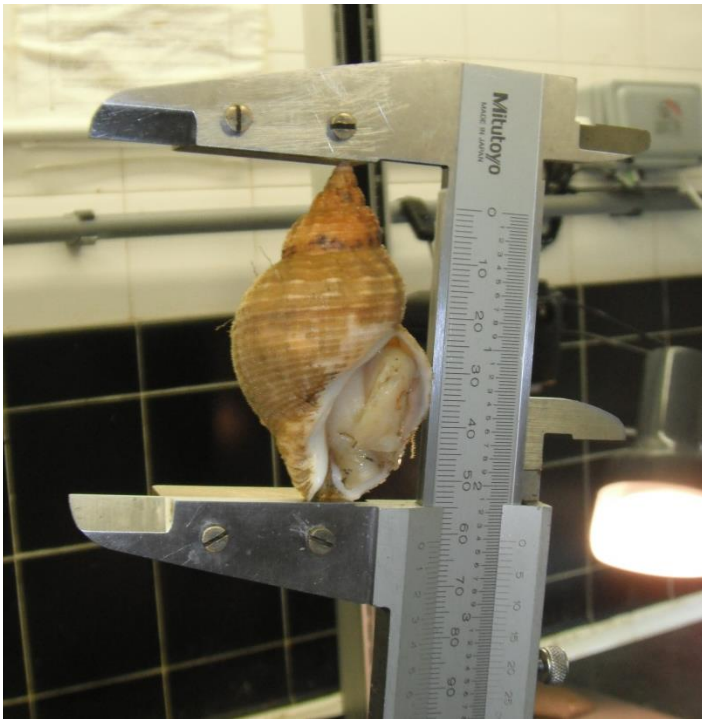
Determination of the Size of Maturity of the Whelk *Buccinum undatum* within the Devon & Severn IFCA District



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1. Executive Summary

Fishing effort in the UK for the common whelk, *Buccinum undatum*, has shown a rapid increase over the last decade, largely attributed to a boom in demand in the Far East. This has lead to concerns over the long-term sustainability of the fishery, whose stocks have never been formally assessed, and in most areas the only management measure is the EU-wide Minimum Size of 45mm.

It is known that distinct populations of whelk exist on a local level, with differing characteristics such as age and size at which sexual maturity is reached. The closed populations have low genetic diversity, resulting from minimal migration between populations. This raises the question of whether one broad-scale Minimum Size is appropriate for a species known to have sub-populations with differing characteristics? A single broad-scale management measure is likely to be too stringent for some sub-populations, whilst insufficient to protect the spawning stocks of others, both resulting in a loss of yield.

The size of maturity (SOM) is defined as the size at which 50% of the population is sexually mature. A previous study by Cefas estimated the SOM for both sexes of whelk in the main fisheries around the country. They found that in most areas the SOM is greater than the 45mm Minimum Size, including within Devon & Severn Inshore Fisheries and Conservation Authority's (IFCA) District, suggesting that the spawning stocks are not receiving adequate protection.

This study aims to produce accurate estimates of SOM, as well as looking at the seasonality of *B. undatum*'s reproductive cycle, to inform the future management of the whelk fishery within Devon & Severn IFCA's District.

Monthly samples of whelks were collected from Exmouth and Ilfracombe over a twelve month period. Biometric data was collected from size and sex stratified sub-samples and used to determine the stage of maturity for each whelk. The data was analysed through logistic regression to provide estimates of SOM by both shell height and shell width. Gonad indices were used to identify times of peak reproductive activity.

The estimates of SOM by shell height were 69.3mm (female) and 70.9mm (male) from Exmouth, and 76.5mm (female) and 76.4mm (male) from Ilfracombe. These indicate that the current Minimum Size is too low to ensure the sustainability of the fishery. The results of the study also show a strong positive correlation between shell height and shell width, meaning that a width based Minimum Size could be considered in place of one based on shell length. This would increase the efficiency of sorting the large volumes of catch by use of riddles.

Reproductive activity appears to occur over the winter months, with a peak in December and January, making a closed season to protect spawning whelks a possibility. However, there was large variation within the results making it difficult to accurately identify the breeding season.

2. Introduction

2.1 The whelk fishery

Over the past decade fishing effort for whelks (*Buccinum undatum*) in the UK has been increasing relatively quickly. In 2002 UK whelk landings were worth just over £4million, for 8,687 tonnes. Whelk landings in the UK totalled 16,000 tonnes in 2012, valued at £10.8million. Of this, the landings in Ilfracombe were 661 tonnes valued at £479,000, while the Exmouth landings were valued at £170,599 for 241.8 tonnes (MMO Annual Statistics), making whelk fishing a significant sector within these two ports in the D&S IFCA District. Whelk landings continued to rise in 2013, with 20,000 tonnes being landed in the UK, worth £13.7million. Of this, 2,014 tonnes were landed in Ilfracombe and 401.8 tonnes in Exmouth, valued at £432,000 and £300,646 respectively. The increase in effort for this fishery has largely been attributed to a boom in demand in the Far East, especially South Korea (Shelmerdine et al., 2007). This increase in effort has raised concerns over the sustainability of the fishery, for which the stocks have never been formally assessed (MMO, 2012).

Whelks are caught using specially designed, baited pots (Photograph 1). Fishing effort for whelk is largely unrestricted; currently the only regulation in place for the whelk fishery within Devon and Severn Inshore Fisheries and Conservation Authority's (IFCA) District is the EU Minimum Size of 45mm shell height. However, it is likely that distinct regional populations of whelks exist, with differences such as shell height often observed. This is due to the relative lack of adult mobility and the absence of a dispersal planktonic life stage, which is present in most shellfish (MMO, 2012).

Photo. 1 Whelk pot

2.2 *Buccinum undatum* biology

The marine gastropod *Buccinum undatum* (the common whelk) is a large, carnivorous snail which feeds on bivalves such as mussels and cockles, as well as dead fish and crabs (MMO, 2012). *B. Undatum* lives subtidally, up to depths of 1200m, but usually preferring depths of 20-30m, and have a wide distribution across the Eastern Atlantic, from Northern Norway to the Bay of Biscay. Their distribution in the Western Atlantic runs from Newfoundland to New Jersey (Weetman et al., 2006).

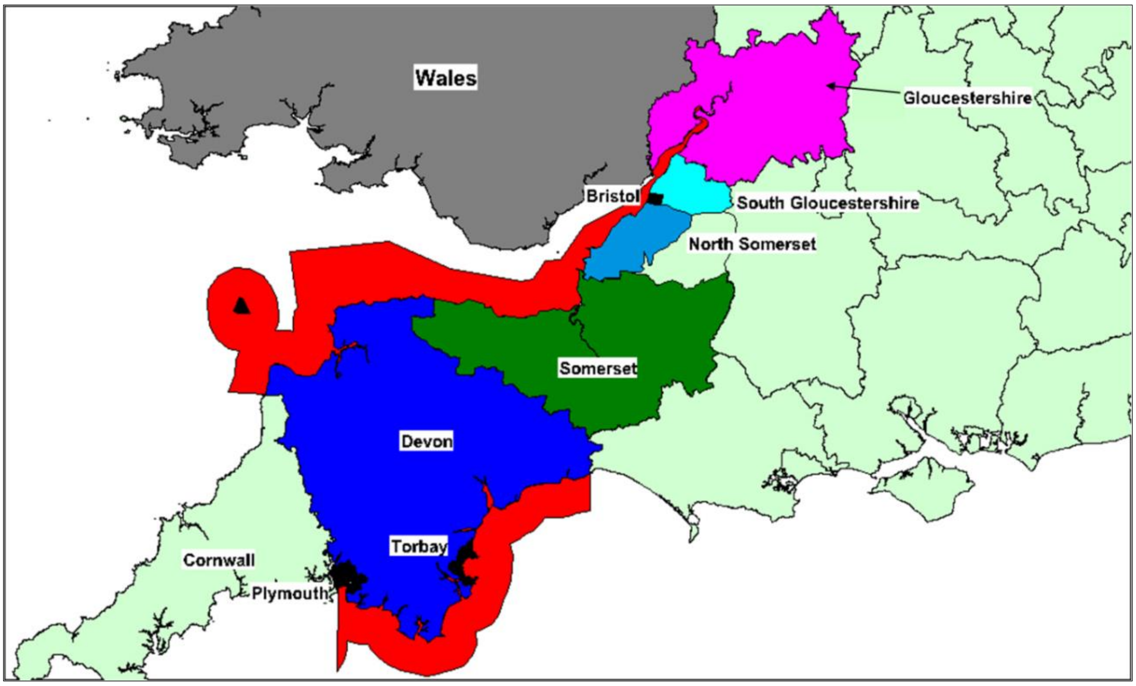
B. undatum has two distinct, separate sexes; the males are distinguished by a large muscular penis which lies folded back within the mantle cavity, posterior to the right side of the head. This is absent in females (Kideys et al., 1993). The fertilisation process, as described by Kideys et al. (1993) and

Martel et al. (1986), occurs internally. Following copulation the spermatozoa are first stored in the bursa copulatrix and later transferred via the ventral channel of the capsule gland to the seminal receptacle. They are kept here until oocytes pass through the albumen and capsule glands where fertilization occurs. The eggs are surrounded by a transparent viscous mass of albumen. The eggs are laid in capsules, with large numbers being deposited, attached to each other. These egg masses are either fixed to floating objects, or to benthic substrate such as mollusc shells or rocks. Martel et al. (1986) described how the period of egg-laying may be extended by the storage of spermatozoa by the female for up to eight weeks. This allows the female to spawn at a time when the external conditions are most favourable, to increase the likelihood of the eggs surviving.

