm (whelk permit)	45mm	45mm	45mm	45mm
Riddle size	25mm (whelk permit)	24mm (whelk permit)			25mm (shellfish permit)	
Permit or License	Whelk Fishery Permit Byelaw It requires fishers to fish in accordance with flexible permit conditions, updated annually.	Whelk Permit Byelaw 2016 – replaced an emergency byelaw. It requires fishers to fish in accordance with flexible permit conditions, updated annually.			Shellfish Permit Byelaw - for whelks, lobster, brown crab, spider crab, velvet crab, cuttlefish and prawns. It requires fishers to fish in accordance with flexible permit conditions, updated every four years.	Permit required for non-commercial fishers (limit of 5 or 10kg).
Pot limit	300 pots per permit for commercial 10 for recreational (whelk permit).	500 pots per permit for commercial 5 for recreaitonal (whelk permit).	Voluntary pot limitation (Lyme Bay Reserve SAC); 500 per vessel with no more than 30 in each string.	Voluntary pot limitation (Lyme Bay Reserve); 500 per vessel with no more than 30 in each string.	Within 3NM, 300 pot limit, for commercial. Between 3-6NM, 600 pot limit, for commercial. 5 pots for recreational (shellfish permits)	

15 https://nffo.org.uk/uploads/attachment/112/ifca-shellfish-management.pdf
16 http://www.lymebayreserve.co.uk/about/the-mou.php
17 http://www.eastern-ifca.gov.uk/emergency-whelk-byelaw/
18 https://www.kentandessex-ifca.gov.uk/130321-new-whelk-fishery-permit-byelaw//

Management measure	Kent & Essex	Eastern	Southern	Devon & Severn	Sussex	North West
Gear modification	Gear tags; Minimum of 10 escape holes, 25mm in diameter (whelk permit).	Gear tags and buoys/ markers; Prohibitions of use of fishing gear other than 'whelk pots' (whelk permit). Two escape holes of ≥24 mm (whelk permit).			Minimum of 4 escape holes, >25mm in diameter (shellfish permit).	
Catch reporting	Monthly submission of catches, fishing effort and areas fished.	Monthly catch returns (whelk permit).	Voluntary fitting of iVMS (Lyme Bay Reserve SAC);			
Emergency byelaws		MLS on the North Norfolk Coast increased to 55mm.				

In the Southwest Irish Sea, the whelk fishery is largely open access and unregulated, and the stock represents one of the few fisheries open to the majority (Fahy, 2008). There are two broad national measures to regulate the fishery; firstly, access restrictions defined under EU regulations and adopted by national law require a fishing licence to fish within inshore waters (Fahy, 2008). The second regulation includes the EU Technical Conservations Measure (TCM) (i.e. MLS). However at the time of the study, Fahy (2008) reported that the TCM was rarely, if at all, enforced and there were no cases of conviction of penalisation for landing whelks undersize (Fahy, 2008).

French management measures focus more on the control of effort and catch. They have a fixed number of permits available for the fishery and restrict the number of pots available per person and per boat to 240 and 720, respectively. Further, they have a daily quota per person of 300 kg and per boat of 900 kg. Finally, they have introduced a number of closed periods, including, weekend and public holiday closures, and the entirety of January.

Further afield, the Fisheries and Oceans Canada department have defined an extensive management plan for the Quebec whelk fishery and closely monitor the harvest[19]. The coastal area surrounding Quebec is divided into fifteen whelk management areas. The Fisheries and Oceans department closely collaborate with local industry to adapt current measures specific to each management area. Furthermore, modifications to current measures are often subject to change throughout the season[20], and may include changes to the MLS, trap limits per license, trap size limits, area restrictions and other license requirements (e.g. weekly logbook submission)[21] (Kenchington and Glass, 1998).

Following the identification of geographic changes in size, age and estimated growth rates in the inshore areas of Shetland, the micro-management of inshore regions, comparable in approach to the strategy implemented by Fisheries and Oceans Canada (Kenchington and Glass, 1998), has been recommended as a potential measure by Shelmerdine (2007). Such a strategy would facilitate an MLS being defined for specific areas, accurately considering the localised differences in SOM (Shelmerdine *et al.*, 2007). Following evaluation of the advantages and disadvantages of de-localised and localised management measures, Tuckey *et al.*, (2007) concluded that national de-localised management, such as the EU-wide MLS for *B. undatum* , in areas containing several genetically different sub-stocks would face potential management issues, such as inability to detect local stock depletion (Shelmerdine *et al.*, 2007). They went on to identify the potential for micro-managed fisheries in Shetland, however comprehensive research on spatial variations of growth rates and SOM prior to plans being implemented is necessary.

