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Annual Fisheries Science Report 2020

Sustainable Fisheries and Aquaculture Group

School of Ocean Sciences

Annual Report for 2020
(Report No. 6)

Isle of Man Fisheries Science

Sustainable Fisheries and Aquaculture Group
Bangor University

PRIFYSGOL BANGOR UNIVERSITY

Isle of Man Government
Reiltys Ellan Vannin

Review of 2020 by Professor Stuart Jenkins

Stuart Jenkins is a Professor of Marine Ecology at the School of Ocean Sciences, Bangor University and is the academic and scientific lead for the Isle of Man.

2020 has been a difficult year for everyone. The fishing industry has been hit by both BREXIT and the global COVID pandemic. Amidst these challenges it is increasingly important that Manx fisheries are informed by the best possible science advice. In August 2020 I was delighted to hear that Bangor University was awarded the contract by the Isle of Man Government to continue providing fisheries science advice to DEFA. This will extend Bangor's commitment to working on the island to 2025 and allow us to build further on the solid foundations we have established in data collection, interpretation and provision of management advice. Preparing the bid to continue working with DEFA and the Manx fishing industry was a useful time to reflect on the contribution which Bangor scientists have made to Manx fisheries over the past 8 years. Data collection and analysis, through both fisheries dependent and independent means, in the mobile gear sector is now at a level comparable with any fishery in the world and is allowing real time understanding of fishing effort and stock status at increasingly high spatial resolution. A large contribution to this has been from the industry-led fine scale scallop survey in 2019 and 2020. Rather than managing scallop stocks at the scale of the Territorial Sea we can now apply measures at the scale of individual grounds and implement rotating closure of areas of seabed to protect new recruits at even smaller scales. A recent innovation is also the ability to hold within season monthly reviews through the Scallop Management Board. This level of understanding of the fishery is fundamental to address many of the challenges currently facing this sector.

Over the past 5 years we have made important advances in the level of understanding of the crab, lobster and whelk fisheries. Our work has enhanced the understanding of these fisheries through both fundamental knowledge of the target species biology, but also through novel use of technology to improve collection of fisheries dependent data. The value and importance of the static gear sector to the island is now comparable with the mobile sector and we look forward to the next few years where we aim to raise the level of data collection. Analysis of the 2020 public consultation of the crab and lobster fishery is proceeding. However beyond the details of that important consultation it is clear that we need buy-in and the adoption of data reporting measures from industry, as well as development of novel science surveys. For the latter we look forward to research contributions from Matt Garratt, a Bangor University trained, Manx resident who is starting a PhD looking at stock assessment approaches in whelk.

The following report gives an insight into the work of Bangor scientists over the last year including our regular monitoring work, novel research and our engagement with fisheries scientists worldwide. Our island based staff, Dr Isobel Bloor and Dr Jack Emerson have continued to work with colleagues from the UK and further afield, and continue to provide leadership in placing management of Manx stocks in a wider Irish Sea context. We also outline our research priorities for the coming years. As always we value the close working relationship with industry and welcome any comments on our plans.

Finally I'd like to wish Dr Jack Emmerson all the best as he moves on from our Bangor team. Jack has provided a depth of knowledge, expertise and enthusiasm to push forward understanding of the static gear sector in the past years. Jack isn't moving far as he takes up a position with DEFA as Sea Fisheries Policy Manager.

Stuart Jenkins

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Industry scallop survey (2020)

MANX FISH PRODUCERS ORGANISATION LIMITED

Survey methods:

At the May 2019 meeting of the Scallop Management Board (SMB) it was decided, in line with scientific advice, that a new industry led, fine-scale scallop survey would add value to the data already collected by the longer-term coarse-scale scientific scallop survey onboard the R.V. Prince Madog. The aim for the industry led survey, which utilises both standard survey dredges and modified queen scallop dredges to better target smaller scallops, was to better assess densities of smaller scallops under MLS (0 – 55 mm for queens and 0-110 mm for kings) that would recruit to the fishery in ~ 2 years whilst also increasing the resolution of the survey stations to enable ground specific trends to be better assessed and to better enable the demarcation of closed areas to protect scallops under MLS during the upcoming fishing season.

This fine-scale industry scallop survey was undertaken for the second year in 2020. The survey was completed onboard two industry vessels (F.V. Benolas and F.V. Sarah Lena) from 18th – 28th April and 21st May 2020 and inline with all local coronavirus restrictions and regulations. The survey extent was expanded from 2019 to include all of the main king and queen scallop fishing grounds (Table 1). All survey areas were split into a fixed grid with a resolution of 1 min (longitude) x 0.5 min (latitude) and each individual ground was subdivided into strata based primarily on depth. Survey cells were sampled randomly within each ground with approximately equal effort in each strata (relative to size) to ensure relatively even distribution of survey effort across each fishing ground and the entire survey area. Within each selected survey cell a 10 minute tow was undertaken at ~ 2.5 knots. Each vessel towed two dredge bars: a 'standard survey dredge bar' consisting of two King and two Queen dredges (Standard Queen dredges had 10 teeth) and a 'juvenile survey dredge bar' of the same design but using modified Queen dredges (modified queen dredges have 17 teeth and a smaller internal mesh) (Figure 1). The design of the 'standard' bar replicates previous survey protocols, whilst the 'juvenile' bar is designed to increase the catchability of very small king and queen scallops. The catch from each dredge was counted and a subsample of up to ~ 50 kings and 50 queens were measured.

Survey timings:

It should be noted that the 2019 industry scallop survey was undertaken in April for the 0-3 nm survey and June for the 3-12 nm survey. The 2020 survey was undertaken in April for both survey zones (with 1 additional survey day in May). It is acknowledged that the discrepancy in survey timing (i.e. 2 month lag in the 3-12 nm zone data for 2020 compared to 2019) may have an effect on comparative inter-annual size-data, since scallops sampled in 2019 had an additional 2 months of growth prior to measurement.

Ground	Zone	Survey Days	Surveyed
TAR	3-12	3	2019 & 2020
CHI	3-12	3	2019 & 2020
EDG	3-12	6	2019 & 2020
POA	3-12	1	2020 only
ECO	0-3	2	2020 only
BRA	0-3	3	2020 only
MGH	0-3	0.5	2020 only

Table 1: Survey areas (ground), location (zone) and survey effort for 2020 (days) as well as which years the grounds were surveyed.

Figure 1: 'Juvenile' survey bar showing the two modified queen scallop dredges in the centre of the bar (17 teeth and smaller mesh) and two standard king scallop dredges on the outside of the survey bar.

Ground inclusion:

Point of Ayre (POA), Maughold (MGH), Bradda (BRA) and the inshore East Coast (ECO) grounds were surveyed for the first time in 2020 and so there was no comparative data from 2019 to compare the abundance patterns to for these grounds. Therefore in order to provide an inter-annual analysis for the Isle of Man territorial waters, only data from the offshore East Douglas (EDG), Chickens (CHI) and Targets (TAR) grounds were included in the comparative territorial waters analysis for both king and queen scallops. All grounds are assessed individually as well in line with data availability.

Covid - 19:

Due to the coronavirus restrictions and border regulations in place in both the Isle of Man and the UK in April 2020 the annual scientific survey, which is usually used for stock assessment, was cancelled. The industry survey, which was completed by local vessels and crew based from Isle of Man ports, was able to be completed in April 2020 in line with all local Coronvirus restrictions, social distancing regulations and border policies. With no long-term time series update available for April 2020 the management advice for both the 2020 queen scallop and the 2020/2021 king scallop fishing seasons was based largely on the data analysis and results from this short-term industry survey, whilst acknowledging the context of longer-term survey outputs from previous quantitative stock assessments and fishery dependent data from the respective fisheries. As stated in the previous section not all fishing grounds have comparative data for 2019 and 2020 as the survey was expanded to incorporate several additional fishing grounds for the first time in 2020.

Reports analysing the industry survey data were prepared in collaboration with the MFPO for both scallop species and presented to the scallop management board (SMB) for discussion of the results. Summaries are presented for each species later within this Annual Report.

The full reports are also available on request from i.bloor@bangor.ac.uk

Industry Survey Results (2020): Queen scallops

The Industry survey index data presented here (Figure 2 & Figure 3) are based on the geometric mean due to the skew in the data and based on juvenile dredges as these appear the most efficient gear for both post-recruits and recruits.

The overall data for the TS indicates that the survey index has increased for post-recruits (over 55 mm) from 3.40 in 2019 to 6.42 in 2020 and decreased for recruits (under 55 mm) from 1.09 in 2019 to 0.82 in 2020. A recruitment peak (i.e. new recruits ~ 25-45 mm or 1 year olds) can be seen in the 2019 survey data. This peak was focused in two key areas at Chickens and Targets which were protected by closures and by 2020 this peak had grown into the fishery. However, no new recruitment peak is present in 2020, this is an important consideration when looking at sustainable management over a > 1 year period.

For TAR, which had no fishing effort during the 2019 queen scallop fishery, the post-recruit index increased (1.50 for 2019 and 7.09 for 2020) whilst the recruit index remained relatively stable (2.16 for 2019 and 1.98 for 2020). The survey index for the closed area at TAR, which was closed in 2018 and 2019 to protect high densities of scallop recruits, increased significantly for post-recruits (0.88 in 2019 to 54.60 in 2020) and was relatively stable for recruits (26.6 in 2019 to 23.7 in 2020).

For CHI, which had a small amount of fishing effort during the 2019 queen scallop fishery (~24 t dredge and ~ 5 t trawl) both the post-recruit index (1.71 for 2019 and 4.61 for 2020) and the recruit index (1.66 for 2019 and 2.43 for 2020) increased. The survey index for within the 2019 closed area, closed to protect high densities of recruit scallops (king and queen), saw an increase for post-recruits (1.10 in 2019 to 71.6 in 2020) and a large decrease for recruits (62.1 in 2019 to 6.37 in 2020). The shift in abundance indices for recruits and post-recruits is a result of growth within the cohort identified in the 2019 survey, which was protected during the 2019 season by a closed area (*note: the highest recorded densities from the industry survey were recorded for post-recruits in a closed area targeted tow at CHI: 327 queenies per 100 m^2*).

For EDG which was the fishing ground with the majority of fishing effort and landings from the 2019 fishery (~543 t) the post-recruit index increased (6.28 for 2019 and 7.10 for 2020) whilst the recruit index decreased (0.68 for 2019 and 0.32 for 2020). The survey index for the hotspot area at EDG, which had the highest post-recruit densities in the TS in 2019 and where the majority of the season's fishing effort occurred, decreased for both post-recruits (90.50 in 2019 to 38.50 in 2020) and recruits (4.22 in 2019 to 1.65 in 2020). These localised decreases within the hotspot area equate to > 50% decline of both indices, indicating that there has been a significant decrease in queen scallop densities within this localised hotspot.

For POA, which had no fishing effort during the 2019 queen scallop fishery and no 2019 survey data, the post-recruit index for 2020 was 4.51 and the recruit index for 2020 was 0.80.

For BRA, which has not had any quantity of recent fishing activity for queen scallops (though historically there has been activity and densities recorded in the longer term survey) and no 2019 survey data, the post-recruit index for 2020 was 3.05 and the recruit index for 2020 was 4.88. There are good densities specifically of recruits at this site which may require consideration of a partial closed area. For queen scallops this area seems to be a transient rather than permanent bed as it doesn't recruit annually and should be considered as such in any management decisions.

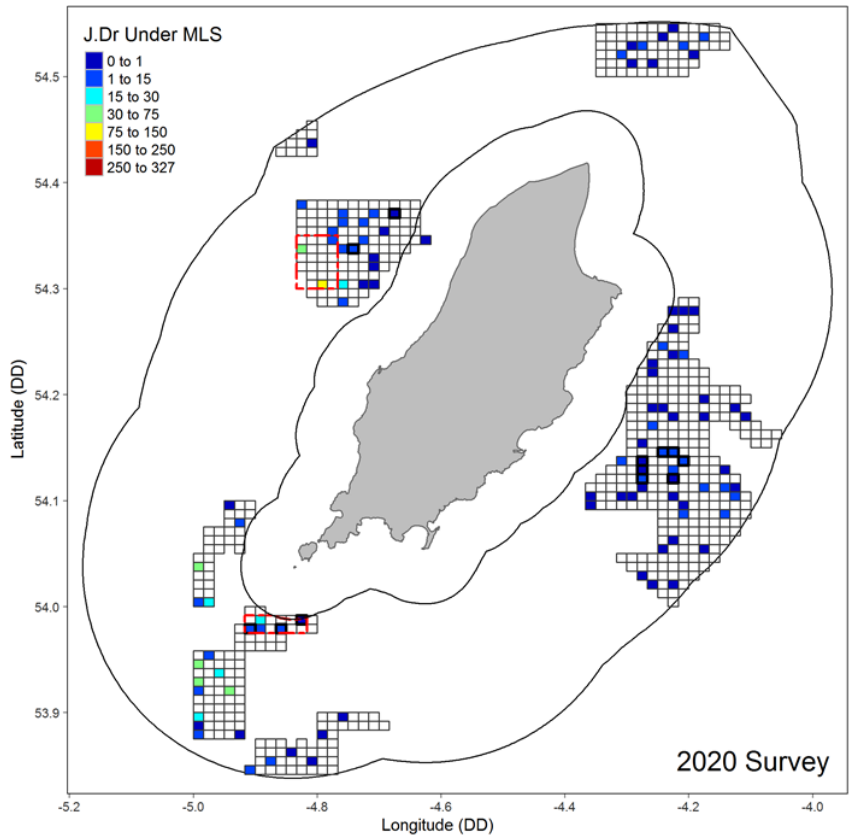


Figure 2: Map illustrating the survey densities for queen scallops under MLS from juvenile dredges for 2020, The red boxes indicate areas closed to king and queen scallop fishing in 2019. Black borders indicate cells that were part of an additional targeted survey and are not included in the main analysis for the TS, or for individual fishing areas (although they are used in the closed area or hotspot analysis).