Whelks lack a planktonic larval phase, and there is rarely migration between populations. This creates a closed population, resulting in low genetic diversity (Shelmerdine et al., 2007) and distinct local populations, with regional characteristic differences such as size and age of maturity, and growth rates. Variations in breeding seasons have also been noted, both between and within localities (Kideys et al., 1993).

2.3 Management

The Devon & Severn IFCA's District covers all tidal waters, out to six nautical miles, within Devon County Council borders in the south and from the Devon and Cornwall County Council boundary to the Gloucestershire County Council border and Wales in the north (Map 1). Within its District Devon & Severn IFCA must manage the exploitation of sea fisheries resources (MaCAA, 2009), to ensure healthy seas, sustainable fisheries and a viable industry. The whelk fishery appears to be increasing within D&S IFCA's District, in particular along the North Devon coast (pers. comms. with Ilfracombe whelk fishermen), with a lengthening of the whelk fishing season and an increase in number of boats fishing. It is known to the IFCA that in the southern part of the District the fishery is more pressurised due to the spatial limitation of the fishery and intensity of effort.



Map 1 The Devon & Severn IFCA District, with the seaward limit shown in red.

The size of maturity (SOM) is the size at which the probability of an individual being mature is 0.5, i.e. the size at which 50% of the population is mature. In 2012-13 Cefas undertook a study to determine the size of maturity (SOM) for both sexes of whelks in all the main fisheries around the country, including Exmouth and Ilfracombe in the D&S IFCA District, using one-off samples from each port. The results of this survey indicated that for the sample taken from Ilfracombe the SOM was 75.5mm for both females and males, and for the Exmouth sample the SOM was 72.4mm for females and 69.2mm for males (Lawler, 2013). This implies that the EU Minimum Size of 45mm is currently doing little to protect the spawning stocks and, therefore, the sustainability of the population. As SOM is known to vary regionally, this year-long study, collecting monthly samples, by D&S IFCA aims to gather the scientific evidence necessary to determine an appropriate Minimum Size for whelks within the D&S IFCA District, as well as any other management measures which may be appropriate. By collecting monthly samples over the course of a year, this study will have a larger total sample size from which to determine the SOM than that of the Cefas study. It will also provide the ability to identify the time of year when the whelks breed and spawn, by looking at monthly variation in gonad sizes.

3. Objectives

Primary aim:

1) To determine the size of maturity of whelks in the D&S IFCA District

   a) Acquire adequate size and sex stratified samples from Ilfracombe (North Devon) and Exmouth (South Devon).
   b) Process whelk samples and compile maturity data and biometrics into a database.
   c) Analyse data using logistic regression analysis to determine size of maturity by sex and by region. Size of maturity will be determined by both shell height and shell width, to determine if a width based Minimum Size would be viable instead of the shell height.

Secondary aim:

2) To identify the peak whelk spawning season

   a) Acquire adequate size and sex stratified samples from Ilfracombe (North Devon) and Exmouth (South Devon).
   b) Process whelk samples and compile maturity data and biometrics into a database.
   c) Analyse data to determine when spawning occurs for each sex, in each region.

4. Methodology

4.1 Equipment

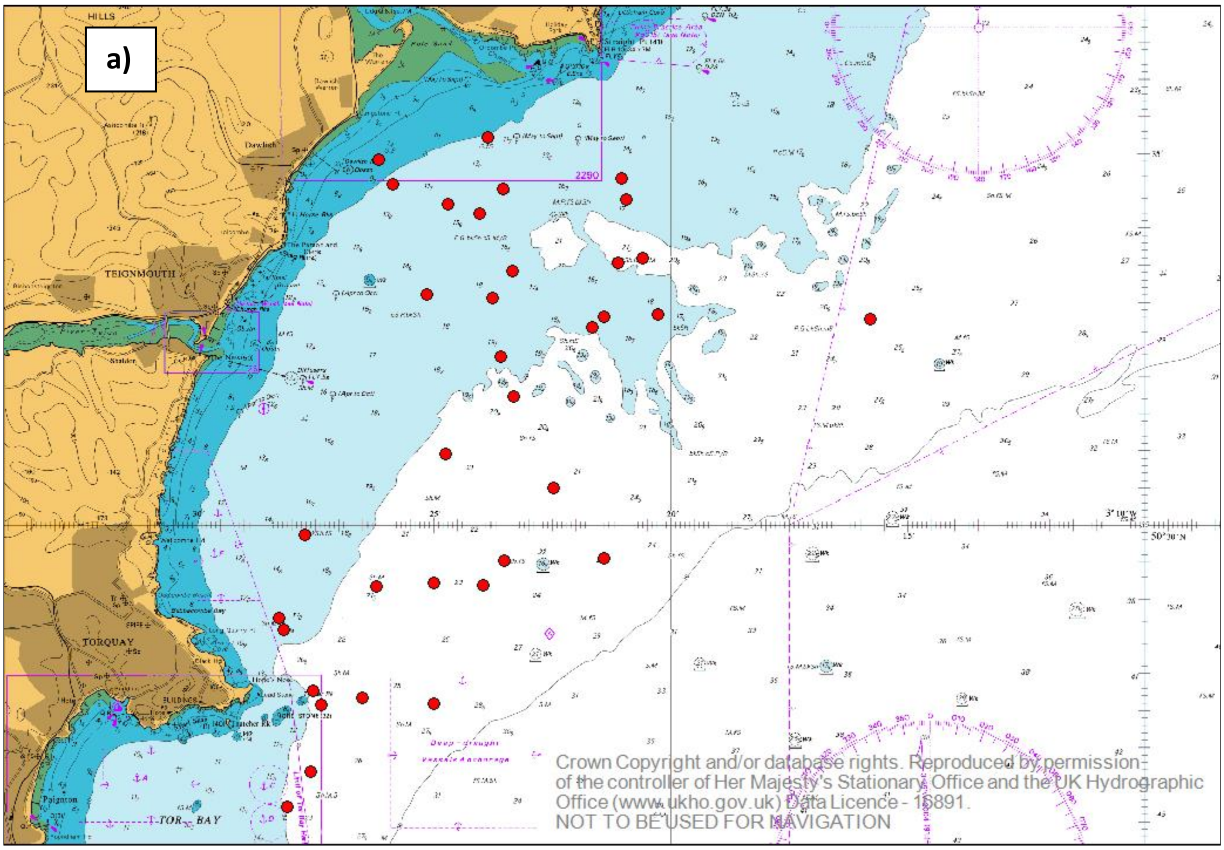
a) Laptop
b) Balance (0.1g accuracy)
c) Callipers
d) Magnifying lens with light
e) Scalpel, forceps, gloves

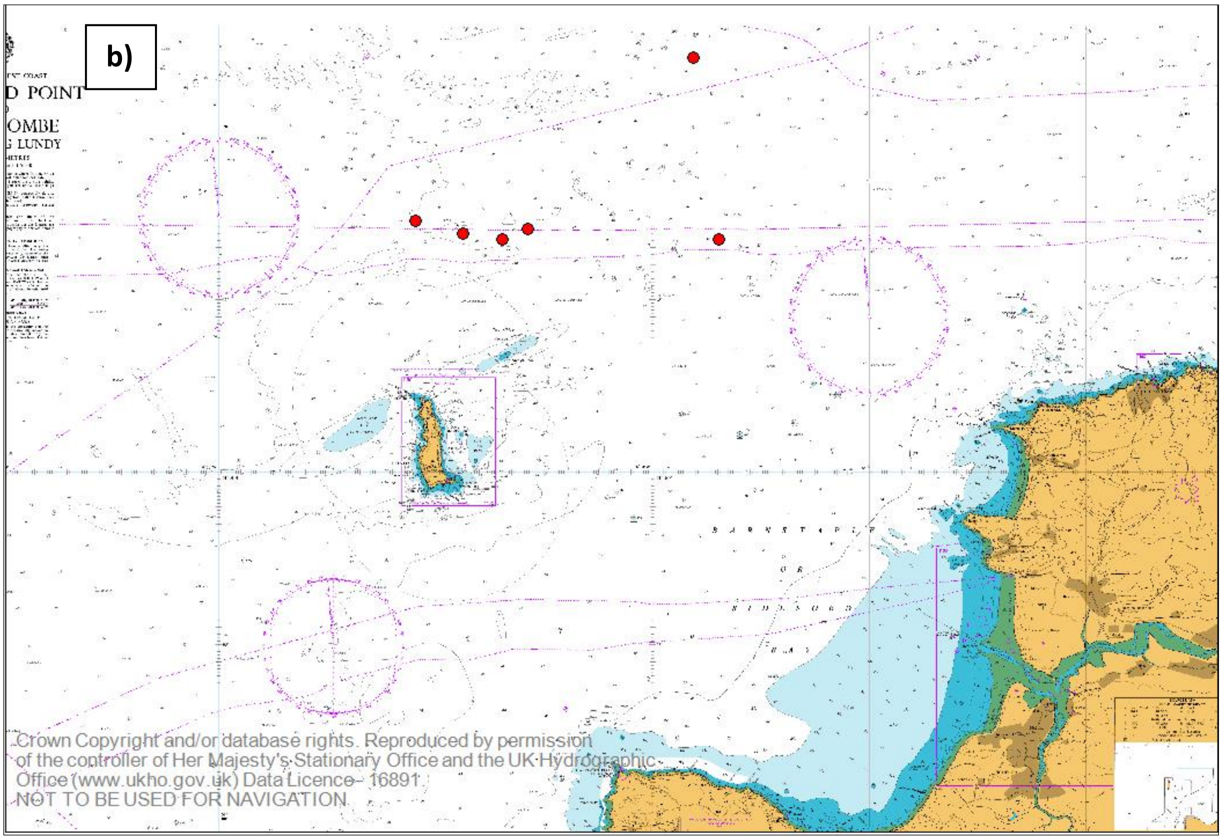
4.2 Size of maturity

Volunteer fishing skippers were enlisted; one in Ilfracombe and one in Exmouth, and one sample of whelks were collected from each skipper on a monthly basis for a period of 12 months (June 2012 – July 2013)(Map 2). Fishers were asked to provide a sample consisting of one bag of un-riddled whelks i.e. representing what is caught directly in each pot, including undersized whelks. Samples were frozen until analysis could take place.