2.5 Issues and Concerns

Given some of the concerns raised there is a likely move towards further regulation, this in turn could lead to the future displacement of fishers into previously unexploited (and less regulated) areas – which is considered to potentially worsen sustainability of the fishery (Morel and Bossy, 2004). Both Martel *et al.*, (1986a) and Gendron (1992) linked significant

[19] http://www.qc.dfo-mpo.gc.ca/peches-fisheries/recreative-recreational/mollusque-mollusc-eng.html
[20] http://www.dfo-mpo.gc.ca/decisions/fm-2012-gp/atl-008-eng.htm
[21] https://www.kentandessex-ifca.gov.uk/wp-content/uploads/2016/01/review-of-whelk-permit-byelaw-appendix-1.pdf

differences in SOM with varying levels of fishing effort, therefore increased changes in effort from traditional fishing grounds to areas previously untouched, particularly under the current MLS, could risk the status of some stocks (Morel and Bossy, 2004). Indeed, there were substantial differences in CPUE between fished sites and non- fished sites. Further analysis indicated a negative correlation in catches of large whelks at fished areas over time; evidence that whelk fishing was having an effect on the prosecuted populations (Morel and Bossy, 2004). Changes to fishing effort at some locations following displacement may therefore results in unsustainable pressure on some stocks (Morel and Bossy, 2004). Hence, additional management measures to the current MLS may need to be implemented, such as effort controls (e.g. pot limits) or spatial restrictions, already enforced in some areas of the country.

Perhaps the most pressing issue is with regards to the definition of the whelk stock itself. Once the individual sub-populations are identified, relevant spatial extents of assessment and management can be determined. This is important due to variable SOM estimates from around the English coast which are largely above the EU MLS (McIntyre *et al.*, 2015). Furthermore, significant differences have been found in SOM between sites and between sexes within some sites. The current MLS therefore probably provides little or no protection to the whelk spawning stock. Expanding research on the stock boundaries and SOM at regional levels is essential in order to further the development of locally appropriate management, including MLS.

Closely linked to concerns over the ineffectiveness of MLS is the usefulness of sorting grids (riddles) (Figure 5), a commonly used tool to separate undersized whelks from commercial catches, has also been questioned as when riddling whelks it is the width that is the relevant measurement, rather than the height of shell (Figure 4) (Lawler, 2013; Stephenson, 2015). Following informal fisher consultations, Lawler *et al.* (2012) indicated that a spacing of 20 mm was most effective at removing whelks above the 45 mm MLS. Further, it was shown that a bar spacing of between 23-24 mm was most successful at retaining whelks with shell length of 55 mm, with effectiveness of riddle size depended on the width to length relationship of whelks at each location (Lawler *et al.*, 2012). Based on the evidence of a strong correlation between width and shell length (Stephenson, 2015), it is suggested that a width based MLS would be more efficient at selecting immature whelks, compared to the current height-based MLS, (Lawler *et al.*, 2012; Stephenson, 2015). Kent & Essex and Sussex IFCAs have introduced byelaws defining a 22 mm and 25 mm riddle space, respectively; this management measure may provide an alternative strategy that can employed across other districts. Furthermore, KEIFCA have conducted some initial studies on the effectiveness of the type of riddle used – i.e. cylindrical and mechanical. This work is essential, in order to effectively implement a change to size restrictions at landing. But note, increasing MLS may not only have potential economic impacts in terms of reductions to catch – studies in KEIFCA district indicate catch reductions of ca. 21% using a 24 mm riddle and 37% using a 25mm riddle – repeat MLS change would see investment in riddles themselves increase.

Escape holes are another regularly utilised tool that aim to reduce the number of undersized whelks from being hauled, prior to landing. There have been some studies that show the efficacy of these, but it by no means can substitute research into riddle efficacy. However, there is generally little opposition to their introduction, so they can pose a relatively simple method that could help sustainability.

Figure 5: Whelk sorting grid (riddle) used to select undersized *B. undatum* (source: AIFCA[22]).