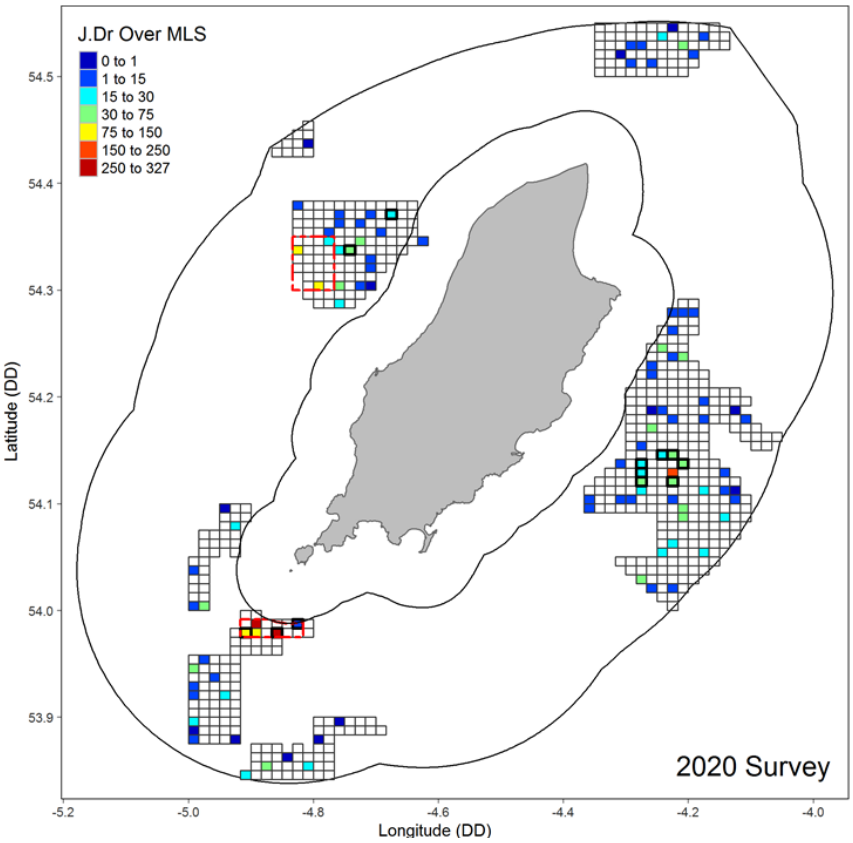


Figure 3: Map illustrating the survey densities for queen scallops over MLS from juvenile dredges for 2020, The red boxes indicate areas closed to king and queen scallop fishing in 2019. Black borders indicate cells that were part of an additional targeted survey and are not included in the main analysis for the TS, or for individual fishing areas (although they are used in the closed area or hotspot analysis).

The full report is also available on request from i.bloor@bangor.ac.uk

Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). Queen Scallop: 2020 Industry Survey Analysis. Bangor University and Manx Fish Producers Organisation Combined Report for the Scallop Management Board, pp. 30.

Queen Scallop Stock Advice (2020)

With no long-term time series available for April 2020 the management advice for the 2020 queen scallop (QSC) fishery was largely based on the data analysis and results from the short-term survey, whilst continuing to acknowledge the context of longer-terms survey outputs from previous quantitative stock assessments and fishery dependent data from the fishery. As previously stated the short-term survey has comparative data from 2019 and 2020 for EDG, CHI and TAR but there is only data for 2020 from POA and BRA (Table 1).

2020 Management Recommendations:

The combined TS survey indices (EDG, CHI and TAR) for 2020 recorded an increase for post-recruits and a decrease for recruits compared to 2019. The survey data from 2019 indicated a good recruitment peak (~ 25 – 45mm queen scallops) which was suitably protected and managed during the 2019 fishing season to enable these queen scallops to grow into the fishery in 2020, as reflected in the 2020 survey data and the increase in post-recruit abundance. A similar recruitment peak is not present in the 2020 survey data and as such management should be considered within a two-year window, i.e. assessing the fishable stock this year (post-recruits) and the potential fishable stock for next year (recruits) together, rather than focusing on the post-recruit densities alone.

A precautionary approach was recommended for management of the 2020 queen scallop fishing season, due to;

- The lack of long-term (5+ years) data required for the ICES Cat 3 data limited approach;
- The observed decrease in the recruit density in the 2020 survey compared to 2019;
- Absence of directly comparable 2019 survey data for several fishing grounds

It was recommended that this precautionary management approach for 2020 should incorporate all of the following three elements:

Spatial management: A spatial divide of the TAC to avoid the entire TAC being harvested from a single area (i.e. a “soft” TAC for each ground) which can also allow flexible spatial management (i.e. individual grounds to be opened or closed).

Closed area management: Managed opening of current closed areas and establishment of new closed areas to continue the protection of high density areas of queen scallop recruits identified in the survey.

In-season reviews: To include scheduled monthly reviews of the fishery and triggered reviews of individual grounds based on in-season fisheries dependent data.

General recommendations for the 2020 queen scallop fishery based on the survey data analysis therefore included:

Trawl TAC:

- An initial precautionary starting trawl TAC for 2020 of 557t (i.e. 0% change from 2019 trawl TAC).

- Scope to adjust the starting trawl TAC by a maximum of 20% based on monitoring of fishery dependent data in-season (i.e. arising from monthly or triggered reviews).
- A split of the TAC between the main four fishing grounds (e.g. based on survey density and the area of each fishing ground) using "soft" TACs.

In-season reviews:

- Consideration of "soft" LPUE thresholds for each ground (based on previous seasons data)
- Monthly reviews of the TAC and fishery (i.e. end of July and end of August)
- Triggered immediate reviews in response to either "soft" TACs or "soft" LPUE thresholds being reached for an individual fishing ground.

Closed Area management:

- A managed opening of the current CHI Closed Area (& discussion about closure for SCE season)
- A closure to protect high density of recruits in the western area of the CHI fishing ground
- A managed opening of the northern section of the TAR Closed Area
- A continued closure of the southern section of the TAR Closed Area (potentially spatially extended for SCE recruits)
- A continued closure of the East Douglas Experimental Research Area (EDGERA) to enable continued monitoring of the recovery of this area as well as scientific trials to better understand recruitment and habitat recovery in this fishery.

Transient scallop beds:

- Management of the queen scallop bed identified in the 2020 survey at Bradda offshore which appears to be a transient rather than permanent queen scallop bed should be considered. There are good densities of recruits within this area which may require management or protection during the 2020 fishing season.

Dredge TAC:

- Any dredge TAC, which is typiccally restricted to the CHI dredge zone, would also need to be considered (total dredge landings from 2019/2020 were only 18.5t of the 58.29t TAC).

Future work on recruitment:

The differences in general oceanography and frontal systems across the territorial sea might lead to long-term recruitment patterns varying considerably among individual fishing grounds. At present we only have two years of data for the three main queen scallop fishing grounds. As the time series continues to extend then the survey data will provide a better insight into what is average, good and poor in terms of recruitment densities for individual grounds. Historical analysis of the scientific survey data would for example indicate that larger recruitment events typically occur at CHI and TAR compared to EDG or POA. A longer term data set will therefore provide more information on what is normal in terms of recruitment at the fishing ground level. This in turn will assist with a longer-term management approach and knowing when to expect above average fisheries within each ground in the coming year(s).

Queen Scallop Trawl Fishery Update (2020)

Management measures at the start of the season:

- The quota for the 2020 Isle of Man queen scallop fishery was initially set at 557 t, which was equal to the TAC at the end of the 2019 season.
- The weekly catch limit for the fishery was initially set at 2695kg per vessel
- The TAC was subdivided among the four main fishing grounds (and a transient ground at Bradda) to create soft monitoring limits for each ground that were monitored every two weeks during the fishery.
- Additional reviews of individual fishing grounds were triggered when 90% of the soft monitoring limits were achieved. The soft monitoring limits for each ground were EDG 235t, TAR 140t, CHI 140t, POA 35t and BRA 7t.
- The fishery opened on Wednesday 1st July

Main management changes during the season included:

- Extension of 90 t to the TAC during Week 11 to increase the TAC from 557t to 647t
- Weekly catch limit increased to 3150kg per vessel from Week 5 onwards.
- EDG closed on Tuesday 8th September due to declines in LPUE
- POA closed on Tuesday 22nd September due to low LPUE
- Closure of the queen scallop trawl fishery on 30th September 2020 as TAC achieved

Total landings (Figure 5) for the queen scallop trawl fishery were ~ 660t (+ 0.79t from Ramsey Bay), following a 90t extension to the TAC in Week 11, with 26 unique vessels reporting landings (4 vessels fewer than 2019). The majority of vessels achieved their weekly catch (this varied weekly from 78.5% to 97.7% of vessels achieving their weekly catch limits). Where the weekly catch limit was not achieved this may have been the balance between the economics of completing an additional trip versus the value of the remaining weekly catch for that vessel.

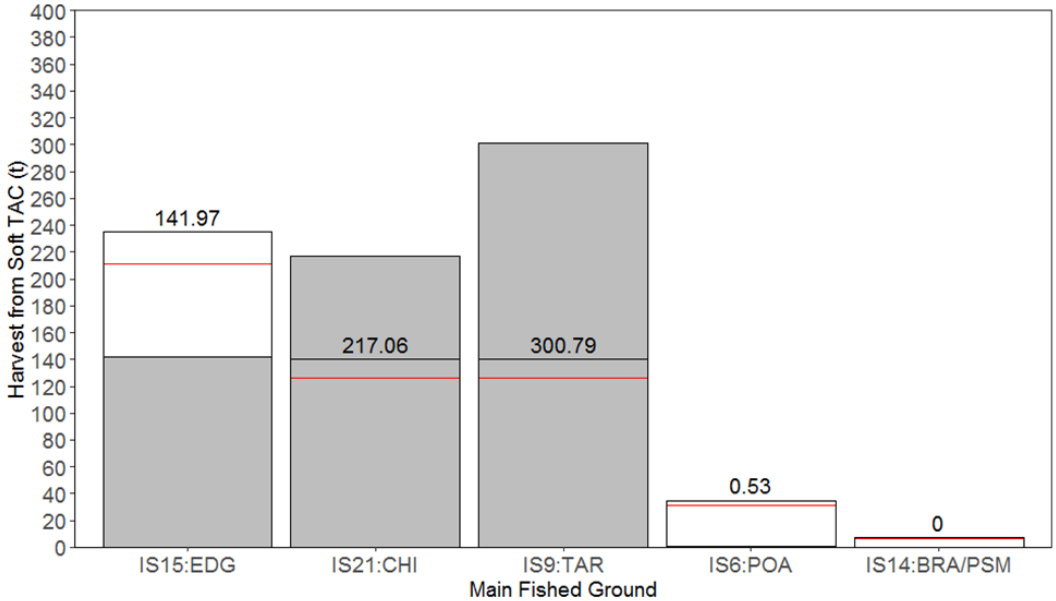


Figure 4: Total landings (t) of queen scallops from four of the main fishing grounds (and one transient ground). Grey portion of column indicates actual landings (shown in t for each bar) and white portion of column indicates the soft monitoring limits where lower than actual landings (red lines indicates 90% of these soft monitoring limits).

Landings from each of the five main fishing grounds are shown in Figure 4 and were monitored against both the soft monitoring limits (see above) and LPUE thresholds modelled using historic data for each ground. East Douglas (EDG) was closed prior to achieving the soft monitoring limit (~142t of 235t landed) due to declines in LPUE below the LPUE threshold set. Chickens (CHI) and Targets (TAR) both remained open despite landings exceeding the soft monitoring limits (~217t of 140t allocated for CHI and ~300t of 140t allocated for TAR landed) as LPUE remained above the LPUE threshold at both grounds. Point of Ayre (POA) was closed despite low landings as the LPUE for the limited vessel trips undertaken was well below the LPUE threshold set for this ground (~ 0.5t of the allocated 35t landed). The transient ground at Bradda (BRA/PSM) remained open for the duration of the season but 0t was landed from this ground.

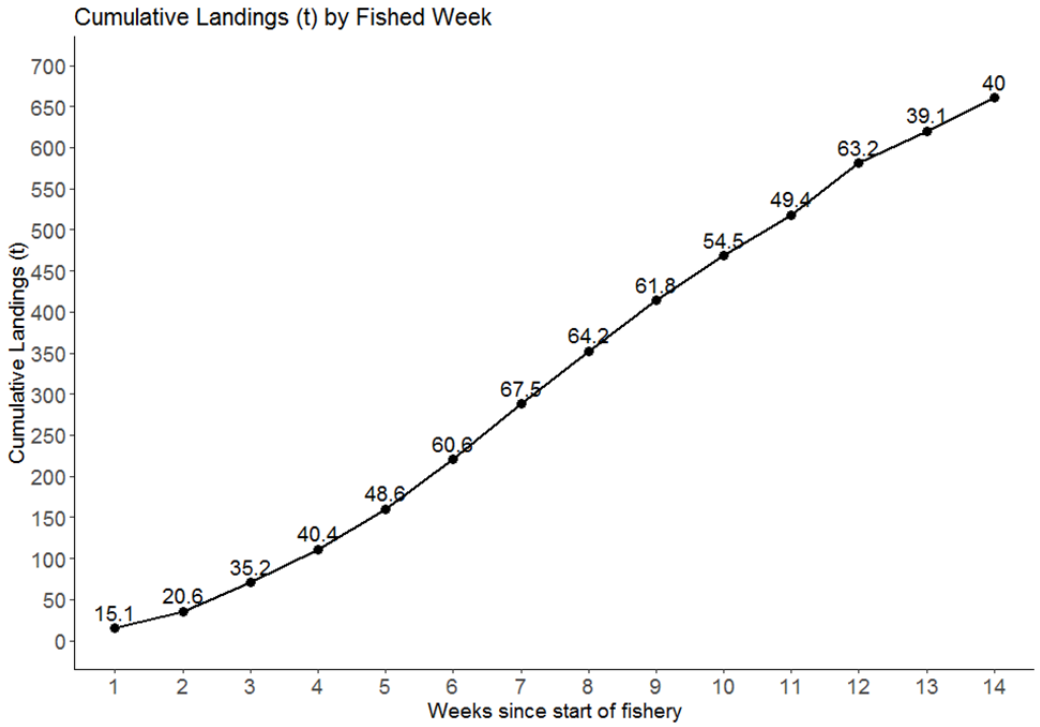


Figure 5: Cumulative landings (t) for the 2020 queen scallop fishing season in the Isle of Man. Points indicate weekly totals.

Queen Scallop Dredge Fishery Update (2020)

The quota for the 2020 Isle of Man queen scallop dredge fishery was 58.29t (equal to the TAC set for 2019). The dredge fishery opened on 1st October and closed on 31st October 2020. Management of the dredge fishery continues to operate differently from the trawl fishery with each vessel being allocated an individual quota that could be fished as and when suited by the vessel during the season.

The four eligible vessels that nominated to participate in the fishery were each assigned an individual quota for the season of 14,575kg. Although the SMB has had discussions about changing the location of the queen scallop dredge fishery, at present the fishery continues to be restricted to a Queen Scallop Dredge Zone on the south of the Island within the Chickens fishing ground and this section of the queen scallop fishery is targeted exclusively by UK vessels.

Total reported landings for the 2020 dredge fishing season were ~ 0.39t with only 1 unique vessel reporting landings. This is a reduction of 1 unique vessel targeting the fishery compared to the previous 2019 fishery when 2 unique vessels fished. Landings per unit effort (LPUE) were standardised to kg per dredge per hour fished and averaged 5.4kg per dredge per fished hour (down from 20 and 23kg in 2019 and 34 and 27kg in 2018 for Week 1 and Week 2 respectively).

Review: King Scallop Fishery (2019/2020)

Electronic monitoring via Nestforms Apps continues to be used in the king scallop fishery providing high resolution data. This allows monitoring and analysis of commercial data for this fishery to be produced in near real-time. The analysis, which is provided on a weekly basis, enables the SMB and DEFA to respond rapidly to conditions in the fishery as they occur.

The total allowable catch (TAC) for the 2019/2020 Isle of Man king scallop fishery was 2049t. This represented a 20% reduction in the quota following further declines in the survey abundance index in 2019. Total reported landings for the Isle of Man king scallop fishery during the 2019/2020 season were ~ 1186t (+ 45.9t from Ramsey Bay which has its own TAC) with 64 unique vessels reporting landings. This was ~ 10 fewer unique vessels than in the previous season (2018/2019). Figure 6 shows the cumulative landings for the king scallop fishery by fished month (totals for individual fished months labelled).