From each sample a size stratified sub-sample was selected for analysis. This consisted of five whelks of each sex, for each of the following size categories; 40-45mm, 45-50mm, 50-55mm, 55-60mm, 60-65mm, 65-70mm, 70-75mm, 75-80mm, and ≥80mm.

The following measurements were collected for each whelk: total weight; shell height (from the apex to the end of the siphonal canal); minimum shell width (the width from the ventral aperture side to dorsal side); maximum shell width (widest part of the shell, either side of the aperture) (Figure 1).





Map 2 a) Locations of Exmouth samples, b) Locations of Ilfracombe samples.

Fig. 1 a) Measuring shell height, b) Measuring minimum width, c) Measuring maximum width.

Individual whelks were removed from their shells using forceps and the following biometric data was collected: shell weight; visceral weight; sex; maturity status (according to Table 1)(Examples presented in Figure 2); digestive gland weight; gonad weight (if applicable).

Maturity Stage	Male	Female
Immature	No differentiation of digestive gland	No differentiation of digestive gland
Maturing	Some differentiation of digestive gland, restricted to dorsal and anterior edge	Some differentiation of digestive gland, restricted to dorsal edge
Mature	Presence of a mature testis (typically brick red in colour and thicker than 2mm in depth)	Presence of a mature ovary (typically yellow in colour and thicker than 4mm in depth)

Table 1 Maturity stage key by sex (Lawler, 2013)

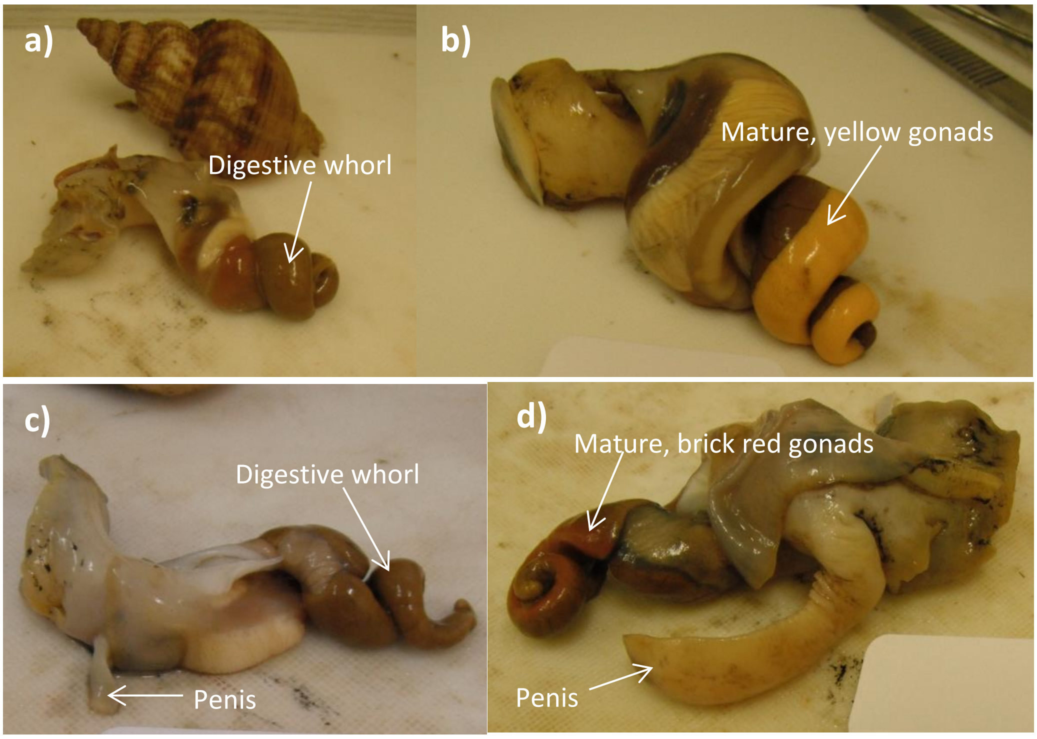


Fig. 2 a) Immature female: no differentiation between digestive whorl and gonad. b) Mature female: gonad clearly differentiated from digestive whorl. c) Immature male: no differentiation between gonad and digestive whorl, undeveloped penis. d) Mature male: gonad differentiated from digestive whorl, penis fully developed.

The size of maturity (SOM) is the size at which 50% of the population is mature, or the probability of a whelk being mature is 0.5. Whelks were classed as either mature or immature and the probability of a whelk being sexually mature by shell length (for each sex, and each site separately) was modelled using binomial logistic regression analysis using the "glm" function within the R statistical modelling software (R Development Core Team, 2013). The results were plotted onto a maturity ogive, using an R-script adapted from Harry et al. (2013), to report the SOM and 95% confidence intervals.

The Pearson's correlation between shell length and shell "minimum-width" was assessed using the "cor" function in R, to determine if there is a relationship between shell height and shell width.

The size of maturity calculations were repeated using the shell "minimum-width" measurement instead of shell length, to determine if a width based Minimum Size would be viable.

4.3 Seasonality of the reproductive cycle

Using the biometric data collected (detailed in section 4.1) from the mature whelks only, gonad size indices (gonad weight standardised to digestive whorl weight) were plotted for each month. Separate plots were created for each sex and each site. These plots show how the gonad size increases as it matures and when the size declines after copulation/spawning.

5. Results

5.1 Size of maturity

Just over 1600 whelks, across both sexes and sites, were dissected to assess their reproductive status.

Figures 3-6 show the maturity ogives, for shell height, for each sex at each site. Estimates of SOM are marked at the point where 50% of the population is mature. Estimates of SOM are also presented in Table 2.

Site	Sex	Estimate of SOM (mm)	Smallest mature observed (mm)	Largest immature observed (mm)
Exmouth	Female	69.3	59	79
	Male	70.9	59	82
Ilfracombe	Female	76.5	62	94
	Male	76.4	66	87

Table 2 Estimates of SOM, with size (shell height) of smallest mature whelk and largest immature whelk in the sample.

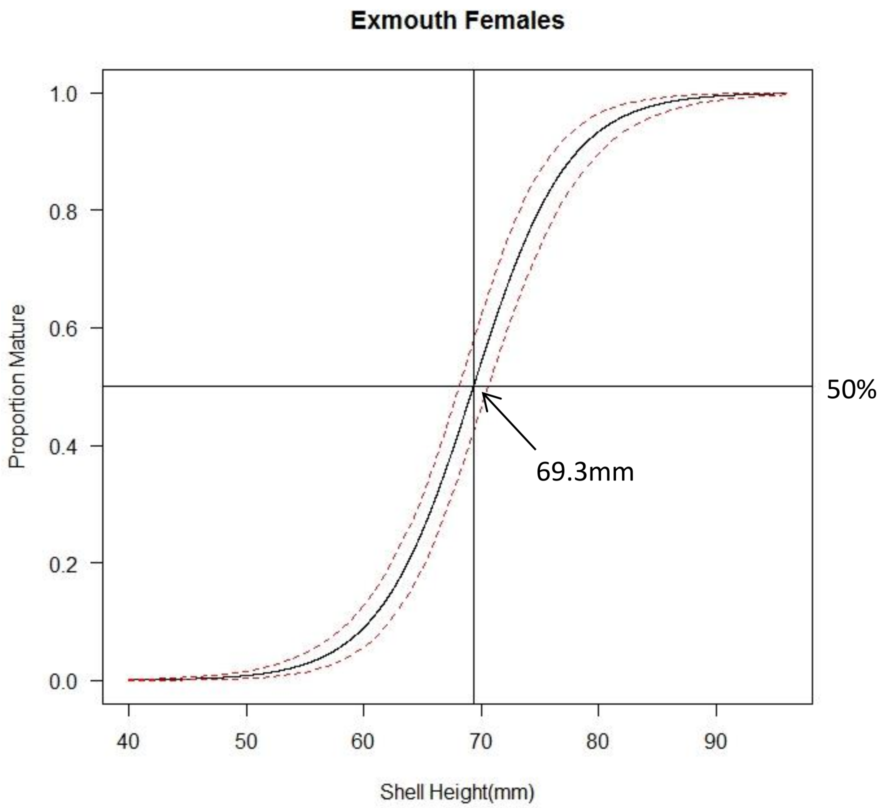


Fig. 3 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for female whelks from Exmouth.

