WORKSHOP ON WHELK FISHERIES (WKWF)

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i Executive summary

This inaugural workshop on whelk fisheries brought together scientists and fishery managers working on whelk fisheries globally. The workshop provided a forum to share best practice and a review of the recently published work and research currently underway. There were two main focuses. First, whelk ageing techniques, ageing error and age data use in stock assessment. A second focus was on current stock assessment approaches and challenges. A final session was available for other whelk research including bait and mortality from riddling.

The main conclusions from the ageing presentations and discussion were that older age classes were only seen in very small numbers resulting in difficulties for growth models to anchor the upper asymptote. Discussion highlighted possible reasons for this as difficulty observing small growth increments on the edge of statoliths, dome-shaped gear selectivity or high mortality past age 5. The group recommended further work in this area.

It was clear from presentation and discussion that whelk species demonstrate high potential for spatial structure and spatial variability of biological parameters and that stock assessment approaches need to consider this. Future work needs to focus on a range of techniques to inform stock structure with possible collaboration with ICES Stock Identification Methods Working Group (SIMWG).

Researchers from across Europe and north America gave presentations on the current status of fisheries, data collection, management and assessment in their countries. Multiple regions have been showing declines in catch per unit effort and concern was raised from southern stock regarding the impact of warming waters with climate change on the reproductive success and mortality rate in these stocks.

Preliminary work has shown potentially significant mortality rates following mechanical whelk riddling. Further research is needed and discussion highlighted gear modification to minimize undersize catch as an important management consideration.

Keywords: Gastropods; ageing; stock structure; stock assessment

ii Expert group information

Expert group name	Workshop on Whelk Fisheries (WKWF)
Expert group cycle	Annual
Year cycle started	2024
Reporting year in cycle	1/1
Chairs	Natalie Hold (UK)
Meeting venues and dates	8-9 July 2024, Centre for Applied Marine Science, Bangor University, Menai Bridge, Wales (27 participants)

1 Introduction

1.1 Motivation and aims

Whelk fisheries, in particular *Buccinum undatum*, are commercially important fisheries for France, Iceland, UK and Ireland with smaller or emerging fisheries in Belgium, Denmark, Sweden, Netherlands and Norway, as well as Canada and the US. Despite their economic value, management of this species has been minimal in most countries up to date. However, recent years have seen growing research activity and management efforts aimed at ensuring the sustainability of these fisheries. Over the course of this rise in interest in whelk fisheries, researchers and managers have often been confronted by similar knowledge gaps preventing the development of stock models needed to improve current management strategies used in whelk fisheries. Therefore, there was motivation from researchers and managers globally to gather to share best practice and recent and ongoing research results, as well as forge research collaborations and set research priorities for the future.

Prior to the workshop the attendees were asked for topic priorities to include in the two-day workshop. First, it was agreed that ageing techniques and errors were an important topic. The inclusion of age data or not within core data collection programmes can determine which stock assessment approaches may be available to assessor and managers in future. However, ageing of whelk is cost and time expensive and so the rationale to invest in these data needs a greater understanding of the benefits and challenges. The aim of day one of the workshop was to highlight current best practice in aging techniques, and discuss how to assess and quantify ageing error, and discuss the issues around identifying older animals which are challenging to age with existing ageing methods.

A second area identified as key to understand for whelk fisheries was spatial stock structure. Many whelk species have life history characteristics such as direct development and low adult movement, that could result in fine scale spatial structure. The aim of day two was to understand the range of methodologies available to researchers when investigating spatial stock structure and to review existing evidence on the topic.

Researchers and managers were invited to give presentations on the data collection, management, assessment and status of stocks in their regions. The aim was to understand broad stock trends and share best practices in overcoming the existing shortcomings by looking at international whelk fisheries but also drawing from similar fisheries which have already cleared the hurdles that the whelk fishery faces.

A final session was made available to share any other research relevant to whelk fisheries.

2 Ageing gastropods

2.1 Ageing methods

There are two main methods for age determination of *Buccinum undatum*, counting growth rings on operculae and counting growth rings in the statoliths (analogous to fish otoliths, Figure 2.1). Early work utilized the opercular rings as they are quick to process (Santarelli and Gros, 1985). However, their accuracy is often low and there is confusion in the literature regarding whether visible lines on the dorsal or ventral surface of the operculum should be used (Hollyman *et al.*, 2018b). Recent work has found the statolith ageing method to be the most reliable and accurate (Hollyman *et al.*, 2018b), with validation confirming annual periodicity of growth rings from growth experiments (Hollyman *et al.*, 2018a, 2018b), isotopic analysis of the shells (Hollyman *et al.*, 2018a, 2020) and analysis of trace elements in the statoliths themselves (Hollyman *et al.*, 2019).

Statoliths (paired, small spherical balls of calcium carbonate) are dissected from individual animals under a microscope and mounted in thermoplastic resin (Hollyman *et al.*, 2018a). Then, under a compound microscope, annual increments in each statolith can be counted to age individual whelk. These age at length data can then be used to calculate growth parameters for whelk populations that are comparable between locations. The main drawback of using statoliths to age stocks is that they are currently costly and time consuming, but it provides the most reliable and accurate age estimates at present.

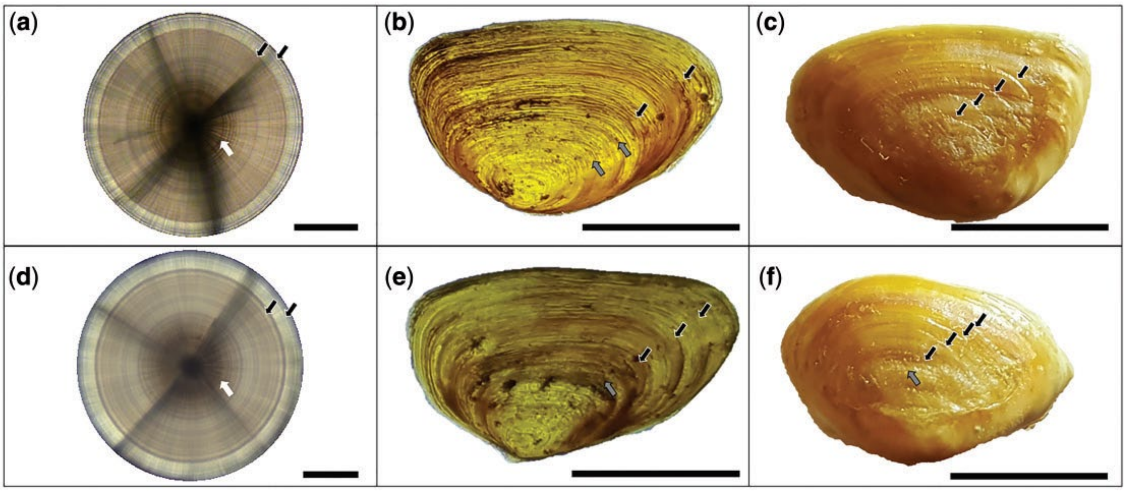


Figure 2.1 Photomicrographs of two 27-month old laboratory reared *B. undatum* statoliths (a and d) with corresponding operculum, external surface (b and e) and operculum inner surface showing the adventitious layers (c and f) (from Hollyman et al., 2018b). Hatching rings are represented by white arrows (a and d), clear growth rings by black arrows and disputed rings by grey arrows. Statoliths and operculum surface rings (a and d and b and e, respectively) were imaged with transmitted light whereas the adventitious layers on the inner surface of each operculum (c and f) were imaged using reflected light. Statolith scale bars indicate 50 mm, operculum scale bars represent 5 mm.

2.2 Validating ages

Validation involves determining when the first growth ring is formed (i.e. is there a birth ring), whether rings are formed annually, whether there are additional rings (so called "check marks") formed during the time of reproductive activity or during periods of slow growth due to storms, excessive heat, etc., and whether the rings at the edge of the statolith of old specimens can be counted reliably. Eleven methods of validation were listed: marginal increment analysis, method of predicted rings in tagged animals, method of predicted growth in tagged animals, tracking strong and weak year classes over time, tracking good and bad growth years (and natural marks) over time, analysing modes in length frequency distributions, chemical marking of statoliths, ageing using stable isotopes or chemical signatures, and using daily growth rings to validate annuli. The first five methods were discussed in detail. Three of the methods require tagging animals; six of the methods have the potential to provide results within two years (though more years will provide better results). For whelk specifically there is difficulty in marginal increment analysis due to edge visibility issues; it is difficult to observe clear cohorts after maturation limiting the use of strong or weak cohorts or modes in length frequency (Hollyman *et al.,* 2018). Refinement of methodology is ongoing at Bangor University to improve visualization of the edge of statoliths to improve confidence in aging of older animals.

2.3 Evaluating readers and *NOT* computing precision

Programs involving the reading of ages from hard parts are often evaluated by computing the average percent error from multiple readings of the age of individual animals. Proponents of this technique claim the method accounts for the age of the animals but studies have shown this is not the case (Brown and Gruber, 1988; Kimura and Lyons, 1991), i.e. the average percent error is a function of the age of the animal. A current limitation is that average percent error does not account for the study design (twenty readings of two animals is treated as the same as two readings on each of twenty fish). Furthermore, discrepancies in assigned ages by multiple readers can be due to: age of the animal, methodology, and variability among animals, so that a single number representing "precision" does not distinguish between any of these factors. It is noteworthy that, in the two studies that proposed using average percent error, the sole conclusion was that Reader B was slightly less precise than Reader A. The authors did not note that the readings from Reader A were generally lower than those from Reader B, and the first readings from Reader B were generally that reader's highest reading for a fish and the second reading was generally the reader's lowest reading. It was suggested that a better measure of precision is the percent agreement or, more generally, the frequency of discrepancies (number of times the disagreement was -2, -1, 0, 1, 2 years).

A prime question is whether two readers are equivalent, i.e. give the same results on average. This can be tested with a χ^2 test of symmetry (Hoenig *et al.*, 1995; Evans and Hoenig, 1998). Three such tests were described; reference was made to the compare2 function in the R package fishmethods (Nelson, 2023). These approaches are currently being used at Bangor University to understand intra- and inter-reader consistency.

3 Growth in gastropods

3.1 Age based growth models

The use of statolith ageing has allowed age based growth models to be developed for some whelk populations. Work in European stocks has found that the growth curves from age data are best fitted using a Gompertz growth model due to the hatching time falling within winter so that growth starts slowly (Hollyman *et al.*, 2018b). Contrastingly in the USA where hatching occurs in the summer von Bertalanffy Growth (VBG) models fit best (Borsetti *et al.*, 2021).

While Gompertz models seemed to fit European populations best, previous work showed that VBG also fit the data well with minimal difference in statistical goodness-of-fit (Hollyman *et al.*, 2018b). Given that many stock assessment and indicator reference points require the VBG model as input, recent work in Wales has tried to fit VBG models to age data. This has resulted in poor fit with unrealistic asymptotic sizes, while the Gompertz seems to fit the upper asymptote to values that appear more realistic. Unreasonable growth parameter estimates (extremely large asymptotic size or x-axis intercept that is years away from the origin) can arise if: 1) sampling is selective for mid-size animals, 2) the data have only a limited range of ages, or 3) there is spatial size segregation of the animals.

Age data for *Buccinum undatum* from statoliths were presented from the UK and the USA. In all locations there were very few to no animals found from older age groups. Gear selectivity affected the catchability of smaller animals resulting, as would be expected, in an under representation of animals below four years. Lack of very small individuals can affect the growth-rate estimation, and thereby the appropriateness of the model used. However, there is also very few animals caught aged above six years (Figure 3.1). This lack of older animals will either be interpreted in stock assessment models as high mortality (fishing and/or natural) or dome shaped selectivity. Although some work on pot selectivity suggests that there is some doming on the right hand descending limb, this does not appear from the work to date to be steep enough to explain this rapid decline (Colvin *et al.*, 2024).

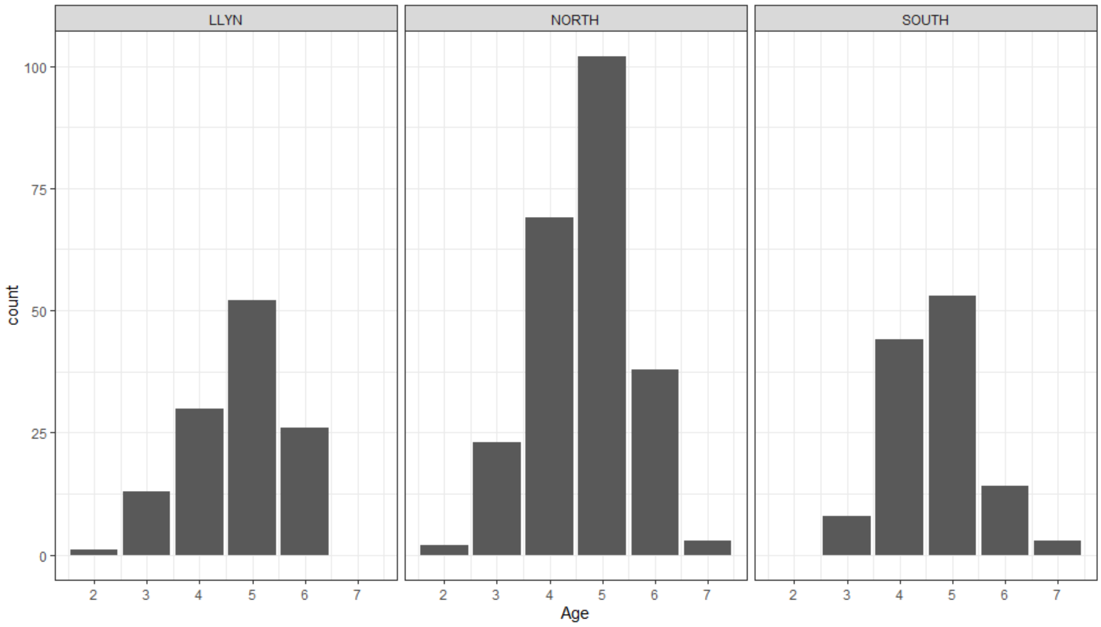


Figure 3.1 Age composition from statolith ageing for whelk from three populations in Wales (Llyn Peninsula, North Wales, South Wales), UK from 2024.

This issue was discussed at length during the workshop with the conclusion that additional work was needed to verify the statolith ages of larger, older animals in the first instance. Whilst younger animals can be easier to age as growth increments are larger and do not suffer from edge effect issues discussed, there are concerns that size selectivity of fishing gear is preferentially providing samples of faster growing 1 to 3 year old whelk and this needs consideration when estimating growth. Once confidence in the age data is confirmed, several suggested solutions were presented. The first is to use the sampling gear that is the least size selective. The second solution is to back calculate sizes to ensure adequate sample sizes for the youngest ages and to avoid issues with size selectivity. The size distribution at each age should be normally distributed, such that the shape of the size distributions provides a diagnostic procedure for problems with gear selectivity. Another solution is to fix the T_o parameter at 0 and only estimate two parameters. This method can be effective, but in some instances can fail to produce a reasonable model fit. A final solution is to fit a different growth model (e.g. Gompertz or Richards instead of a von Bertalanffy curve). It is not clear under which circumstances this is appropriate.

Work from a paper (Borsetti *et al.*, 2021) was presented during the workshop and showed that there is a significant difference in the growth and maturity patterns between *B. undatum* populations in the UK and the US (Figure 3.2). The linear relationships between latitude and asymptotic length, asymptotic length and instantaneous growth rate and size and age at maturity seen across UK populations do not hold once US population are included, suggesting differences in growth between these distinct populations. This could be due to significant genetic differences across this spatial scale, but it should also be noted that UK populations were all commercially exploited, whereas the US population was an unexploited population.

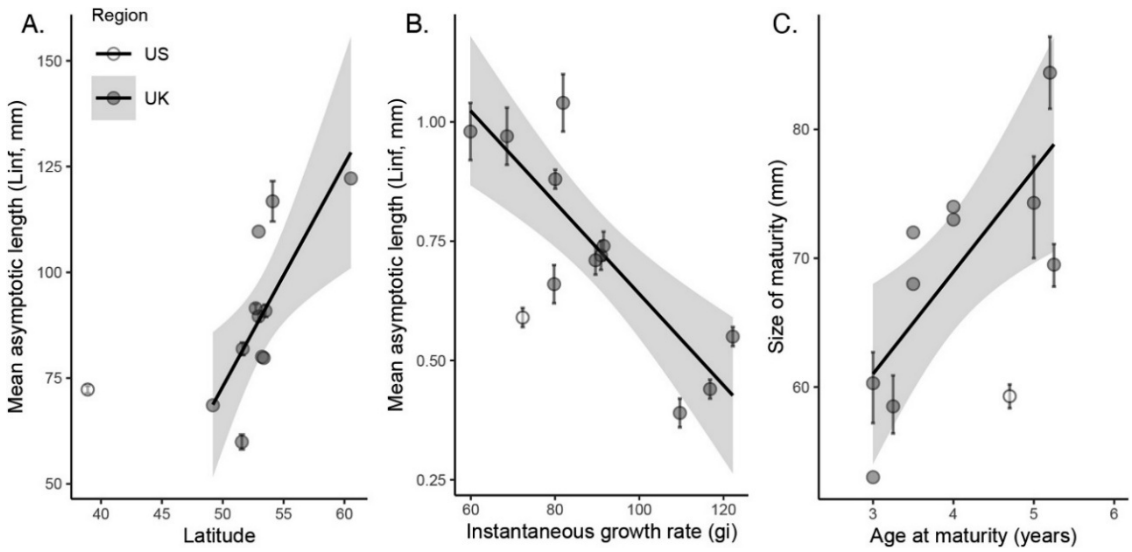


Figure 3.2 Comparison of Gompertz growth coefficients from populations assessed using statolith obtained from published literature (from Borsetti *et al.*, 2021) [UK, grey; USA, white] A. Trend in mean asymptotic length (L∞, mm) by latitude. Error bars represent standard errors. If exact latitudes not available, approximate location based on study details. B. Trend in instantaneous growth rate (gi) by mean asymptotic length (L∞, mm). Error bars represent standard errors. C. Trend in size of maturity with 95% confidence intervals and approximate age-at-maturity.

3.2 Shell damage and repair

Whelks are vulnerable to damage from a variety of factors, including feeding, predation, burrowing, mechanical fishery gears, and riddling, a process used in the whelk fishery to grade catch by size. Often these incidences of shell damage are recorded as scars on the shell surface following periods of re-growth. Understanding the process(es) involved in shell repair following damage and the consequent recovery mechanizms is important for the continued sustainability of whelk fisheries because widespread damage could influence survival and growth rate; important characteristics that affect productivity at the level of fished stocks. However, there is currently little work into the frequency and degree of shell damage in inshore fisheries, and the mechanizms of repair of the whelk's shell.

In recent studies, the capabilities of shell growth and repair in *B. undatum* were investigated experimentally by implementing laboratory-controlled mechanical damage to the shell under differing regimes of temperature (5–15°C) and feeding rates for three size ranges of whelk. Rates of shell re-growth, microstructural changes and trace element incorporation were assessed, with significant differences in rates of shell repair occurring with whelk size, small juveniles repairing quickest and adults the slowest. Repair rate was slower across at the colder temperatures. Total shell length growth was seen to be less in damaged shells than for undamaged control whelk in all size classes, although this was not significant within the experimental setup. The overall composition of the shell is not seen to greatly differ between repaired and unrepaired shells, or across the different treatments. (Colvin *et al.*, 2022, 2023) (Figure 3.3). Repetitive damaging of discarded whelks through riddles or conflict with other towed gear, may therefore affect the growth rates within the population. The time to repair damage of a size ~40% of the aperture width was between 30 days (small juveniles) and >65 days (adults), potentially leaving these whelks more vulnerable to predation during this time.

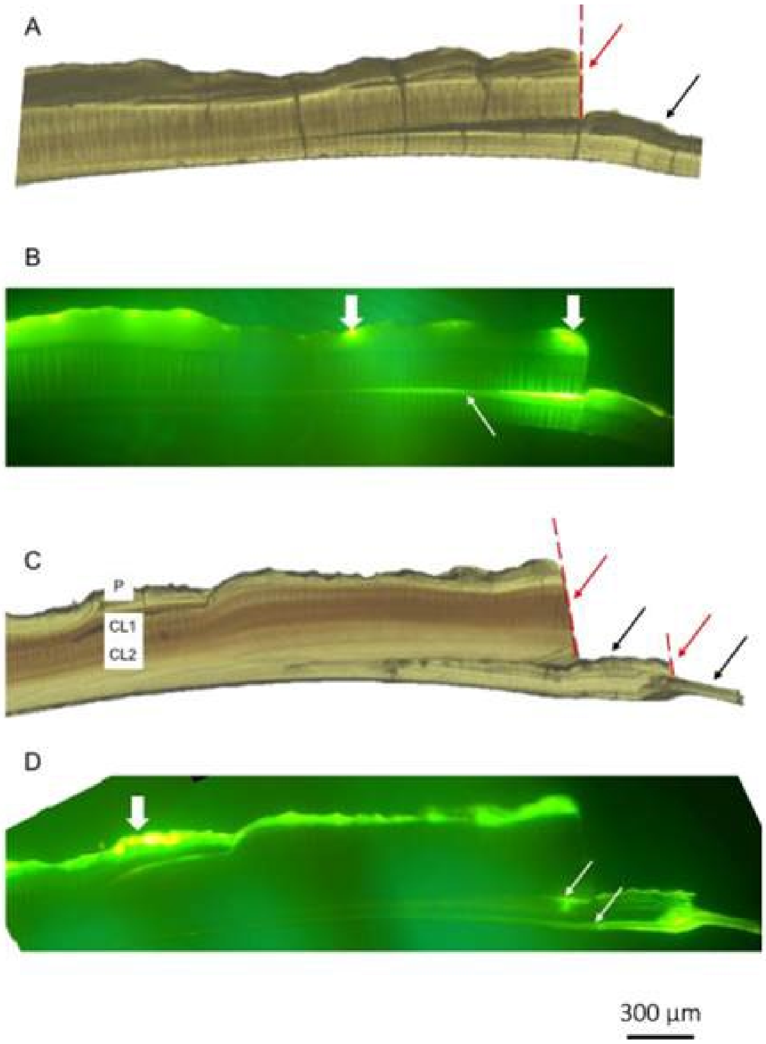


Figure 3.3 Thin shell sections of *B. undatum* in transmitted light (A and C) and in U.V. light (B and D). A) Damaged shell (red arrow) and re-growth (black arrow), B) shell section in (A) to show incorporation of Calcein (thin white arrow (incorporation), thick white arrow (absorption)), C) section to show appearance of a double damaged shell (red arrows mark the first and second incidents of damage. Black arrows indicate post-damage re-growth) and D) shell section in (C) to show damage and incorporation of Calcein (white arrows). P = periostracum, CL1 and CL2 = crossed lamellar layer. The outer periostracum absorbs the Calcein and fluoresces under U.V. light (Large white arrow) (Colvin *et al.*, 2022).