'Soft' monthly targets were introduced as guides to aid fishery management and monitor the uptake rate of the TAC over the season (Table 2). If a soft target was either exceeded or not achieved in a given month this provided a cue to the Scallop Management Board (SMB) to discuss whether current daily catch limits (DCL) remained appropriate. Soft targets were calculated by allocating the TAC proportionally among months based on historical landings patterns (averaged from 2012/2013 season to the 2015/2016 season). May, the final month of the season, was the only month where the soft target was exceeded. The DCL was maintained at 560kg for the majority of the season with around 56% of vessel trips achieving ~ 516kg or above during these standard DCL periods (for economic reasons the DCL was temporarily increased to 630kg in December when the price of scallops is higher with the Christmas market; only around 35% of vessel trips achieved ~586kg or above during the increased DCL period). Total landings for the 2019/2020 season were around 42% less than the actual TAC.

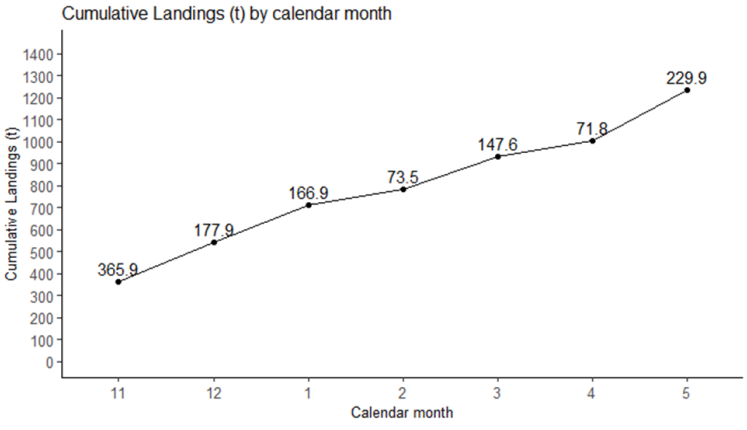


Figure 6: Cumulative landings (t) over the 2019/2020 king scallop fishing season in the Isle of Man. Points indicate monthly totals.

Table 2: Soft monthly targets (t) based on average landings from previous seasons compare to actual landings per month (t). Proportion indicates the percentage of the soft targets achieved within each month.

Month	Soft Target	Landings	Proportion
Nov	479	365.9	76.39
Dec	198	132	66.65
Jan	210	166.9	79.47
Feb	336	73.5	21.88
March	348	147.6	42.41
April	284	71.8	25.28
May	194	228	117.5
Total	2049	1186	57.87

Figure 7 illustrates the mean landings per unit effort (LPUE) by week standardised to kg per hour fished per dredge (kg/Dr/HrF) at each of the main fishing grounds for the last three fishing seasons (e.g. 2017/2018 to 2019/2020). For 2019/2020 LPUE was highest at the limited permit only fishery that occurs in December within the Fisheries Management Zone of Ramsey Bay (~ 40kg/Dr/HrF) (*N.B. A commercial survey also took place in Ramsey Bay towards the end of the season*). For 2019/2020 the LPUE at all other grounds ranged between 0 and 10 kg/Dr/HrF.

In Figure 8, landings are reported by main fished ground and separated by colour for each month to show the spatial location of landings. There was a relatively even split of landings across the season from five of the main fishing grounds (IS9: Targets, IS21: Chickens; IS15: East Douglas, IS14: Bradda/Port St Mary and IS10: Maughold) with IS9: Targets recording the highest proportion of landings.

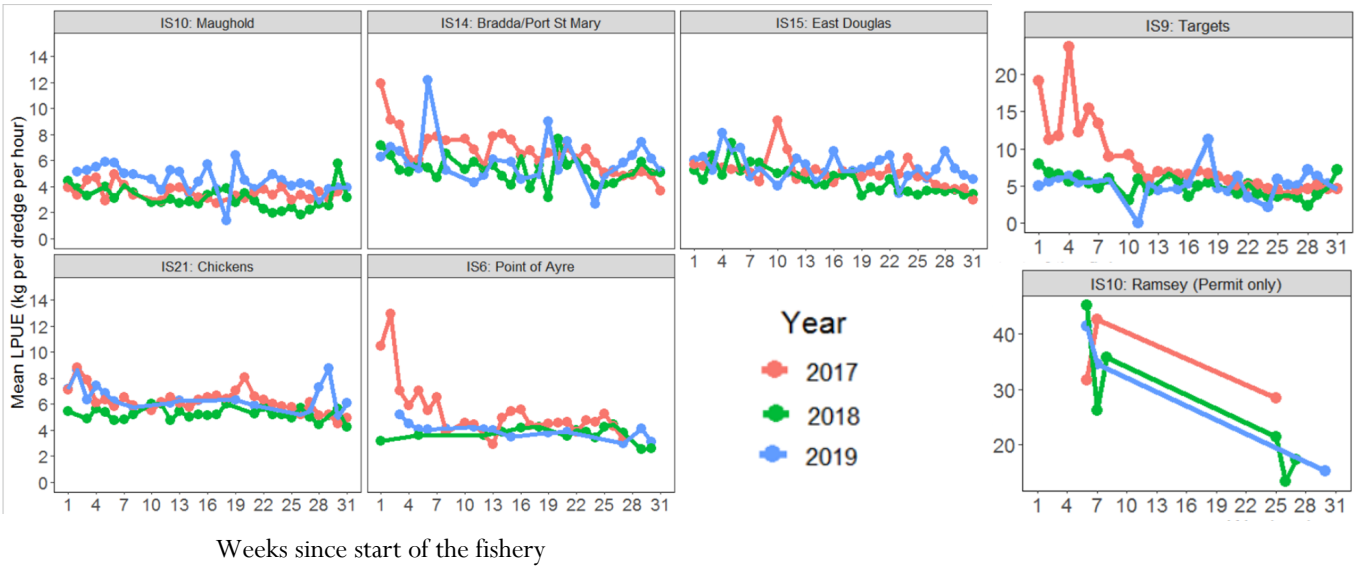


Figure 7: A comparison of LPUE (kg per dredge per hour fished) for the 2018/2019 (blue), 2018/2019 (green) and 2017/2018 (red) king scallop fishing seasons averaged by week and displayed by main fished ground. ***Note the different scales on the y-axes for Ramsey and Targets***

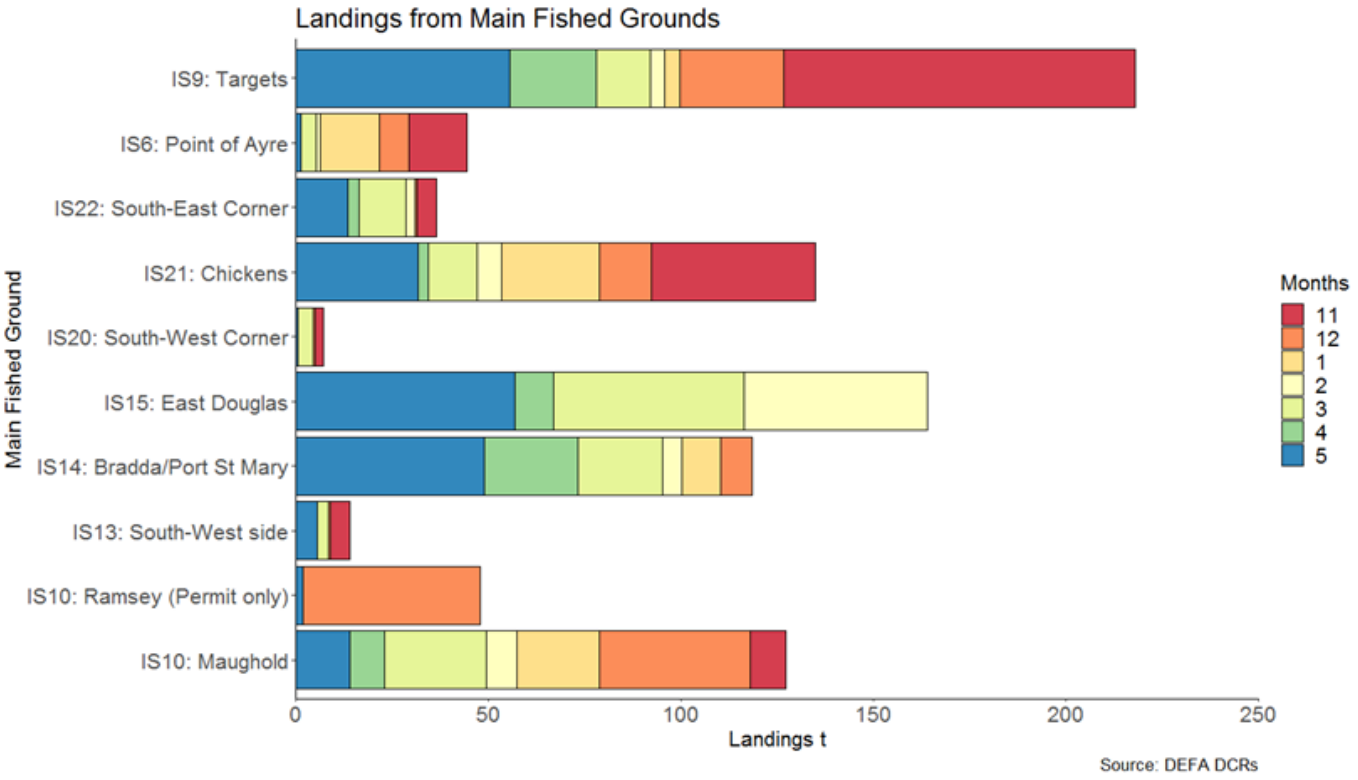


Figure 8: Total landings (t) of king scallops by month from the 10 main fished grounds for the 2019/2020 fishing season.

Industry Survey Results (2020): King scallop

The Industry survey index data presented here (Figure 9 & Figure 10) are based on the geometric mean due to the skew in the data and based on juvenile dredges and standard queen scallop dredges for recruits (i.e. king scallops < 90mm) and standard king and standard queen for post-recruits (i.e. ≥ 90mm) as these appear the most efficient gear types respectively for each.

The industry led survey only had comparable data from 2019 and 2020 for three of the main king scallop fishing grounds (East of Douglas [EDG], Chickens [CHI] and Targets [TAR]) with data from the remaining 3 -12 nm fishing ground at Point of Ayre [POA] and the 0-3 nm fishing grounds Bradda [BRA], East Coast [ECO] and Maughold [MGH] available only from the most recent survey (i.e. 2020). Analyses were undertaken for each individual ground for 2020 but only the three fishing grounds (EDG. CHI and TAR) surveyed in both years were included in the inter-annual analysis for the combined territorial waters section.

The overall data for the TS showed a slight **decrease in the survey index for recruits** (under 90 mm) from **0.17 in 2019 to 0.14 in 2020** and **an increase for post-recruits** (over 90 mm) from **0.60 in 2019 to 0.72 in 2020** (Table 3).

For TAR, the survey index had increased for post-recruits (over 90 mm) from **0.62 in 2019 to 0.86 in 2020** as well as for recruits (under 90 mm) **from 0.10 in 2019 to 0.17 in 2020**. *Note: the highest recorded densities for king scallops for 2020 were recorded in the southern area of the Targets fishing ground, east of the current Closed Area: ~ 10 king scallops per 100 m^2 (recruits).*

For CHI, the survey index within the whole fishing ground has decreased for recruits (under 90 mm) from **0.11 in 2019 to 0.09 in 2020** and remained constant for post-recruits (over 90 mm) **at 0.60 in 2019 and 2020.** The survey index within the 2020 newly opened area (NOA) which was closed for the 2019 king scallop fishing season to protect high densities of recruits, saw an increase for post-recruits (1.68 in 2019 to 2.46 in 2020) and a decrease for recruits (1.90 in 2019 to 0.75 in 2020).

For EDG, the survey index within the whole fishing ground has decreased for recruits (under 90 mm) from **0.30 in 2019 to 0.15 in 2020** and increased for post-recruits (over 90 mm) **from 0.59 in 2019 to 0.72 in 2020.** The survey index for targeted survey cells (which were located within a hotspot area for queen scallops in 2019), indicates high densities of post-recruits in this area (**geometric mean of 2.83 and a maximum recorded density of 7.03 in 2020**) following relatively high levels of recruits in 2019.

Table 3: A summary of changes in survey density for over and under 90 mm king scallops by ground. Landings (t) are also displayed for 2019/2020 king scallop fishing season for each ground and indications of fishing inside or outside of the 3nm limit (source: DCRs).

Area	Ground	2019 <90mm	2020 <90mm	Diff.	2019 >90mm	2020 >90mm	Diff.	Landings t 2019/20
T.S.	T.S.	0.17	0.14	-	0.60	0.72	+	1186
3-12 nm	EDG	0.30	0.15	-	0.59	0.72	+	401
	TAR	0.10	0.17	+	0.62	0.86	+	218
	CHI	0.11	0.09	-	0.60	0.60	=	179
	POA	NA	0.13	NA	NA	0.67	NA	44
0-3 nm	ECO	NA	0.12	NA	NA	0.60	NA	24
	BRA	NA	0.19	NA	NA	0.96	NA	288
	MGH	NA	0.12	NA	NA	0.72	NA	31

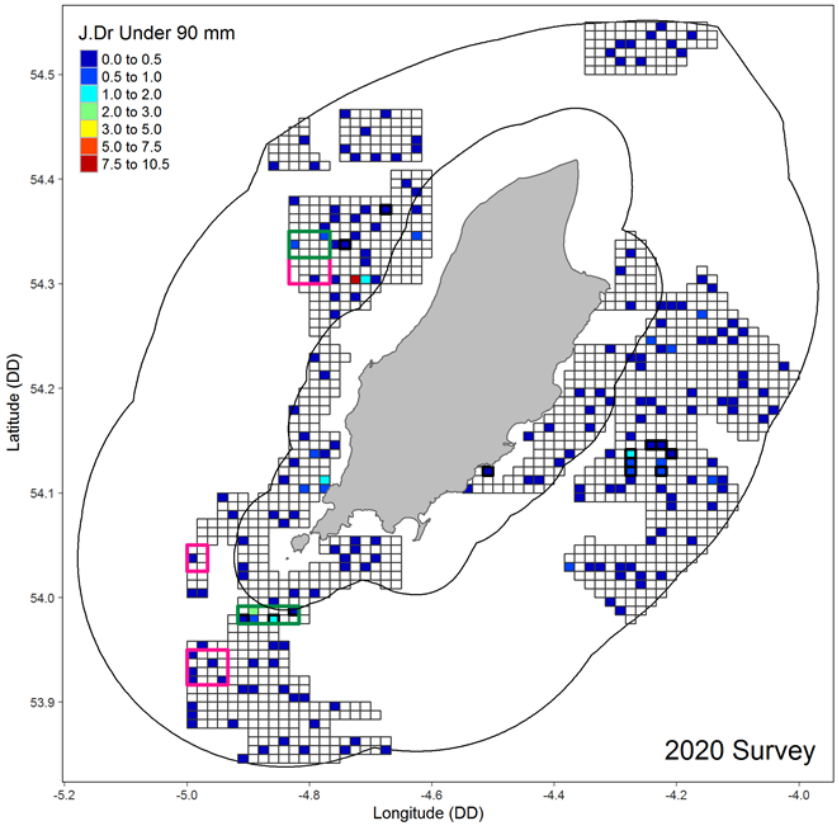


Figure 9: Map illustrating the survey densities (scallops per 100 m2) for king scallops under 90 mm from juvenile and standard queen scallop dredges for 2020. The green boxes indicate areas that were re-opened for the 2020 queen scallop fishing season whilst the pink boxes indicate areas that were closed during the 2020 queen scallop fishing season. Black borders around individual survey cells indicate cells that were part of an additional targeted survey and were not included in the main territorial sea analysis.