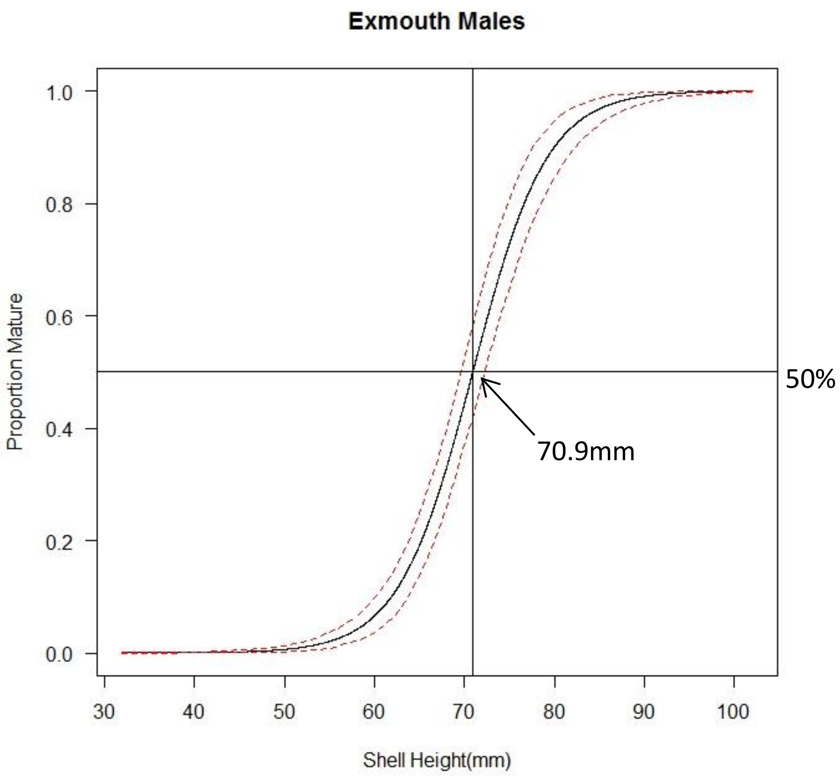


Fig. 4 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for male whelks from Exmouth.

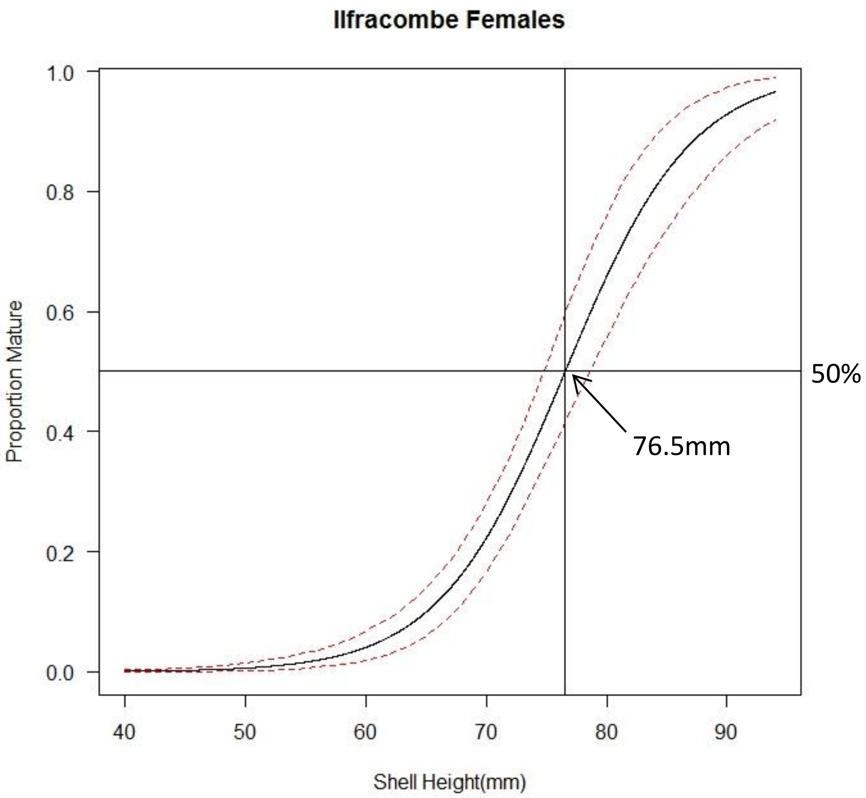


Fig. 5 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for female whelks from Ilfracombe.

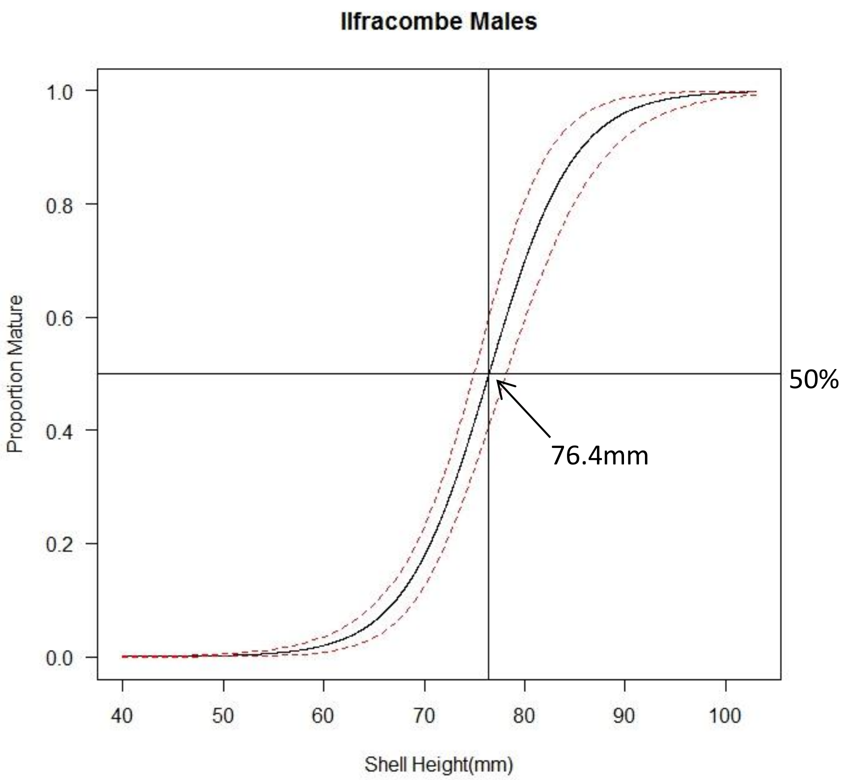


Fig. 6 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for male whelks from Ilfracombe.

There is a strong positive correlation between shell height and the minimum shell width for all sub-samples, meaning that as shell length increases the shell width also grows at an equivalent rate. This is depicted in figures 7-10. The Pearson's correlation coefficients for each sub-sample are presented in table 3. The relationship between shell height and shell width means that for a Minimum Size or SOM based on shell height a corresponding shell width could be identified.

Site	Sex	Pearson's correlation coefficient
Exmouth	Female	0.925
	Male	0.939
Ilfracombe	Female	0.957
	Male	0.926

Table 3 Correlation between shell height and minimum shell width for each sex, by site.

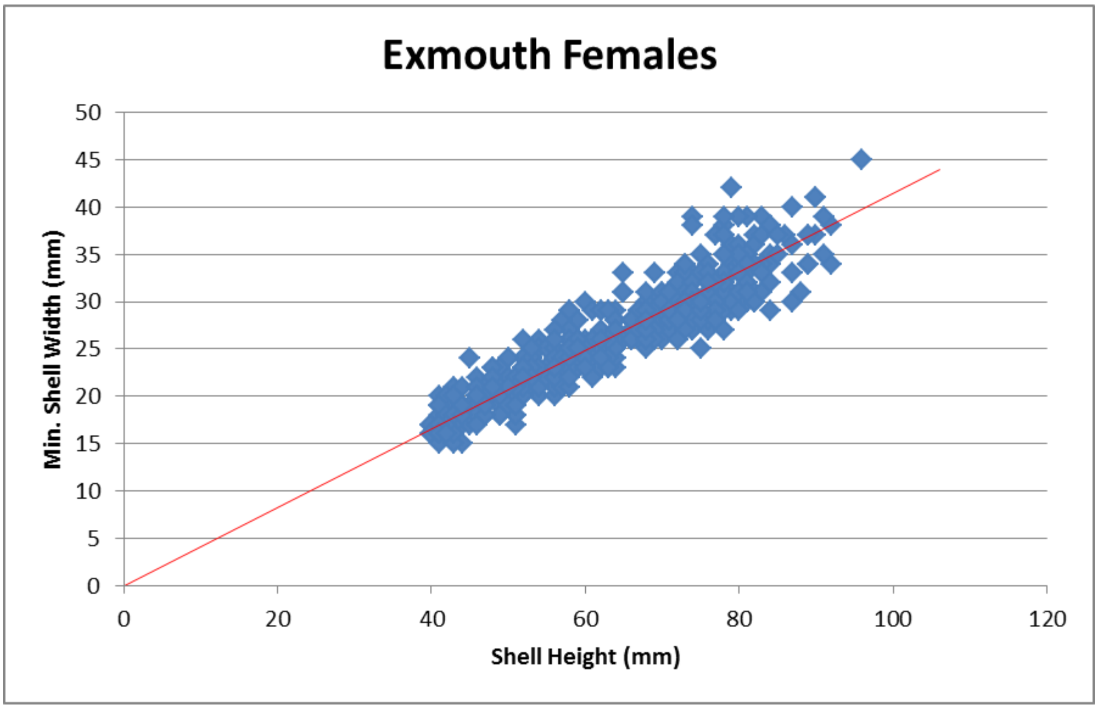


Fig. 7 Relationship between shell height and shell width, for female whelks from Exmouth.