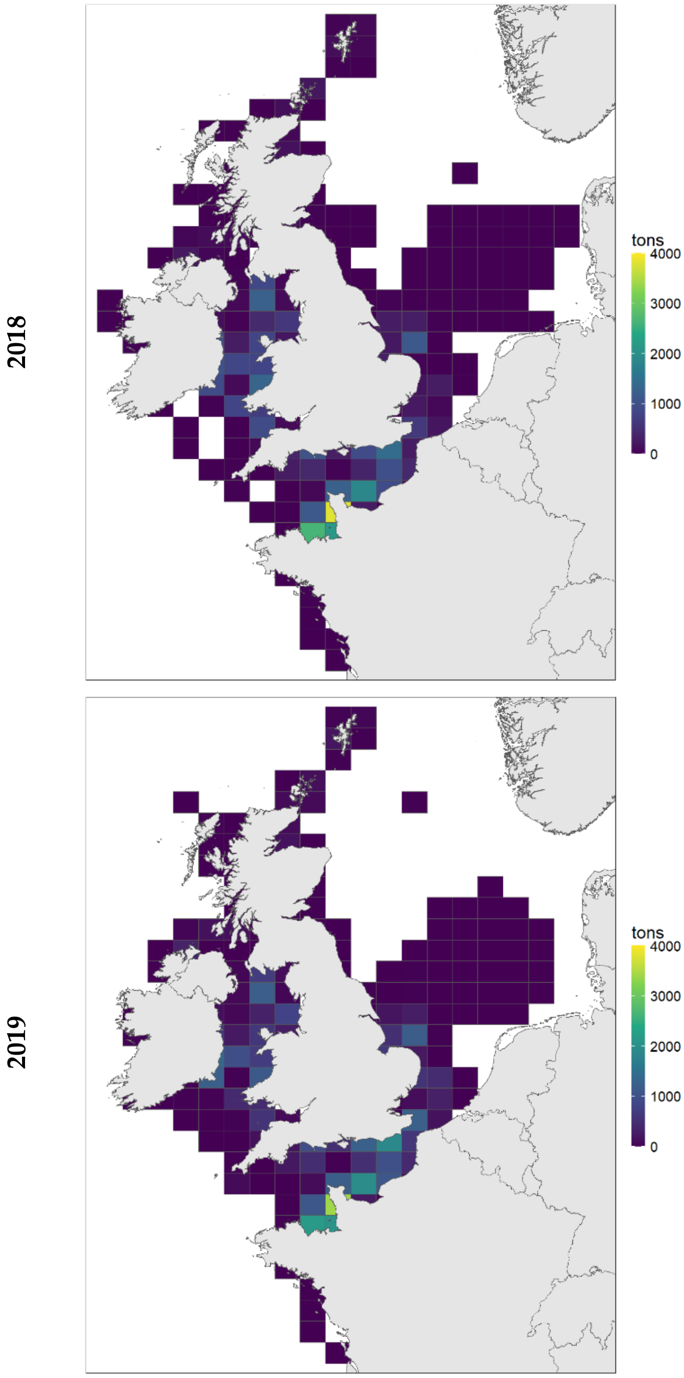
4 Regional whelk fishery updates

FAO statistics on the landings of whelk, by country, from 2018–2022 are shown in Table 4.1. The majority of these landings will be for the common whelk, *Buccinum undatum* in Europe, with France, UK and Ireland responsible for over 90% of these landings.

Table 4.1 FAO statistics on the landings of common whelk in weight (tons) and as proportions (%) of total annual landings, by country, from 2018–2022.

FAO FishStat (“Whelk”)	Landed Weight (tons)					Percentages (%)			
Country (Name)	2018	2019	2020	2021	2022	2019	2020	2021	2022
Belgium	43	270	608.3	209	79	0.63	1.48	0.55	0.26
Channel Islands	839	877	211.44	177.4	185	2.04	0.51	0.46	0.61
Denmark	300	139	80	89	100	0.32	0.19	0.23	0.33
Faroe Islands	0	0	0	0	0	0.00	0.00	0.00	0.00
France (Atlantic)	15 596.34	15 443.36	12 466.51	11 972.77	10 107.12	36.01	30.36	31.28	33.13
France (Mediterranean)	4	1.93	1.85	3.81	2.19	0.00	0.00	0.01	0.01
Germany	0	0	0	0	1	0.00	0.00	0.00	0.00
Iceland	195	351	0	171	291	0.82	0.00	0.45	0.95
Ireland	5 196	5 033.73	4 966.57	5 802.91	4 803.33	11.74	12.10	15.16	15.75
Isle of Man	993	940	667.01	533.86	534	2.19	1.62	1.39	1.75
Netherlands (Kingdom of the)	209	259	649	377	281		1.58	0.98	0.92
Norway	350	341.63	216.29	6.79	29.4	0.80	0.53	0.02	0.10
Portugal	0	0	0	0.02	0	0.00	0.00	0.00	0.00
Saint Pierre and Miquelon	23	46	0.03	0	0	0.11	0.00	0.00	0.00
Spain	0	0.02	0.01	0.03	0.05	0.00	0.00	0.00	0.00
Spain	0	0	0.01	0	0.06	0.00	0.00	0.00	0.00
Sweden	1	2	2.6	0.38	0.39	0.00	0.01	0.00	0.00
UK	18 353.67	19 186.68	21 188.57	18 931.44	14 091.44	44.73	51.61	49.46	46.19
Total	42 103.01	42 891.35	41 058.21	38 275.4	30 504.98	100	100	100	100

Landings for the UK (MMO statistics), Ireland and France by ICES rectangles (2018–2022) have been provided by members of this working group and the distribution of landings by ICES rectangles is shown (Figure 4.1).


2018
tons
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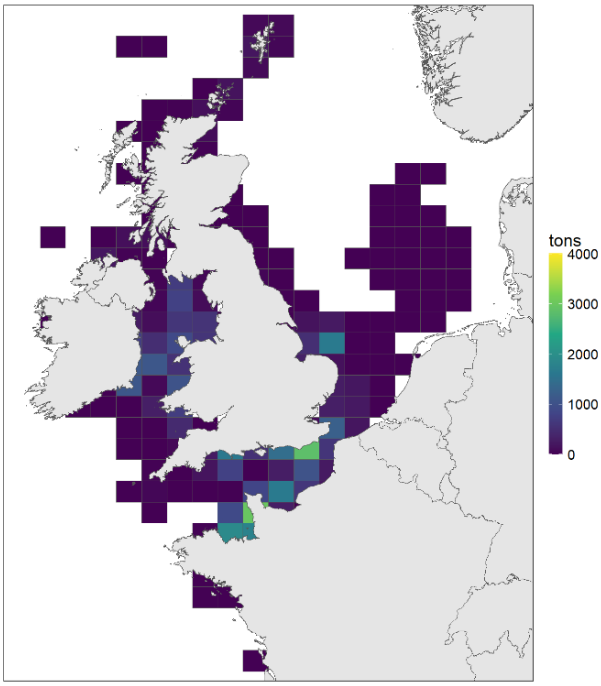
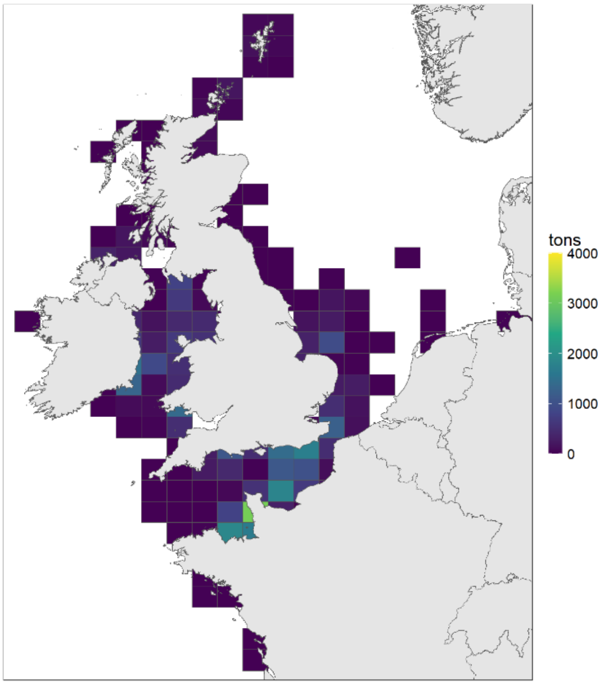
2020



2021



2022

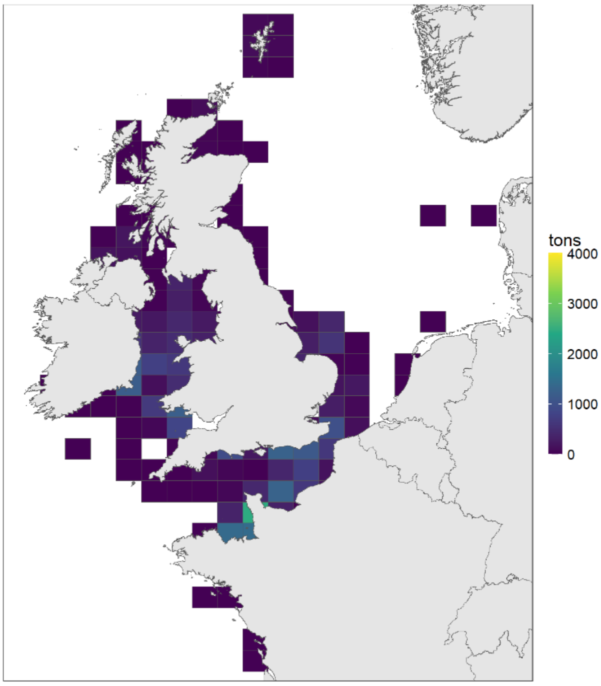


Figure 4.1 Landings weight (tons) of common whelk for the UK (MMO statistics), Ireland and France by ICES rectangles (2018–2022) (Marine Management Organisation, 2023).

4.1 France, Granville Bay

Normandy is France's leading region for whelk fishing, and it's in the Bay of Granville that this inshore fishery is oldest (over 50 years). The fleet fishes in three fishing zones on the west of the Cotentin Peninsula (Figure 4.2). Following the UK's departure from the European Union (EU) and the subsequent dissolution of the Granville Bay Treaty, discussions between the UK, EU, France and Jersey on access and supervision of Normandy whelk fishing vessels in Jersey territorial waters are still ongoing. The whelk fishery is carried out by small vessels of less than 12 m, targeting whelks with traps at a depth of less than 40 m. Between 1995 and 2005, production exceeded 10 000 tonnes for a fishing fleet of 81 vessels.

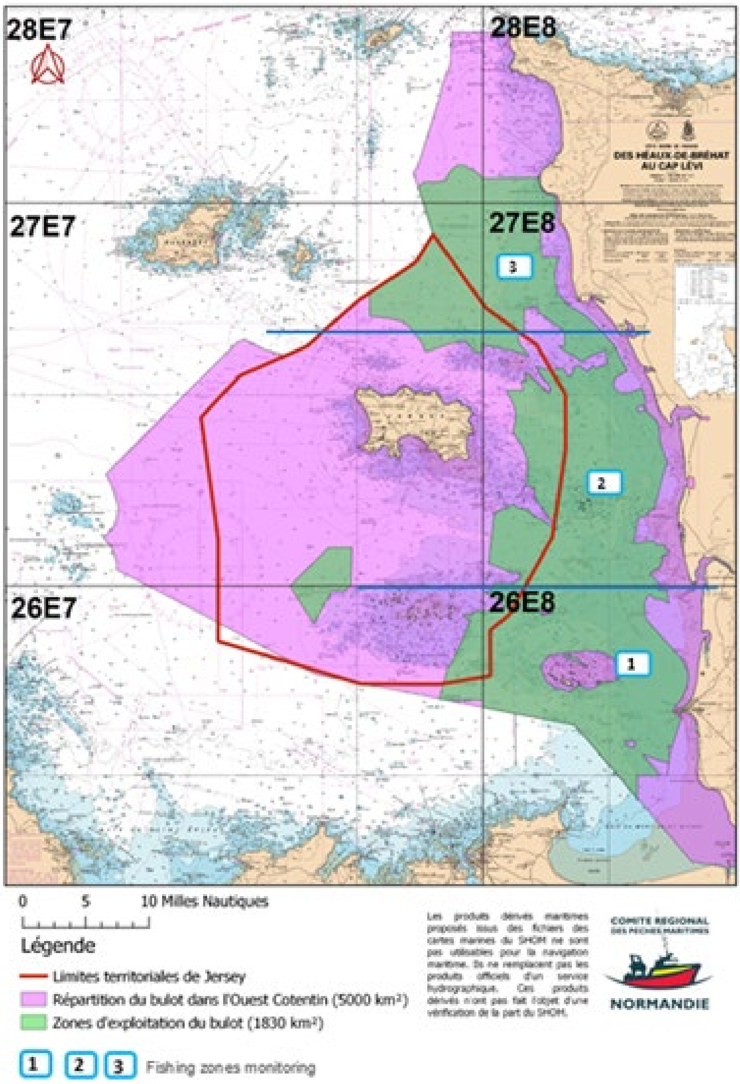


Figure 4.2 Fishing zones (green) of the Normandie whelk fleet. Purple areas represent the wider distribution of the whelk stock, and the territorial limit of Jersey is marked in red. (source, CRPMEM, Normandie).

4.1.1 Control size by sorting

During this period of high activity (1995–2005), the sorting of whelks on board fishing vessels was imperfect, resulting in a large number of undersized whelks being landed (<45 mm). From 2002 onwards, several actions were undertaken with the CRPMN to improve whelk sorting on board fishing vessels and thus guarantee a minimum rate of undersized whelks in marketing circuits. Three objectives were set:

- Determine the narrow width dimension of legal sized whelks (45 mm in length)
- Take inventory of sorting equipment on board fishing vessels
- Determine the performance of on-board sorting equipment (mechanical vs. manual) according to use (sorting time and speed, slope).

The width of a 45 mm long whelk is over 20 mm, so the sorting equipment used, which is mostly 19 mm (or even smaller), is unsuitable. This explains the high rate of undersize landed, ranging from five to 35% of the weight of the catch. A major awareness-raising and communication campaign is underway to steer the industry towards more efficient and appropriate sorting. In 2006, the majority of the industry was equipped with mechanized sorting cylinders with 20 mm grid spacing. This led to a clear reduction in the number of undersized whelks landed, and a whole series of checks were carried out at auctions. In 2009, sorting efforts continued with a compulsory increase in the sorting grid to 22 mm. This measure makes it possible to reject undersized whelks and thus protect potential spawners.

4.1.2 Temperature effects on biological and reproductive cycles

Since 2008, investigations have been carried out to gain further knowledge of whelk biology, and in particular to update data on its reproductive cycle. The BULOCLIM[1] and BESTCLIM[2] research programs focus on the maturity and reproductive cycle as a function of temperature (Lm50%, gametogenesis, % spawning and hatching).

In a first step, the study of maturity as a function of temperature was approached by comparing different geographical origins along a north–south gradient. The aim was to compare the maturity of the Cotentin whelk with other sites (Scotland, Ireland, Oléron on Atlantic coast) and at three time, February, June and November. Sexual maturity of whelks seems to appear between July and November.

The average size at which 50% of whelks are sexually mature appears in November and varies according to geographical location. Maturity gaps can be attributed to temperature differences between the sites studied.

In November, stage III was observed on more than 50% of individuals at all sites (Figure 4.3). However, there were significant variations in the size of the animals at sexual maturity, depending on the site. The animals had reached sexual maturity in November in the major size classes, with individuals over 100 mm in Scotland, over 70 mm in Ireland, between 52 and 58 mm for whelks in Cotentin and from 45–48 mm for those in Oléron.

In addition, the impact of temperature was studied on the gametogenesis (Figure 4.4) and egg-laying of Cotentin whelk (Figure 4.5 and Figure 4.6).

Temperature has been shown to have a negative affect on reproduction (Smith *et al.*, 2013). Exposed to water that is too warm, adult males[3] show a delay in the onset of gametogenesis (presence of residual spermatozoa from the previous cycle), with 30% of males failing to mate with females. This delay is still visible in June and is not observed in individuals exposed to cold or normal temperature.

[1] BULOCLIM : https://www.smel.fr/wp-content/uploads/2015/07/RAPPORT-TECHNIQUE-BULOCLIM.pdf

[2] BESTCLIM: https://www.smel.fr/wp-content/uploads/2018/02/BESTCLIM-2015-2016.pdf

[3] Experiments not carried out on females.

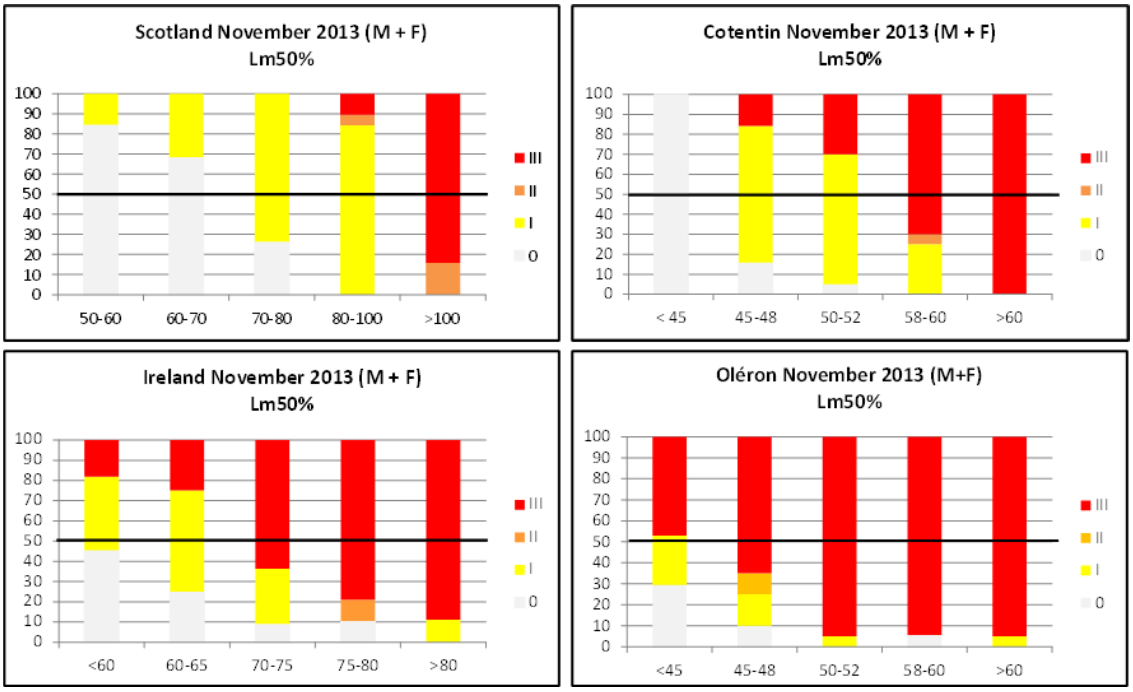


Figure 4.3 Length at first maturity in November for male and female (Lm50) on whelk samples from different sites.

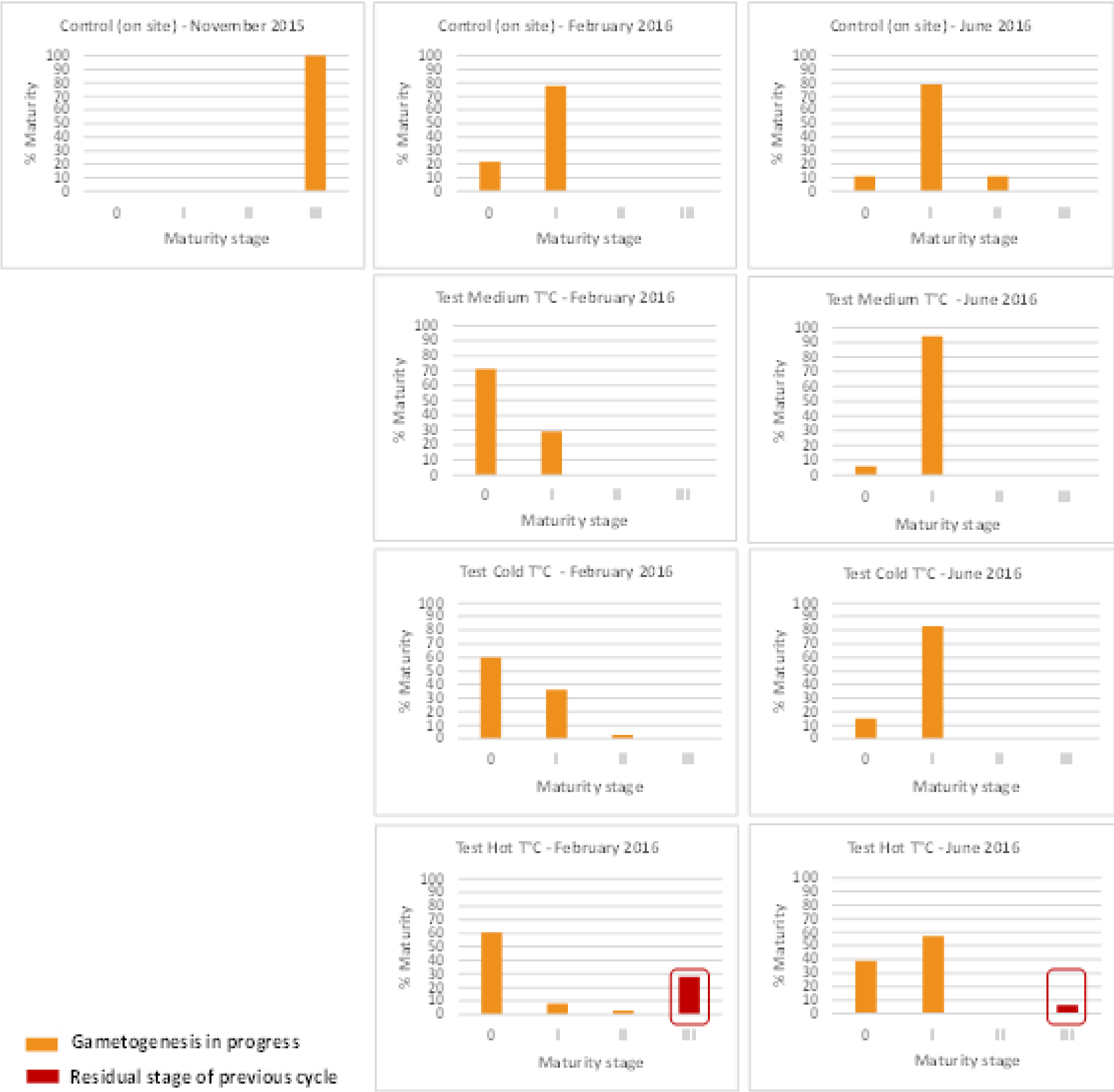


Figure 4.4 Data from histological monitoring of males in the wild (control) and in laboratory at 3 different temperatures. The orange bars indicate the % of animals at each stage of gametogenesis. Red bars indicate that the corresponding stage is a residual stage (gametes from the previous cycle).

A correlation between the number of egg-laying and temperature has been confirmed. It is three to four times lower in a warm temperature than in a cold one. Whatever the temperature, most egg-laying takes place between December and January. It extends into February at the lowest temperatures. This effect of temperature on the number of eggs laid by females inevitably has an impact on recruitment.