For POA, which has no comparative data for 2019, the **post-recruit index for 2020 was 0.67** and the **recruit index for 2020 was 0.13**.

For ECO, which has no comparative data for 2019, the **post-recruit index for 2020 was 0.60** and the **recruit index for 2020 was 0.12**.

For BRA, which has no comparative data for 2019, the **post-recruit index for 2020 was 0.96** and the **recruit index for 2020 was 0.19**.

For MGH, which has no comparative data for 2019, the **post-recruit index for 2020 was 0.72** and the **recruit index for 2020 was 0.12**.

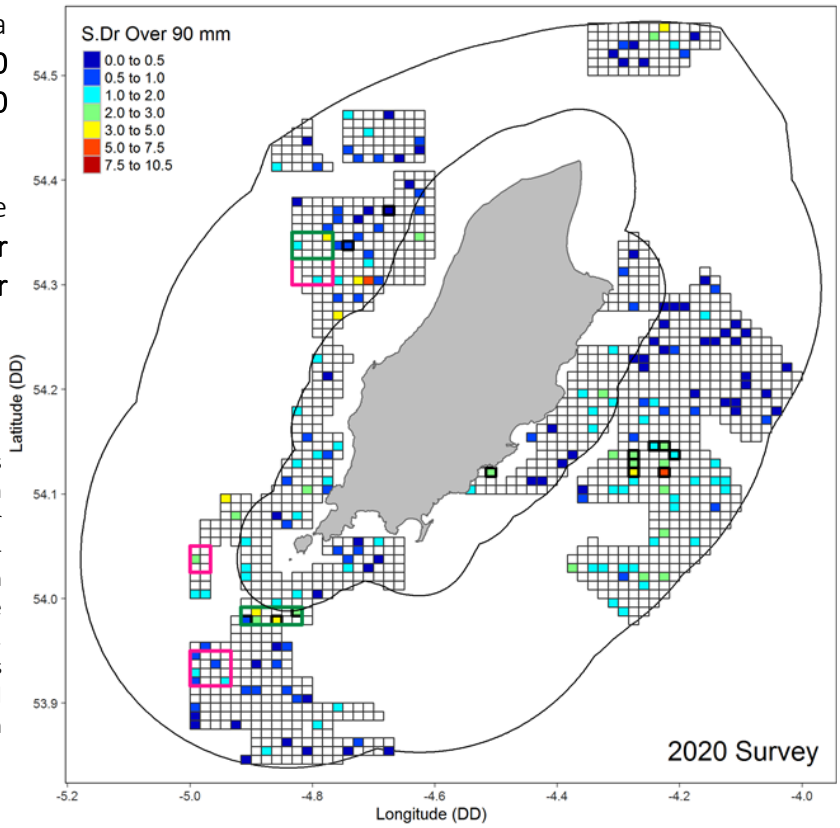


Figure 10: Map illustrating the survey densities (scallops per 100 m2) for king scallops over 90 mm from king and standard queen scallop dredges for 2020. The green boxes indicate areas that were re-opened for the 2020 queen scallop fishing season whilst the pink boxes indicate areas that were closed during the 2020 queen scallop fishing season. Black borders around individual survey cells indicate cells that were part of an additional targeted survey and were not included in the main territorial sea analysis.

The full report is also available on request from i.bloor@bangor.ac.uk

Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). King Scallop: 2020 Industry Survey Analysis. Bangor University and Manx Fish Producers Organisation Combined Report for the Scallop Management Board, pp. 38.

King Scallop Stock Advice (2020/2021)

With no long-term time series available for April 2020 the management advice for the 2020/21 king scallop fishery was largely based on the data analysis and results from the short-term industry led survey, whilst continuing to acknowledge the context of longer-term survey outputs from previous quantitative stock assessments and fishery dependent data.

2020/2021 Management Recommendations:

The short-term high-resolution survey index for 2020 recorded an increase for post-recruits and a decrease for recruits compared to 2019 where inter-annual comparisons were available for the TS (Table 3).

Although survey data suggests that the abundance of king scallops has increased in most areas of Isle of Man territorial waters, a precautionary approach is recommended for management of the 2020/21 king scallop fishing season, due to;

- The lack of long-term (5+ years) data required for the ICES Cat 3 data limited approach;
- The observed decrease in the recruit density in the 2020 survey compared to 2019 (with the exception of a small area in TAR);
- Absence of directly comparable 2019 survey data for several fishing grounds
- The 2019/20 fishing season landing only 58% of the allocated TAC (1186 t out of 2049 t).

It is recommended that the precautionary management approach for 2020/2021 king scallop fishery should incorporate all of the following three elements:

- **In-season reviews:** Monthly reviews of the fishery by the SMB or a subgroup for the entire TS fishery should be scheduled as standard.
- **Spatial monitoring and management:** Spatial monitoring for each individual ground should be undertaken as part of the in-season review to allow flexible spatial management (i.e. individual grounds to be opened or closed) based on the real-time data collected by the fishery. High density areas within a ground (i.e. TAR or EDG) may require additional fine scale management to avoid high fishing intensities and excessive fishing mortality.
- **Closed area management:** The continued management of NOA and current/new closed areas is required to protect high density areas of post-recruits and recruits (king and queen scallops).

General recommendations for the 2020/2021 king scallop fishery based on the survey data analysis produced here therefore include:

TAC:

- When considering the setting of a TAC for the 2020/2021 fishing season, consideration should be given to the fact that although some recovery has been seen within the territorial waters, this is based on harvesting of 1186 t rather than the 2049 t set as the TAC for 2019/2020.
- Scope for adjusting the TAC during the fishing season is required based on fisheries-dependent data (i.e. Daily Catch Return Forms), which is collected in near real-time during the season combined with industry feedback on market conditions.
- Soft TACs which trigger a review should be set for each ground using last year's landings data (i.e. for EDG the initial soft TAC would be 401 t).

In-season reviews:

- Monthly reviews of the TAC and fishery with consideration of LPUE and fishing intensity within each fishing ground.
- ***Triggered Reviews:*** As per the current management trial for queen scallops during the 2020 fishing season, near real-time monitoring of "soft" TACs and "soft" LPUE thresholds for individual grounds could also be used for king scallops to trigger an immediate review by the SMB of an individual fishing ground (i.e. if the "soft" TAC for a ground is met then the LPUE and fishing activity in the area would be assessed to see if the ground should be closed or the "soft" TAC extended to enable the ground to remain open).

Closed Area management:

- The NOA at CHI and TAR contains high densities of queen scallops and king scallop post-recruits (1-5 king scallops per 100 $m^{2)}$. Continued management of this NOA should be discussed by the SMB to ensure that the number of vessels and fishing effort within the area is constrained.
- The closed area at BRA was put in place to protect juvenile queen scallops within a transient bed (i.e. there is not regular recruitment of queen scallops within this area). The benefits of the continued closure of this area during the king scallop fishing season should be discussed.
- The closed area at TAR was put in place to protect high densities of juvenile queen scallops within a ground that has been recovering over recent years. The benefits of the continued closure of this area during the king scallop fishing season should be discussed by the SMB. In addition, ithe extension (or replacement) of the area to the east of the current closure which has the highest density of king scallop recruits recorded during the 2020 survey is recommended.
- Management or closure of the hotspot area at EDG, which has a high density of scallops the majority of which (~ 75 %) were below 110 mm at the time of the April survey, should be discussed by the SMB. One recommendation would be to close this area at the start of the fishery and to undertake additional survey tows within the area to ascertain the size range of the scallops (i.e. have they grown to MLS) before any additional management is considered.

Long-term fisheries management plan:

A long-term management plan (LTMP) for the king scallop fishery is essential for ongoing monitoring, management and recovery of this stock. The LTMP should include a set of aims and goals for the fishery, to provide DEFA, Bangor and the SMB with clear direction in formulating management advice. A LTMP would necessarily include and benefit from collaborative input from industry, including both catching and processing sector considerations.

Irish Sea Management:

The Irish Sea king scallop fishery should be managed at the appropriate spatial scale, which would ideally relate to the functional unit (FU) of the stock. Unpublished genetic and oceanographic research indicates that northern Irish Sea populations of king scallops may be considered a singular, connected functional unit of many sub-populations. The most appropriate unit for managing the fishery in Isle of Man territorial waters may therefore be the Northern Irish Sea FU. It is vital that work continues towards achieving a collaborative management approach for king scallop stocks within the different regions of the Irish Sea.

ICES Workshop on Scallop Ageing (WKSA)

9th –13th March 2020, Marine Scotland Science, Aberdeen, Scotland

The ICES Workshop on Scallop Ageing (WKSA) was set up to review and compare current scallop age reading methodologies, standard operating procedure and quality assurance processes across member institutes and to collaborate to develop best practice. During the workshop the institutes shared expertise and methodologies to develop: understanding; agree standard principles and consensus ageing for reference sets; appraise the potential use of SmartDots; and discuss future exchange programmes.

Figure 11: Delegates assessing and ageing reference shell sets individually and within consensus groups

The WKSA compared current ageing methodologies and quality assurance processes used by member institutes. Preliminary results from analysis of previous scallop exchanges for age determination showed inconsistencies within and among exchange participants and institutes. The WKSA aimed to collaboratively identify and understand the criteria and variables that can introduce differences in age assessments among experienced readers. By obtaining a clear understanding and standardisation of age reading procedures the aim of the WKSA was to improve the accuracy and precision of age reading of king scallops. Progress at the workshop included:

- **SmartDots:** SmartDots is a digital age reading platform developed within ICES. It was introduced to the group as a possible mechanism for future ageing exchanges in king scallops and/or as a potential training tool. The group trialled the platform using a set of high resolution images of scallop shells that had been uploaded to the system. The general consensus was that, whilst the platform could provide significant advances logistically when compared to previous ageing exchanges, more work to investigate the collection of images of sufficient quality to access ageing digital needs to be undertaken first. Once the group are confident that age assessment can be completed using digital photographs then this could become a useful tool for training or shell exchanges.

- Standardised procedures for improving consistency in ageing: The group discussed reasons behind individual aspects of the pre-existing methodologies and how they varied among institutes. Different methodologies reflect confidence in visibility of annuli (annual growth rings), which are influenced by growth, geography and habitat. It was clear that there are morphological differences in the shells from different regions and that annuli might not always be visible to the naked eye. A standard protocol alone was therefore not considered suitable and a set of standardised principles was agreed instead by comparing the methodologies presented and drawing on commonalities to improve consistency in ageing.
- Microscope ageing methods: Microscope ageing was identified as an essential technique for ageing shells presented challenges to ageing or quality checking by eye. A number of institutes concluded that they would look to include microscopes in future as part of their quality assurance. The group agreed that training in microscope shell ageing would be a beneficial part of a further workshop proposed for 2021.
- Reference shell sets: Consensus ageing that included both visual and microscope techniques reduced variation in age determination and the group agreed that consensus ageing was required to produce a reference set of shells for each institute. Establishing a validated reference collection of shells for each institute has been set as a term of reference (ToR) for the next meeting of the WKSA proposed for 2021.

Figure 12: International delegates at the ICES Workshop on Scallop Ageing held at Marine Scotland in March 2020.

The full Report from the Workshop on Scallop Ageing (WKSA) is now available on the ICES website. The citation for this report is:

ICES. 2020. Workshop on Scallop Ageing (WGSCALLOP).

ICES Scientific Reports. 2:57. 43 pp. https://doi.org/10.17895/ices.pub.6090

The next workshop is scheduled to take place in 2021 but has yet to be confirmed due to current travel restrictions as a result of the global Covid-19 pandemic.

ICES Working Group on Scallop Stock Assessment

5th –9th October 2020, virtual via video conferencing

Due to the global Covid-19 pandemic and associated travel restrictions, the 2020 WGScallop meeting was held virtually using video conferencing. The meeting, chaired by Lynda Blackadder from Marine Scotland, was opened on 5th October and was attended by 27 participants from 11 countries (including England, Wales, Isle of Man, Northern Ireland, Ireland, USA, Norway and Iceland) and 14 institutions.

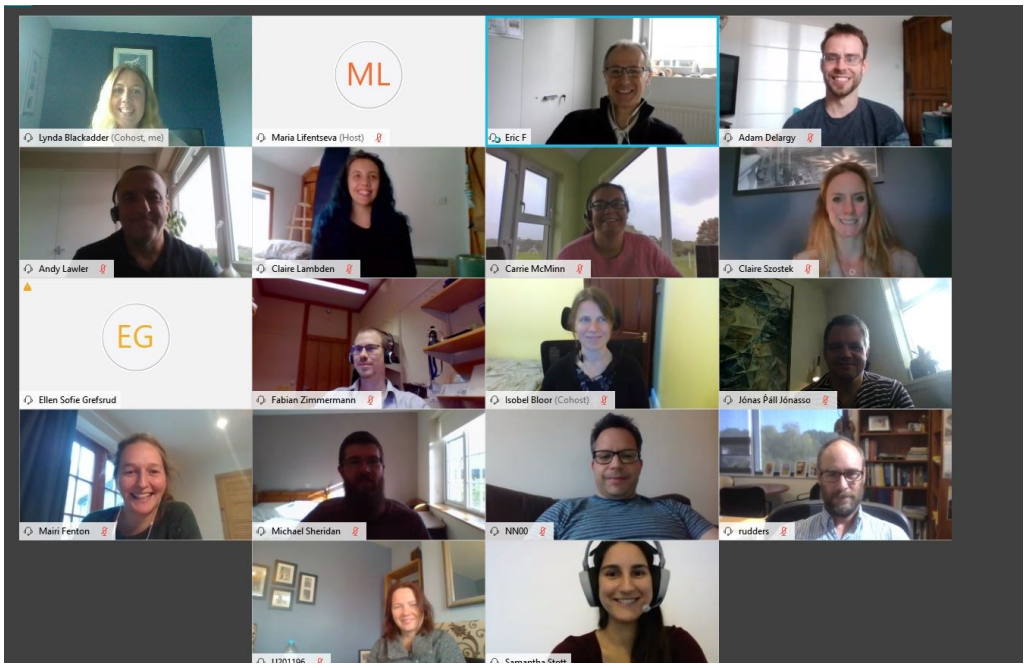


Figure 13: International delegates at the ICES Working Group meeting held via video conference in October 2020.

The ICES Scallop Assessment working group (WGScallop) discusses the key issues surrounding scallop species and is working towards the development and improvement of appropriate stock assessment methods. This is achieved by sharing expertise on survey methodologies, advances in technology and recent studies on various scallop species (i.e. dredge efficiency, incidental and discard mortality, growth, and genetics). Progress at the meeting included:

- **Data call:** WGScallop issued an annual data call through ICES for scallops for the first time. Landings and effort data for scallop species in ICES areas 2,4,5,6,7, and 8 for the years 2000—2019 were requested. Nine countries provided data in some capacity . Data were checked by WGScallop and a number of issues with the data were highlighted. Provisional landings data are provided in the report and work is ongoing to refine the data call and standardise formatting of the data and cross checks.