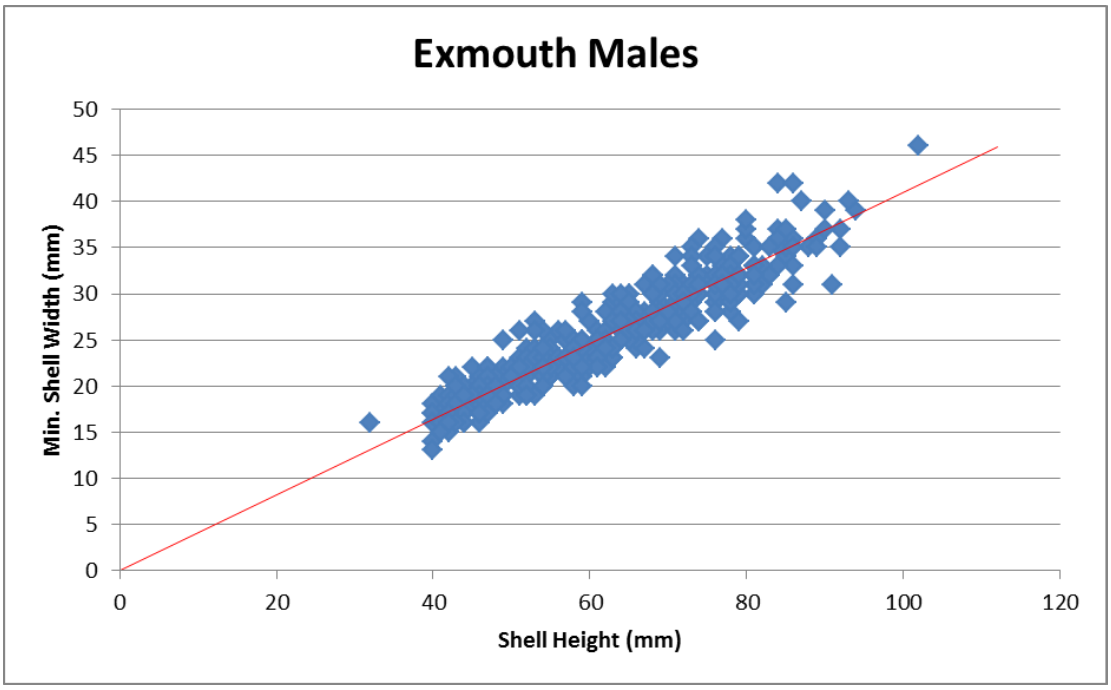


Fig. 8 Relationship between shell height and shell width, for male whelks from Exmouth.

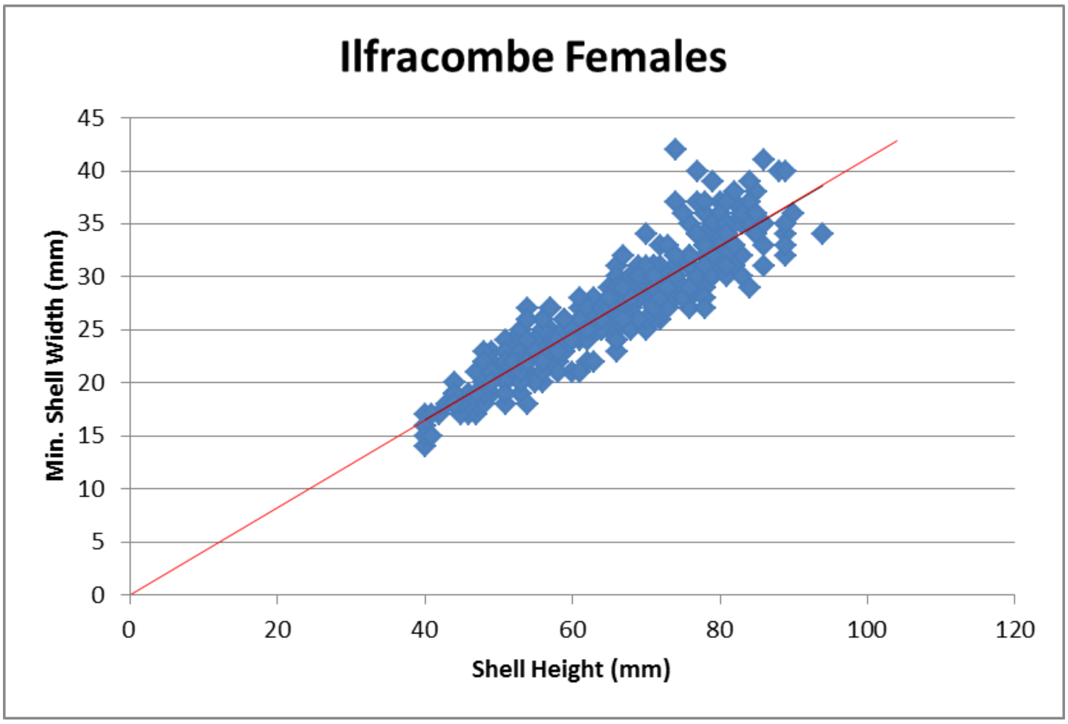


Fig. 9 Relationship between shell height and shell width, for female whelks from Ilfracombe.

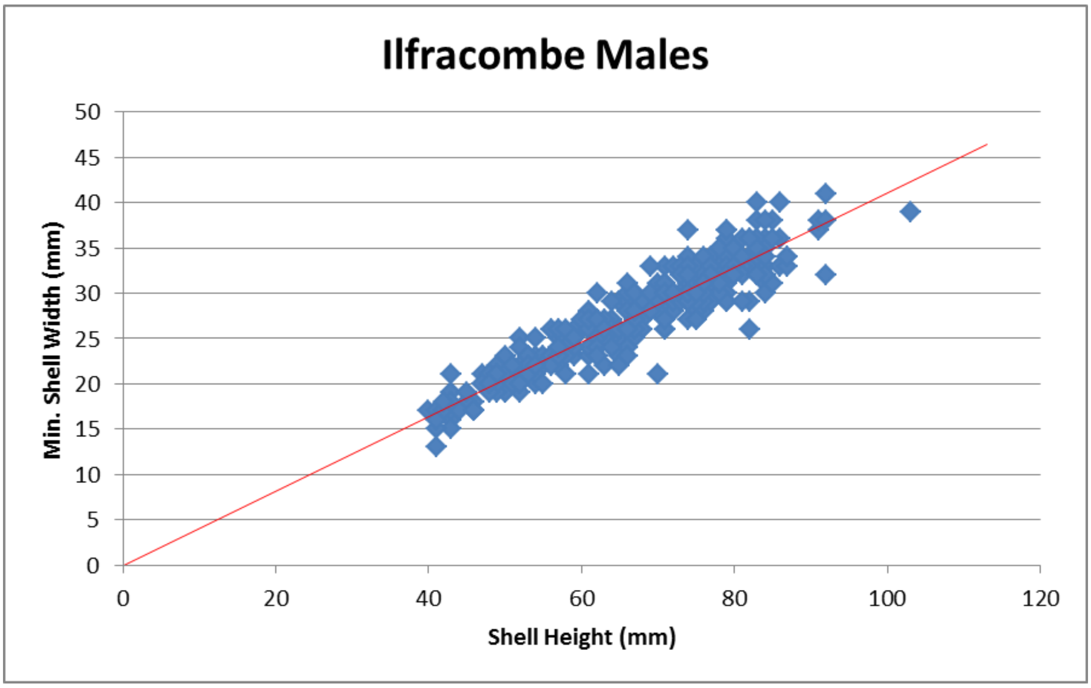


Fig. 10 Relationship between shell height and shell width, for male whelks from Ilfracombe.

Figures 11-14 show the maturity ogives, for minimum shell width, for each sex at each site. Estimates of SOM are marked at the point where 50% of the population is mature. Estimates of SOM are also presented in Table 4.

Site	Sex	SOM estimate using shell width (mm)
Exmouth	Female	28.6
	Male	29.1
Ilfracombe	Female	31.7
	Male	31.5

Table 4 Estimates of SOM using minimum shell width, by sex and by site.