Clearly, the main concerns over the conservation status of whelks relate to their specific life history traits. The fast early growth, SOM, low fecundity, reproductive strategy, sedentary life style and generally long life span makes this fishery susceptible to unsustainable exploitation (Valentinsson *et al.*, 1999). In addition to their slow rate of recruitment, these characteristics result in limited genetic mixing between populations, therefore making them at risk to recruitment overfishing with high, unsustainable yields early on (Gulland, 1983; Hilborn and Walters, 1992)

The need to effectively age *B. undatum* is vital to understand the highly variable relationship between its habitat, SOM and rates of growth (Haig *et al.*, 2015). Unlike fish or bivalve molluscs, whelks and other gastropods have been described to possess less recognisable growth marks as an indicator of age (Kideys, 1996). Hence, the current use of operculum rings to age individuals is unreliable (Kideys, 1996). With that being said, recent research by Hollyman *et al.*, (2017) reported that growth rings in wild and laboratory reared whelk statoliths displayed clear, negatively correlated cycles in magnesium and sodium; thus supporting previous findings that growth rings displayed visible annual periodicity (Hollyman *et al.*, 2017). Bangor University have now conducted a large body of work on age determination, in collaboration with CEFAS, Kent and Essex IFCA, and the Welsh government. Geo-validation of distinct periodic growth formation in *B. undatum* has the potential to allow fisheries scientists to accurately determine the age of individuals; adding a much needed monitoring tool for future stock assessments in areas exposed to commercial activities.

Determining the level of whelk biomass within UK inshore waters is important for accurately defining the stock status and setting sustainable TACs in the future. However, similarly to age determination, there is currently no general consensus on the most appropriate and effective system for assessing *B. undatum* population densities, with a number of methods being employed (Borsetti *et al.*, 2018; Kideys, 1993). Kideys, (1993) investigated the population density of *B. undatum* around the Isle of Man, using four different approaches; pot sampling; SCUBA; mark-recapture experiments, and underwater television. Although results obtained by each strategy were comparable, mark-recapture and underwater television generated overestimates of whelk density (Kideys, 1993). On the other hand, diving surveys and pot

[22] http://www.association-ifca.org.uk/Upload/K%20and%20E%20IFCA%20Whelk%20story%20.pdf

samplings estimations showed similarities, suggesting pot sampling is an effective and efficient strategy for determining densities of whelks (Kideys, 1993).

In contrast, Borsetti *et al.*, (2018) indicated that the high selectivity of pots - leading to variations in catchability based on size of individuals and the consequent mobility, dietary range and seasonality of sampling – means that data from this method may not be suitable for estimating population density. Selectivity of larger, more mobile whelks resulted in some investigations only recording large whelks in density calculations, underestimating the true population density (Borsetti *et al.*, 2018; McQuinn *et al.*, 1988). Similarly, it has been suggested that catch rates in baited traps vary significantly by bait type and soak time, with density estimates using this method relying heavily on ambiguous calculation of the estimated area of attraction (Borsetti *et al.*, 2018; McQuinn *et al.*, 1988). Hence, Borsetti *et al.*, (2018) suggested an alternative approach, justifying their method on the aggregating behaviour of benthic invertebrates and other gastropods molluscs (Heip, 1975; Kosler, 1968). Here, Borsetti *et al.*, (2018) assessed population density using a dredge sampling design, allowing analysis on spatial distribution to be made, unlike previous studies, where baited pots may influence levels of aggregation.

Finally, there are some regional concerns with regards to the sustainability and management of the bait used for whelk fishing. In many fisheries the bait used is brown crab (*Cancer pagurus*), and/ or the lesser spotted dogfish (*Scyliorhins canicula*). This raises some concerns that species could be being caught and used directly as bait without being landed and therefore not recorded – or indeed that undersized crabs could be being used, which again could undermine the sustainability of that fishery. Data regarding the type of bait used, and the potential sources of this, should be considered as part of the data requirements under the regional permitting schemes. This would allow for further investigation of the sustainability of the various types of baits used.

2.5.1 Regional Research Progress

There is clearly a certain level of background research that is necessary, at a regional level, in order to inform the implementation of regionally specific measures – including understanding the SOM and genetics of sub-populations, for example. However, non-biological research, such as the efficacy of new riddle deigns, only need to be completed nationally. This highlights the importance of regional collaboration across the IFCAs and with the MMO and CEFAS, for example, in order to avoid duplication of effort where possible while also promoting the verification of findings through replication.