- **Stock assessment for North Irish Sea:** Significant progress was made towards this term of reference (ToR) in Year 2 with the subgroup developing universal templates for each institutions to collate their survey data and landings in a standardised format that can be used for exploratory modelling. The data were collated prior to the meeting and initial exploratory assessments were undertaken using a simple surplus production model (input data includes survey biomass, swept area and commercial landings and discard data) and a more complex surplus production model (which requires an additional time-series of effort data—kW days).

Initial discussions based on these exploratory assessments highlighted a range of challenges and the sub group plan to meet regularly over the next 12 months to continue to progress this ToR. This will include the trialling of relevant stock assessment methods and the standardisation of survey and commercial input indices.

- **VMS Polygons (King Scallops):** To assist with defining stock assessment extents the WG provided polygons indicating the extent of king scallop fishing based on a long term time series of vessel monitoring system (VMS) data (i.e. 2009—2019). This enabled the fishing areas of national fleets to be mapped and quantified across the Irish Sea. Preliminary maps are presented below (Figure 14) and will be verified with industry and additional available information next year. For example VMS is not compulsory for EU vessels under 12m (unless fishing for scallops in the Isle of Man territorial waters) and so data is missing from a portion of the fleet.

- **Scientific survey review:** Scallop surveys continue to be an important data source for the stock assessment in many areas and it is acknowledged that a break in the survey time-series (years with no data) is not ideal. In some situations it may make the provision of management advice particularly difficult. The Covid-19 global pandemic has caused significant disruption for most institutes and their annual scallop surveys, including the Isle of Man survey which was cancelled in April 2020 due to national lockdowns and CV restrictions.

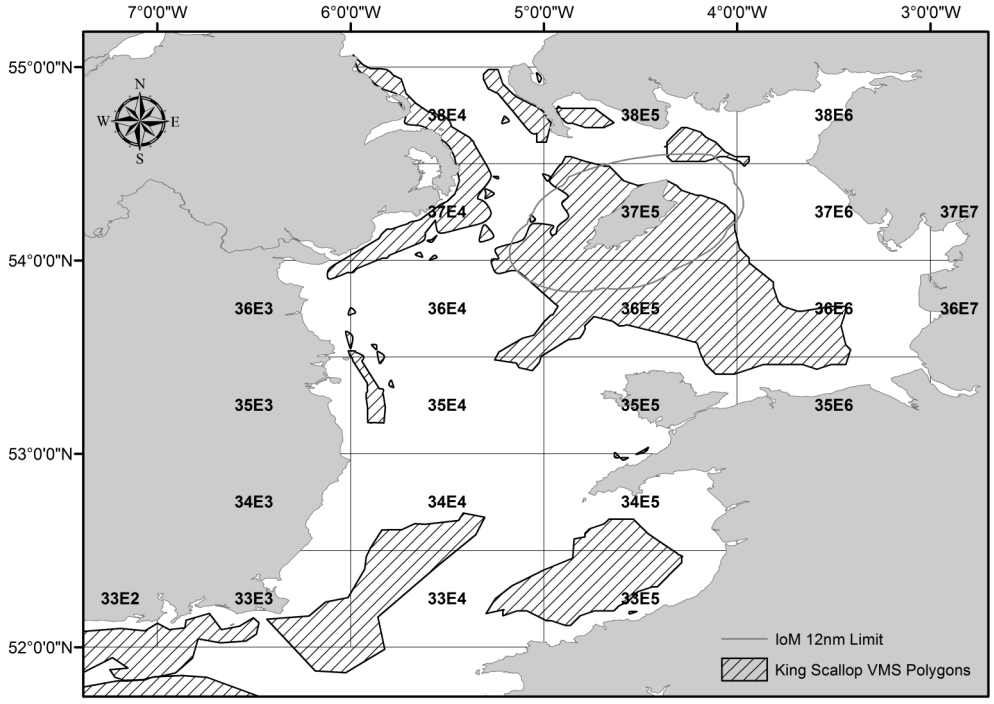


Figure 14: VMS polygons showing the outer extent of historical king scallop fishing activity in the north Irish Sea.

The full 2020 Report of the Scallop Assessment Working Group (WGScallop), which covers all terms of reference and a summary of all progress from the meeting, is now available on the WGScallop community page. The citation for this report is:

ICES. 2020. Scallop Assessment Working Group (WGSCALLOP).

ICES Scientific Reports. 2:111. 57 pp. https://doi.org/10.17895/ices.pub.7626

The next meeting will be hosted by the Marine & Freshwater Research Institute in Iceland from 4th – 8th October 2021 (Covid-19 travel restrictions permitting).

Potting Sector Fisheries: Crab, Lobster & Whelk

The potting sector of the fishing industry on the Isle of Man remains defined by three target species; crab (*Cancer pagurus*), lobster (*Homarus gammarus*) and whelk (*Buccinum undatum*). These three fisheries face separate challenges and gaps in scientific knowledge, but with some common themes. By collaborating closely with industry and DEFA, Bangor University is working to understand and address these challenges. During 2020, the Isle of Man Government launched a public consultation on the management of crab and lobster fisheries within Isle of Man waters. The consultation was largely based upon the discussions held within the crab and lobster working group, which Bangor University supported by way of data analysis and providing evidence.

Covid-19 had a significant impact on fishing activity in Isle of Man waters during 2020, both on the supply (i.e. vessels going to sea and hauling gear) and demand (market demand for seafood products, which sets prices) of shellfish. As a result, much of the fisheries dependent data presented here is significantly affected by these events, and temporal trends over years must acknowledge possible covid-19 related effects.

Whelk (*Buccinum undatum*) Fishery Update

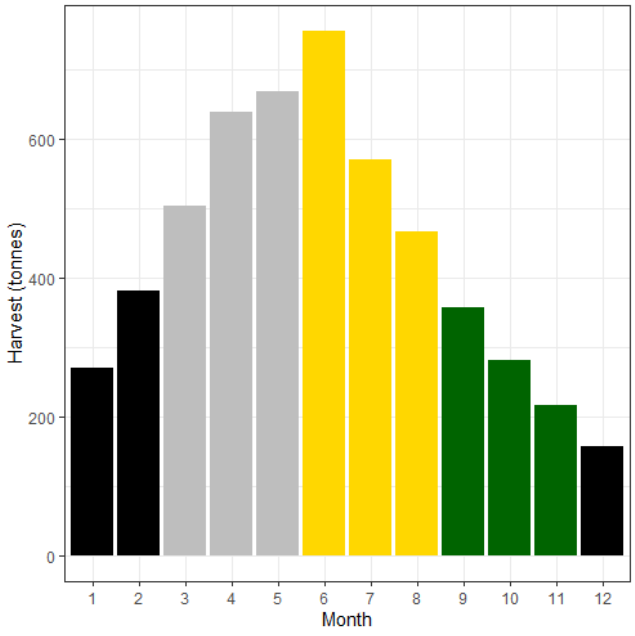
Management of the whelk fishery in the Isle of Man territorial sea is not yet informed by stock assessments and fisheries-independent surveys of stock biomass. Additionally, spatial information (VMS or equivalent) is absent for the vast majority of whelk fishing activity (i.e. landings by vessels <12 m length overall). Trends in fisheries-dependent data are therefore presented on a whole territorial sea level.

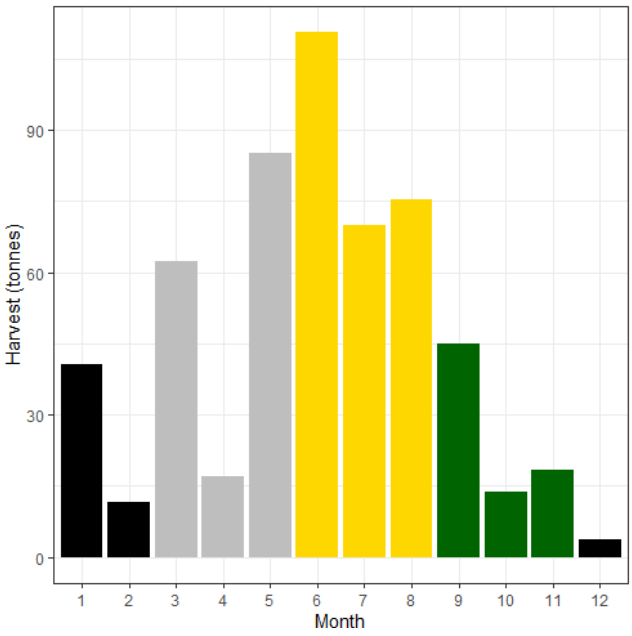
In 2020, the landings of whelk into the Isle of Man was 519 t, a reduction equal to -37% compared to 2019. The total effort by Isle of Man registered vessels was c.305,000 pot-lifts, a reduction equal to -20% compared to 2019. Therefore, the average Manx whelk vessel lifts 507 pots per day-at-sea.

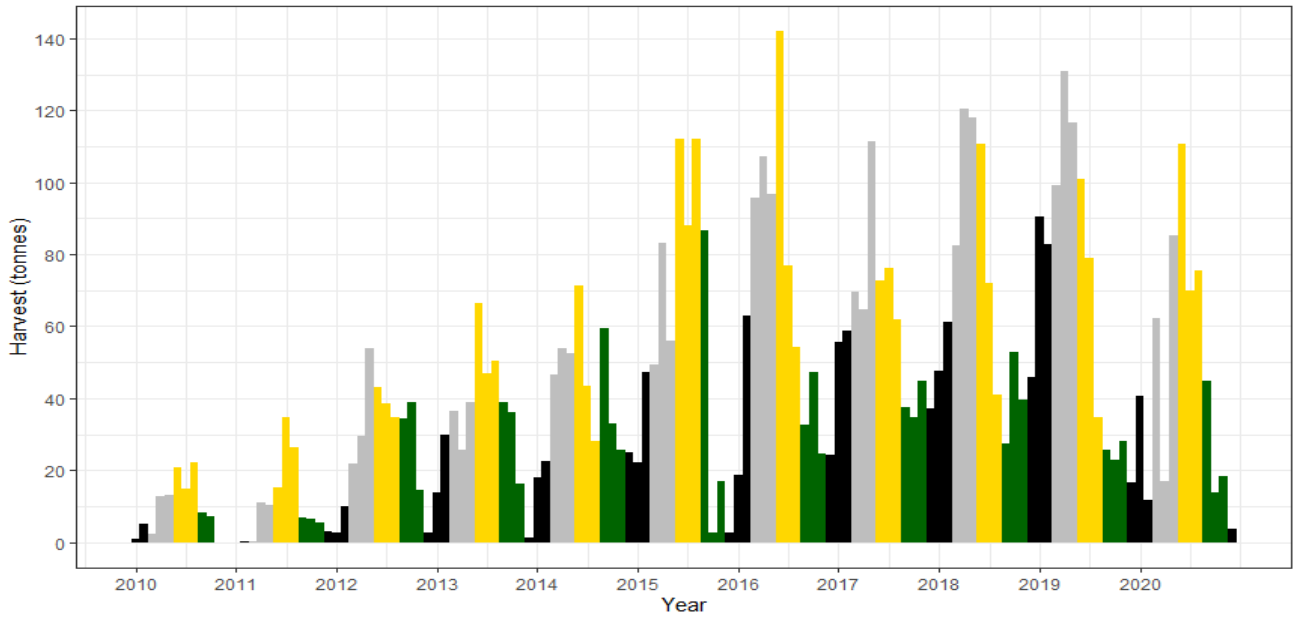
The spring fishery (represented by grey bars) was significantly impacted by the covid-19 restrictions, and although the summer fishery (shown in yellow bars) exceeded 2019 landings, total landings in 2020 were below the annual landings of the preceding 5 years, i.e. since 2014. A similar pattern and spring lockdown effect can be seen in the effort (pot lift) data.

Although the effect of covid-19 on fishing opportunities (days at sea) and landings must be acknowledged, the landings-per-unit-effort (LPUE) data available for 2020—i.e. the number of whelk that were landed per pot-haul—show an overall decrease relative to recent years. Excluding the spring fishery and focussing on the summer and autumn fishery data, the LPUE was below 2 kg pot^{-1}. The overall annual average LPUE (1.7 kg pot^{-1}) is the lowest on record since 2010, being 21% lower than in 2019.

The explanation for the decline in LPUE in 2020 compared to previous years is unclear. Following the change in MCRS in 2018 (from 70 mm to 75 mm TSL) a reduction in LPUE was expected. However, the fishery appeared to be able to maintain LPUE immediately after this technical measure was introduced. It is therefore possible that declining LPUE may reflect reduced stock abundance, either as a result of overfishing, poor recruitment, increased mortality from other sources, or a combination of issues.







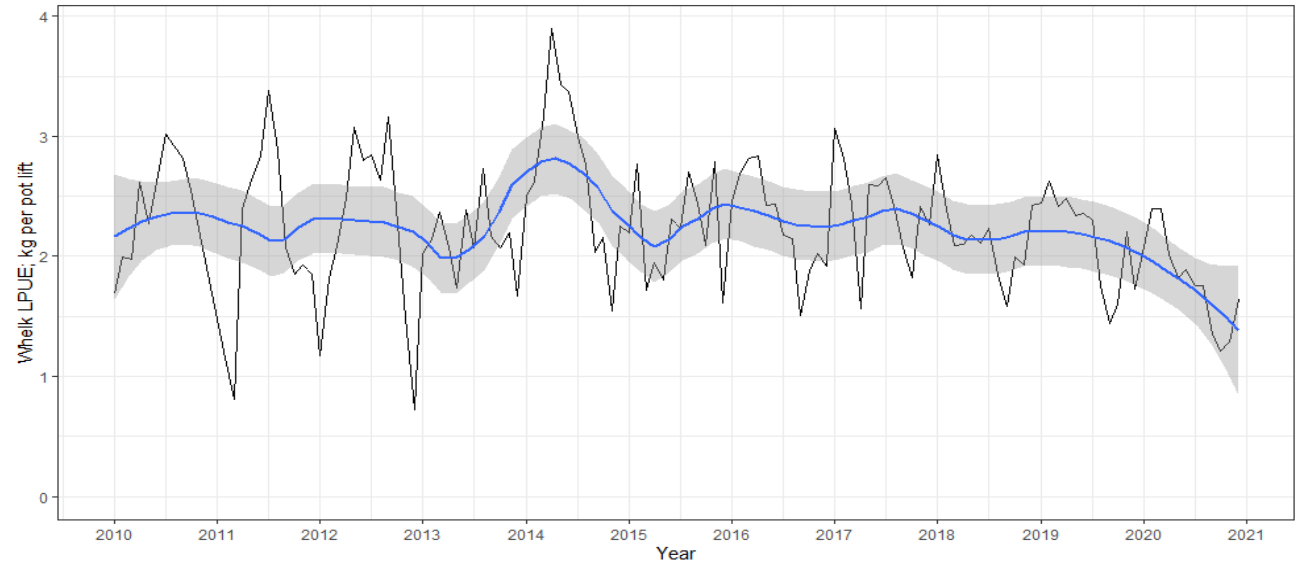


Figure 15: The monthly harvest 2010-2019 (top-left) compared to 2020 (top-right) of *Buccinum undatum*. Landings by month 2010—2020 (centre). The landings-per-unit-effort (LPUE) of *Buccinum undatum* 2010-2020 (bottom). Colours indicate season, where black = winter, grey = spring, yellow = summer, and green = autumn.