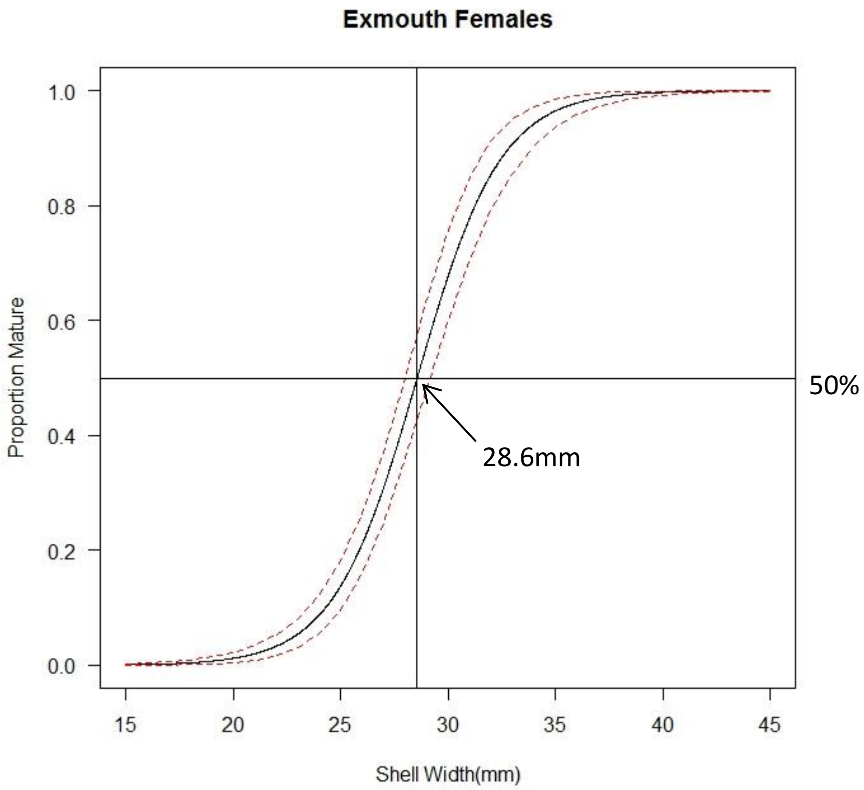


Fig. 11 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for female whelks from Exmouth.

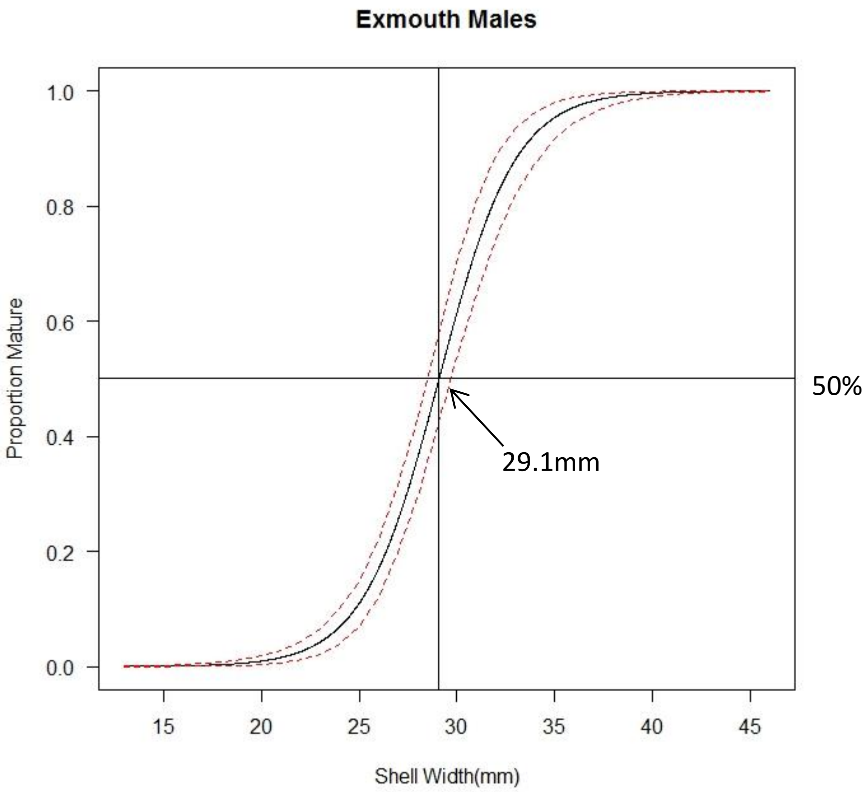


Fig. 12 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for male whelks from Exmouth.

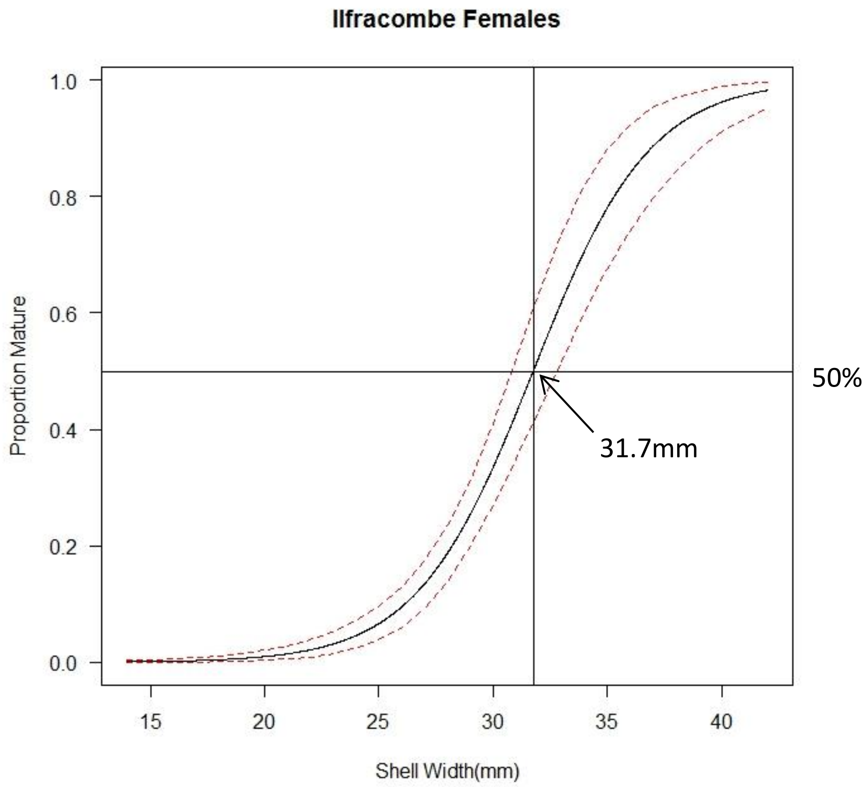


Fig. 13 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for female whelks from Ilfracombe.

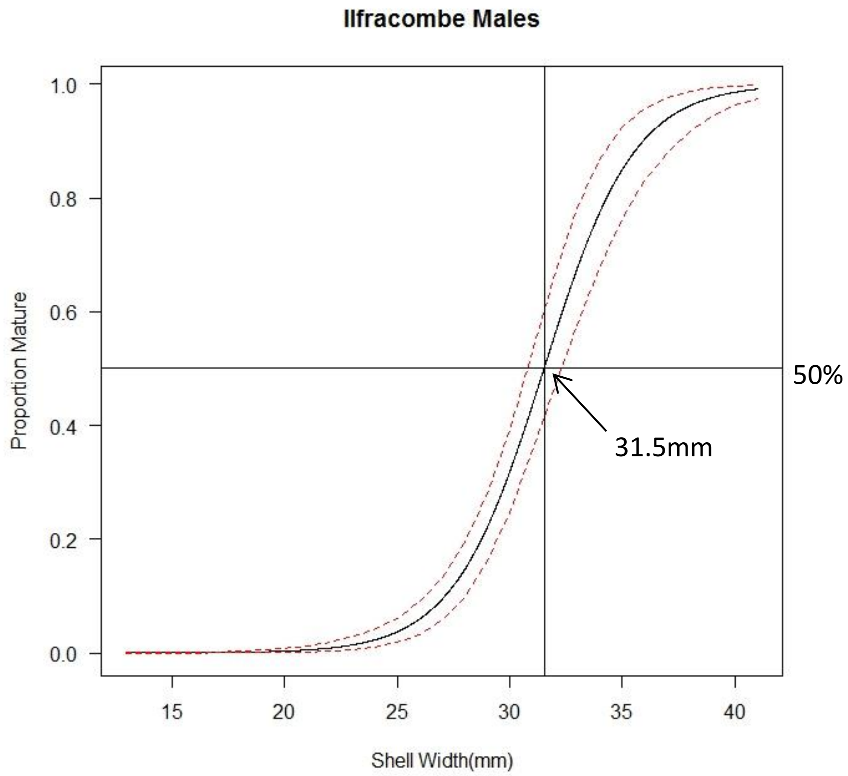


Fig. 14 Probability of a whelk being mature against whelk size, with 95% confidence intervals, for male whelks from Ilfracombe.

5.2 Seasonality of the reproductive cycle

Indices of gonad size (gonad weight standardised to digestive whorl weight) were plotted by month, for each sex at both sites (Figures 15-18). These plots show how the gonad size increases as it matures and when the size declines after copulation/spawning.

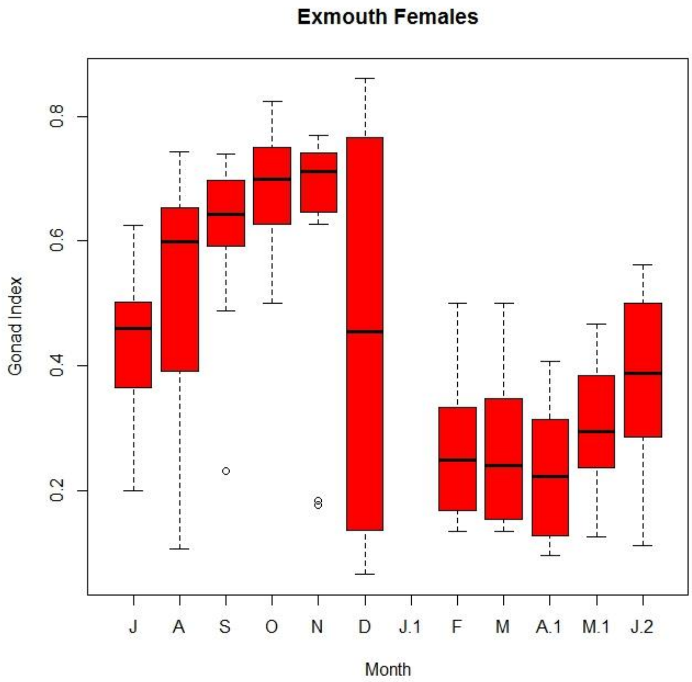


Fig. 15 Box and whisker plot showing distribution of gonad index for each sample month, for female whelks in Exmouth. (No sample was collected in January due to poor fishing weather).