The intracapsular development time and the hatching rate of egg-laying decrease significantly with higher temperature (Figure 4.6). Egg incubation time (December to February) is 2.5 months for clutches exposed to a warm cycle (13 to 11°C), and 4 months for those exposed to a cold cycle (9 to 5°C). In the western Channel, the average is around three months. Water that is too warm also causes significant degradation of the clutches, greatly reducing their hatching rate (20% compared with 60 to 65% for a normal or cold scenario).

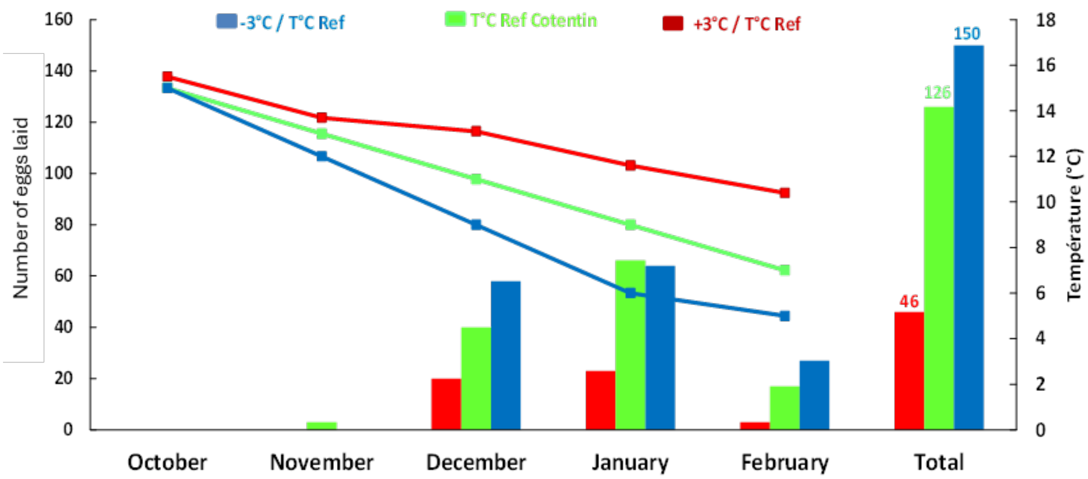


Figure 4.5 Number of whelk eggs laid in controlled structures as a function of exposure temperature.

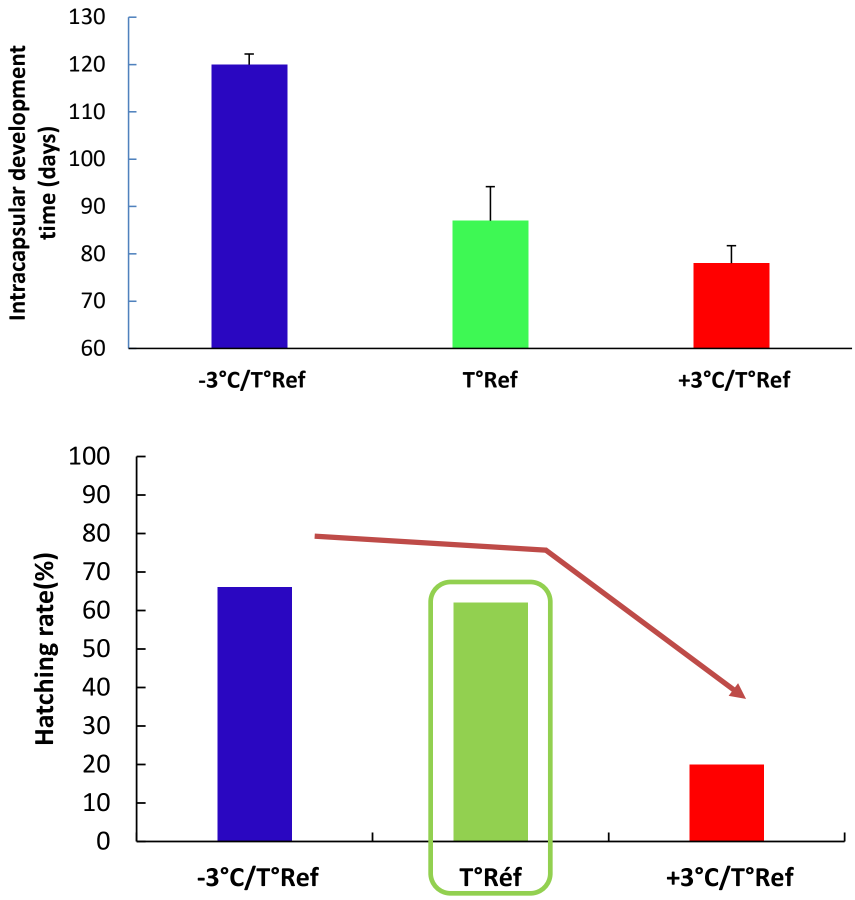


Figure 4.6 Intracapsular development time (top) and hatching rate of egg-laying (bottom) as function of temperature.

4.1.3 Fishing effort, landings, and landings per unit effort (LPUE, DPUE in France)

In terms of fishing regulations, several measures are in place to control the fishing effort: type of fishing gear, opening and closing periods, landing size, quotas, on-board sorting equipment and landing ports.

The number of licenses in Granville Bay is limited, and the system implemented aims to reduce the total number of licenses each year (for every three licenses surrendered, only two are reallocated). This strategy has resulted in a steady reduction in the total number of licenses, from 80 in 2008 to 63 in 2024, a reduction of over 20% (Figure 4.7).

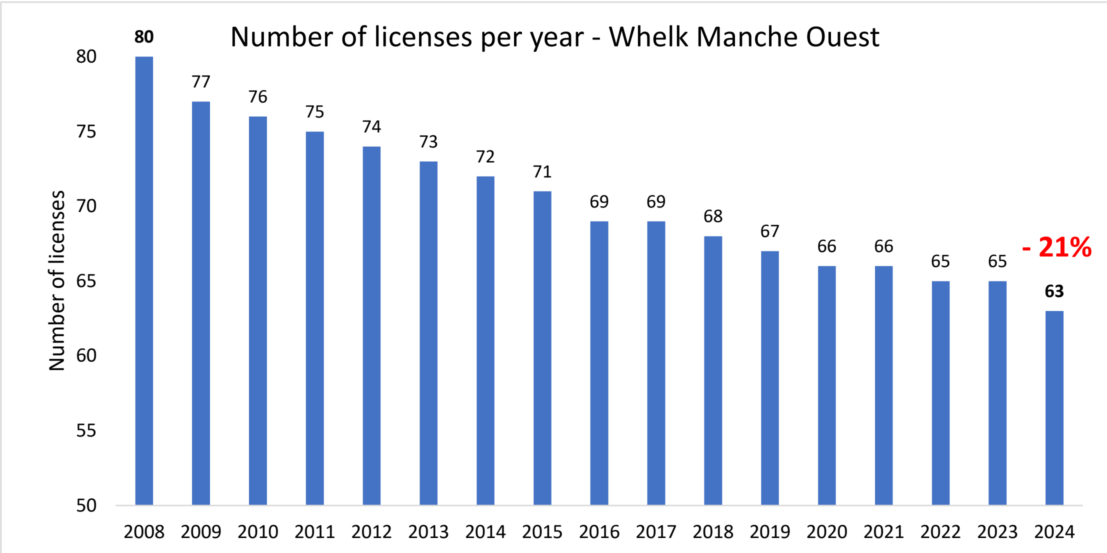


Figure 4.7 Number of licences to fish for whelk from 2008 to 2024 (source: CRPMEM Normandie).

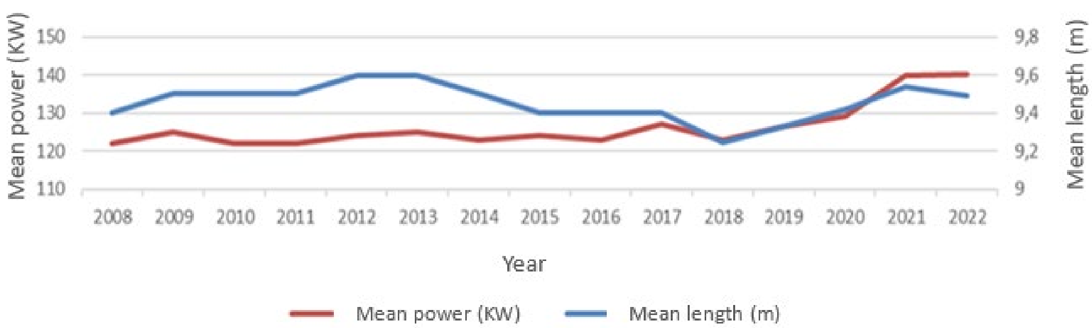


Figure 4.8 Mean length and power of whelk vessels since 2008 (source: CRPMEM Normandie).

The mean length of whelk vessels has not changed significantly since 2008, but there has been a small increase in the mean power (in KW) of vessels in the fleet in recent years because any new vessels tend to be heavier than the older vessels that they replaced (Figure 4.8).

Total landings fluctuate around 5000 and 6400 tonnes per year from 2010 to 2019 (Figure 4.9) but have dropped below 5000 tonnes due to reduced fishing effort during the COVID-19 pandemic and reductions in limit on number of pots and the daily whelk quotas per crew member introduced in 2020. In 2023, the daily quota is 210 kg per man on board, with a maximum of 630 kg for a three-man crew.

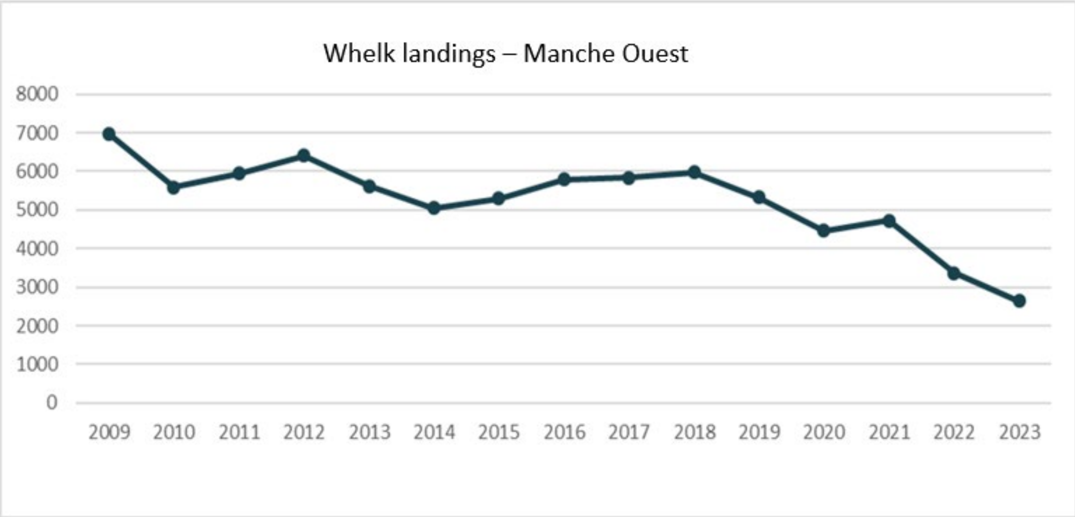


Figure 4.9 Total landings of whelks from 2009 to 2023 by vessels with a BULMW licence from the ICES rectangles 26E7, 26E8, 27E7, 27E8, 28E7 and 26E8 (source: CRPMEM Normandie and DGAMPA).

Landings data are provided by the SACROIS project (DGAMPA, Ifremer) including only vessels with a whelk license and landings from the ICES 26E7, 26E8, 27E7, 27E8, 28E7 and 28E8 constituting the UoA. The most of landings are from rectangles 27E8, 26E8 and 27E7 corresponding to the fishing zones 1, 2, and 3 (Figure 4.2 and Figure 4.10).

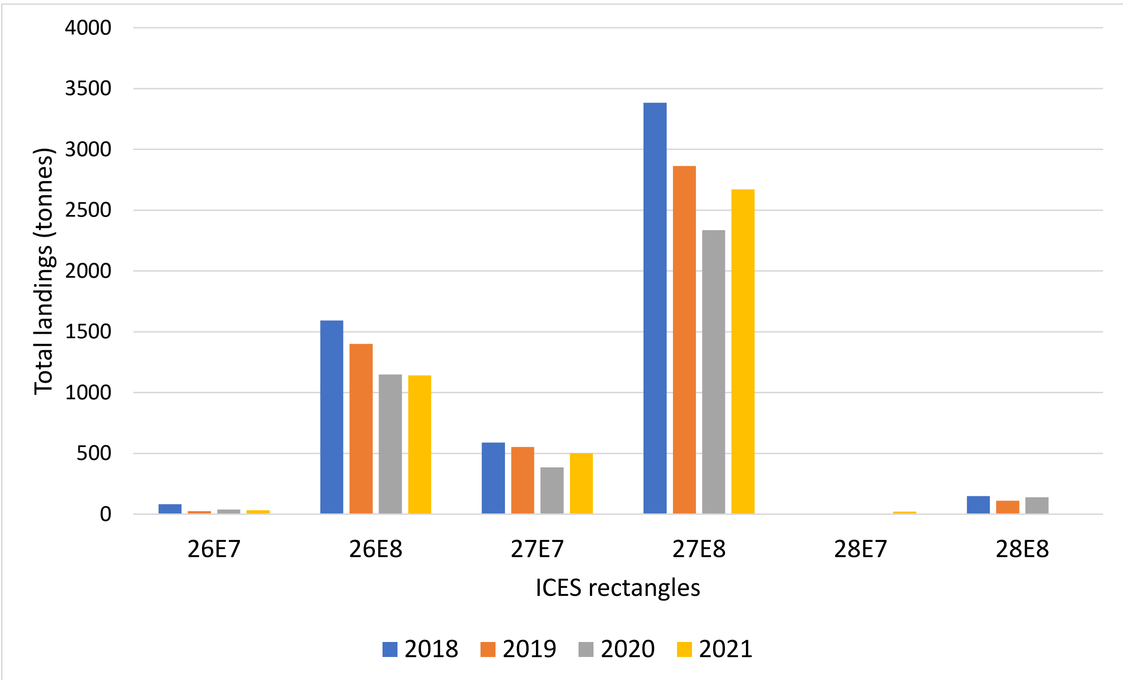


Figure 4.10 Total landings of whelk per ICES rectangles in French waters.

The main stock indicator for the whelk stock in Granville Bay is landings per unit effort (LPUE – DPUE in French), which can be used as a proxy of stock abundance. The main source of data on LPUE is a self-sampling scheme initiated in 2009, based on a reference fleet of fewer than 10 vessels which are considered representative of the whole fleet targeting this stock. In 2017, LPUE dropped below the trigger reference point ("seuil d'alerte") of 110 kg/100 pots, and has remained below that reference point for the last 4 years although any decline in observed LPUE appears to have stabilized and LPUE increased slightly in 2021 (Figure 4.11). The slight increase observed in 2021 may be due to the reduction in both the maximum number of pots and in the daily catch quota per crew member implemented in 2020 in response to the initial decline in LPUE (Figure 4.12). In 2022 the decline in LPUE continues and falls below the trigger limit ("seuil d'alarme") in 2023.

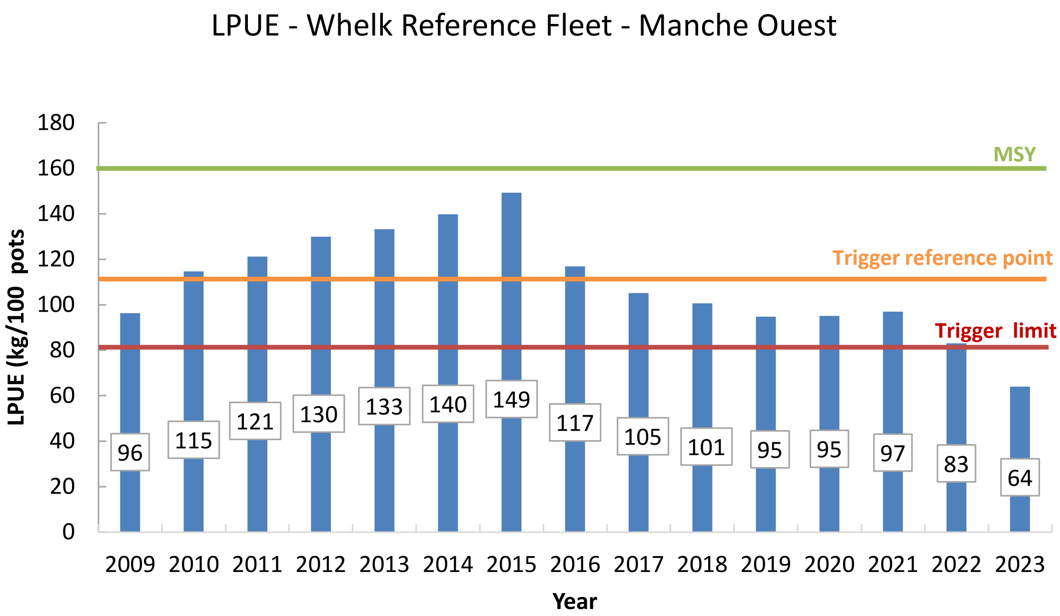


Figure 4.11 Landings per unit effort (LPUE) – DPUE in French – for the Normandie whelk fishery from 2009 to 2021. Data are from the reference fleet of 9 vessels compiled by CPRMEM Normandie and SMEL. Horizontal lines show the MSY (green), trigger or seuil d'alerte (orange) and limit or seuil d'alarme (red) reference points as defined by Whelk Commission in 2021 (Source: CPRMEM Normandie and SMEL).

In parallel, a catch-per-unit-effort monitoring program was also launched in 2009, based on annual scientific campaigns headed by SMEL and to provide stock status indicators (CPUE[4], abundance index associated with fishing effort, size structure and frequency). This monitoring is used to guide and adapt fishery management measures.

From 2009 to 2019, the observer program was based on sampling catches on board vessels at variable locations throughout the year. Starting in 2021, a new protocol has been implemented under the COGECO project from 2021 to 2023. Sampling takes place on board referent vessels over four successive days at a fixed time of year (March/April) and at five fixed locations. The results for the last three years are therefore not entirely comparable with those of previous years. Nevertheless, the same downward trend in commercial catches has been observed since 2019 (Figure 4.12).

[4] CPUE differs to LPUE as all sizes of animals caught are recorded rather than those landed that are above minimum landing size only.

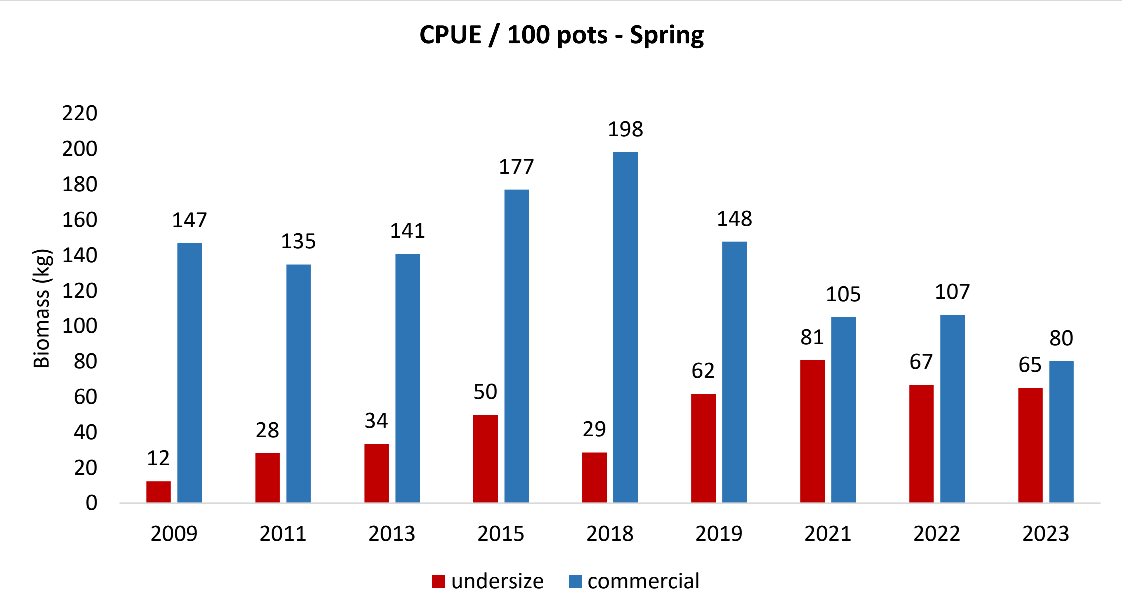


Figure 4.12 Catch per unit effort (CPUE), commercial and undersized whelks, sampled in February to April from the observer programmes in 2009 to 2023 (source: SMEL).

4.2 Jersey

Within the Bailiwick of Jersey, the exploitation of whelks is relatively recent. The previous 30 years has seen the expansion and development of the fishery within local waters. Currently, the species is targeted by approximately 70 vessels from both Jersey and France. Jersey vessel landings peaked in 2018 at 839 tons, since then there has been a significant decrease to 9 tons landed in 2023 (Figure 4.13). LPUE has also seen declines from 3 to 0.7 kg per pot. Within the management team in Jersey, the stock is seen as under pressure.

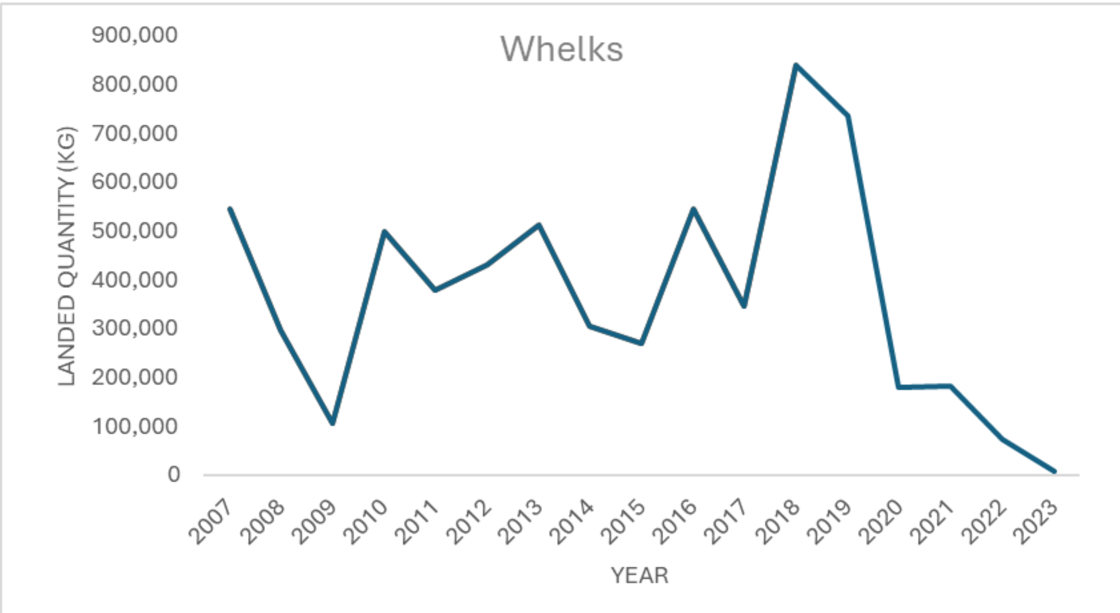


Figure 4.13 Time-series of landings from Jersey vessels within Bailiwick of Jersey.