European Lobster (*Homarus gammarus*) Fishery Update

The European lobster fishery in the Isle of Man territorial sea has produced between 40 and 60 tonnes of lobster annually over the period 2007-present (Figure 19). Landings in 2020 were low at 32.5 tonnes, equal to a decline of -33% compared to 2019. Effort in the fishery also declined from 268,000 to 203,000 pot lifts, equal to a decline of -24% compared to 2019, and from 1,412 days to 1,009 days at sea equal to a decline of -29% compared to 2019. Annual average landings-per-unit-effort (LPUE) also declined from 0.18 to 0.16 kg pot^{-1} (-11%) over the same period, which is the lowest annual value observed in the time series. Declines in LPUE in the fishery are difficult to verify from logbook data alone, considering that the lobster and edible crab fishery (see overpage) are reported as a 'mixed' fishery, owing to the use of a common pot design. Efforts are underway to improve the reporting system in order to separate the data for each fishery and improve the accuracy and precision of logbook data.

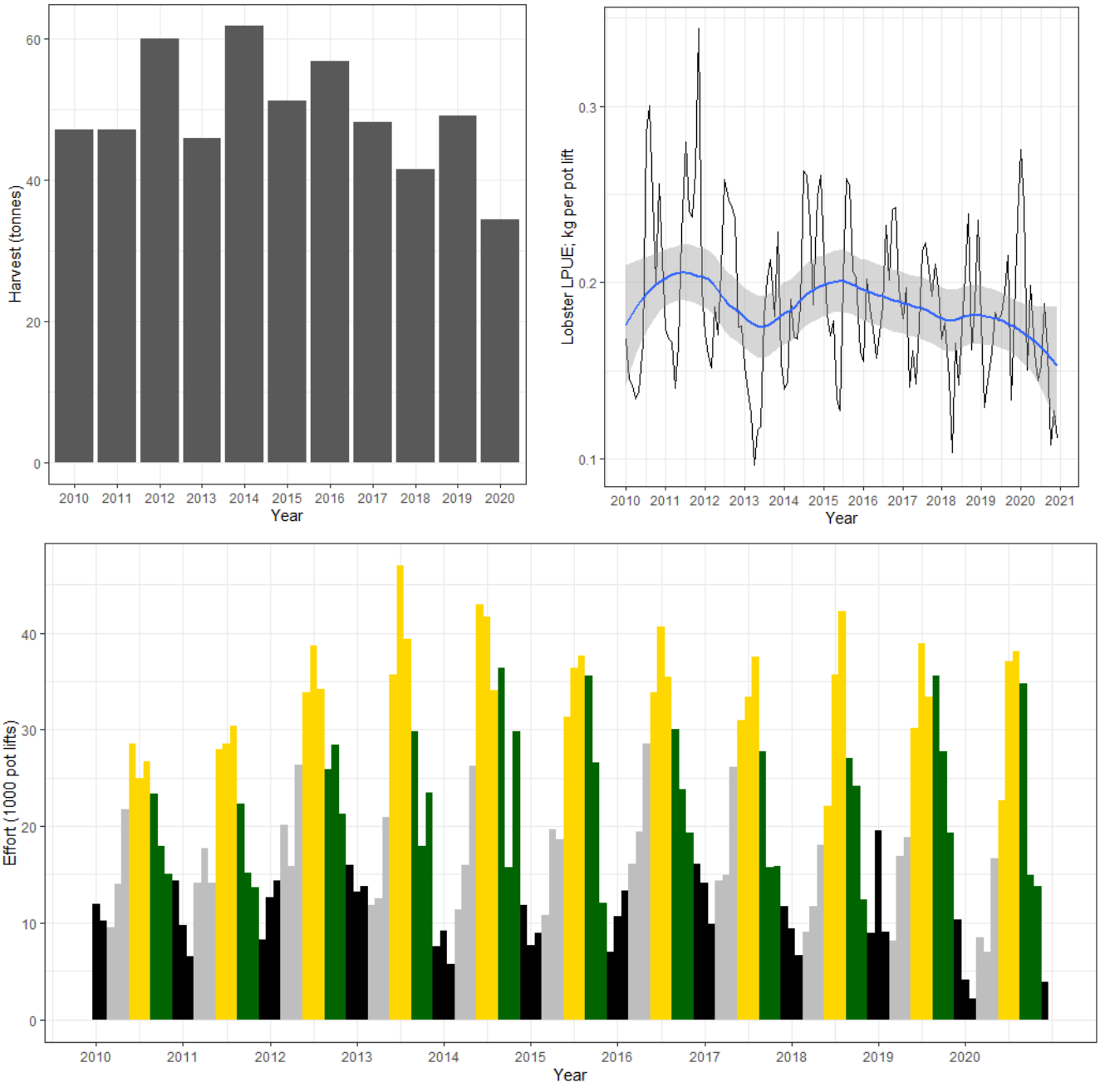


Figure 16: The harvest (top-left) and estimated landings-per-unit-effort (LPUE) of the European lobster (*Homarus gammarus*) fishery (top-right) in the Isle of Man territorial sea. The monthly effort (pot lifts) by month is shown coloured by season (bottom). Data: DEFA.

Edible Crab (*Cancer pagurus*) Fishery Update

The edible crab fishery in the Isle of Man territorial sea has typically produced between c.400 and c.550 tonnes each year over the past decade. 2018 was an exceptional year for the fishery, producing over 575 tonnes, whilst 2019 saw harvest levels return to previous levels (~475 tonnes). In 2020, landings and effort declined to 369 t and 295,000 pot-lifts, equal to a decline of -20% and –26% relative to 2019 respectively. The fishery is principally an autumn fishery, and therefore the direct impact of covid-19 lockdown on landings is less significant compared to whelk, although the wider effect on markets, demand, and prices must be acknowledged when interpreting data. There was no evident change in LPUE compared to 2019. Similar to lobster fishery data, there are issues with reporting effort for 'mixed' crab and lobster activity. However, the fisheries are becoming increasingly distinct (seasonally and temporally). Efforts are underway to change the reporting system to provide more accurate and precise logbook data.

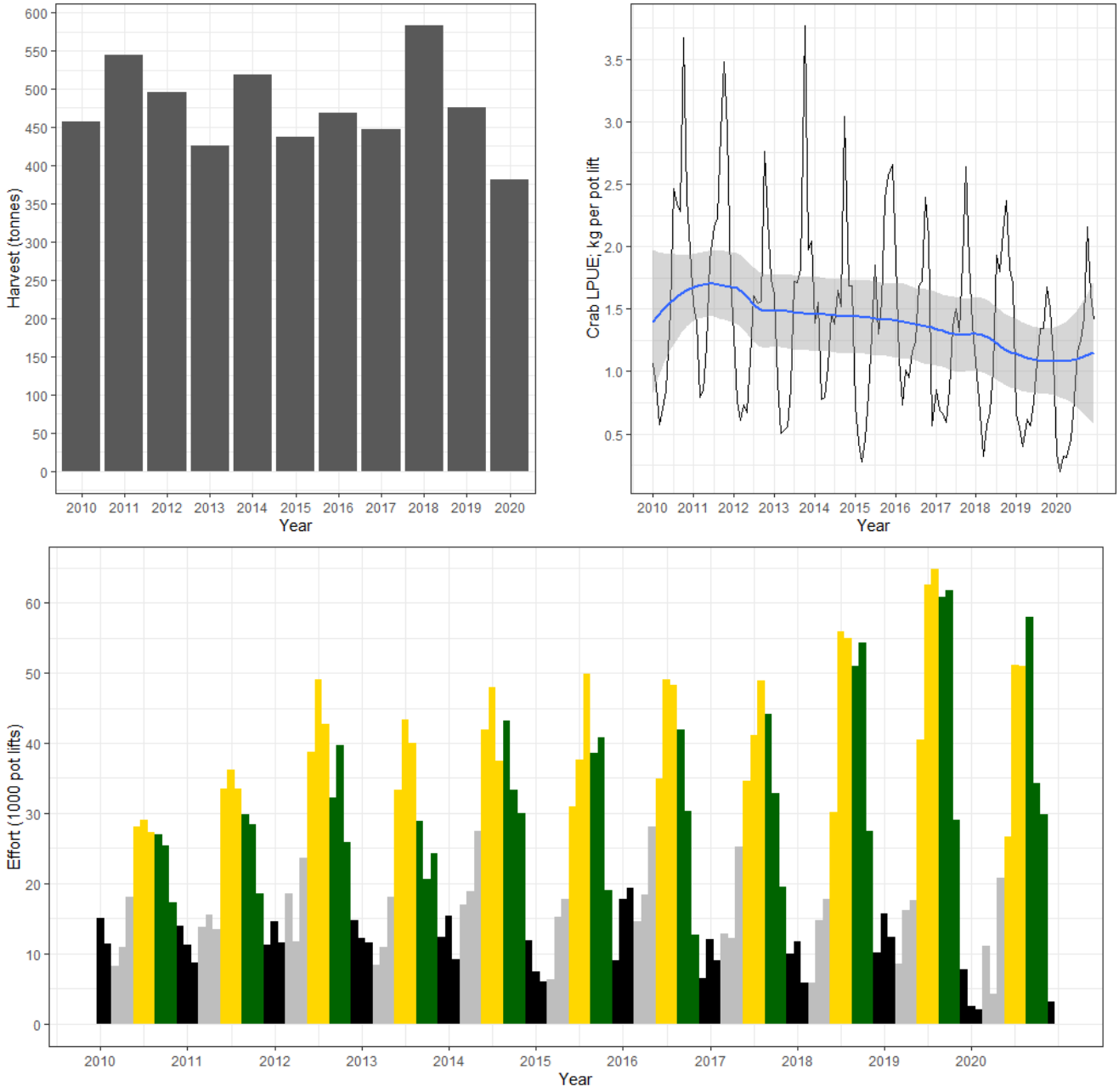


Figure 17: The harvest (top-left) and estimated landings-per-unit-effort (LPUE) of the edible crab (*Cancer pagurus*) fishery (top-right) in the Isle of Man territorial sea. Effort by month (bottom). Data: DEFA.

Crab and Lobster Consultation

The recent trends in fishing effort and landings in the edible crab and European lobster fisheries led to the formation of an industry working group with representatives from processors as well as Manx and UK catching sectors, DEFA officers, and Bangor University scientists. Within the group, a series of themed discussions led to the development of the consultation paper that highlights the numerous issues and opportunities evident within the fishery. The process has aimed to align the exploitation of crab and lobster fisheries with the 'Sea Fisheries Strategy, 2016-2021' (DEFA, 2015), which includes an overall aim to:

- Obtain and apply basic fisheries science data to enable sustainable management.
- Apply an effective range of fisheries management measures within the territorial sea, supported by robust enforcement.
- Develop sustainable fisheries to ensure reliable seafood production.
- Safeguard the long-term viability of the Manx sea fisheries industry with regionally-relevant management.

Figure 18: Manx Cat, PL2 Source: DEFA

The consultation was launched in November 2020 for a period of 6-weeks. A summary of responses will be produced by DEFA officers. The consultation addressed a number of key challenges and opportunities facing the industry:

1. Management of the fishery, including licencing, latent capacity, and pot allocation mechanisms
2. Recreational crab and lobster pot fishing
3. Minimum Conservation Reference Size (MCRS) changes
4. Spatial Management opportunities in pot fisheries
5. Technical measures, e.g. marking and setting of gear, escape gaps,
6. Options for a long-term industry-supported scientific research programme
7. Diversification options, including a Velvet crab (*Necora puber)* fishery

Bangor University supplied a series of evidence-based reports, which were designed to support and inform stakeholders responding to the consultation. The full reports are available online, and are summarised in the following pages.

Crab & Lobster Consultation Evidence: Licences & Latency

There has been a moratorium on the allocation of additional crab and lobster licences by DEFA since 2016 in order to reduce the potential displacement of effort resulting from the Isle of Man King Scallop consultation. Currently there are a total of 51 IOM crab and lobster licences . The number of current active licences is 49. Commercially licenced vessels range in size, from 3.9 m to 15.7 m overall length (LOA). The mean vessel size is 9.11 m LOA.

The majority of vessels are under 10 m (U10) with the most licenced length-metier being the under-8 m category. The total effort allocated to the fishery varies by length category (Figure 19). Most of the allocated potting effort is attached to licensed >10 m vessels, where 8-10 m and under-8 m have 8,600 and 6,750 respectively (75% of total allocated effort in the fishery). The 10 – 12 m category has 3,400 pots allocated to 6 licenses and the > 12 m category has 2,000 pots allocated to 4 licenses (Figure 19A).

Latent licenses, defined as those vessels that do not meet the eligibility criteria set out in the consultation (a single days fishing reported in the ICES Rectangles 35E5, 37E5 and 38E5 between 01/01/2016 and 30/06/2018, using fishing pots (FPO) and landing either *Cancer pagurus* and/or *Homarus gammarus*) in compliance with licence conditions and Isle of Man Sea Fisheries Regulations, are significant in the fishery.

In total, 14 of the 49 licenses (28%) have not been associated with any edible crab or European lobster landings using baited pots. These 14 latent licences have 6,150 pots allocated to them, or 30% of the total number of allocated pots actively licenced in the territorial sea. Latent licences are represented by red bars in Figure 19B.

Given the recent landings, effort and LPUE trends in the fishery, together with the data-poor status of both stocks, it is recommended that the risk of increased effort via latency is addressed. The consultation sought views from industry on the perceived risk of this latency, and potential solutions.