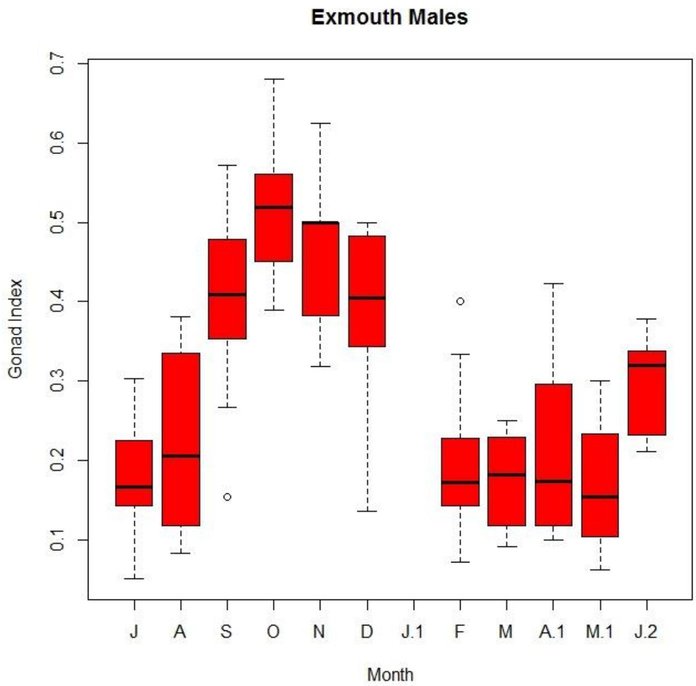


Fig. 16 Box and whisker plot showing distribution of gonad index for each sample month, for male whelks in Exmouth. (No sample was collected in January due to poor fishing weather).

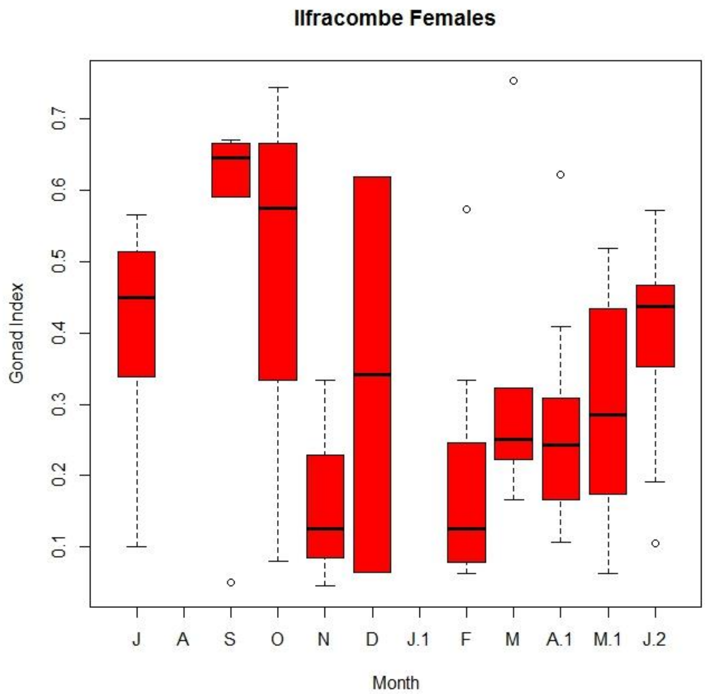


Fig. 17 Box and whisker plot showing distribution of gonad index for each sample month, for female whelks in Ilfracombe. (No sample was collected in January due to poor fishing weather, or August as the fisherman did not fish that month)

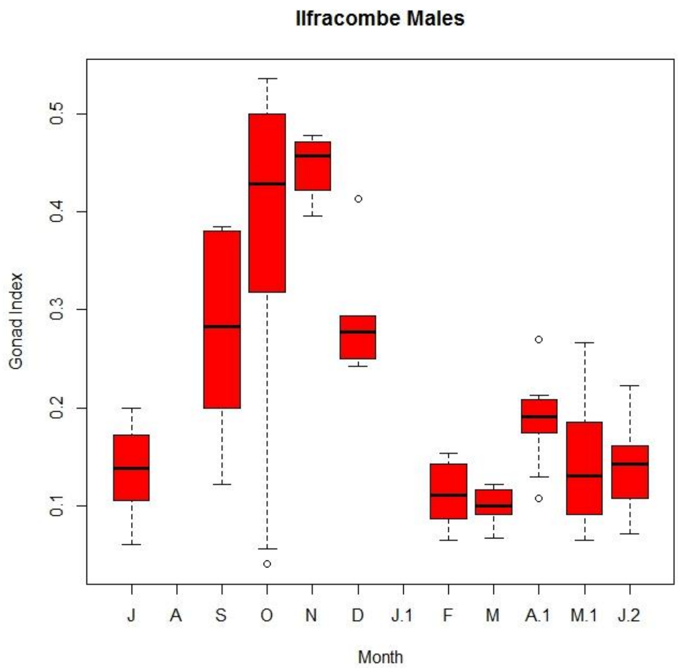


Fig. 18 Box and whisker plot showing distribution of gonad index for each sample month, for male whelks in Ilfracombe. (No sample was collected in January due to poor fishing weather, or August as the fisherman did not fish that month)

6. Discussion

6.1 Size of maturity

There is little variation in SOM between sexes at each site, but a clear difference in SOM between Exmouth and Ilfracombe. Previous studies have also found regional differences in SOM for *Buccinum undatum* (Gendron, 1992; Fahy et al., 2006; Cefas 2013). These regional differences could be explained by environmental factors, such as sea temperature, or anthropogenic influences, such as fishing pressure, or a combination of both. It is known that increased fishing pressure and adult mortality can lead to changes in population age and size at maturity, i.e. populations get younger and smaller with fishery selection. Rochet (1998) explained that short life is associated with a small size and early age at maturity, as increased adult mortality selects for earlier maturation at a smaller size. This could be a compensatory response to the pressure on the stock, as Fahy et al. (2006) suggest that maturation at a smaller size could lead to higher productivity. Estimates of whelk age at both the 45mm Minimum Size, and at the SOM for each site (using 70mm for Exmouth, and 76mm for Ilfracombe) are detailed in table 5. Estimates suggest that whelks in Exmouth reach maturity at around 3.5 years, while those in Ilfracombe mature at about 3.75 years. The smaller SOM and younger age of maturity for whelks from Exmouth would suggest that this population is under greater pressure from fishing than the Ilfracombe population. These ages are merely approximations based on the findings of a study by Cefas (Lawler, 2013).

	Age at Minimum Size (years)	Age at SOM (years)
Exmouth	1.75	3.5
Ilfracombe	1.75	3.75

Table 5 Approximate ages at EU Minimum Size and SOM. Estimated from Lawler, 2013.

There is little difference between the average sea temperatures for North and South Devon, so it unlikely that this is the cause of the variation between the two sample populations. Figure 19 shows the average monthly sea temperatures for North and South Devon, using Ilfracombe and Plymouth, respectively, as the sampling stations. There is an average of 0.3°C difference between the two coasts. However, data was not available for the sea temperature at Exmouth, so Plymouth was used to represent South Devon. Therefore, as the temperature difference between Ilfracombe and Exmouth is unknown, this cannot be completely ruled out as an influence on the SOM variation.

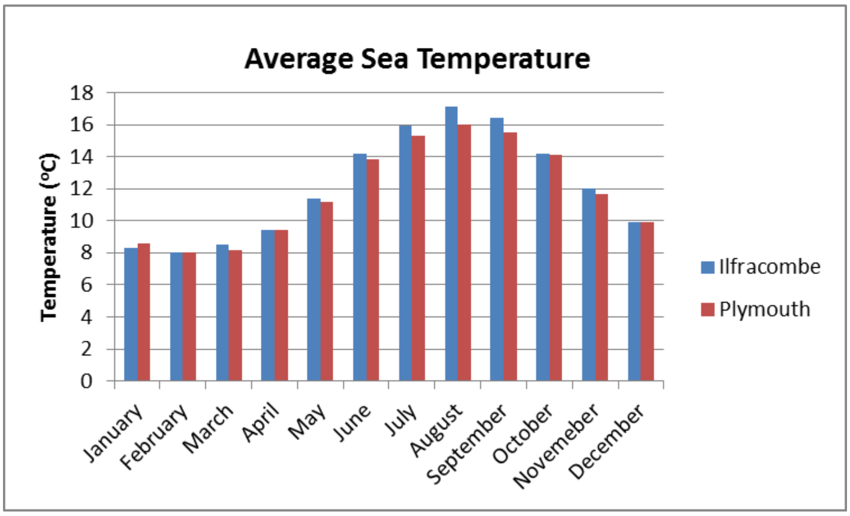


Fig. 19 Average monthly sea temperatures for Ilfracombe and Plymouth (Cefas, 2014)

Another possible source of variation is the behaviour of the whelks themselves. It is known that mature female edible crabs will not enter baited traps just after spawning (Lawler,2013); therefore a disproportionate amount of immature females would be caught during spawning season. However, it is not known if whelks behave similarly, but seasonal timing of sampling is known to give different estimates of SOM. Nevertheless, this potential source of variation should have been avoided by collecting samples on a monthly basis for a period of twelve months, therefore avoiding any bias that a one-off sample which may coincide with spawning season may bring.