Brexit and the subsequent TCA negotiations were significant events for the island. Now due to third country classification, export of whelks is no longer possible into French markets. Future concerns for the fishery include rising sea temperatures, gear conflict and export routes. The lack of export markets partially explains the significant decrease in landings, a further cause for concern comes from a declining LPUE. Alongside the development of the fishery, annual trials have been conducted at fixed sites throughout Jersey waters. Beginning in the mid-1990s, total weight per pot remained constant after 1996–2002 when the stock was first exploited. However, pot weight composition has been changing with the weight of sized whelks decreasing, and an increased weight of undersized whelks. This cumulated in 2023 which saw the lowest catches on record since the trials began (Figure 4.14) at 0.62 kg whelks per pot.

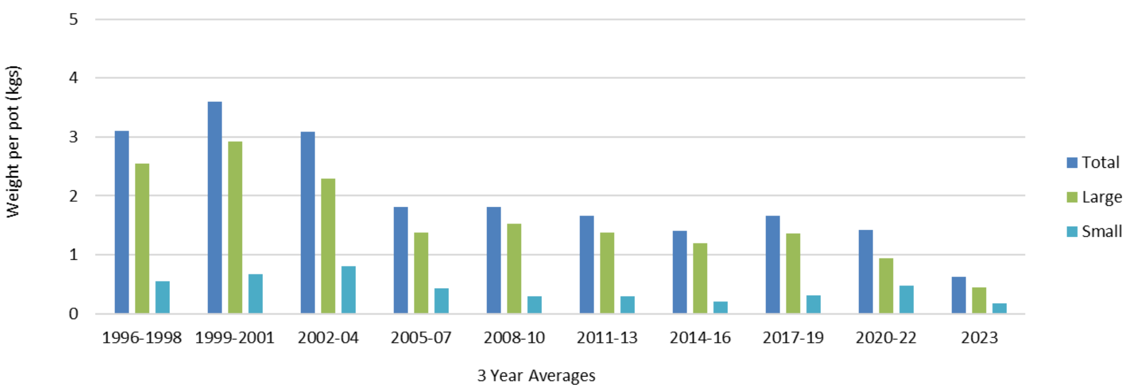


Figure 4.14 Three-yearly average whelk weight per pot (kg) between 1996 and 2022. 2023 is stand-alone for comparison.

Located towards the southern edge of its range, Jersey waters are generally warmer and shallower than the surrounding areas.

In response to these declines, an enhanced program of research is being undertaken. Based around historical sample sites, the program aims to establish if there is a single large meta population or several smaller populations in Jersey waters. The two key avenues of research are size at maturity and genetic profiling over a variety of spatial scales. Size of maturity results are still in the early stages, but initial results indicate that there are some noticeable differences between locations. The genetic profiling lab work is still being undertaken, and results are due in early 2025.

4.3 Eastern Channel

Whelk plays a crucial role in artisanal fisheries in the Eastern English Channel (EEC), particularly in France and Normandy. Over the past two decades, there has been a significant growth in whelk landings—from 100 tons caught by 16 vessels in 2010 to 3600 tons landed by 98 vessels in 2023 (Figure 4.15). The EEC's whelk exploitation involves three distinct fisheries located in the Bay of Seine, Haute Normandie, and Northern France. These fisheries began operating in the mid-2000s for the former two and in the mid-2010s for the latter. This development comes against the backdrop of the difficulties faced by fishers due to the collapse of groundfish stocks. Seeking alternatives, fishers turned to whelk as a valuable and non-exploited resource in the EEC. Regulation and management of whelk fishing are carried out at the regional level. Various measures are in place, including a maximum number of licenses, daily quotas, restrictions on the number of traps and, temporary fishing closures. However, the minimum landing size remains consistent across the EEC at 45 mm. Examining catch trends reveals a peak in 2019 followed by a decline until 2023. The simultaneous decrease in catch across the three fisheries warrants investigation. One potential factor is climate change, as the EEC is at the southern boundary of the whelk distribution area.

To enhance our understanding of whelk population dynamics, a collaborative project called 'Mecanor[2]' was conducted between 2020 and 2022. Fishers and researchers worked together to assess whelk, lobster, edible crab, and spider crab resources. Notably, histological analysis of gonads provided initial estimates of size at maturity - 54 mm in the Bay of Seine and 57 mm in Haute Normandie. Additionally, a preliminary stock assessment was carried out in a data-poor context. This assessment relied on landing data and Length Per Unit of Effort (LPUE), using three methods based on the Surplus Production Modelling approach (CMSY, SPiCT, and JABBA). However, due to variability of the outputs among models and low confidence levels in LPUE (which relies on fishing days rather than trap numbers), the results are not yet considered sufficiently reliable. A future project on whelk population and fisheries will investigate the impacts of thermal conditions and climate change (temperature variations and marine heatwaves) on whelk life history and burrowing behavior. In addition, the project will aim to improve whelk stock assessment and fisheries management.

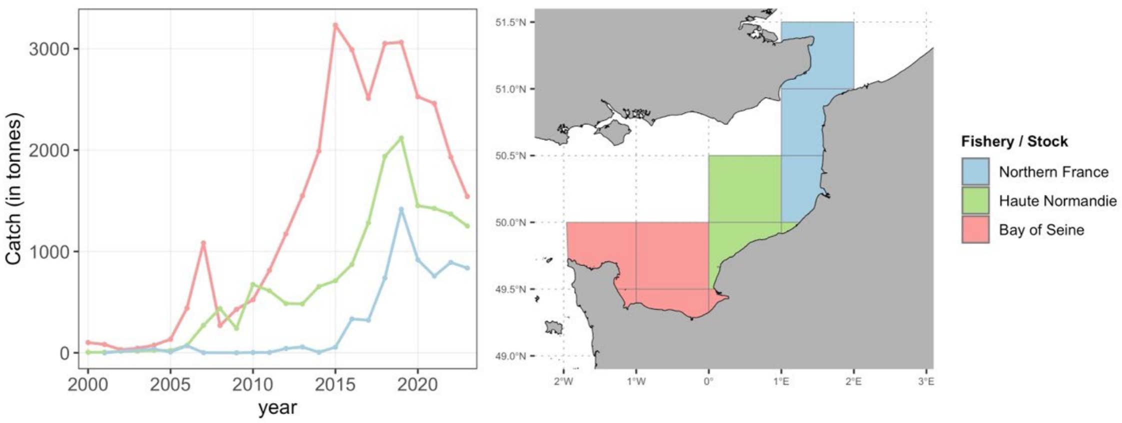
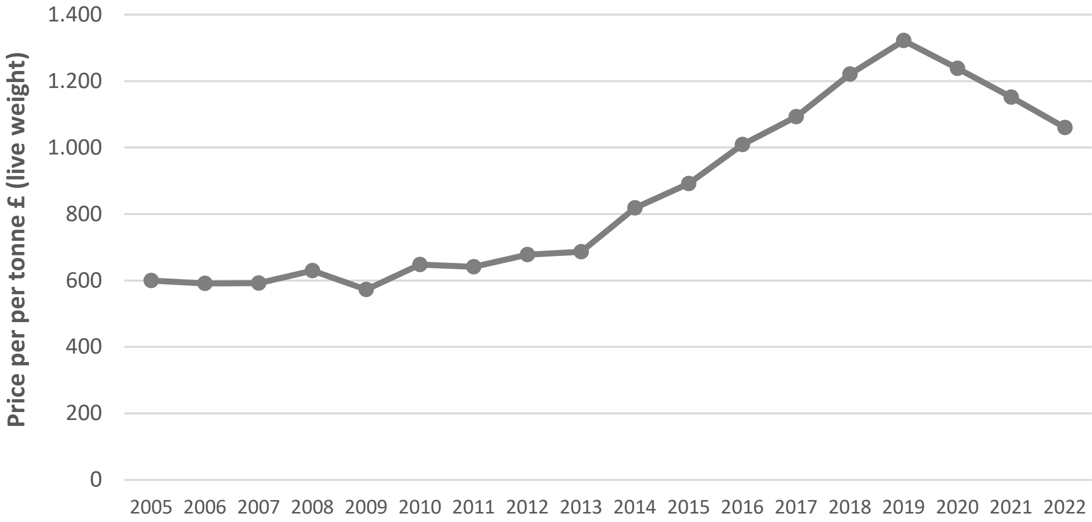


Figure 4.15 Time-series of catch and map of each of the three fisheries, Bay of Seine, Haute Normandie and Northern France.

4.4 Wales

Common whelk have been fished commercially in Wales since the early 1900s, with annual landings of 4500 tonnes reported in 1911 for England and Wales (Dakin, 1912). The fishery expanded in the early 1990s due to new markets in Japan and South Korea (Fahy *et al.*, 2000), increasing catch value (e.g. £230 per tonne in 1990 to consistently >£1000 since 2016; Marine Management Organisation 2023) (Figure 4.16A). Landings into the UK have increased approximately tenfold over the last two decades (Figure 4.16B; FAO 2023). In contrast, available data of annual landings into Wales by UK vessels since 2008 show more consistent trends, although with a peak in landings in 2017, with an average of 4300 tonnes landed between 2018–2022, at an average annual first-sale value of £5.1 million (Figure 4.16B; Marine Management Organisation 2023).

A



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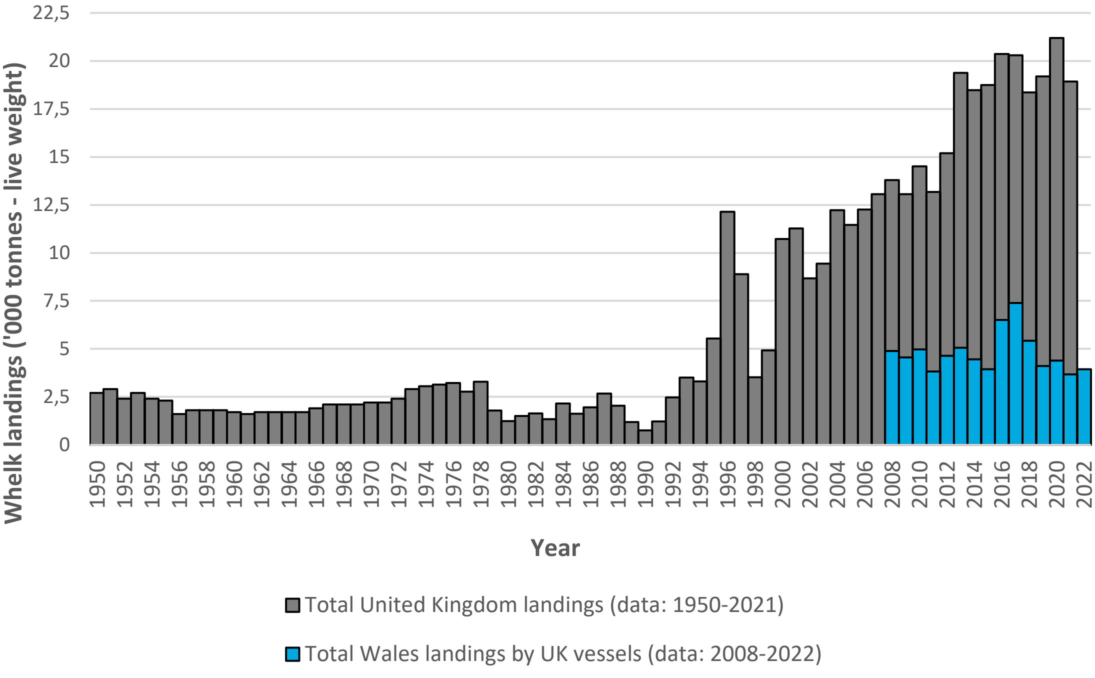

Figure 4.16 Whelk fishery value and landings through time. A. Average price of whelk landed by UK vessels into the UK 2005-2022. Before 2005, whelk estimates were included with "Other Shellfish" (Marine Management Organisation, 2023); B. Total common whelk landings into the UK in 1950-2021 (grey bars; FAO 2023) and into Wales (blue) by UK vessels in 2008–2022 (Marine Management Organisation, 2023).

Today, whelk is one of Wales's highest value fisheries (second only to the cockle fishery; H. Edwards, Welsh Government *pers. comm*. 2024), with landings ranging from 3500–7000 tonnes each year, and a first sale value of £4 to 8 million (Welsh Government, 2024) (Figure 4.17). At its peak, the whelk fishery was worth £8 million in 2017, with a record high of almost 7000 tonnes of whelk landed by UK vessels into Wales (Marine Management Organisation 2023; Figure 4.17). Since the peak in landings in 2017, new Welsh Government legislation to protect the stock and enhance the sustainability of the Welsh whelk fishery has come into force. A phased-increase in the Minimum Landing Size (MLS) for whelk in Welsh waters was introduced with the Whelk Fishing

(Wales) Order (2019), with an increase from the EU-wide MLS of 45 mm (EC regulation No 850/98, 1998) to 55 mm in July 2019, and then to 65 mm in July 2020. This legislation was proposed in response to increasing pressure on the stock and the intensification of whelk harvesting. Since the new legislation in 2017, annual whelk landings have declined, likely due in part to EU-exit export issues, export catch certificate requirements, and COVID-19 disruption. In 2022, the last reporting period, the total value of whelk landings into Wales in 2022 was £4.4 million, decreasing from a high of £7.4 million in 2017. These declines have been in part due to legislation following concerns at high landings but also due to declines in the price per kg (Seafish *pers. comms*. 2024). Nonetheless, the value of the fishery has remained greater than the value of all other fisheries species landed by UK vessels into Wales since 2015 (Marine Management Organisation 2023), though noting that the cockle fishery gathered on shore is the highest value fishery overall.

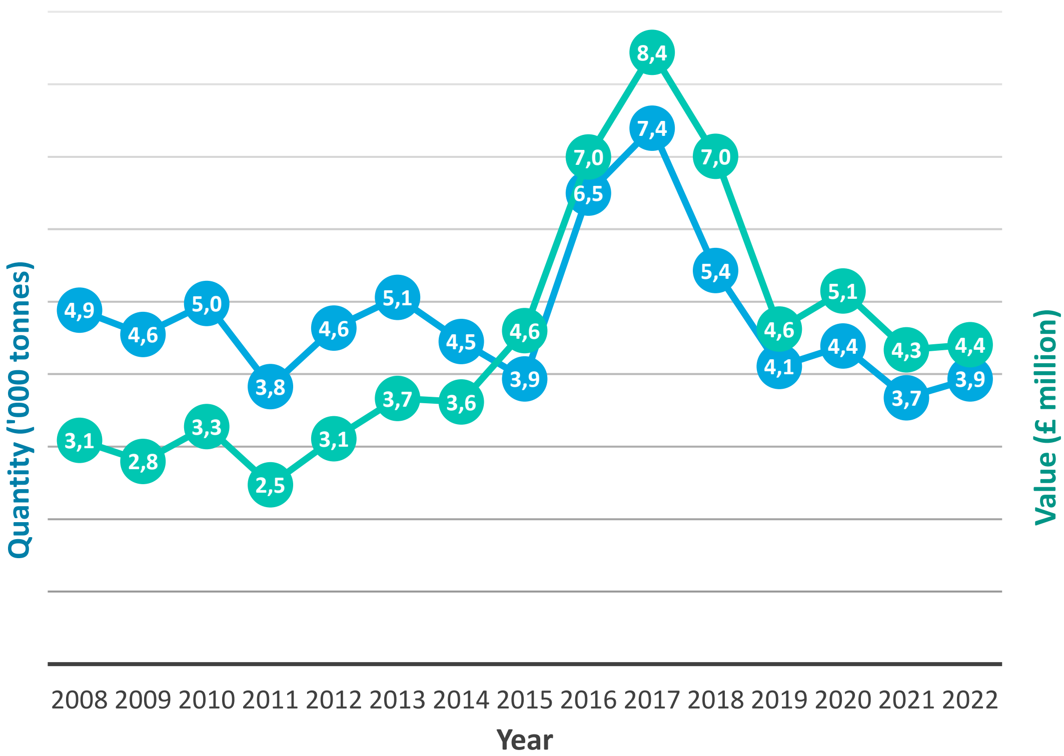

Figure 4.17 Whelk landings into Wales by UK vessels (blue) and annual value of landings (orange): 2008 to 2022 (Marine Management Organisation, 2023).

4.4.1 Fishery methods

Whelk fisheries across Wales, and the UK more broadly, use baited plastic pots, which come in two main forms; 'lay down' and 'inkwell'. Pots are attached in series to a footrope, referred to as a 'string', 'fleet', or 'train' (hereon described as 'strings'); there may be up to hundreds of pots per string, depending on vessel deck area. Strings of pots are typically deployed onto the seabed and left for 24–36 hrs before being hauled (referred to as 'soak-time'). Fishers typically haul, bait, and redeploy their pots every 24–28 hrs, as after this point the efficiency of the bait, often a mixture of crab and fish, reduces and catch rates decline, suggesting whelk can escape traps (Bennett, 1974; Fahy, 2001; Jennings *et al.*, 2001). Bycatch in whelk pots is low, however often non-target crab species and starfish can be caught (Moore and Howarth, 1996). Landings occur across all months in Welsh waters, although at lower levels in winter. This is likely due to the number of small boats within the fleet being weather dependant, seasonal variability of catch-per-unit-effort (CPUE), market demand, and the cost of alternative fishing opportunities.

Whelk fishing vessels typically aim to comply with MLS regulations through the use of riddles when sorting the catch (Figure 4.18). The riddle is formed of a tray under a series of metal bars at a set MLS width to allow any whelk less than the MLS to drop through, be separated from the catch, and then re-released. The specified MLS-set distance between the bars is determined by whelk shell length-width calculations. However, morphological variation in whelk shell dimensions can cause some undersized individuals to be retained on the riddle (Fahy *et al.*, 2000; Shelmerdine *et al.*, 2007; Heude-Berthelin *et al.*, 2011). A survey of a commercially riddled catch (27-28 mm riddle-width) had a length at first capture (50% of the mode of the catch) of 60 mm and 50% of catch retained at 50 mm (Figure 4.19).

Figure 4.18 Whelk riddle used to separate whelk above the size of set bar-width from smaller individuals under minimum landing size (image copyright: Jack Emmerson).

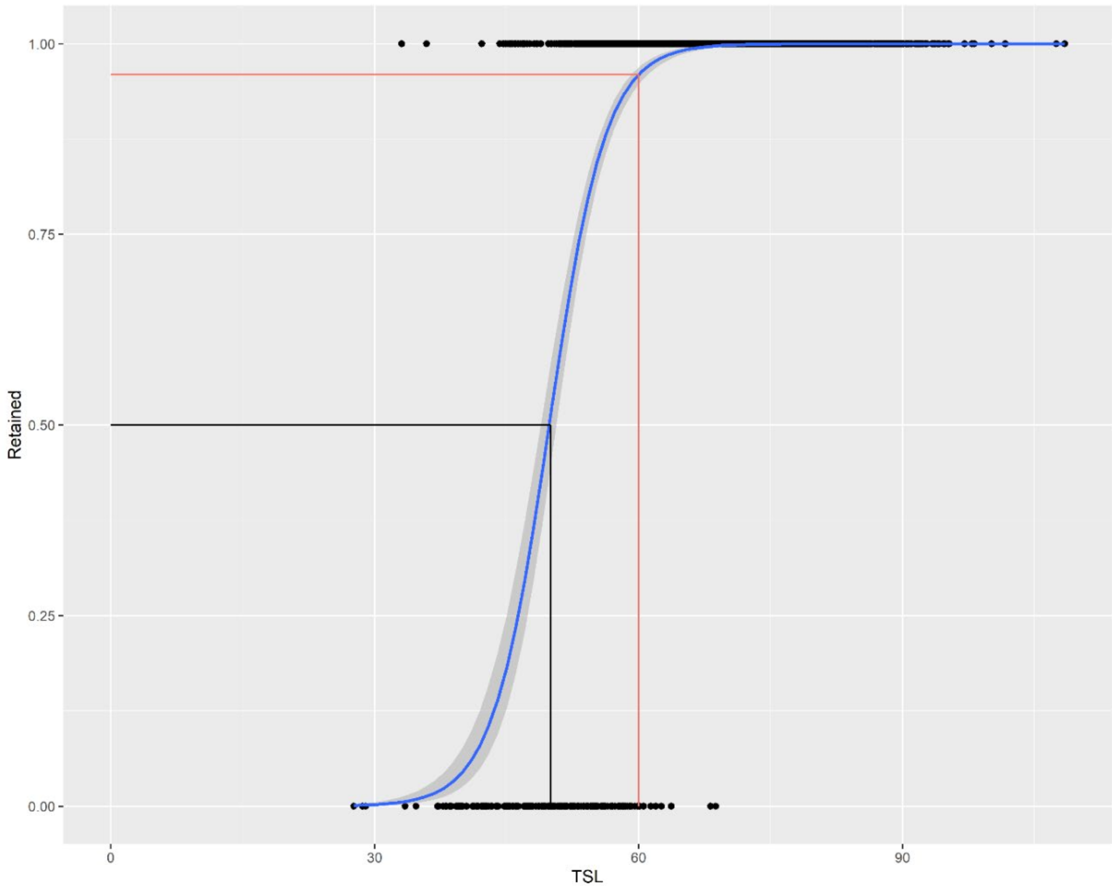

Figure 4.19 The selectivity curve of a 27–28 mm bar-spaced riddle applied to the Llyn Peninsula whelk fishery. Blue line shows a logistic regression for the proportion of the catch retained by the riddle, the black line shows the size at which the riddle was retaining 50% of the catch and the red line is the Length at first capture calculated as the size class at 50% of the mode of the catch.

4.4.2 Current regulating framework for management of whelk

Management of the whelk fishery in Welsh waters is the responsibility of the Welsh Government, implemented by the Fisheries Division. In many cases, management decisions for the whelk fishery in Wales are improved and developed through co-management with advisory input from stakeholders in the Wales Whelk Advisory Group (WWAG). Due to the national importance of the whelk fishery, Wales has a statutory obligation to ensure that sufficient management is in place to ensure the species achieves Good Environmental Status (GES), set-out in the Marine Strategy Regulations (2010) which transpose the Marine Strategy Framework Directive. The Welsh National Marine Plan supports the achievement of GES as defined by the 11 descriptors in the UK Marine Strategy[5]. Additionally, Welsh Government also has statutory duties pertaining to the Well-being of Future Generations (Wales) Act (2015), the Environment (Wales) Act (2016), and UK Fisheries Act (2020). The Fisheries Act 2020 and the Joint Fisheries Statement will require all stocks to be managed through a Fisheries Management Plan and it is expected that such a plan will be developed for whelk in Wales in 2027.

Within the Welsh Zone, the regulating framework for management of whelk by Welsh Government issues permitting requirements, annual catch limits, flexible monthly catch limits, and a specified MLS of 65 mm to allow more whelk to breed before being captured (https://www.gov.wales/whelk-fishery-catch-limits). The Whelk Fishing Permit (Wales) Order (2021) introduced new management measures to safeguard the stock including, for the first-time, adaptive management to ensure the long-term sustainability of the fishery. The new measures incorporated stakeholder input and were based on scientific data-poor stock assessment methods and appraisal. In the reporting period 2022–2023, the Annual Catch Limit (ACL) for whelk in Wales which can be taken by all permitted vessels combined was 5298 tonnes, which was set from the average of the annual catch for the reference period 2015–2019. The flexible Monthly Catch Limit (MCL) was initially set at 50 tonnes per vessel in March 2022 and subsequently reviewed monthly to ensure the ACL was not exceeded and the benefit of the fishery was spread across the permit period in line with historic fishing patterns.