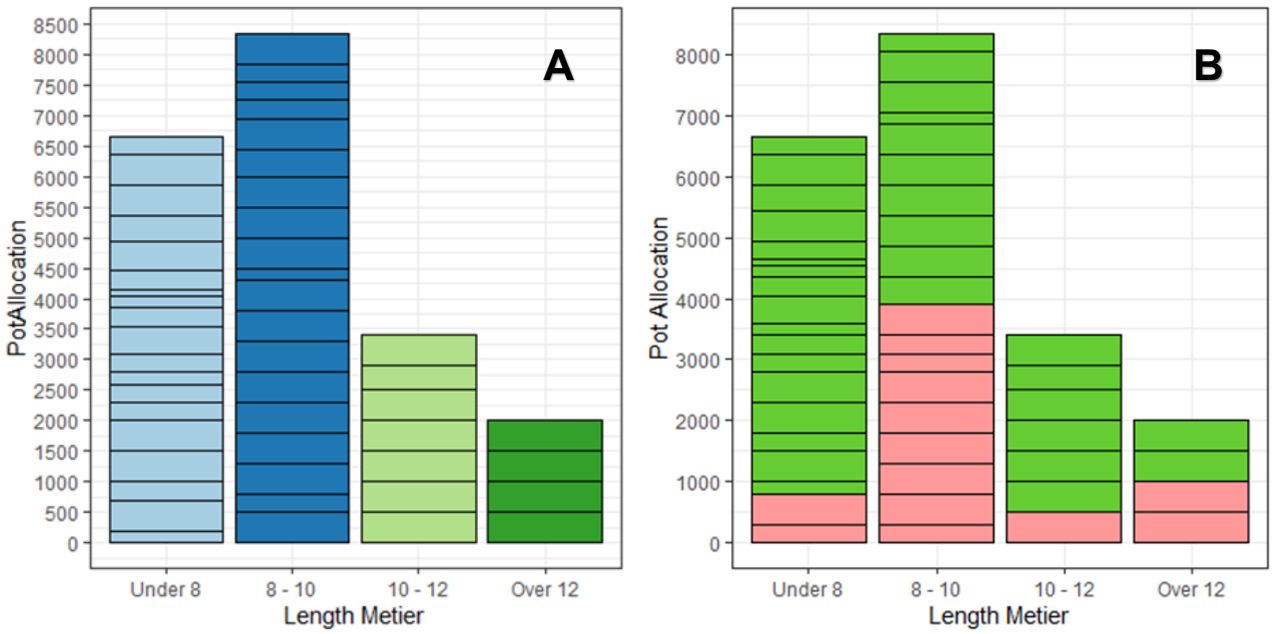


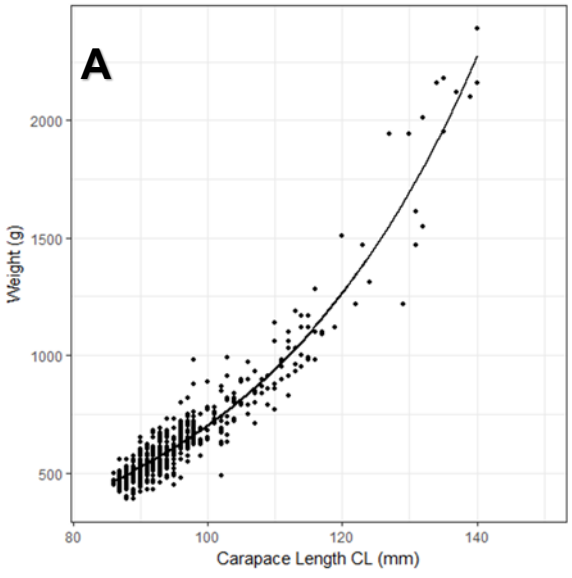
Figure 19: **A.** The allocation of fishing effort (pots) per licence, grouped by length class. **B**. The latent (red) and active (green) licences within each of the size-classes.

Crab & Lobster Consultation Evidence: MCRS

The Minimum Conservation Reference Size (MCRS) - i.e. legal landing size, has been revised and raised based on biological reference points such as size-at-maturity and reproductive output (e.g. King scallops and whelk) as well as economic benefits of harvesting larger animals (e.g. Queen scallop). Maturity analysis of European lobster estimates physiological maturity at 83 mm CL (± 3 mm), which is below the current MCRS (87 mm). However, onboard observations have also noted that 50% of observed females carry eggs at a size 93 mm CL ('functional maturity').

Furthermore, some fishers argue that there are potential economic benefits to increasing the MCRS to 90 mm CL, because the size-weight curve displays a non-linear relationship (Figure 20). For example, an 87 mm lobster is expected to grow by approximately 11 mm CL to 98 mm CL following ecdysis (moulting), i.e. 13% growth rate. However the weight of a 98.3 mm lobster is approx. 696 g, which is a 47% increase from the animals previous weight (480 g). The weight of a 90 mm lobster is 510 g (i.e. 6.2% heavier than 87 mm). In effect, this means increased revenue from the same number of individuals.

We evaluated the short– and long-term economic consequences of a change in MCRS using population structure data (size distribution) and growth rates from mark-recapture data. The model assumed a closed population, with effort, catch, and recruitment rate constant through time (i.e. constant fishing mortality, *F*) and stable economic market conditions. The model considered different rates of natural mortality (*N*) and both a single-step increase, and a phased-approach to increasing MCRS.



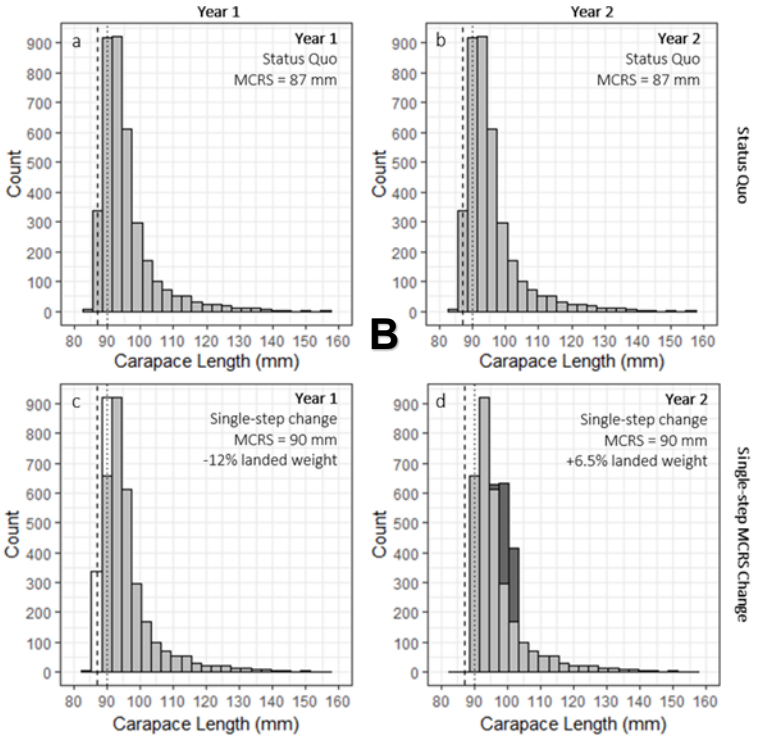


Figure 20: **A.** The size-weight relationship of European lobster. **B**. the demographic model of a change in MCRS from 87 mm to 90 mm.

Crab & Lobster Consultation Evidence: MCRS (continued)

Under a single step-change in MCRS to 90 mm, lobsters between 87 mm and 90 mm CL would be excluded from the harvest in Year 1. The model estimates such a change would reduce the total landed weight by 12%. As the forgone catch in Year 1 moult and recruit into the fishery the next year, they will have increased in both size and weight. The model predicts that when natural mortality is 0%, the harvested weight in Year 2 is 6.5% greater than the status quo. The additional harvest weight of Year 2 will decrease if an estimate of natural mortality rate is included in the model (as a portion of the unfished stock die). This means that harvest improvements reduce from +6.5% (with no natural mortality) to +4.1%, +3.2% and +2.4% when natural mortality rate is modelled at 10%, 15% and 20% respectively. A similar, but delayed effect, is observed under a phased-approach. The results of each model are shown in Table 4.

Table 4: The modelled changes in harvests (%) resulting from a change in MCRS from 87 mm to 90 mm for European lobster under different assumptions of Natural mortality, and with a single-step and phased approach to MCRS increase.

	Single-step				Phased-approach (89 mm)			
Natural mortality estimate	0%	10%	15%	20%	0%	10%	15%	20%
Year 1 compared to status-quo	-12.0%				-6.7%			
Year 2 compared to status-quo	+6.5%	+4.1%	+3.2%	+2.4%	-1.7%	-2.8%	-3.3%	-3.9%
Year 3 compared to status quo	+6.5%	+4.1%	+3.2%	+2.4%	+6.5%	+4.1%	+3.2%	+2.4%
Number of years for net-benefit to be achieved	2.8	3.9	4.8	6.0	3.3	4.3	5.1	6.4

The simulation model for a change in MCRS to 90 mm for the Isle of Man lobster fishery suggests that, depending on the approach taken and the rate of mortality in the population:

- it could take between 2.8 and 6.4 years for the cost of the transition to be recovered in the new harvesting regime (i.e. reach a net-benefit),
- opting for a phased-approach reduces the initial negative impact but increases the time in which a net-benefit could be realised by approximately 0.5 seasons,
- in the long-term, annual yield is estimated to increase between 2.4% and 6.5% compared to baseline (current harvests) depending on mortality rates, unless mortality exceeds 31% at which point there is no benefit to MCRS change.

Figure 21: Lobster creels and lobster measuring onshore at the processing factory

Crab & Lobster Consultation Evidence: Size at Maturity

In addition to the potential economic benefits of increasing MCRS for Lobster, Bangor University has undertaken work to assess the reproductive biology of the population, and specifically to determine any biological requirement for increasing the size at which Lobster can be harvested in Isle of Man territorial waters. We assessed a number of maturity definitions using a number of different methods / observations outlined in Table 5.

Table 5: A description of the methods of maturity assessment in male and female European lobster.

Method	**Females**	**Males**
Functional maturity	Presence/absence of eggs	*NA*
Morphometric maturity	Width of the abdomen	Size of the crusher claw
Physiological maturity	Staging of the ovaries	Presence/absence of sper-matophores
Behavioural maturity	Staging of the pleopods (cement glands)	*NA*

Functional maturity, based on observations at sea, and adjusted for potential effects of biennial spawning of larger females >104 mm CL, estimates L_{50} to be 89.4 mm, which is above the current MCRS of 87 mm (Figure 22). Physiological maturity, based on laboratory dissections of 92 female lobsters ranging from 60-120 mm CL, suggested that L_{50} is around 83 ± 4 mm CL. However, if evidence of previous spawning is not incorporated into the analysis, then the L_{50} estimate increases to 90 mm CL.

With regard to management implications for the fishery for European lobster within the Isle of Man, these results suggest the current MCRS of 87 mm CL is biologically appropriate for females based on examination of the ovaries (i.e. MCRS is above 50% physiological maturity, at 83 mm CL). However, onboard observations suggest functional maturity (89 mm CL) may be higher than the current MCRS after accounting for biennial spawning in large individuals and spawning season effects. A precautionary approach would be to increase MCRS to 90 mm.

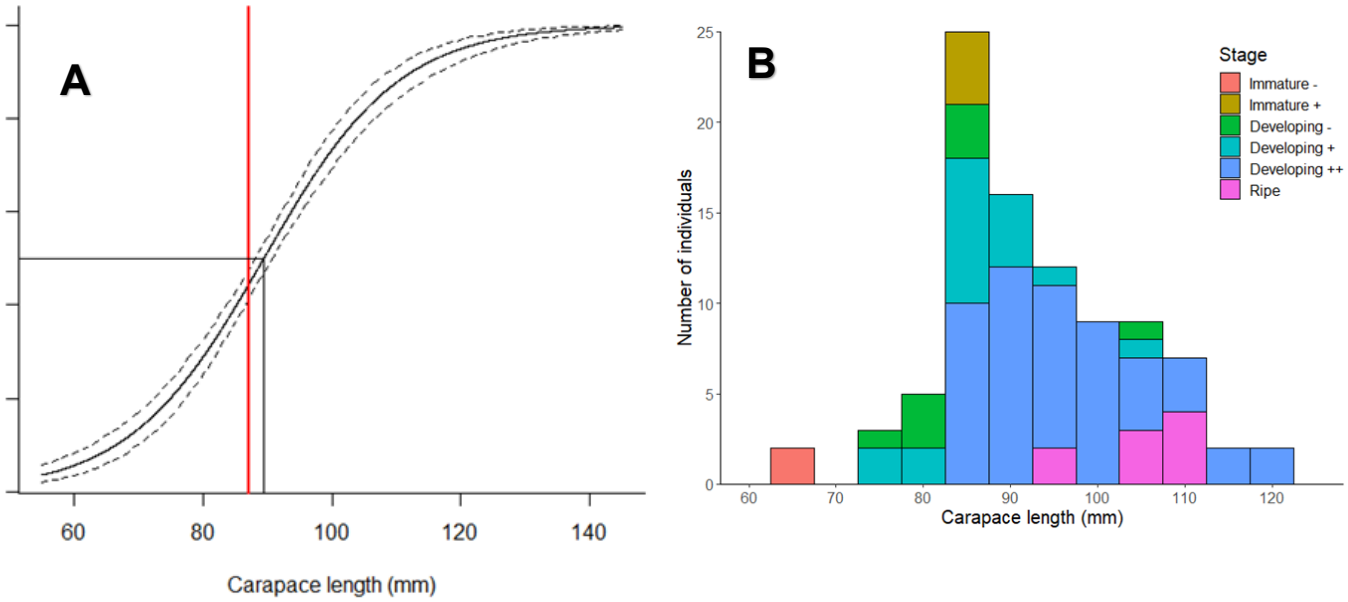


Figure 22: A. The functional maturity ogive of European lobster, showing L50 estimate (black line) to be above MCRS (red line) at 90 mm CL. B. The proportion of female lobsters by gonad stage and size, which estimates physiological maturity to be 83 ± 4 mm CL.

Whelk: A Standardised Survey Methodology

In March 2020, Bangor University scientists produced a report for the Welsh Government as part of their Marine Evidence Framework, which has important recommendations for enhancing Manx approaches to whelk stock assessments. The report provides recommendations for fishery-dependent monitoring, fishery-independent surveys and additional research of common whelk (*Buccinum undatum*) populations. The recommendations were made by consideration of whelk biology and ecology, current available data and management, scope for expansion of data collection and management, potential stock assessments used to estimate whelk stock status and best survey practice for whelks. These considerations were reviewed through the available literature and expert opinion of the authors and other UK and international scientists.

The recommendations span fishery-dependent monitoring, fishery-independent annual surveys and additional biological research, and are presented in three levels; minimum requirements, strongly recommended and highly useful.

The recommended minimum survey include collection of fine spatial scale catch and effort data, an annual fishery-independent and research to define the spatial structure of populations and the wider stock unit. Strong recommendations include collection of fishery –dependent and –independent individual size, age and maturity data on a biennial basis. Highly useful recommendations include monitoring of environmental conditions in addition to the above, as well as gear/methodological comparisons of different survey techniques, for example mark-recapture, trap-based, and trawl-based survey methods.

Implementation of the minimum requirements would result in data indicative of population status of whelks in the short term, and would gather data for simple (surplus production) stock assessment models to estimate stock sizes in the medium term. Implementation of the strong recommendations would allow for more detailed (length- or age- structured) stock assessment models to estimate stock size in the long term, and would provide further useful indicators of stock status in the short term. Lastly, implementation of the highly useful recommendations are likely to improve the reliability, and reduce uncertainty of both stock status indicators and stock assessment estimates.

Although the report was produced for Welsh Government, and some of the specific recommendations refer to work in Welsh waters, the report can be usefully applied directly to ongoing work in the Isle of Man whelk fishery. In fact, much of the fisheries-independent aspects of the recommendations are already partially in place for activity within Isle of Man waters.

There is also some evidence that beam trawl surveys, which took place as part of a Queen scallop juvenile survey, can be effective at catching common whelk for the purpose of fisheries-independent scientific surveys. Mobile-gear survey methods overcome some of the logistical challenges of trap-based surveys, as well as avoiding some challenging aspects of modelling trap-based LPUE (e.g. conspecific competition, bait attraction, area of attraction, effects of tides and habitat on locomotive ability , etc.). However, beam trawls are not without co-variate effects, and they can also introduce uncertainty into abundance estimates.

Working towards a fisheries-independent survey, and stock assessment advice for the whelk fishery is a priority for the remaining period of this contract (until Sep 2025). The report to Welsh Government provides a useful evaluation and blueprint for future work, and will guide a 3-year PhD project set to start on whelk fisheries in the Isle of Man in April 2021.