Whelk fishers in Ilfracombe have noticed different population sizes within their fishing ground (pers. comm.), stating that the further East they fish, i.e. towards the Bristol Channel, the whelks caught are smaller. They also believe that the biggest whelks are to the North of their ground. Therefore the fishers collecting the samples were asked to collect the samples from their typical fishing ground, to ensure the sample was representative of the main fishery.

The SOM estimates from this study are all well above the EU Minimum Size of 45mm: Exmouth females 69.3mm; Exmouth males 70.9mm; Ilfracombe females 76.5mm; Ilfracombe males 76.4mm. This suggests that the current Minimum Size is doing little to protect the spawning stocks in D&S IFCA's District. A similar study (Ilano et al., 2003) on the Japanese whelk, *Buccinum isaotakii*, fishery found that their Minimum Size of 70mm was insufficient, as their female whelks reached maturity at around 100mm. They therefore recommended an increase in Minimum Size to 100mm to allow whelks to reproduce at least once before being harvested. They also recommended an increase in mesh size of the gill nets used in the fishery, to exclude small whelks (Ilano et al., 2003). Shelmerdine et al. (2007) describe how pressure from the local fishermen lead to the Shetland Shellfish Management Organisation (SSMO) increasing the Minimum Size for *B. undatum* to a shell length of 75mm within the 6-mile limit around Shetland. An increased Minimum Size has also been suggested for the whelk fishery in the Southern Irish Sea (Fahy et al., 1995).

As this study has found, as well as others mentioned previously, it seems that one broad-scale management measure, i.e. the EU Minimum Size for whelk, does not provide adequate protection for all the sub-stocks within the European whelk population. Tuckey et al. (2007) evaluated the advantages and disadvantages of both localised and large-scale management. Localized management is appropriate in situations when there are real spatial differences and distinct sub-stocks, as has been found for whelk populations around the UK. This is because if an average is used from a large-scale assessment, and applied to all sub-stocks then for some sub-stocks restrictions will be too stringent, while in others the restrictions will not be sufficient to meet the management goals. Both these situations result in a loss of yield. If a large area is managed by the EU Minimum Size, but consists of several sub-stocks, then there are several management issues which may arise such as the inability to detect stock depletion and the potential loss of genetic diversity, as well as yield (Shelmerdine et al., 2007). Increasing importance on marine protected areas and conserving biodiversity is leading to more emphasis being placed on management which takes into account stock complexity. Preservation of the full diversity of spawning stocks within management units should become a principle of management under the "precautionary principle", according to Stephenson (1999).

The large volumes of whelk that are landed make any Minimum Size difficult to enforce. Most vessels use on-board sorting devices known as riddles, effectively metal grids where the bars are spaced at a distance which allows small whelks to fall through whilst keeping marketable whelks separate. In some areas management measures incorporating sorting devices have been introduced, to aid enforcement of the Minimum Size. In South Wales there is a byelaw prohibiting the landing of whelks which can pass through a 35mm spaced sieve, and in the Sussex IFCA District there is a limit on the amount of whelks in a landing that can pass through a 25mm riddle (MMO, 2012). Even with the use of riddles there is still scope for inconsistency, as whelks fall through the riddle sideways but the Minimum Size is based on shell length. However, this study has shown there is strong correlation between shell length and shell width, so for any Minimum Size or SOM based on shell length a corresponding shell width could be identified. Therefore a Minimum Size based on shell width could be considered as a management option, using the width based SOM estimates as a guideline. This would allow fishers to use a riddle of an appropriate size to sort their catch.

6.2 Seasonality of the reproductive cycle

Copulation, where the males pass sperm onto the females to fertilize their eggs, usually takes place between three weeks and two months before the females spawn and release the eggs (Kideys et al., 1993). Therefore the gonad indices would be expected to show the male gonads maturing, and increasing in size, before those of the females. Then there should be a sudden decline in male gonad size after copulation, shortly followed by a decline in female gonad size, when spawning takes place. After copulation and spawning the gonads of both sexes will start to increase in size as they start to mature again.

The gonad index graphs show how the average gonad sizes of mature whelks change over the 12 month sampling period. For Exmouth females there is a general increase towards December, with a fall in gonad size in January/February, before starting to increase again. This suggests that the eggs are maturing until December, and then spawning takes place in January or February. However, as no sample was collected in January it is not possible to identify exactly when spawning occurs. Exmouth males show a similar pattern, with gonad size increasing until October when there is a small decrease until December when there is a steep drop in gonad size occurring between December and February. This suggests some whelks start copulating between October and December, but the majority of copulation occurs through December, and possibly January. But, again, as there was no sample for January we cannot tell when this occurs, although it is usually three to eight weeks before spawning (Kideys et al., 1993).

The Ilfracombe gonad indices are less clear, although it appears that copulation takes place throughout November to January, when the male gonad indices show a decline. The females appear to spawn in November. But this is followed by an increase in the gonad indices for December, and as there is no sample for January it is difficult to identify the extent of the spawning time. Therefore, the Ilfracombe results are less conclusive than those from Exmouth. This may be due to the lack of samples from August and January, or to not having enough mature whelks in each sample. For example, in the Ilfracombe samples there were only three mature female whelks in November, and two in December. This could be resolved by collecting larger samples.

Another source of variation could arise from the fact that is often difficult to tell the difference between an immature whelk and a “spent” whelk, i.e. one that has recently copulated/spawned. Therefore some whelks that are in fact mature may be wrongly classed as immature. Again, a larger sample size would reduce the influence that this would have on the overall result.

Although it is difficult to accurately identify the copulation and spawning seasons in this study, other studies have been able to so. A joint project between Cefas and Sussex IFCA looked at whelk populations in Eastbourne and Selsey. They found that mating occurs in both areas in September or soon after, and the females in Eastbourne spawn between September and November, while those in Selsey spawn in November/December.

A study of the Japanese whelk fishery identified mating as likely to occur around March, and egg-laying taking place between May and September. This lead to a recommendation to set fishing periods to exclude times of copulation and egg-laying, which would enhance recruitment (Ilano et al., 2003).

7. Conclusions

7.1 Management implications

The results of this study suggest that the current *Buccinum undatum* Minimum Size of 45mm is too low to protect the spawning stock, and recruitment over-fishing is likely to be occurring. This study has provided plausible estimates for SOM based on shell height: 69.3mm (female) and 70.9mm (male) from Exmouth, and 76.5mm (female) and 76.4mm (male) from Ilfracombe. These estimates could be used as a basis from which to review the current Minimum Size.

The study has also shown a strong relationship between shell height and shell width, meaning that a width based Minimum Size, which would make sorting the large volumes of catch with a riddle more effective, would be viable. Plausible estimates of SOM based on shell width were calculated: 28.6mm (female) and 29.1mm (male) from Exmouth, and 31.7mm (female) and 31.5mm (male) from Ilfracombe. Again, these figures provide a good guide on which to base a Minimum Size.

At both sites it appears that mating and spawning take place during the winter, with peak breeding activity occurring during December and January. Therefore a closed season during these months could be considered to protect the spawning whelks. However, further research into the seasonality of the reproductive cycle would provide more information on the exact timings. Larger sample sizes and a full set of samples from twelve months would increase the accuracy of the timing estimates.

7.2 Future work

It has been reported to Devon & Severn IFCA by a local whelk fisherman that the whelks in the Start Bay area of their District are believed to be smaller than elsewhere. Samples should be collected from this area to gain estimates of SOM which can be compared to those of Exmouth and Ilfracombe, and used to inform any decisions on future management strategies.

If a Minimum Size based on shell width were to be introduced, work to find the most effective riddle size for this width could be undertaken. Research into the effectiveness of different riddle sizes for sorting catch has been carried out by Sussex IFCA and Kent & Essex IFCA, who have since introduced management measures based on the use of riddles within their respective Districts. Sussex IFCA Byelaws state that “No person shall, in using a vessel within the District, remove any whelk which would pass through a riddle or any like instrument the bars of which are no less than 25 millimetres apart” (Sussex IFCA, 2014), while Kent & Essex IFCA require that “All whelks must be graded for size using a riddle constructed of parallel bars no less than 22 mm apart.” (Kent & Essex IFCA, 2014).

Kent & Essex IFCA has also studied the effect of introducing escape gaps of varying size into whelk pots. They found that escape gaps were an effective method for reducing the numbers of undersize whelks caught, and have since introduced the requirement to have “at least 2 escape holes no less than 22 mm in diameter positioned at least 150 mm from the base and no less than 50 mm from the top” of each pot (Kent & Essex IFCA, 2014). The escape gap sizes chosen by Kent & Essex IFCA are based on a Minimum Size of 45mm, however if Devon & Severn IFCA decide to amend the Minimum Size within their District a comparable study could be undertaken.

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