Below, is a brief summary of the research efforts to date for each IFCA. The information is taken form the recent 2018 TAG conference Whelk workshop report.

2.5.1.1 Kent and Essex IFCA

KEIFCA have conducted a suite of research projects, largely in collaboration with Bangor University.[23] They focused on sampling whelks from four different management zones within the district, determining spatial distributions of length, width, sex-ratio, maturity and age. The research appears to corroborate the long-held view of the fishers, that the whelks caught in

[23] www.kentandessex-ifca.gov.uk/wp-content/uploads/2018/01/KEIFCA-whelk-report-24JanPH.FINAL_.pdf

Essex are of a smaller size, on average, than those in Kent. Furthermore, data on SOM, growth rates and age at maturity, show that increasing the riddle size regulations from 22 mm to 25 mm, offered greater protection to immature whelks and enhanced the likelihood of each individual reproducing once before capture and removal from the fishery.

Using a platform of almost five years of studies and research specific to the district, KEIFCA have introduced a number of considered conditions as part of their Whelk fishery Permit Byelaw – and are continuing to explore novel solutions to increasing sustainability, such as the introduction of new riddle designs.

2.5.1.2 Sussex IFCA

Sussex IFCA have also conducted SOM research within their district – they were part of a Cefas study from 2009 to 2011 that investigated SOM across several regions of England (McIntyre *et al.*, 2015). The study found that SOM in the district was approximately 58 mm for both sexes, and that there was some degree of spatial variation within the district – the riddle size has subsequently been increased to 25 mm in the district, via the Shellfish Permit Byelaw, which affords greater protection to the immature (smaller) whelks.

Cefas led a further study in the district, which investigated the efficacy of escape holes in whelk pots. This study revealed that increasing the size of escape holes recued the number of both undersized and commercial sized whelks in the catch – but the proportion of undersized whelks was reduced with increasing diameter. The shellfish Permit Byelaw stipulates a minimum of four escape holes, with diameter of 25 mm.

2.5.1.3 Eastern IFCA

EIFCA are also conducting research into spatial variation of SOM at multiple sites around Lincolnshire, Norfolk and Suffolk, to determine whether current management is appropriate. Within the district, the MLS is set at 55 mm, affording additional protection to the spawning stocks – however, research is continuing, to investigate is this affords sufficient protection. EIFCA have also trialled a number of riddle sizes in the district, to determine their efficacy.

2.5.1.4 Devon and Severn IFCA

Between 2014 and 2016 DSIFCA completed extensive research to determine SOM and the spawning period across the district. This supplemented previous Cefas led research that estimated SOM in the main fishing grounds across England (Lawler, 2013). All the studies found that SOM in the DSIFCA district is greater than the current MLS of 45 mm – therefore offering insufficient protection to the spawning stock in the region. DSIFCA have proposed an increase in MLS to 65mm, in order to offer greater protection to the districts stocks. They propose that any introduction should be done in a phased approach, to allow fishers to adapt gear and reduce the direct impact on landings and income. There is also some discussion regarding the introduction of a width-based MLS, which may make selection with a riddle more effective. Finally, some research elucidated that whelks in the district were actively spawning between November and February. They proposed that a closed season during these months could be considered to protect the spawning whelks.

2.5.1.5 Cornwall IFCA

The whelk fishery in the CIFCA district is very small, largely restricted to one patch of ground off St Agnes, targeted by a single local vessel. From minimal sampling of this ground, preliminary findings suggest that the local stock consists of small individuals, however no further work has been conducted to corroborate this.

2.5.1.6 North Western IFCA

Whelk fishing is minimal in the NWIFCA district, although, given the recent increase in value per tonne, interest in the fishery is increasing. A Cefas-led research project determined that the current MLS is below that of SOM in the district (Lawler, 2013), and as such the IFCA is looking at introducing a new flexible commercial permitting byelaw – prior to an anticipated boom in the whelk fishery.

2.5.1.7 North Eastern IFCA

Due the small size of the whelk fishery in the NEIFCA district, only sparse *ad hoc* biometric sampling has been undertaken to date.