4.4.3 Registered fishing fleet and landings in 2022–2023

In the whelk fishery permit period 2022–2023, 98 permits were issued, with 55 permits actively fishing for whelk. For this first permit period, there was no fee as Welsh Government wanted to better understand the costs of permitting and ensure these costs were accurately calculated and proportionate. In December 2022, a nominal fee for a whelk fishing permit was charged to fishers to contribute to the cost of monitoring the fishery through annual stock assessment surveys, at a cost per vessel of £285 per year.

Of the 2022–2023 set ACL, 5031 tonnes (95%) were landed. The first point of sale value was £5.9 million, priced at £950 to £1500 per tonne. At the end of the period 267 tonnes of the ACL remained unlanded. The ACL for the next period (2023–24) was set at 4768 tonnes, reduced by 10% based on scientific advice following length based-indicator assessment.

There were no changes to the MCL during the permit period. In December 2022 to February 2023, there were significantly higher monthly landings, likely due to the settled weather during this period. The MCL for start of 2023–2024 period remained set at 50 tonnes, with subsequent monthly review in line with landings and the 2023-2024 ACL.

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[5] Welsh Government. 2020. Monitoring and Reporting Framework: Welsh National Marine Plan. https://www.gov.wales/sites/default/files/publications/2020-01/welsh-national-marine-plan-monitoring-and-reporting-framework.pdf

4.4.4 Annual survey and length-based indicator assessment: 2024

Following the introduction of the annual catch limit regulations in 2021/2022, scientific annual stock assessment surveys were carried out in September 2022 to gather life history information to allow data-limited length-based indicator assessment of the stock status (building on baseline surveys conducted in 2020/2021). Fishers were asked to add scientific pots on to the end of their commercial strings that were adapted with smaller drainage holes and mesh to retain smaller whelk than the commercial pots. These whelks were dissected in the laboratory at Bangor University and data collected to inform regional length-weight, size at maturity and growth parameters. Age was determined using statolith methodology discussed in section 2.1.

The first September 2022 survey used fisher participation to collect samples from across known whelk grounds from commercial and scientific pots. Data gathered included:

- Weight (kg) whelk per pot
- Length frequency of all whelk caught
- Sex, maturity and weight of all whelk caught
- Age through statolith analysis of a random 50 whelk per pot (~300–400 per region surveyed).

In 2024, VMS/iVMS for all vessels in Wales became available with data from 2022 and 2023. This allowed fishing activity to be mapped using a clustering approach rather than a strict vessel speed filter (ping rate for most boats was 10 minutes). These commercial fishing areas were then mapped, with a 1 km buffer added around the identified fishing areas to ensure as much whelk habitat was included as possible. Total survey effort for the 2024 annual survey was then allocated proportionally to each distinct region based on area and stations allocated randomly. Fishers were asked to add a scientific pot to a commercial string at each site and retain total catch from one commercial pot and the scientific pot per station. It was intended that this randomized station method would minimize bias in CPUE indices over previous fisher chosen sites.

Growth parameters used to calculate stock health indicators were derived from data spanning all surveys from 2020–2024, apart from 'Cardigan Bay' which was only sampled in 2023 and 2024 and so uses growth parameter data from only 2023–2024 (Table 4.2).

Table 4.2 Life-history parameter estimates (95% lower and upper confidence intervals in brackets) for whelk stocks in Welsh waters. Linf is the asymptotic length, gi the growth rate at the inflection point, t0 the average length (mm) at age zero all from the Gompertz growth function calculated in the R package FSA. wbeta is the power parameter in the length weight relationship, LMAT is the size at which 50% of the population are mature and L95 is the size at which 95% of the population are mature.

Region	Linf	gi	t0	wbeta	LMAT	L95
Cardigan Bay	103.14 (91.24 | 139.44)	0.44 (0.22 | 0.72)	2.42 (2.01 | 3.05)	2.65 (2.57 | 2.73)	77.27 (75.24 | 79.03)	100.85 (96.42 | 105.94)
Llyn	102.62 (96.45 | 111.47)	0.45 (0.39 | 0.51)	2.60 (2.42 | 2.86)	2.73 (2.69 | 2.77)	67.65 (66.43 | 68.70)	91.16 (89.05 | 93.16)
North	91.70 (88.39 | 96.16)	0.62 (0.56 | 0.68)	3.09 (3.00 | 3.19)	2.73 (2.68 | 2.78)	63.84 (63.25 | 64.41)	87.58 (86.13 | 89.15)
South	105.79 (95.13 | 122.89)	0.35 (0.28 | 0.42)	2.89 (2.54 | 3.41)	2.72 (2.66 | 2.77)	66.64 (65.74 | 67.54)	88.63 (86.00 | 91.29)

A series of length-based indicators were calculated from these life-history parameters for each population/site surveyed. Some indicators need to be calculated using total catch (unriddled pot catch) and some using landings data (riddled pot catch). Currently there are no landings size frequency data available. Therefore, we truncated the commercial sampling pot datasets to act as a proxy for the size frequency of the landings. Data on length of whelk, retained using a riddle on a commercial whelk boat (riddle width 27–28 mm), has previously been used to calculate the length at first capture (L_c) and the value at which scientific length data would be truncated to represent landings. This value was 60 mm (Hold *et al.*, 2021). Therefore, length data from the samples was truncated to ≥60 mm in total shell length and used only length data collected in 2023 to act as a proxy for landings size frequency in 2023 fishing season. The following parameters were then calculated (following ICES WKLIFE in Hold *et al.*, 2021):

1. Optimum size for capture (L_{opt})
2. Mean size of the largest 5% of the catch ($L_{max5\%}$)
3. Proportion of "megaspawners" or greater than 10% larger than L_{opt} (P_{mega})
4. The shell length at the 25% percentile of the landings ($L_{25\%}$)

All calculations and models were carried out in the software R.

To allow assessment of the population, previously determined reference points of indicators of healthy size and age structure from ICES WKLIFE are used (Table 4.3). See Hold *et al.* (2021) for all references and evidence used to develop these.

Table 4.3 Indicator reference points for the Welsh whelk stock. A stock is described "in poor status" if indicators are below reference points, satisfactory if they are equal to the reference points, and good if they are over the reference point. $L_{25\%}$ and L_c assess the conservation of smaller individuals in the stock. $L_{max5\%}$ and P_{mega} assess the conservation of larger individuals in the stock.

Indicator	Good status	Reference point status	Poor status
$L_{max5\%}$	$L_{max5\%} / L_{inf} > 0.8$	$L_{max5\%} / L_{inf} = 0.8$	$L_{max5\%} / L_{inf} < 0.8$
P_{mega}	$P_{mega} > 0.3$	$P_{mega} = 0.3$	$P_{mega} < 0.3$
$L_{25\%}$	$L_{25\%} / L_{MAT} > 1$	$L_{25\%} / L_{MAT} = 1$	$L_{25\%} / L_{MAT} < 1$
L_c	of $L_c / L_{MAT} > 1$	of $L_c / L_{MAT} = 1$	of $L_c / L_{MAT} < 1$

The length-based indicators developed through ICES WKLIFE are primarily based on theory and evidence from finfish, with some simulations across taxa (Miethe *et al.*, 2019). Further work is being carried out to understand how the specifics of whelk life history may impact the appropriateness of these indictors. For example, estimates of natural mortality (M) from literature and empirical data suggest M is quite high at around 0.6 on average, this combined with generally slow growth (k ~ 0.2) would indicate unusual life history (slow growth, high mortality) and a high M/k life history invariant of ~ 3 (compared to the average of 1.5 for most teleost fish) (de Vooys and van der Meer, 2010; Laptikhovsky *et al.*, 2016; Borsetti *et al.*, 2022).

4.5 Isle of Man

The Isle of Man common whelk fishery is key component of the Manx inshore potting fleet, being an important species relative to diversification and seasonality of the fleet. The whelk fishery is managed under a species-specific permit, with permits introduced in 2017, prior to this the fishery was accessed under the Isle of Man general shellfish permit. These species-specific permits are the primary management method for the fishing with the total number of permits currently capped. Permits have no monetary value, are non-transferable and are returned to the Isle of Man government upon sale of the originally entitled vessel. In conjunction with vessel caps, effort limitations are currently enforced, with vessels entitled to a maximum of 1000 whelk pots per permit and a minimum conservation reference size (MCRS) of 75 mm total length. The value and total tonnage of the fishery has fluctuated over time, with peak landings occurring in 2019 at ~800 tones, with similarly high levels of effort reported over this period ~400 000 pot hauls per year (Figure 4.20). Information relative to annual changes in effort and landings is available due to statutory reporting requirements under the monthly shellfish reporting mechanizms for all vessels, in which effort (no. pots hauled per day) and kg landed are required to be reported by day. This data is available from the late 1990s however the accuracy and reliability of data improves since 2010. There is currently no harvest control rules or long-term management plan for the Isle of Man Whelk fishery, with the fishery currently monitored through the use of standardized landing per unit effort (LPUE). Standardized LPUE has seen to be gradually decreasing since 2010 with a high of 2.5 kg/pot at this time, more rapid declines are observed since 2017, with a time-series currently at an all-time low of 1.5 kg/pot (Figure 4.20).

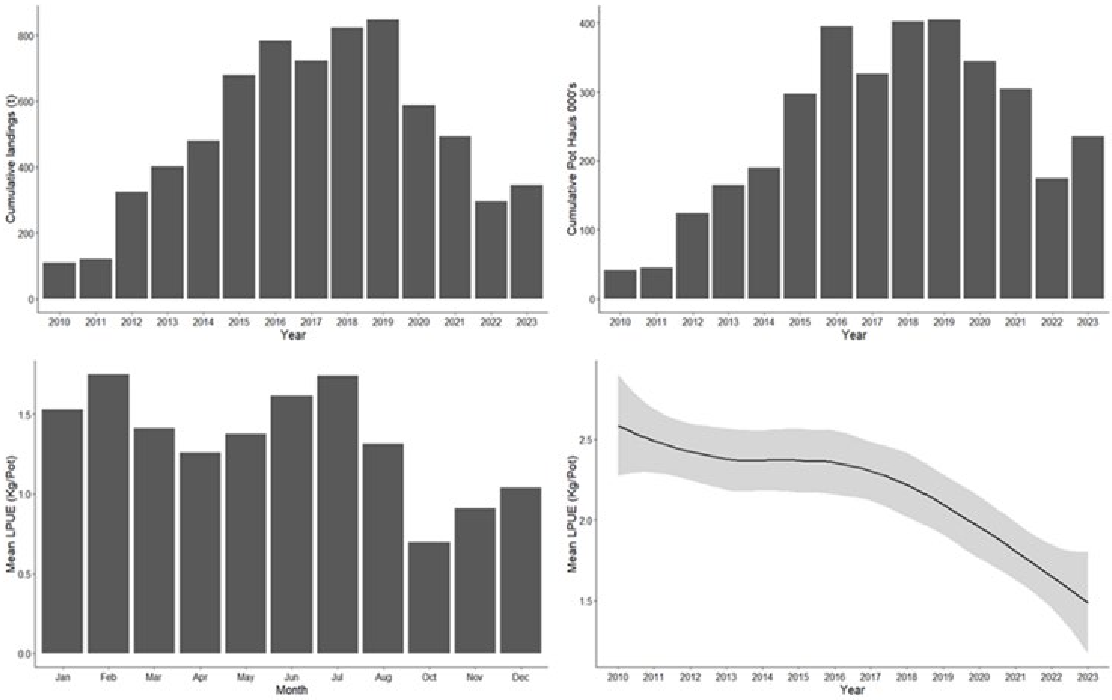

Figure 4.20 Common whelk fishery cumulative landings in the Isle of Man Territorial Sea per year from 2010 to 2023 (top left); Cumulative pot hauls per year in the Isle of Man Territorial Sea (top right); Monthly mean landing per unit effort (LPUE—kg/pot haul) (bottom left); Whelk LPUE trend for the whole Isle of Man (bottom right).

Further information on the status of whelk stocks, published research on whelks and other fisheries in the Isle of Man can be found at: http://sustainable-fisheries-iom.bangor.ac.uk/.

4.5.1 Advancing stock assessment methods for whelk fisheries in the Isle of Man and Wales

The whelk fishery in the Isle of Man (as with much of Northwest Europe) is classed as data deficient. In order to progress the management of whelk stocks, appropriate data collection frameworks and stock assessment methods are needed. This includes the development of fishery-independent surveys to detect long-term changes in population density and identifying maximum sustainable yield target and limit reference points using existing and new data sources. Work undertaken as part of a PhD at Bangor University has investigated potential methods for assessing abundance and stock health in whelk fisheries, trialling these in both the Isle of Man and Wales, which is summarized in the following sections.

Gear trials – fishery-independent indices

Establishing fishery-independent methods for whelk and other pot fisheries remains a key research priority, due to the numerous potential issues in the use of commercial LPUE as an index of abundance. In this first piece of work, comparative gear trials were conducted in a whelk fishing area using three gear types: 2 m beam trawl, pots, and baited underwater cameras (BRUVs). Comparisons were conducted under a randomized stratified survey design with abundance indices calculated for each gear type across seven survey squares (Figure 4.21). Similar spatial patterns in relative abundance were identified by all three gears on a linear scale, with the closest relationship found between pot CPUE (individuals pot^{-1}) and beam trawl densities (individuals m^{-2}), indicating commercial pots may provide a valid index of abundance in a fishery-independent setting. However, the size selectivity of these two gears was not comparable, with the beam trawl targeting smaller whelks and a much narrower size distribution. Overall, commercial pots were the most statistically robust differentiating low- and high-density sites, while exhibiting low rates of bycatch and shell damage compared to towed gear.

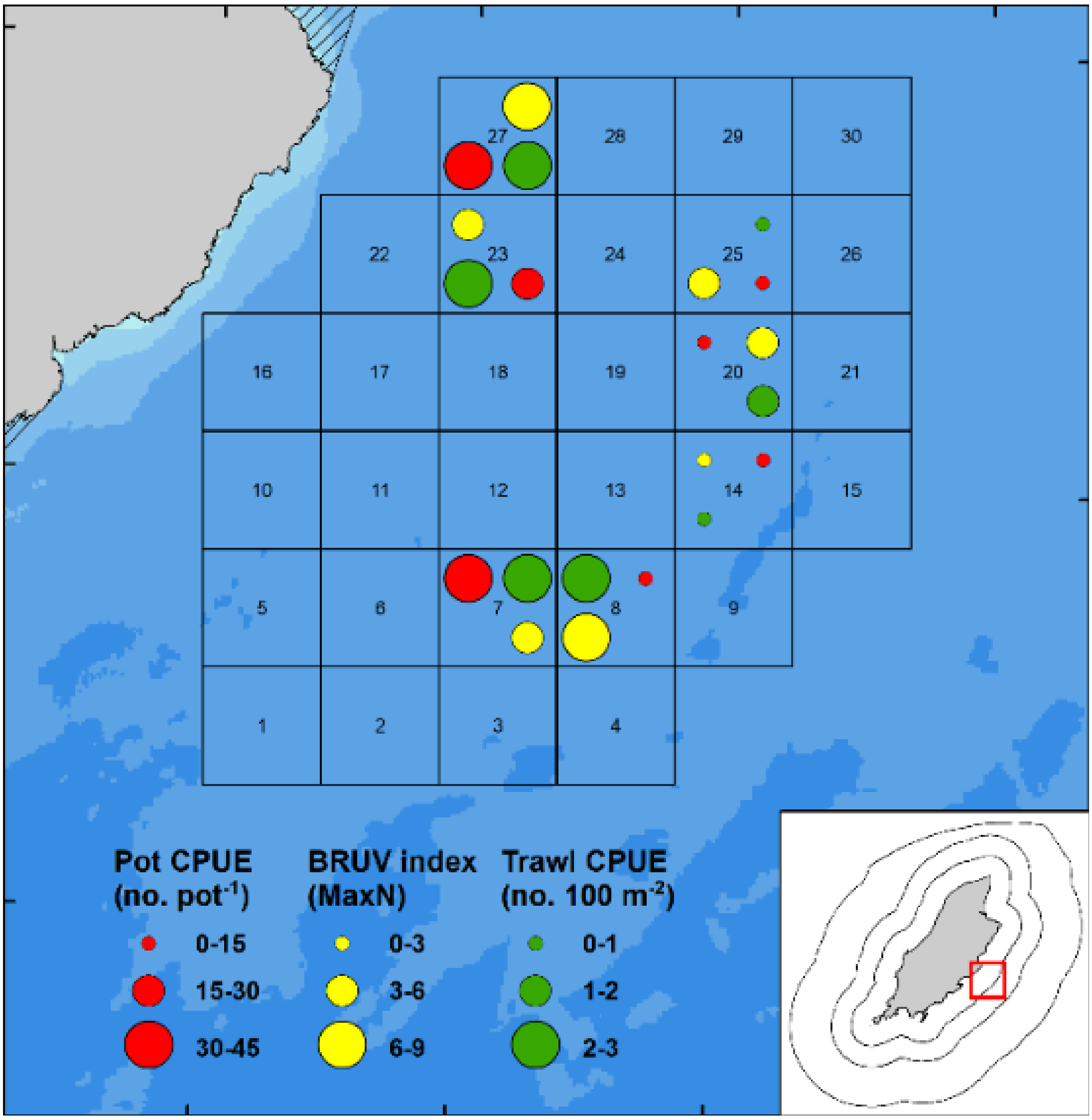

Figure 4.21 Extent of gear comparison trials and recorded differences in *B. undatum* abundance metrics derived from each gear type per survey square.

Development of BRUV indices

Following successful gear trials, the design of the BRUVs was improved and extended battery packs obtained allowing for longer deployments (15 hrs as opposed to two hrs using standard GoPro batteries). Further surveys were then completed in two whelk fishing areas exhibiting differing CPUE, with deployments replicated over a spring-neap tidal cycle, to investigate the influence of tidal currents on abundance estimates. Results indicated that peak abundances occurred around 3–7 hrs after deployment (Figure 4.22), highlighting the minimum soak time needed in whelk surveys. A significant linear relationship was found between BRUV abundance indices and CPUE from commercial pots across the two fishing areas, with a general pattern of declining abundance with increasing tidal strength.

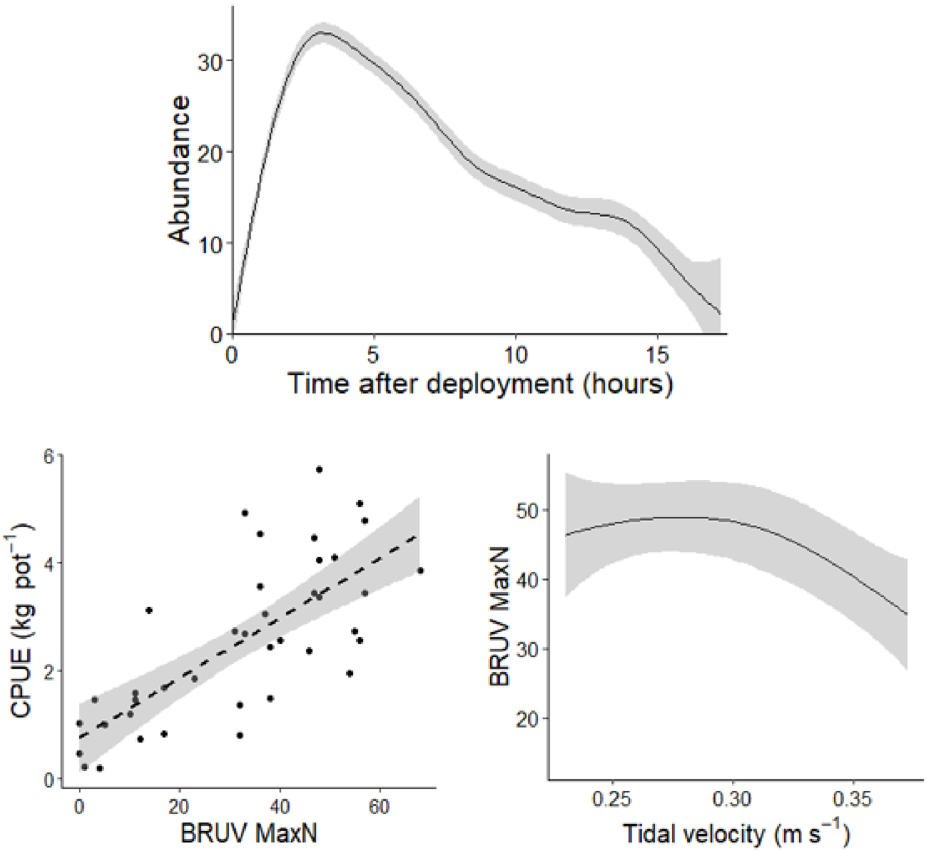

Figure 4.22 Recorded changes in *B. undatum* abundance relative to time after deployment (top); Linear relationship between MaxN abundance indices and commercial CPUE (bottom left): Non- linear relationship between MaxN abundance indices and tidal velocity (bottom right).

Further information on the use of BRUV to estimate abundance and its relationship with CPUE can be found: http://dx.doi.org/10.1093/icesjms/fsae127.

4.5.2 Trapping area and density estimates

Translating catch rates to density on the ground provides the basis to monitor changes in abundance over time. In the context of static baited gear, trapping area/swept-area (and thus density) is a far more complex calculation compared to mobile gear types owing to the complexity of bait plume dispersal and the innate behavioural element surrounding capture. Estimates of density, however, could be obtained through the use of pot spacing experiments, with the trapping area calculated through recorded changes in CPUE relative to changes in spacing between adjacent/competing pots. This method was trialled using strings of commercial whelk pots with pot spacings ranging from 4 to 50 m, and a comparative estimate was also calculated using arrival data from BRUV deployments and locomotion rates to estimate distance travelled. Both methods provided comparable results, with the radius of the trapping area measuring 6–7 m (~120 m^2 total area). These results suggest commercial pot spacings typically used in UK whelk fisheries (12–20 m) are appropriate to avoid interactions and maximize catch rates.

Further information on the use of pot spacing to estimate trapping area can be found: http://dx.doi.org/10.1093/icesjms/fsad178.

4.5.3 Size-based indicators

For data-limited fisheries, size-based indicators provide a means to monitor stock status using size frequency data and life-history information (growth, maturity, natural mortality). A baseline assessment was completed for the Isle of Man whelk fishery using a suite of length-based indicators recommended by ICES (Table 4.4), with the aim of determining the appropriateness of these indicators for whelk stocks and their sensitivity to uncertainty in life-history parameters.

Table 4.4 Length-based indicators and corresponding reference points used by ICES. L_{mat} = length at 50% maturity; L_{opt} = optimum harvest length; M = natural mortality; L_∞, k = von Bertalanffy growth parameters.

Indicator	Calculation	Reference point	Healthy stock status	Category
$L_{max5\%}$	Mean length of largest 5%	L_∞	$L_{max5\%}/L_\infty > 0.8$	Conservation (large individuals)
P_{mega}	Proportion of individuals above L_{opt} + 10%	0.3	$P_{mega} > 0.3$	
L_c	Length at 50% of modal abundance	L_{mat}	$L_c/L_{mat} > 1$	Conservation (immatures)
$L_{25\%}$	25th percentile of length distribution	L_{mat}	$L_{25\%}/L_{mat} > 1$	
L_{mean}	Mean length of individuals above L_c	$L_{opt} = L_\infty \frac{3}{3 + M/k}$	$L_{mean}/L_{opt} \approx 1$	Optimal yield
L_{mean}	Mean length of individuals above L_c	$L_{F=M} = \frac{kL_\infty + 2ML_c}{2M + k}$	$L_{mean}/L_{F=M} > 1$	MSY

Regular pot sampling was conducted over two fishing seasons (2023/24) to monitor the length-frequency distribution of catches, with maturity and statolith dissections undertaken to calculate relevant reference points. Historic length data and maturity information from 2015/16 was also utilized to explore whether any changes in stock status could be identified using these indicators, in the context of a consistent declining trend in LPUE observed in the fishery during this period (Figure 4.20).

Results of the assessment were variable, with some indicators suggesting healthy stock status ($L_{max5\%}$, P_{mega}, $L_{F=M}$) and others suggesting poor or mixed status (L_c, $L_{25\%}$, L_{opt}). However, some of the outputs were highly uncertain due to a poor understanding of whelk natural mortality rates relative to growth (i.e. the M/k ratio of the species), which will need to be resolved to formally apply these indicators and other length-based methods in whelk fishery assessments. Furthermore, the indicators did not detect any signs of overfishing in the population, with no changes in length-frequency distributions or sizes of maturation compared to 2015/16, highlighting a potential discrepancy with the declining LPUE trend and conclusions that would be drawn using catch-based models.

4.6 Ireland

4.6.1 The whelk fishery in the southwest Irish Sea

Whelk fisheries in Ireland started in the 1960s and were fully developed by the 1990s as new markets in Asia led to increased market price. The vast majority of the landings are taken by vessels generally under 12 m in length in the southwest Irish Sea and landed into the ports of

Rosslare, Courtown, Wicklow, Arklow and Dun Laoghaire. Since 2015, landings have fluctuated between 5000–6000 tonnes (Figure 4.23). The fishery is currently managed by a minimum landing size of 25 mm shell width. Previous assessment of the stock was carried out in the early 2000s (Fahy *et al.*, 2000) and relied on age data derived from the operculum to estimate life-history parameters (LHP), but this is now considered obsolete (Hollyman *et al.*, 2018a, 2018b). New LHPs were estimated for whelk landed into Arklow, Courtown and Wicklow harbours using an updated version of the Electronic Length Frequency ANalysis (ELEFAN) method (Taylor and Mildenburger, 2017). A monthly port sampling programme provides detailed information about the size distribution of the landings by port since 2007. Size samples collected on a given date were first raised to the total landings of sampled vessels by size grade, and second, to the monthly total landings in a given port (Table 4.5; Figure 4.24). We compared LHP estimates across several initial ELEFAN settings, primarily the moving average (MA), and used bootstrapping to include uncertainty around LHP (Figure 4.25). LHP were used to derive growth overfishing reference points (F_{max}, $F_{0.1}$) within a Yield-Per-Recruit (YPR) framework. Preliminary results indicate growth overfishing in the Arklow and Courtown harbours fishing areas but not in the area fished by vessels out of Wicklow (Figure 4.26). Further work is needed including validation of the LHP by, for instance, comparing with LHP derived from statolith age estimates. In addition, improved estimates of natural mortality could be obtained from unfished populations. Selectivity of whelk pots used in the Irish Sea fishery also need to be estimated.

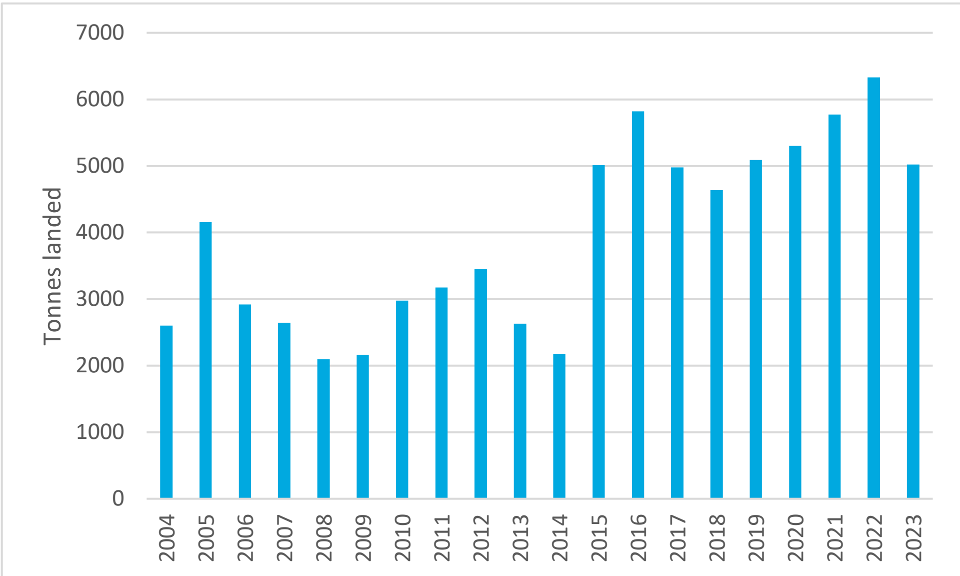

Figure 4.23 Landings of whelk into Ireland 2004–2023.

Table 4.5 Total number of boats, months, sampling events and whelk measured (raised to landings) as part of the port sampling programme by analysed harbour (2014–2022). Boats are nested within Ports. Work is ongoing to reconstruct the remaining time-series.

Year	Port	Sampled boats	Sampled months	Sampling events	Whelk sampled
2014	Arklow	9	9	47	4 971
	Courtown	4	6	19	2 235
	Wicklow	9	11	34	2 777
2015	Arklow	12	9	31	3 877
	Courtown	5	7	14	1 514
	Wicklow	10	9	28	2 519
	Arklow	11	11	33	5 126

2016	Courtown	4	8	14	1 897
	Wicklow	11	11	39	5 507
2017	Arklow	8	12	43	3 982
	Courtown	4	9	31	3 575
	Wicklow	8	11	44	3 935
2018	Arklow	10	11	42	3 817
	Courtown	7	10	34	3 123
	Wicklow	10	11	50	4 941
2019	Arklow	13	11	55	5 008
	Courtown	8	7	20	2 450
	Wicklow	10	8	24	1 831
2020	Arklow	12	8	39	3 498
	Courtown	3	7	11	867
	Wicklow	11	10	36	4 365
2021	Arklow	12	9	54	5 673
	Courtown	3	7	15	1 383
	Wicklow	14	11	51	4 249
2022	Arklow	20	7	31	2 914
	Courtown	8	6	14	1 199
	Wicklow	13	8	30	2 931

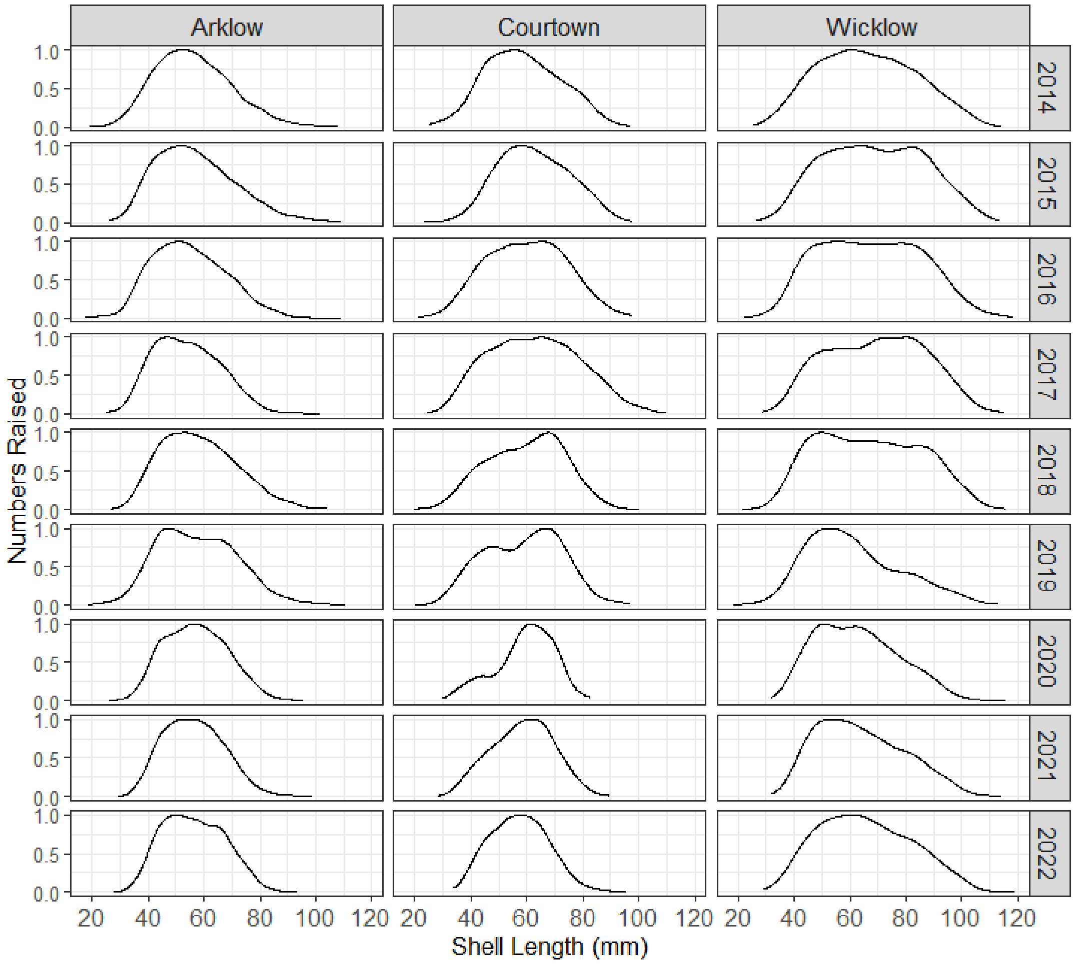

Figure 4.24 Whelk size distribution at harbour level from port sampling data raised to the total landings. Number of whelk measured presented in a scale from 0–1 for visualization.

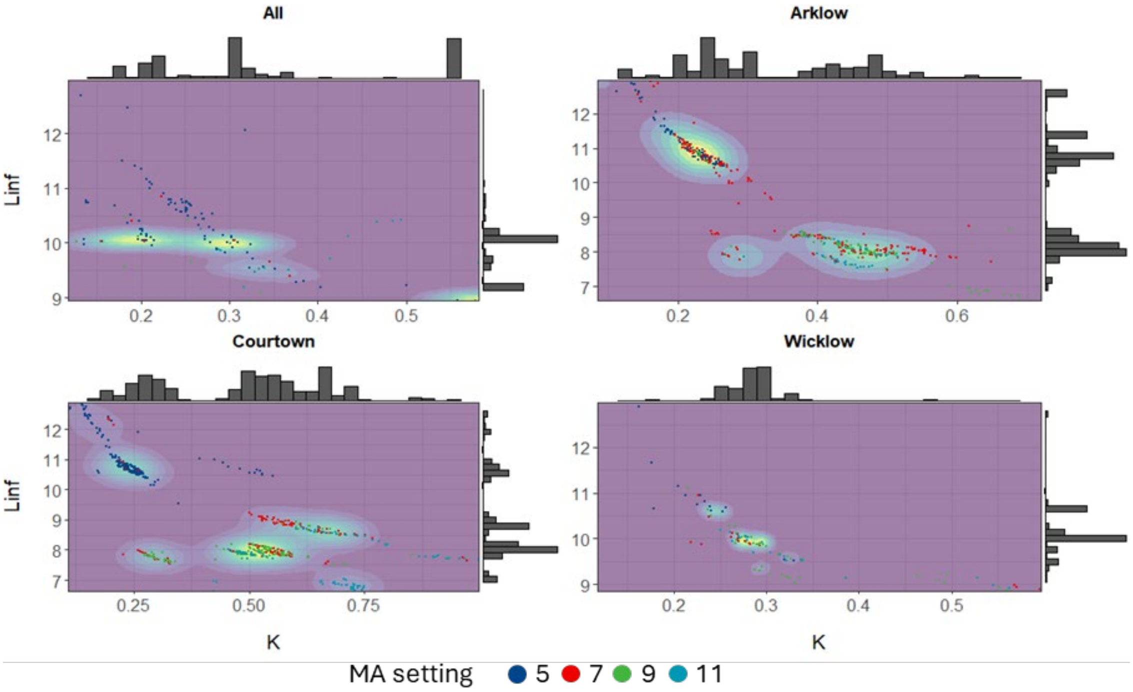

Figure 4.25 Two-dimension kernel density plot displaying the most likely combination of L_{inf} (y-axis) and K (x-axis). Colour of the points defines the MA setting input. Background colour intensity reflects most likely combination of life-history parameters by overlapping each parameter estimate histogram.

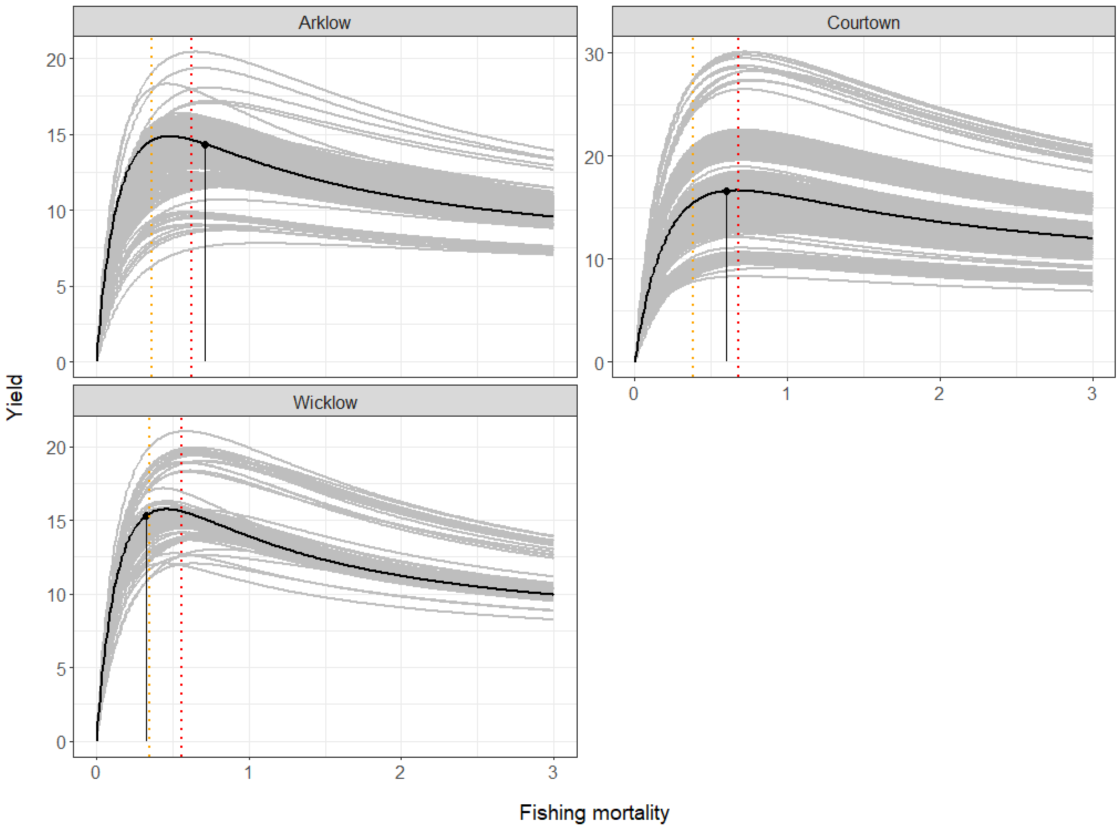

Figure 4.26 YPR curves (grey lines) resulting from bootstrapped life-history parameter estimates under four different MA settings and current fishing mortality (black dot) resulting from the median values of L_{∞} and K under MA=5 (black line). $F_{0.1}$ and F_{max} at harbour level in orange and red respectively.

4.7 USA

4.7.1 Mid-Atlantic region

The recent expansion of the unmanaged waved whelk (*B. undatum*) fishery on the Mid-Atlantic continental shelf of the United States has spurred research into local life-history parameters Currently, *B.undatum* remains unregulated in the United States, the southern extent of the species' range, but fishery development is starting to occur. Recent landings of *B. undatum* have fluctuated in the USA, with a peak of 1571.8 mt in 2013, declining to 21.6 mt in 2015 (NOAA Analysis and Program Support Division, *pers. comm.*). With commercial interest in *B. undatum* rising, establishing baseline life-history data is crucial to stock assessment and future management. In 2015, a comprehensive survey assessed population structure, sex ratios, relative abundance, and size of sexual maturity for whelk in the Mid-Atlantic (Borsetti *et al.*, 2018), revealing regional variability of length distribution, sex ratio, and size of maturity, with a preference for greater depths compared to UK populations. Size-at-maturity estimates compiled globally indicate considerable variability and suggest that current management regulations for 90% of assessed populations fall below the estimated size of maturity, potentially increasing the risk of recruitment overfishing (Figure 4.27) (Borsetti *et al.*, 2018). Further research demonstrated that spawning in the Mid-Atlantic Bight (MAB) occurs around 7–8°C, warmer than temperatures for Canadian populations but cooler than some UK counterparts (Borsetti *et al.*, 2020).

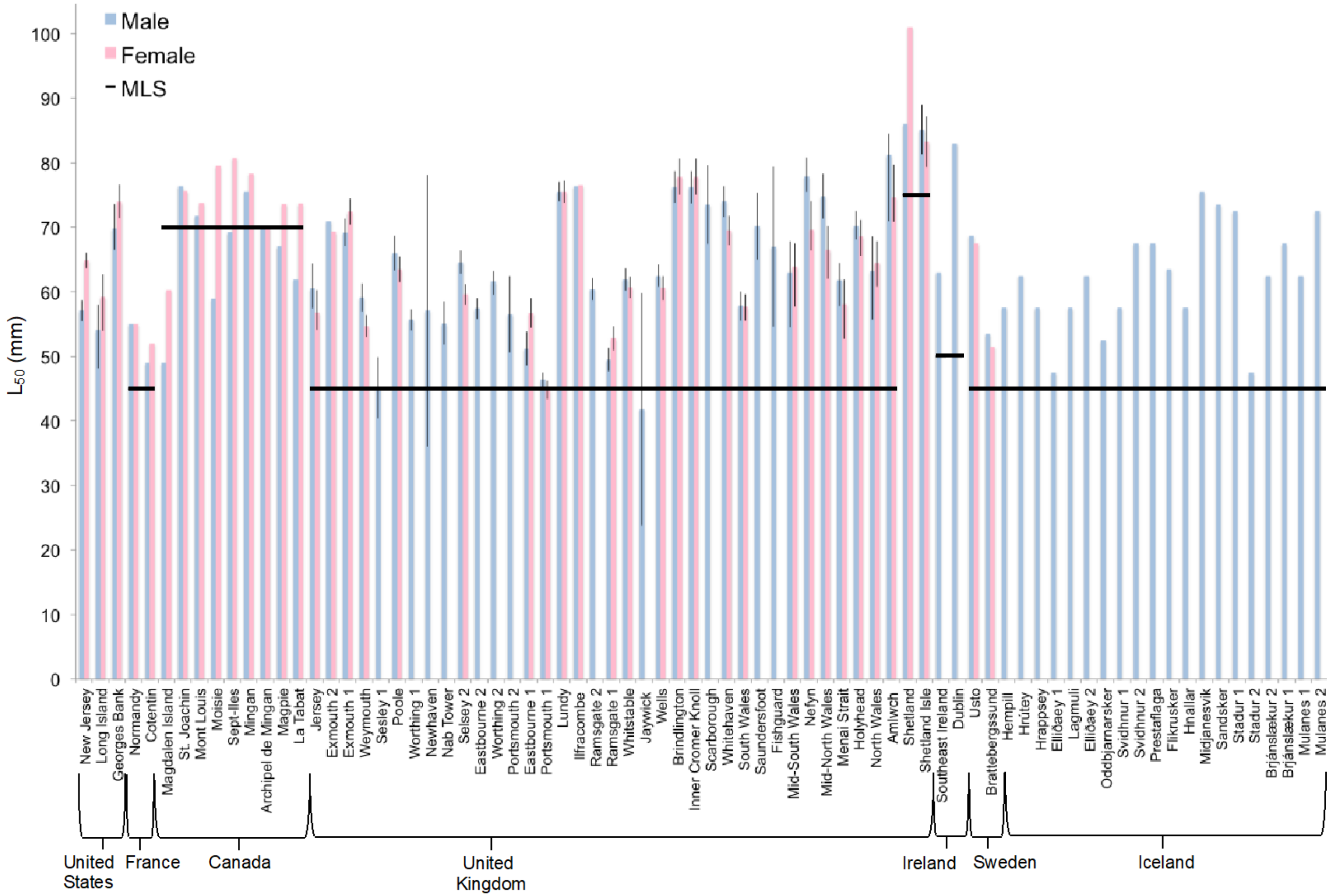

Figure 4.27 Size of maturity for male (blue) and female (pink) whelk obtained from published literature and assessment reports of whelk populations. The 95% confidence intervals (if available) are provided, and data are grouped by country, then latitude. Minimum landing size enforced in each country is represented with the heavy black line.

Growth models tailored to MAB whelk data highlighted differences from UK populations, potentially due to distinct life-history strategies and environmental influences, such as reproductive timing linked to local temperature (Borsetti *et al.*, 2021). A statolith chronology spanning a 10-year period (2009–2018) demonstrated that growth increased with higher annual temperatures; however specific seasonal bottom temperature had varying effects on growth. Increasing bottom temperature during summer, the anticipated egg-development and hatching period in this region, resulted in an age-dependent decline in growth with a positive effect on younger whelk and a negative effect on older whelk growth. Additionally, statolith age-frequency data were used to estimate natural mortality for this unexploited Mid-Atlantic Bight whelk population (0.45–0.60 $year^{-1}$) (Borsetti *et al.*, 2022). Due to the unexploited state of this population, the mortality estimate in this study can be assumed to be a true reflection of natural mortality and thus compared with mortality estimates for populations under varying degrees of exploitation to understand how exploitation affects population dynamics.

Globally, the whelk fishery is expanding; however, in the Mid-Atlantic, it remains in its early stages, with USA stocks considered largely unfished. Collecting life-history data prior to intense exploitation offers critical insights into this sensitive population, with results contributing to broader ecological understanding by allowing comparisons with other populations worldwide.

4.7.2 Massachusetts

The Channeled whelk, *Busycotypus canaliculatus* (Family Busyconidae), grows to larger size (20 cm maximum length) than the common whelk, *Buccinum undatum* (Family Tudiclidae, 10 cm maximum length) but has a similar life history, pot fishery and markets.