2.5.1.8 Southern IFCA

Whelk fishing in the Southern IFCA district is considered an *emerging fishery*, and although it is significant in comparison to other regions (Figure 2) – it is not a priority fishery. As such, no research has been conducted to date.

2.5.1.9 Northumberland IFCA

The whelk fishery in NIFCA, is minimal, and as such there has been no research or survey work conducted. Some whelk are now started to be landed, given the increase in value per tonne, but only as a bycatch product of the primary lobster fishery.

3 Management Recommendations

This section synthesises the above information in order to present a number of recommendations regarding the management of the common whelk.

Of paramount importance, before the successful implementation or change of any management, is the establishment of a platform of relevant research. Gaps still remain in current knowledge, in particular; definition of stock boundaries; catch data collection; monitoring of management and stock assessments; SOM and age-size curves for specific areas; and timing of whelk spawning. There is increasing discussion of the need for, and move towards, fully documented fisheries – part of this would require the accurate recording of catch locations, and a likely link to the use of inshore-VMS. The eventual and likely aim of fully-documented fisheries is to ensure that managers and decision-makers are fully aware of what is being caught, where is it being caught and how is it being caught. This increases the feasibility of having bespoke regional management measures across the country.

3.1 Summary

Evidently the greatest concern regarding the sustainability of English whelks relates to their life history traits. Specifically, limited dispersal rates of both adults and juveniles and the subsequent observed reduction in connectivity between populations. This in turn can lead to variability in maturity between and within regions - SOM in particular being highly variable and the current EU MLS often falls below it – even increases implemented by some IFCAs may not go far enough. Furthermore, genetic analyses suggests that there is little mixing between sub-populations, on quite small spatial scales, again increasing vulnerable to localised overfishing.

However, it is largely only the last few decades that these biological vulnerabilities have been exacerbated, due to the overall (global) increase in demand for whelks. Effort has increased in response, both on unexploited populations and due to new entrants into established fisheries. This in turn has highlighted a general absence of appropriate regulation, particularly with regards to the control of entry and effort. This issue was recently raised in US whelk fisheries, where concerns of increasing effort were compounded by limited regulation. They concluded that while the current situation was not an issue, it was vital to pre-emptively safeguard against future threats.[24]

Clearly, one solution to a lack of regulation is to introduce new measures that focus on controlling or capping effort and reducing the landings of juveniles, to the extent possible. Indeed, several management strategies have been suggested (and implemented) throughout the British Isles, including limits and modification to pots, closed seasons and regionalised micro-management. Currently, a promising approach has been the introduction of a number of flexible whelk fishery permit schemes – permitting future opportunities to better control effort and exploitation, should the fishery change.

However, introducing new regulations or permitting schemes must be done so cautiously. They must firstly be effective for the (sub-)population in question, and as such require robust scientific observation upon which to base them. Further, it must take into consideration the

[24] http://seagrant.gso.uri.edu/the-secret-life-of-whelks/

potential socio-economic impacts of rule change. That is, the potential negative short-term economic impacts to fishers should not outweigh the subsequent gains in yield or sustainability – balancing people's livelihoods against maintaining biological sustainability. Hence, where increases to MLS are required, for example, a gradual, stepped approach is advisable in order to ease short-term economic losses. Indeed, given the spatial variation in length frequency data, a single increase in MLS would impact fishers disproportionately.

3.1.1 Recommendations

Below, five key recommendations are presented, based on consideration of the supporting literature. These are supported by further discussion in Table 4.