Channeled whelk have separate sexes with internal fertilization and ovipary. In late summer, females lay strings of up to 150 capsules (20–100 embryos/capsule) attached to substrate. Shelled juveniles hatch in spring. Juveniles and adults prey on bivalves. Growth is relatively slow (subadults growth ~1 cm/year) with females growing larger, and maturity is relatively late (50% maturity at 10 years for females and 7 years for males)

There is a long history of channeled whelk fisheries off Massachusetts, USA. Native Americans used whelks and other molluscs for wampum beads. Channeled whelk have been caught as bycatch in several demersal fisheries since the 1800s. A commercial pot fishery developed in the 1970s. During a decline in the southern New England lobster fishery, fishing effort shifted to whelk (Figure 4.28). Commercial landings increased in the 2000s, peaked, then decreased. The current annual revenue in Massachusetts is ~$5M (~£4 M, ~€5 M).

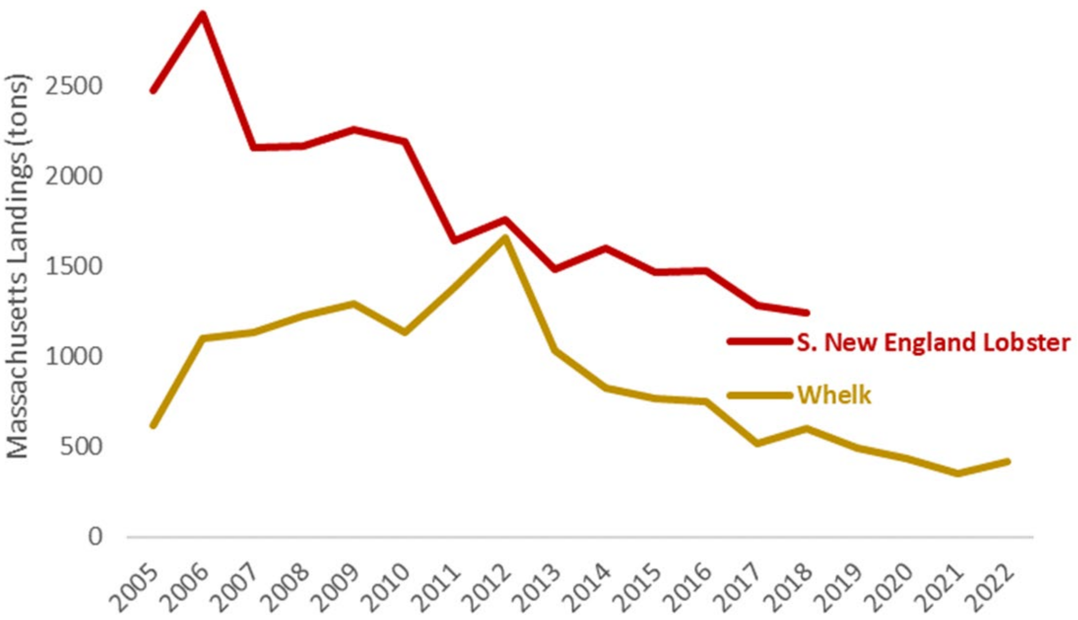

Figure 4.28 Commercial landings of channeled whelk and the southern New England stock of American lobster in Massachusetts, USA.

Each coastal state manages their coastal whelk fishery separately. The Massachusetts whelk fishery is managed with limited entry, minimum size limit, trap limits and seasons. There has been a minimum shell width for the Massachusetts fishery since the late 1980s, initially 7 cm, based on markets. Massachusetts has limited entry, a 200-trap limit, and a December-April closed season since the 1990s. However, these regulations could not effectively limit fishing effort from displaced lobstering.

Recent biological studies indicate that size and age at maturity vary significantly among areas and sexes, and females are not mature at the market-based size limit (Wilcox *et al.*, 2021). Accordingly, Massachusetts began a gradual increase the minimum size (7.3 cm in 2013, 7.6 cm in 2015, 7.9 cm in 2017) toward the female size at maturity in the primary fishing area (9.8 cm). In 2024, the scheduled increases were stayed in response to industry concerns about decreased catch, predominance of sublegal whelks, and female-only fishery, until new research on maturity and population dynamics is available.

The University of Massachusetts Dartmouth is collaborating with fishers to sample maturity by sex, size, age and area (sampling in 2021–2023 included 1406 males and 748 females). Results confirm sexual dimorphism, large size at maturity and geographic variation (Stokesbury *et al.*, 2024). The next step in the research plan is to use the information available to condition a spatial operating model for evaluating the effectiveness of alternative management procedures (minimum size, slot limits, seasons, areas, etc.).

4.8 Shetland

Historically, whelks (*B. undatum*), locally called buckies, were predominantly fished in the western region of Shetland during summer closure of the velvet crab fishery. Whelk fishing now takes place earlier in the year and across a larger part of the island group. Harvesting is conducted using pots, with a local minimum landing size of 75 mm, compared to the national minimum landing size of 45 mm. A total of 27 boats were targeting whelk in the last 10 years which reduced to 14 in 2023. In 2023 a 600-pot limit was introduced, however due to further concerns from fishers of localized overfishing, the season was reduced further from seven to five months, with a closure period from July to January 2024. Through consultation with the Shetland Shellfish

Management Organisation (SSMO) advisory group and SSMO board, the fishers agreed to a shorter season.

The fishery has seen fluctuations since the SSMO was established in 2000 with the lower landings attributed largely to change in market access. The later years have seen increased landings and landings per unit effort (LPUE), despite the reduced number of vessels targeting whelk (Figure 4.29). Due to the nature of the fishery and limited data, there are no biological reference points and is reliant on landings per unit area, including spatial data, as means of assessing the fishery. Currently, there are no concerns for whelk stocks and management practices are in place to prevent recruitment overfishing.

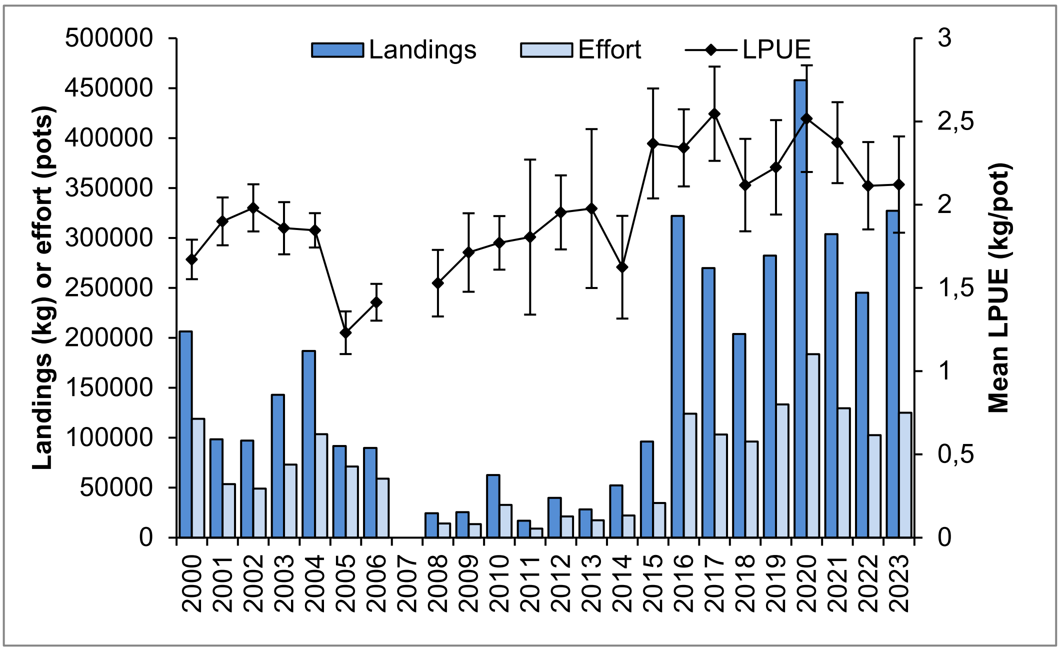

Figure 4.29 Total whelk landings, total number of pots, and the mean LPUE obtained from SSMO logbook date including 95% confidence intervals.

5 Spatial structure

5.1 Accounting for complex spatial structure in stock assessment and fishery management

Whelk fisheries present several challenges for stock assessment and fisheries management because they have negligible movement, and the lack of mixing results in spatial patterns among areas, local density-dependence or environmental effects, and patchy resources that can be quickly depleted (Orensanz *et al.*, 1998; Cadrin, 2024). Although some newly hatched whelks climb complex substrate and can inflate their foot to float in the water column (Harding, 2011), early life stage dispersal appears to be similar to older juveniles and adults (~10 m/day, ~100 m/month) (Sisson, 1972; Edmundson, 2016).

These challenges can be confronted by identifying spatial units that conform to a unit stock assumption (i.e. self-sustaining and homogeneous) for stock assessment and fishery management. Stock identification can be based on the information available. Spatial patterns in fishery and survey data (catch series, catch rates, size or age composition) can indicate discrete stocks for assessment and management. Ideally, genetic variation can identify reproductively isolated populations. For example, Askin *et al.* (2022) found locally isolated populations, and isolation-by-distance for channeled whelk *Busycotypus canaliculatus* that is consistent with low dispersal rates.

If population structure is more complex (e.g. connectivity among areas), stock boundaries should encompass a complete metapopulation while monitoring subpopulation trends. Subpopulations with negligible post-larval connectivity can be assessed and managed with per-recruit reference points. If there are spatial patterns in vital rates (growth, survival, maturity) selectivity or spatial fishing patterns, post-recruit dynamics should be modelled within areas. The combined yield or spawning potential per recruit cannot be derived from average inputs (growth, survival, maturity, selectivity, fishing mortality). However, local demographics can be derived from spatial sampling of life history and fishing patterns and combined for metapopulation estimates (Truesdell *et al.*, 2016; Cadrin, 2024).

5.2 Evidence of fine scale spatial structure in whelk populations

The common whelk, *Buccinum undatum*, lay egg masses attached to hard substrates or floating objects, where the larvae develop and hatch directly as benthic snails (Kideys *et al.*, 1993). As adults whelk are slow moving, covering distances of approximately 10 m a day towards a food source (Himmelman, 1988). Therefore, connectivity between whelk populations is likely to be to be low with potential for stock structure at relatively small scales.

Genetic studies have shown two monophyletic common whelk lineages; eastern Atlantic (Iceland, UK, Norway) and western Atlantic (Greenland and north America), with further divergence between Greenland and north America. The genetic distance between these continental lineages is of a similar magnitude to interspecific genetic distances between the Pacific and Atlantic *Buccinum* species (Magnúsdóttir *et al.*, 2019b, 2019a) such that these populations should be considered as different evolutionary units. Within these lineages, evidence from mitochondrial, microsatellite and RAD markers show a strong isolation by distance pattern, with significant genetic differences at the scale of ~20 to 50 km (Pálsson *et al.*, 2014; Magnúsdóttir *et al.*, 2019b; Goodall *et al.*, 2021; Morrissey *et al.*, 2022). These finer scale genetic distances tend to occur where there are natural geographic barriers. For example, in Iceland, populations inside and outside a bay were significantly different, although only 20 km apart. In the southeast of England, the Thames Estuary was seen to act as a natural barrier to genetic connectivity. While genetic evidence exists for isolation by distance and some natural barriers to geneflow, genetic mixing appears to be maintained across fairly large-scales, mostly likely through stepping stone connectivity due the contiguous nature of the species (Morrissey *et al.*, 2022) and occasional "rafting" of egg masses that detach from rocky and benthic attachment.

Fine scale population structure is also supported through phenotypic variability. For example shell shape and colour has been shown to vary over fine spatial scales and these phenotypic traits have been shown to correlate with genetic structure (Goodall *et al.*, 2021), although some environmental plasticity is also suspected to be driving morphological variation in some locations (Magnúsdóttir *et al.*, 2019b).

Life-history parameters of size at maturity and growth have also been shown to vary over various spatial scales. For example, growth has been shown to vary over large spatial scales with temperature likely driving latitudinal patterns; larger, slower growing whelk in higher latitudes and smaller, faster growing whelk at lower latitudes (Hollyman, 2017; Emmerson *et al.*, 2020). However, finer spatial scale growth variability is also apparent where differences are seen between sites as close together as 20 km, which seem to be driven by temperature (Emmerson *et al.*, 2020). Size at maturity did not show clear latitudinal patterns in a broad scale study (Haig *et al.*, 2015) which suggested that local conditions (depth, temperature, benthos) had a stronger influence over maturity than broader latitudinal scale drivers. There is large individual variation in growth and size at maturity and it is unclear if this is genetically mediated individual differences or plasticity due to admixture locally across environmental gradients. Of note however, is that differences in life-history parameters are seen at a similar spatial scale as the genetic distances discussed.

Overall, morphometric, genetic and life-history data suggests that population structuring occurs, with populations 20 to 50 km apart unlikely to be mixing. However, due to the contiguous nature of this species and the broad range of habitats it is found upon, delineating stock units for assessment and management is challenging and stepping-stone geneflow is likely.

The channeled whelk, *Busycotypus Canaliculatus*, shows similar evidence of low dispersal rates. Wilcox *et al.* (2021) and Stokesbury *et al.* (2024) found that size and age at maturity of channeled whelk vary significantly among local areas. Askin *et al.* (2022) found locally isolated populations, and isolation-by-distance for channeled whelk that is consistent with low dispersal rates.

6 BIM Whelk Bait Project (BIMWBP)

Project team: Liam Strachan[6], Dr Colin Hannon[6], Dr Francesco Nocci[6], Dr Martin Gammel[6], Dr Philip White[6], John Boyd[6], Dr Maria Hayes[7], Dr Michael Gallagher[8], Dr Deirdre Brophy[6]

Bait supply, consistency and security for the economically important common whelk (*Buccinum undatum*) fishery in Ireland has recently come into focus. A decline in brown crab (*Cancer pagurus*) stocks has reduced the viability of this preferred and traditionally productive bait species (Bord Iascaigh Mhara, 2023; Marine Institute and Bord Iascaigh Mhara, 2023). The BIM Whelk Bait Project is an ongoing collaboration between Ireland's Seafood Development Agency (BIM) and the Marine and Freshwater Research Centre (MFRC) at ATU Galway, Ireland, which builds upon work initiated in Nofima, Norway. The research aims to develop a sustainable alternative bait for the whelk fishery, thereby reducing dependence on brown crab. The work is co-funded by the Government of Ireland and the European Maritime, Fisheries and Aquaculture Fund (EMFAF).

Advice on project design and implementation is provided by a multi-actor stakeholder platform comprising researchers, processors, fishers and other industry representatives. During bait development, processing side-streams and underutilized species were combined with a food gelling agent (binder) to produce a low volume bait that is easy to handle and more attractive to fishers. Laboratory trials showed that a bait containing green crab (*Carcinus maenas*) is attractive to live whelk. When tested at sea under commercial fishing conditions the gelled green crab bait produced similar catch rates compared to unprocessed green crab. Performance also compared favourably to that of the traditional brown crab bait.

Progress on the project to date indicates that the use of brown crab in the whelk fishery could be reduced by developing formulated baits from currently underutilized resources. This could contribute to achieving maximum sustainable yield (MSY) in the Irish brown crab fishery (Marine Institute and Bord Iascaigh Mhara, 2023). Currently, work is underway to scale up the production of an alternative formulated bait and to conduct comprehensive testing at sea. Additionally, analysis is ongoing to characterize the chemical profile of the odour plume that elicits a foraging response in whelk and to reduce bait volume using hydrolysis.

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7 Whelk survival and whelk pot selectivity

7.1 Whelk survival

Effect of whelk sorting on uprighting time

To comply with Minimum Conservation Reference Sizes (MCRS) fisher use on-deck sorting devices (riddles). Handling on deck exposes whelk to a series of stressors that potentially negatively affects the post-discard survival of undersized whelk. In a laboratory-based study predator susceptibility was assessed measuring the time it requires whelk to upright themselves after being size selected using rotary or manual riddle. We identified increased righting times for whelk that passed a rotary riddle and a manual flatbed riddle (Figure 7.1 and Table 7.1) but without significant differences between the two sorting strategies.

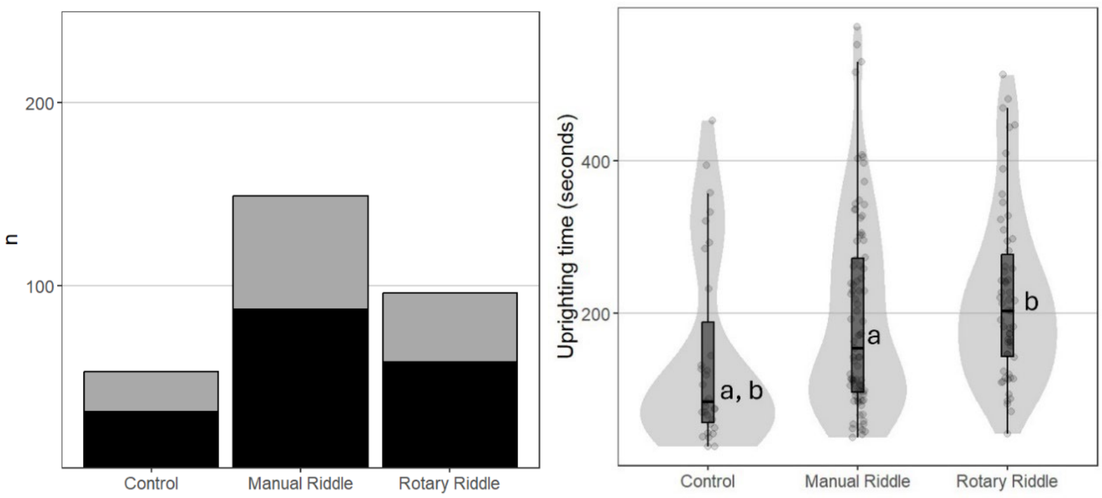

Figure 7.1 Proportion of individuals that successfully right themselves below 10 min (black) and that did not show any response (grey) of the three treatment groups: control, manual riddle, rotary riddle (left). Mean up-righting time between the three treatment groups (right). Significance differences between treatments are indicated with letters a (p=0.0164) and b (p=0.0002). Boxplots indicate median, interquartile range (IQR) and standard (1.5) IQR range (whiskers).

Table 7.1 Statistics summary of the non-parametric Kruskall-Wallis test comparing the mean up-righting of the three treatment groups (manual riddle, rotary riddle, control).

Treatment		Treatment	p-value	
Manual Riddle		Control	0.0164*	
Rotary Riddle	vs	Control	0.0002*	Kruskal–Wallis
Rotary Riddle		Manual Riddle	0.1019	

Mark Recapture

To assess the effect on survival of the impaired ability to respond and to upright themselves, whelk were marked with distinctive rubber bands comparing rotary and manual riddle to hand-picked (control) whelk (Figure 7.2). In total 1813 undersized whelk (≤ 53 mm TSL) were tagged using rubber bands (Table 7.2). After three weeks one recapture attempt was made, re-capturing 379 individuals across treatments (Table 7.3). The fieldwork was done at two locations with identical strings (14 pots each). The recapture rates were calculated on pot basis (total 28). Recapture rates varied significantly between control and rotary riddled (Figure 7.3). No significant difference was found between flat-bed riddle (manual riddle) and the control group (Figure 7.3). The samples size was relatively small, and there are plans to repeat the experiment in 2025.

Table 7.2 Total individuals marked with distinctive rubber bands. Only undersized whelk (< 53 mm TSL) were marked.

Marking	Rotary riddle (four holes)	Handpicked (no holes)	Flat-bed riddle (two holes)
String 1	223	194	219
String 2	553	272	352
Total	**776**	**466**	**571**

Table 7.3 Total tagged individuals recaptured.

Recapture	Rotary riddle (four holes)	Handpicked (no holes)	Flat-bed riddle (two holes)
String 1	39	54	43
String 2	61	111	71
Total	**100**	**165**	**114**

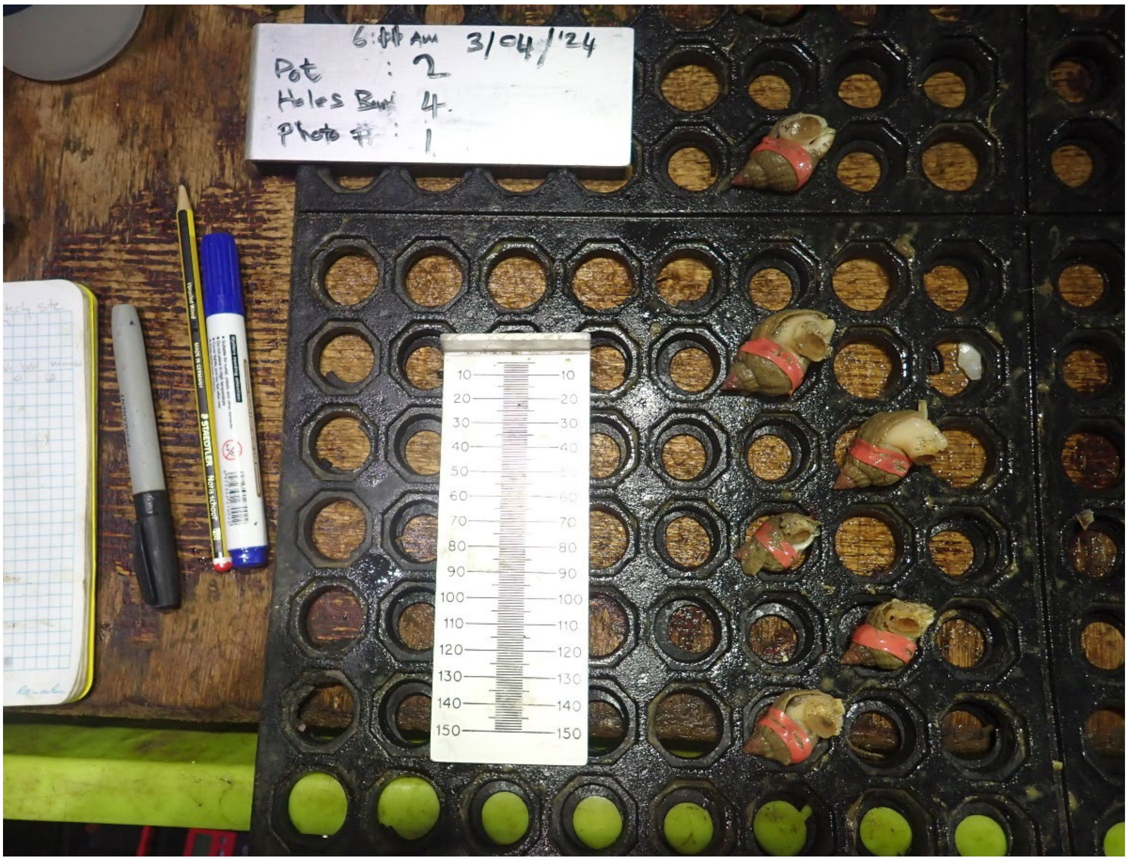

Figure 7.2 Photograph of recaptured banded (marked) whelks from a pot during the Mark and Recapture study.

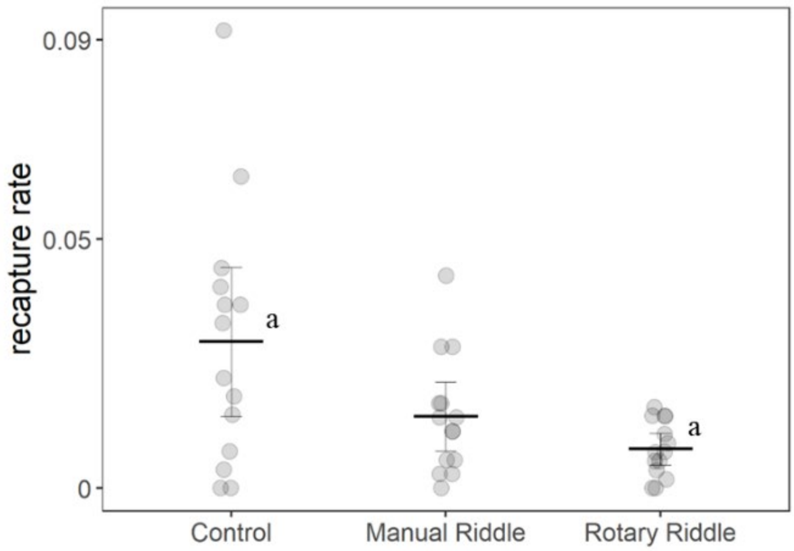

Figure 7.3 The mean recapture rates, accompanied by 98% confidence intervals (error-bar) with individual data points for the 14 pots of string 2. One-way ANOVA revealed statistically significant differences in recapture rates among treatment groups (p = 0.0245). Significant differences, indicated by letter a (Tukey Honest Significant Difference).

7.2 Whelk pot selectivity

Two groups within the workshop have recently undertaken work on whelk pot selectivity and presented the work.

7.2.1 Whelk pot selectivity and soak time

Pot Selectivity

Using a paired gear study experimental data was collected (TSL) from whelk captured in control pots with small escape gaps and pots with 25 mm escape gaps (Figure 7.4) as well as an alternative gear design (Figure 7.7). After careful model comparison we concluded that a logistic selection model that considers contact probability of whelk with escape gaps (Clogit) provides best fit to the data collected. Soak time was found to be an important factor influencing the efficiency of pots to size select whelk. Hence, selectivity parameters differed significantly at long (46 hrs) and short (18 hrs) soak time. At soak times above 45 h, 97% (93–99%; 95% confidence intervals) of whelk that enter a pot are size selected and at short soak times below 24 h, which are more common, 75% of the catch make contact with the escape gaps (Figure 7.5). Hence, at short soak times the observed discard rate was significantly higher (9.3–14.3 %; 95% confidence intervals) than at long soak times (0.3–2.0%; 95% confidence intervals). At the same time the unintended escape of sized catch is neglectable at long soak times.

Figure 7.4 Whelk pot with four escape gaps at the upper four corners and drainage holes at the sides.

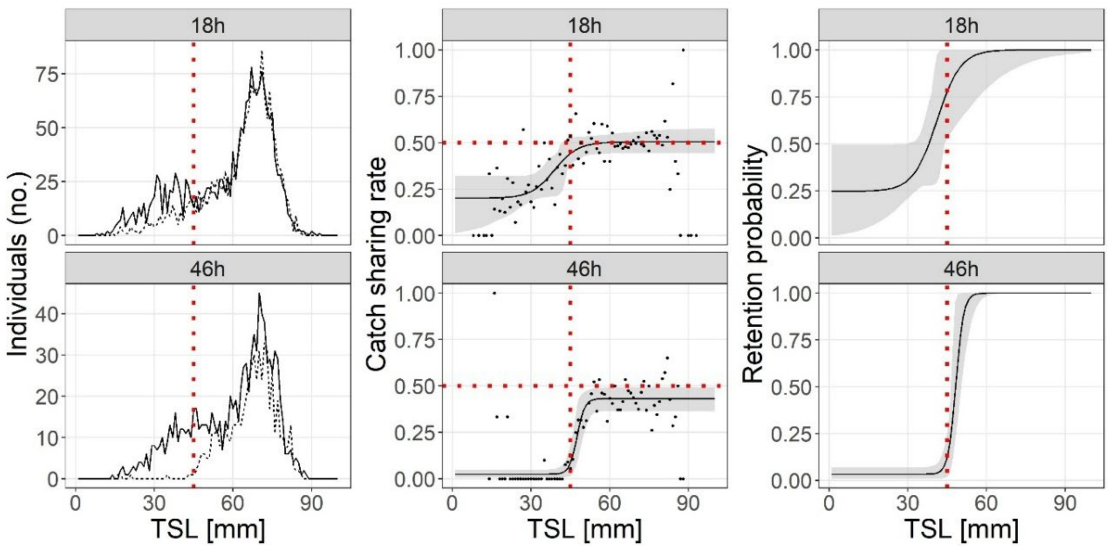

Figure 7.5 Population structure in control pot (black) and test pot with 4 escape gaps (32 mm) stippled (left). Catch sharing rate (middle) and the size selection curves (right) for the pot with 4 escape gaps and control pot at soak times of: 24-hrs (top) and 46-hrs (bottom). Minimum conservation reference size = 45 mm (red vertical dotted line); 95% confidence intervals (grey ribbon).

Riddle Selectivity

Due to the remaining undersized whelk in the pot, secondary selection is necessary on-deck using sorting grids. While the escape gaps are round holes, the sorting grids are aligned parallel. Currently escape gaps are equal in diameter to the minimum riddle width. We compared therefore the selective properties of a pot with 25 mm escape gaps (Figure 7.6A) and a rotary riddle with 25 mm distance between the bars (Figure 7.6B). The resulting size selection curves are significantly different. The whelk shell is not perfectly round; therefore 25 mm round escape gaps select towards smaller shell length than a riddle with 25 mm distance between the bars. Following, we estimated the probability of whelk that are retained in the fishing gear but finally discarded by the on-deck sorting (Figure 7.6C).

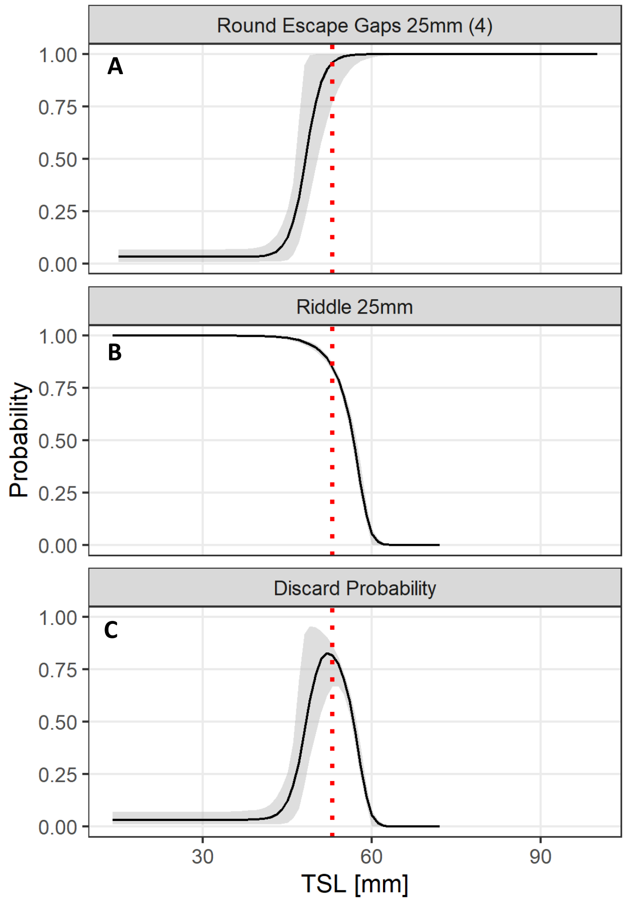

Figure 7.6 Size selection curve of a 25 mm escape gap after 46-hrs soak time (A). Retention curve of a rotary riddle with 25 mm distance between the bars (B). The probability of whelk that are retained in the fishing gear to be discarded (C). Minimum conservation reference size = 53 mm (red vertical dotted line); 95% confidence intervals (grey ribbon).

Alternative Gear Design

The issue of undersized whelk discard is due to insufficient soak time, that does not permit all whelk to get in contact with the escape gaps or the size of the escape gaps. A separate gear design was tested that instead of four escape gaps, was equipped with 30 escape gaps, and at a larger diameter (32 mm) (Figure 7.7). However, the problem of undersized whelk in the pot at short soak times (24 hrs) persisted. The observed discard rates ranged between 7.8–15.0% (95% confidence interval). This illustrates, that at short soak times, the limitation is not the availability of escape gaps but whelk not seeking escape (Figure 7.8).

Figure 7.7 Alternative gear design, 32 escape gaps at 25 mm diameter.

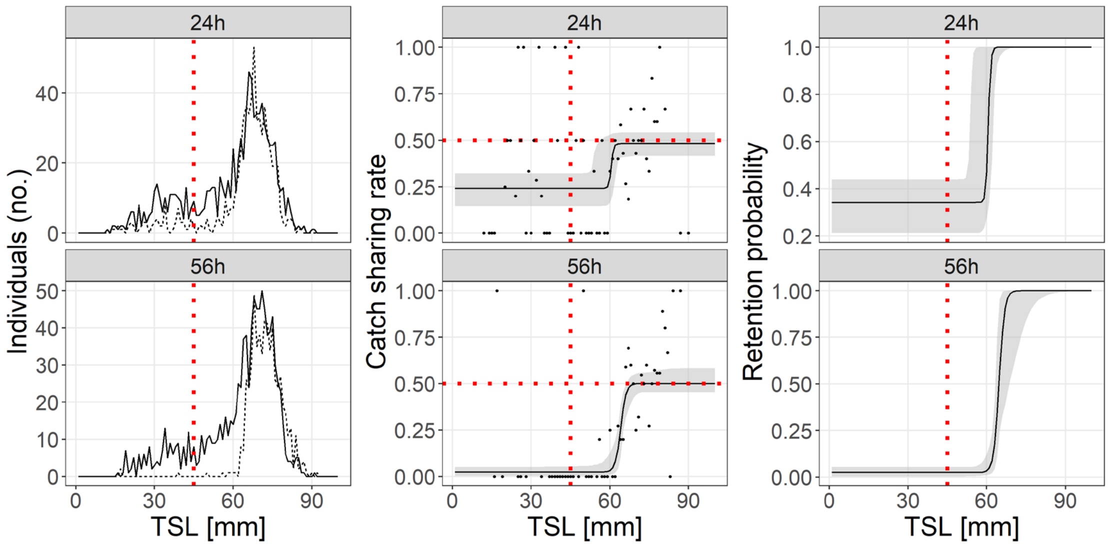

Figure 7.8 Population structure in control pot (black) and test pot with 30 escape gaps (32 mm) stippled (left). Catch sharing rate (middle) and the size selection curves (right) for the pot with 30 escape gaps (32 mm) and control pot at soak times of: 24-hrs (top) and 46-hrs (bottom). Minimum conservation reference size = 45 mm (red vertical dotted line); 95% confidence intervals (grey ribbon).

7.2.2 Size selectivity of whelk pots

Size selectivity of whelk pots in Wales (Figure 7.9) has been estimated using a mark-recapture study to understand the likelihood of recapture in difference size classes (Colvin *et al.*, 2024). Analyses showed a clear dome-shaped size selectivity shape of the catch in pots pre-riddling, with a rapid decline in selectivity of small animals and a slightly shallower decline in selectivity of larger animals Figure 7.10). These patterns were observed following a 48-h soak time and therefore, in light of the above evidence, the domed selectivity may be less steep with shorter soak times.

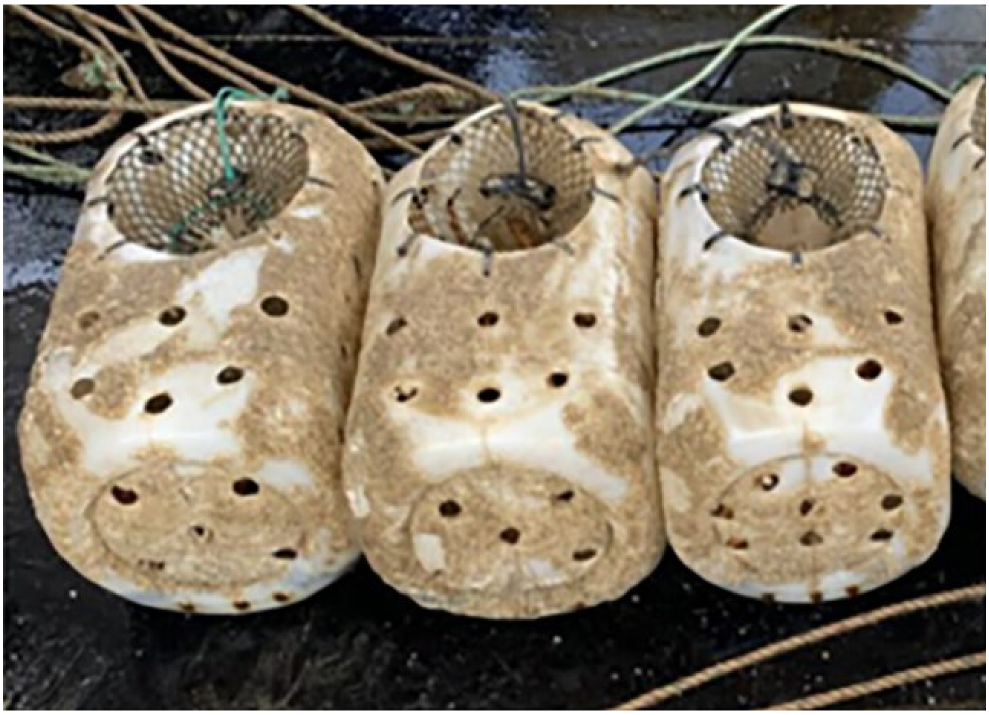

Figure 7.9 Lay-down style whelk pots used in the mark-recapture study to estimate whelk pot selectivity.

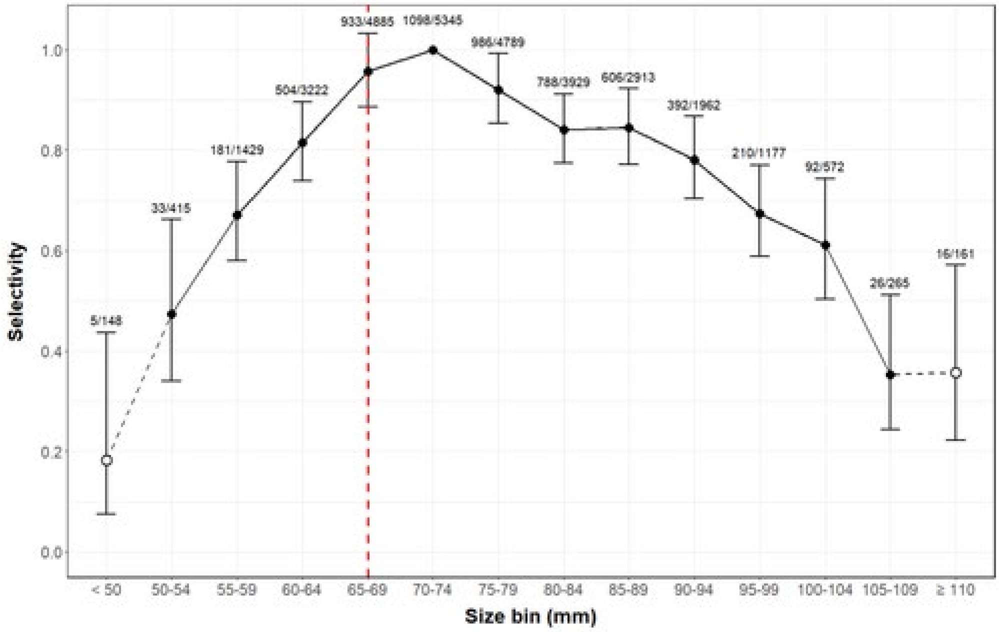

Figure 7.10 Maximum likelihood estimates of selectivity (±2 standard errors) for the Welsh common whelk fishery across two commercially fished regions. The vertical red dashed line indicates the current Welsh minimum landing size of 65 mm. Dashed lines to open circles represent groups that are not true size bins: the left-most bin refers to whelks less than 50 mm, and the right-most bin refers to whelks greater than or equal to 110 mm. The fractions represent the number of recaptured whelks divided by the number marked within each size bin.

7.3 Future work and terms of reference

The final afternoon of the workshop was taken up with an open discussion on priorities for future research to support whelk fisheries and what future Terms of Reference (ToR) should be included and are summarized below.

ToR A: Fishery dependant data

1. What landings data is currently being collected within each country/region and what are its limitations?
2. What landings data can be accessed through ICES, and can these be collated for use within this group?
3. Diversity of gear used by fisheries within and between regions.
4. Can we collaborate with other ICES groups e.g. WGScallop to look at overlap of whelk fisheries with towed gear fisheries?
5. LPUE standardization

ToR B: Fishery-independent data

1. Fishery-independent survey design.
2. Whelk tagging methods and surveys

ToR C: Stock structure

1. Review guidelines from ICES SIMWG and their application to whelk stocks, in particular variability of biological parameters.
2. Collate existing data that can be used for stock structure analysis (including from ToR A)
3. Review fisher knowledge data that can be used to understand stock structure and standardize fisher questionnaire for wider use.

ToR D: Climate Change

1. Review existing research on the implications of climate change for whelk

It was decided that the group would like to meet for a second workshop in 2025. This meeting would provide opportunity to present work to the group and decide on the future of the group e.g. continued workshops or an ICES working group. The above potential ToRs will be discussed and agreed upon for either future workshops or as a three-year Terms of Reference for an ICES working group.

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Annex 1: List of participants

Name	Institute	Country (of institute)
Natalie Hold	Bangor University	UK
Bella Voak	Centre for Environment, Fisheries and Aquaculture Science	UK
Charlotte Colvin	Bangor University	UK
Ella Brock	Seafish	UK
Emma White	Marine Institute	Ireland
Eric Foucher	National Institute for Ocean Science - Ifremer	France
Francis Binney	Government of Jersey	UK
Guillermo Martin	Marine Institute	Ireland
Hubert Du Pontavcie	National Institute for Ocean Science - Ifremer	France
John Hoenig	Virginia Institute of Marine Science	United States
Julie Gross	Virginia Institute of Marine Science	United States
Kaitlyn Charmley	Fisheries and Oceans Canada	Canada
Kun Xing	Dalian Ocean University	China
Laurence Hegron	SMEL	France
Leander Harlow	UHI Shetland	UK
Liam Strachan	Atlantic Technological University	Ireland
Liese M. Carleton	Marine Institute	Ireland
Matthew Coleman	Bangor University	UK
Matthew Garratt	Bangor University	UK
Michel Kaiser	Heriot-Watt University	UK
Moritz Eichert	Heriot-Watt University	UK
Oliver Tully	Marine Institute	Ireland
Phil Hollyman	Bangor University	UK
Phillip Haupt	Inshore Fisheries and Conservation Authority	UK
Phillip Langlois	Government of Jersey	UK
Sarah Borsetti	Rutgers, The State University of New Jersey	United States

Sarah Clarke	Marine Institute	Ireland
Steven Cadrin	University of Massachusetts Dartmouth	United States
Vanessa Simons	Inshore Fisheries and Conservation Authority	UK

Annex 2: Resolutions

The **Workshop on Whelk Fisheries** (WKWF), chaired by Natalie Hold, United Kingdom, will be established and will meet in Bangor, Wales, United Kingdom, 8–9 July 2024 to:

Share best practice when aging whelks from statoliths;

Discuss aging error and the advantages/disadvantages of routinely collecting age data over length converted catch data;

Discuss current stock assessment approaches and challenges for this species;

Consider continued work on whelk aging within the ICES community;

Consider continued collaborative working on stock assessment approaches specific for whelk fisheries.

WKWF will report by 16 September 2024 for the attention of ACOM and SCICOM.

Supporting information

Priority	Currently there are no whelk specific working groups or workshops addressing the whelk fishery. The activities of this workshop aim to share expertise in mollusc aging using statoliths as well as understanding aging error. It will also provide a platform to share ongoing research in this area, specificallly assessment approaches and challenges.
Scientific justification	Whelk fisheries, in particular *Buccinum undatum*, are commercially important fisheries for France, Iceland, UK and Ireland with smaller or emerging fisheries in Belgium, Denmark, Sweden, Netherlands and Norway, as well as Canada and the USA. This species has minimal management in most countries at present, although there appears to be an upturn in the research activity aimed at these fisheries. This inaugural workshop aims to bring together scientists already working on whelk fisheries from across Europe and north America to share best practice and spark collaborations as well as provide a review of the recently published work and that currently underway. There will be two main focuses: first, whelk aging techniques, error and use in routine data collection and stock assessment;second, a focus on current stock assessment approaches and challenges and direction of research/travel for stock assessment for whelk.
Resource requirements	The research programmes which provide the main input to this workshop are already underway and resources are already committed. Sponsorship for this workshop is secured from the English IFCA Association and SeaFish. This will go towards travel grants to allow face-to-face attendance at the workshop. The additional resource required to undertake additional activities in the framework of this workshop is negligible.
Participants	The workshop is expected to be attended by 15 people from e.g. UK, Ireland, Iceland, France, USA and invites will be sent wider across other existing ICES WG contacts.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are no obvious direct linkages with the advisory committees at this moment.
Linkages to other committees or groups	There is a very close working relationship with other non-quota shellfish working groups such as WGSCALLOP and WGCRAB, with many attendees working across these species too. In addition, we expect to utilize the outputs from WKLIFE group as most whelk stocks are category 3 or 4. One attendee is also on WKLIFE.
Linkages to other organizations	None at present

Annex 3: List of abbreviations and acronyms

ACL	Annual Catch Limit
ATU	Atlantic Technological University
BIM	Bord Iascaigh Mhara
BIMWBP	Bord Iascaigh Mhara Whelk Bait Project
BRUV	Baited Remote Underwater Video
CRPMN	Normandy Regional Committee for Maritime Fishing
CRPMEM	Hauts-de-France Regional Committee for fishery and aquaculture
CPUE	Catch Per Unit Effort
DPUE	[LPUE in French]
EC	European Commission
EEC	Eastern English Channel
ELEFAN	Electronic Length Frequency Analysis
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EU	European Union
FAO	Food and Agriculture Organization
GES	Good Environmental Status
ICES	International Council for the Exploration of the Sea
iVMS	inshore Vessel Monitoring System
LHP	Life History Parameters
LPUE	Landings Per Unit Effort
MA	Moving Average
MAB	Mid-Atlantic Bight
MCL	Monthly Catch Limit
MCRS	Minimum Conservation Reference Size
MFRC	Marine and Freshwater Research Centre
MLS	Minimum Landing Size
MMO	Marine Management Organisation
MSY	Maximum Sustainable Yield
NOAA	National Oceanic and Atmospheric Administration
PVC	Polyvinyl chloride
SIMWG	Stock Identification Methods Working Group
SMEL	Synergie Mer & Littoral
SOM	Size at Maturity
SSMO	Shetland Shellfish Management Organisation

TCA	Trade and Cooperation Agreement
ToR	Terms of Reference
TSL	Total Shell Length
UK	United Kingdom
USA	United States of America
VMS	Vessel Monitoring System
WKWF	Workshop on Whelk Fisheries
WWAG	Wales Whelk Advisory Group
YPR	Yield-per-recruit