- **Increase data reporting requirements:** The first key step is to ensure sufficient data to allow for the definition of stock boundaries and monitoring of sub-populations of whelks. Increasing local reporting requirements at spatially appropriate levels is an essential step to understanding suitable management for each area. This could be fulfilled by promoting fully-documented fisheries - using new technologies and remote electronic monitoring. Ensuring that data reporting is a condition of any whelk licensing scheme is important.
- **Prevent active gear-types:** There are sufficient examples of whelk trawl fishery collapse - US, Netherlands and Georgia (Shalack, 2011) - to recommend that the expansion of English whelk fisheries into using active gears, such as trawls, should be prevented. Pots, by their nature, have reduced catchability as the target populations decline, relative to active gears. However, that is not to say that pot fishing cannot lead to overexploitation. Indeed, there is evidence of this from high-profile fisheries such as the Norwegian lobster fishery, and as such, it is important to also ensure that effort is manageable.
- **Procedure to control effort:** Whelk fisheries are often considered "*boom and bust"* i.e. catches increase while demand is high, until catch rates become less economically attractive. The primary route to minimise *boom and bust* is via effort (or access) controls – often some form of limited licencing or permitting scheme. Effort caps are particularly important in those regions that have seen rapid increases e.g. SuIFCA, EIFCA, KEIFCA. Although there is insufficient evidence to state the level at which effort should be capped, it is vital to have a flexible and proactive procedure in place that can monitor catches (CPUE, not landings) and then cap or reduce effort if they decline.
- **Appropriate MLS:** Size or age at first capture should be appropriate for the local sub-population, in order to reduce or avoid localised overfishing. Therefore, assuming sufficient data and that stocks are defined, regionally appropriate MLS should be put in place. A UK-wide increase in MLS, for example, would impact some fishers more than others, and further, offer greater protection to some stocks over others. However, although ensuring MLS is biologically relevant, this does not ensure sustainability and therefore controlling effort is considered a more important first step, especially considering the wide variation in SOM, even between shallow waters and deep waters.
- **Regionalisation:** Clearly, the (social, economic and biological) sustainability of whelk fisheries is variable at relatively small-scales, and as such fine-scale management should be encouraged. Having variable technical regulations - including MLS - appropriate to sub-populations is achievable, but requires effective monitoring and enforcement – consideration also needs to be given to the issue of effort displacement in to offshore waters (>12 NM).

Table 4: Synthesis of key sustainability issues and the recommended responses.

Sustainability Issue	Recommended Response
Lack of robust information	
Most concerns regarding the sustainability of English whelks are framed by the lack of suitable data, and that subsequently stock status across much of its distribution is unknown. This is seen by many as potentially **exacerbating the risk of over-exploitation** – as all fisheries management decisions must be supported by data. The lack of comprehensive and regionally-specific biological information has resulted in a level of **uncertainty over the current status** and distribution of whelk population(s). Furthermore, the absence of stock assessment ensures that TAC or effort caps cannot be meaningfully set. Data shortages need to be addressed before any strategy can be fully-adopted. Despite significant efforts being made in some inshore regions, **systematic data collection is required** across large swathes of the UK. This is particularly important for whelk as a species, because of the observed spatial variance, and the likelihood of spatially discrete populations. Understand what is being caught, where it is being caught and how it is being caught, is paramount.	There is a need for **increased effort (and funding)** into ensuring suitable data collection is occurring in all regions of England, and the UK as a whole. The methods that are employed must be **replicable and comparable** – therefore, there must be some sort of centrally managed alignment. Furthermore, subsequent changes to management must be based upon the **best available information** – therefore data collection should be ongoing, to ensure management can react to changing scenarios. Minimum **data requirements** include metrics for catch (landings and discards), effort (including soak time), location of catch and bait used. This is probably most easily achieved as a condition as part of regional **whelk permitting schemes**. Comprehensive **research of spatial variations of biometric variables**; growth rates, SOM, age at maturity and genetic variation, are underway and must be completed **prior to the implementation of new management measures**. This information cannot be pooled, but must be replicated in each region.
Low dispersal rates	
Whelks are more **susceptible to overexploitation** due to their low rates of dispersal – both as adults and due to lack of a planktonic larval stage. This creates **reduced connectivity between populations**, and has three key implications; - It could create **spatially distinct populations**, especially with respect to SOM and size frequency distributions;	The biology of whelks reiterates the importance of having **spatially appropriate information**, but also for having spatially appropriate **regional management**. The IFCAs provide the blueprint for this approach, and must be supported in order to ensure that each region has regulations and byelaws that are appropriate to their district.

Sustainability Issue	Recommended Response
- It could mean that whelks are **susceptible to localised depletion**, due to limited recruitment and replacement; - It may lead to **protracted recovery** times if overfishing does occur; and **impair reproductive success**.	This spatially sensitive approach must also be considered when **recording catch locations**, in order to be able to detect localised populations, and subsequently depletions. Reduced density can impair local reproductive success – therefore research may need to use stratified surveys (i.e. recording all whelk sizes) as well as biological and CPUE data. For example, Denmark undertakes mussel dredging to determine local densities in Limfjord region.
Biological spatial variability	
Linked to the limited dispersal rates, are the well documented **significant spatial differences** in terms of size distributions, growth rates, age at maturity and SOM. This report has also made clear that these life history traits imply that **some whelk populations will be more vulnerable to overexploitation** than others. This suggests that **large-scale management is not a practical solution**, and that temporally and spatially **localised management** strategies are essential.	The literature provides li**ttle support for a blanket approach to management**, especially to EU-wide MLS determination. Instead, localised small-scale management within the fishery should be considered on a region-by-region basis, assessing the practicality and implications of each measure in turn – as stated, the IFCAs fulfil this role. The most useful technical regulation currently in use is implementing an MLS – this, therefore, **must be determined through localised assessments** to establish SOM (Lm_{50}) across the district, or at a smaller scale if necessary (for example, north and south coast of the DSIFCA district). Any significant change to MLS, should be done on an incremental basis, perhaps 5mm increments – but note, an impact assessment must be conducted that considers biological, social and economic sustainability. More broadly, identifying discrete populations could lead to developing **localised management areas** where modifications to measures are subject to periodic change, and may include changes to MLS– as is the case in the whelk fishery of Quebec

Sustainability Issue	Recommended Response
Increasing effort	
Evidence of **increasing effort in most areas** creates concern that whelks could be being overexploited - which could lead to local or regional population crashes. Indeed, EIFCA observed a 30,000% increase in landings in one decade, alongside reducing CPUE. This typifies the response from stakeholders that this fishery is considered a "*boom and bust*" fishery. This issue can be **exacerbated by seasonally displaced effort** – whelks being an alternative for fishers that predominantly target other shellfish. However, the whelk fishery provides a valuable seasonal alternative, and it is expected, as other fisheries decline or undergo increased restrictions, further pressure could be exerted on the whelk fishery following fisher effort displacement; hence, potentially leading to further unsustainable exploitation. Generally, whelk fisheries are unrestricted, lightly regulated and require minimal capital investment to cover entry costs - , potentially encouraging "*boom and bust*" fishing. Lack of regulation, it is argued, may encourage a short term, opportunistic harvesting regime, which is not conducive to maintain biologically sustainable fisheries	If effort continues to rise, the simplest form of control is to introduce an effort-cap or limit entry. There are several methods; limited permits, limiting landings, trap-limits or allocating quotas – given the dearth of data to support estimation of quota or TACs, **limiting entry appears the most feasible approach**. This could be in the form of a licensing or permitting scheme, which allows flexible conditions to entry based on recent data. Permit schemes are an **effective, enforceable way of controlling effort but must allow for periodic review**, informed by current scientific advice, environmental change and stakeholder inputs. Another method for reducing effort, particularly when there are seasonal increases, is through implementing closed seasons. These are often positioned at times when the population is most vulnerable to exploitation (e.g. spawning seasons). The literature is rather inconclusive with regards to the specific timing of spawning – and so a **spawning closed season may be ineffective**, with regards to protecting the spawning stock, but could still reduce effort levels. Furthermore, if adjacent district closed seasons are not aligned, there could be increased displacement of effort. Positioning the closed season during times of increased effort, particularly from seasonally displaced from other fisheries, could safe guard the stock, but would **likely have additional socio-economic implications**. Closed seasons should only be considered if there is good evidence of precise spawning occasions, as the potential social impacts, in terms of loss of income, could outweigh any biological benefits to stock sustainability.

Sustainability Issue	Recommended Response
Socio-economic impacts	
Whelks are often a seasonal alternative for fishers that predominantly target crab and lobster (McIntyre *et al.*, 2015), as such whelk fisheries can contribute important income in some regions. However, there is also a number of large-scale vessels, which are capable of fishing inshore or offshore, or between districts. Ensuring that any proposed or implemented management measure doesn’t impact these two ends of the fleet segment disproportionately will be a major challenge.	Changes to regulations **should be phased in**, however, it is also important to ensure that there are a **minimum number of phased increases**, as fishers could incur costs if they have to repeatedly change their measuring equipment etc. Changes such as this, therefore, must be done in consultation with stakeholders. Further, any measure bought in, whether through a flexible permitting scheme, a stand-alone byelaw or as a nation-wide measure, must be **assessed in terms of its social and economic impact to all segments of the whelk-fleet, as well as the biological benefits**.

Annex 1 References

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