Whelk Research Trip: Orkney, Scotland

Bangor University scientists travelled to Stromness (Orkney, Scotland) to work on a collaborative project with Orkney Sustainable Fisheries Ltd scientists based in the University of Highlands and Islands on the 6th Jan 2020. The trip was both a knowledge-transfer and collaboration exercise focussing on whelk (*Buccinum undatum*), which is fished for in Isle of Man territorial waters and Scottish waters around the Orkney islands.

Having published an ageing and size-at-age modelling methodology in peer-reviewed journals, our scientists travelled to Orkney with examples of statoliths from Manx waters and assisted in the preparation and analysis of similar samples from Orkney.

The methodology that has been tried and tested in Manx and Welsh waters proved to be transferable and therefore successful for samples at the far north of the British Isles. An immediate observation was that the overall size-structure of whelk populations harvested in Orcadian waters, and the modelled size -at-age growth curve, confirms the hypothesis developed in the Irish Sea; that whelk reach a greater size ($L\infty$) in cooler waters. Orkney Sustainable Fisheries (OSF) scientists are continuing to build a Scottish dataset and hope to publish their findings in 2021. The additional data from the cool waters around the Orkney Islands will enhance our understanding of the drivers of variable whelk population dynamics, which is important for developing appropriate harvesting and management strategies.

Figure 23: **A.** Stromness, Orkney

ICES Working Group on Crab and Lobster

Bangor scientists attended an online meeting of the ICES Working Group on the Biology and Life History of Crab and Lobster in November 2020.

Presentations were delivered by a host of fisheries scientist from numerous research institutes, and included a range of crab and lobster fisheries throughout the ICES Area. The most commonly discussed fisheries were the edible crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*) fisheries in northwestern Europe. However, a series of interesting material was presented and discussed on Arctic crab fisheries by Norwegian and Canadian scientists.

Bangor University delivered a presentation on some work undertaken in the Isle of Man territorial sea, entitled "Integrating gear-in gear-out sensors and mobile reporting in the Irish Sea edible crab fishery for the purpose of supplying high-resolution fishery-dependent data". A general feedback and overall consensus within the group was reached, which highlighted concerning trends emerging in edible crab fisheries throughout the ICES Area (inducing France, UK, and the Republic of Ireland), and that a greater collaborative effort is required going forward for improving assessment of stocks.

Figure 24: ICES Working Group on Crab Biology and Life History online meeting, Nov 2020.

Habitat Mapping (Marine Nature Reserves)

In order to feed into management plans, habitat surveys were completed in 2016 in each of the Isle of Man's existing Marine Nature Reserves (MNRs): Ramsey Bay; Laxey Bay; Douglas Bay; Baie ny Carrickey; Port Erin Bay; and Niarbyl Bay. Underwater cameras attached to a towed sledge (or drop-down system in the case of Baie ny Carrickey) were used to collect information in each area on habitat types and species distributions. GoPro video footage provided a good overview of the characteristics of each area, and high quality still images from a SLR camera (in waterproof casing) were used to extract more detailed information including species counts and percentage cover data. In some MNRs the videos were also used to count scallops and calculate densities throughout the surveyed area.

Between 2016 and 2019, the data from these areas were analysed by five separate people and therefore there were slight discrepancies in the methods used. In 2020 the analysis was standardised and re-run across all areas. Reports were produced for DEFA on each of the MNRs presenting the results in a standardised format. These six reports provide crucial information on species distributions, scallop abundance and seabed habitat types in Isle of Man marine protected areas (Table 6), which are key in safeguarding the long-term sustainability of commercial fisheries within the Isle of Man territorial waters.

For each MNR, a species list is available along with habitat maps based on percentage cover data and/or EUNIS classification. Habitats based on percentage cover were classified using SIMPROF (similarity profile) analysis. The habitats are compared statistically and described in terms of characterising species, depth range, substrate type, mean species richness, faunal abundance and percentage cover of algae. Additional information available for certain MNRs include scallop density and size, and the distribution and percentage cover of priority species such as maerl and seagrass.

Table 6: Information available in MNR reports: RAM = Ramsey Bay; LAX = Laxey Bay; DOU = Douglas; BNC = Baie ny Carrickey; ERI = Port Erin Bay; NIA = Niarbyl Bay.

Information	Marine Nature Reserve					
	RAM	LAX	DOU	BNC	ERI	NIA
EUNIS habitats	✓	✓	✓	✓	✓	✓
SIMPROF habitats	✓	✓		✓	✓	✓
Species list	✓	✓	✓	✓	✓	✓
Percentage cover data	✓	✓		✓	✓	✓
Species count data	✓	✓		✓	✓	✓
Scallop density	✓	✓			✓	✓
Scallop size		✓				✓

MNRs with the highest diversity, defined by taxonomic richness and the number of distinct habitats, were Ramsey Bay and Baie ny Carrickey. MNRs with medium diversity were Douglas Bay, Port Erin Bay and Niarbyl Bay, and the MNR with the lowest diversity was Laxey Bay. This is because Laxey Bay MNR was dominated by sandy habitat, while the other MNRs contained a more diverse array of substrate types (including rocky areas), leading to a wider variety of epifaunal species. Mean species richness in still images ranged from 2 in Laxey Bay to 11 in Baie ny Carrickey, and mean algal cover from 1% in Laxey Bay to 48% in Baie ny Carrickey (Table 7). Mean scallop density (*Pecten maximus*) ranged from 0.6 per $100m^2$ in Laxey Bay to 27 per $100m^2$ in Port Erin Bay. Port Erin Bay is the oldest marine protected area in Manx waters (by about 20 years), and mean scallop density in the area was > 6 times higher than any other MNR.

Depending on habitat type, scallop densities in Port Erin Bay from 10-minute video tows reached as high as 92 per 100m^2.

The data from these MNRs will feed into management efforts and provide useful baseline information with regard to species records and future monitoring. The overall aim is to work towards zoned management approaches based on this habitat information. In 2018, four additional MNRs were established (West Coast, Langness, Calf and Wart Bank, and Little Ness), increasing the total protected area of the inshore territorial sea (0-3 nm) to 52%. A high priority in the future will be to survey these areas using the same methods.

Table 7: Characteristics of Isle of Man MNRs that have been surveyed: size of MNR; total number of taxa identified; number of EUNIS habitats; species richness (mean number of taxa in still images); mean percentage cover of algae in still images; mean scallop density per 100m^2 of video tow.

Characteristic	Marine Nature Reserve					
	RAM	LAX	DOU	BNC	ERI	NIA
Size (km^2)	96.98	3.97	4.64	11.37	4.34	5.66
No. distinct taxa	117	59	117	87	137	118
No. EUNIS habitats	16	8	9	18	9	11
Species richness (taxa per image)	6	2	-	11	6	4.5
Algal cover (%)	16	1	-	48	7	12
Scallop density (no. 100 m^{-2})	4	0.6	-	-	27	4

Figure 25: Two examples of stills images from Port Erin video survey showing habitats and species encountered.

Full reports available on request:

Garratt, M.J., Bloor, I.S.M., Emmerson, J.A. and Jenkins, S.R. (2020) . Benthic Habitat Mapping: Baie by Carrickey MNR. Bangor University Report.

Garratt, M.J., et al., (2020). Benthic Habitat Mapping: Port Erin Bay MNR. Bangor University Report.

Garratt, M.J., et al., (2020). Benthic Habitat Mapping: Douglas Bay MNR. Bangor University Report.

Garratt, M.J., et al., (2020. Benthic Habitat Mapping: Laxey Bay MNR .Bangor University Report.

Garratt, M.J., et al., (2020). Benthic Habitat Mapping: : Niarbyl Bay MNR .Bangor University Report.

Garratt, M.J., et al., (2020). Benthic Habitat Mapping: : Ramsey Bay MNR. Bangor University Report.

Video analysis of spring-toothed Scallop Dredges

Simon Wills is a 3rd Year undergraduate student from Bangor University who is currently undertaking an industry placement year within the Fisheries and Aquaculture research group in the School of Ocean Sciences. As part of his placement year he has been involved in discrete projects involving Isle of Man commercial fisheries. This has included laboratory work dissecting and measuring queen scallops, literature reviews on North Irish Sea connectivity and video analysis of a series of videos of spring-toothed scallop dredges collected on the annual spring scallop research survey which is presented here.

Understanding the efficiency of dredging in various sediment types is key to sustainably maximising catch potential. The aim of this small project was to gain insight into the consistency of tooth penetration and seabed contact of the dredge and how sediment type affects it. A sample of 53 total videos were provided, with a subsample of 28 taken to be analysed in detail. This subsample was selected based on visual clarity and sediment type – with a 4-tier system being used to allow an equal representation of sediment type within the subsample. Among the subsample, sediment type was analysed further and categorised in a 9-tier system, with 9 being mostly large gravel/ stones and 1 being purely fine sand. This initial categorisation will be useful for formalising the standardisation of dredge spring tension, which is varied depending on sediment type, for each survey site.

Seafloor topography is a significant effector of contact and penetration as seen in many of the videos. Interruptions in dredge contact with the seabed were observed within the videos for example, where the dredges encounter large rocks and boulders contact with the seabed is lost for short periods which would impact dredge efficiency. Preliminary results indicate that for tows in sediment tiers 1-8 dredge contact was relatively consistent (i.e. typically ≥ 95 % contact time), whilst for tows in sediment tier 9 (large gravel/stones) had slightly lower dredge contact time (~87—95 %) (Figure 27). Tooth penetration was also shown to vary with sediment tier, with penetration depth typically lower for both king (left dredge) and queen (right dredge) scallop dredges in tier 9 than tier 1, although there was variation in penetration depth among the different sediment tiers (Figure 28). Further work on the analysis of the video dredge data will be undertaken to ascertain whether this data can be usefully integrated into the preparation of survey data for stock assessment purposes in the future.

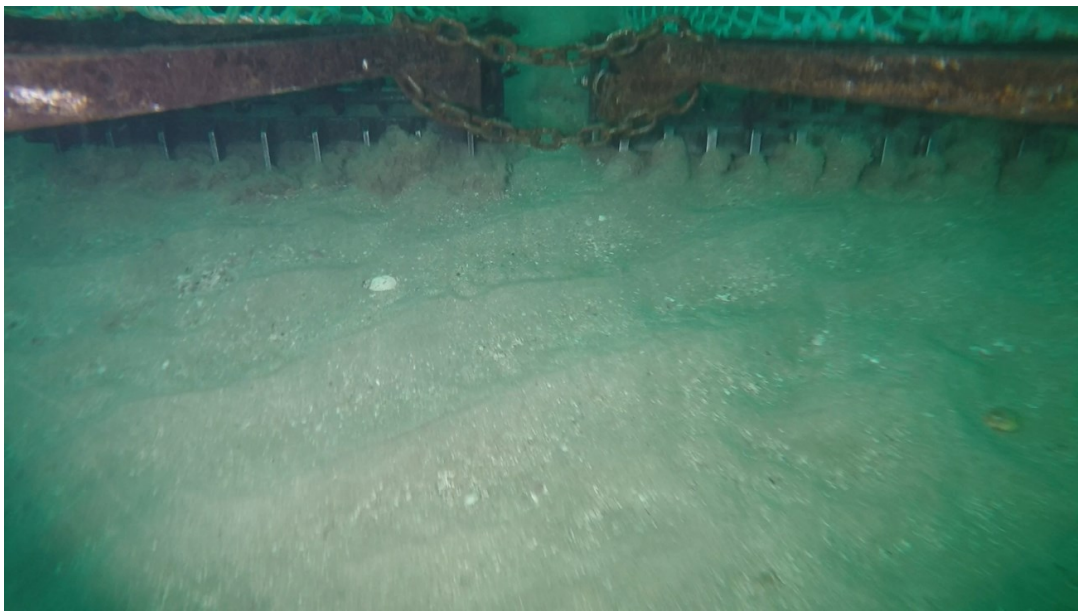


Figure 26: A n example still from the dredge video data with the king scallop dredge left and the queen scallop dredge right

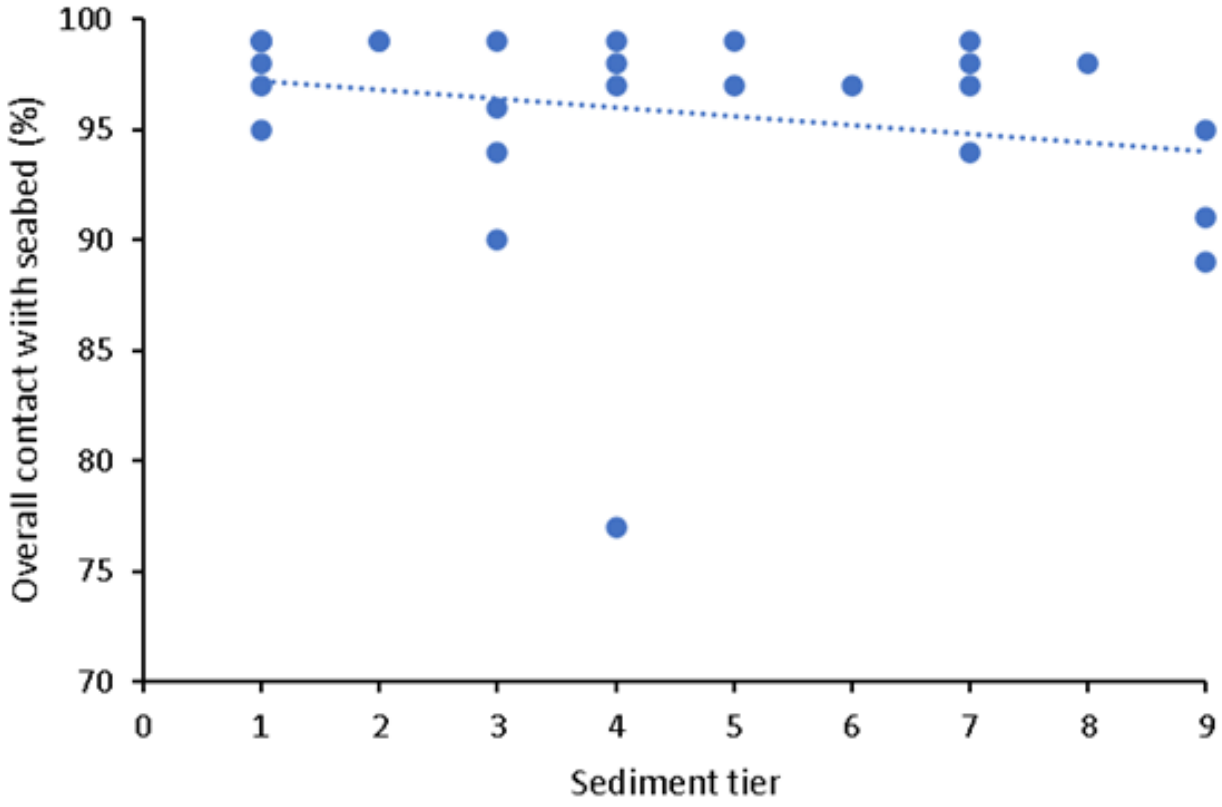


Figure 27: A graph showing each dredge's overall contact with the seabed and how it relates to sediment tier

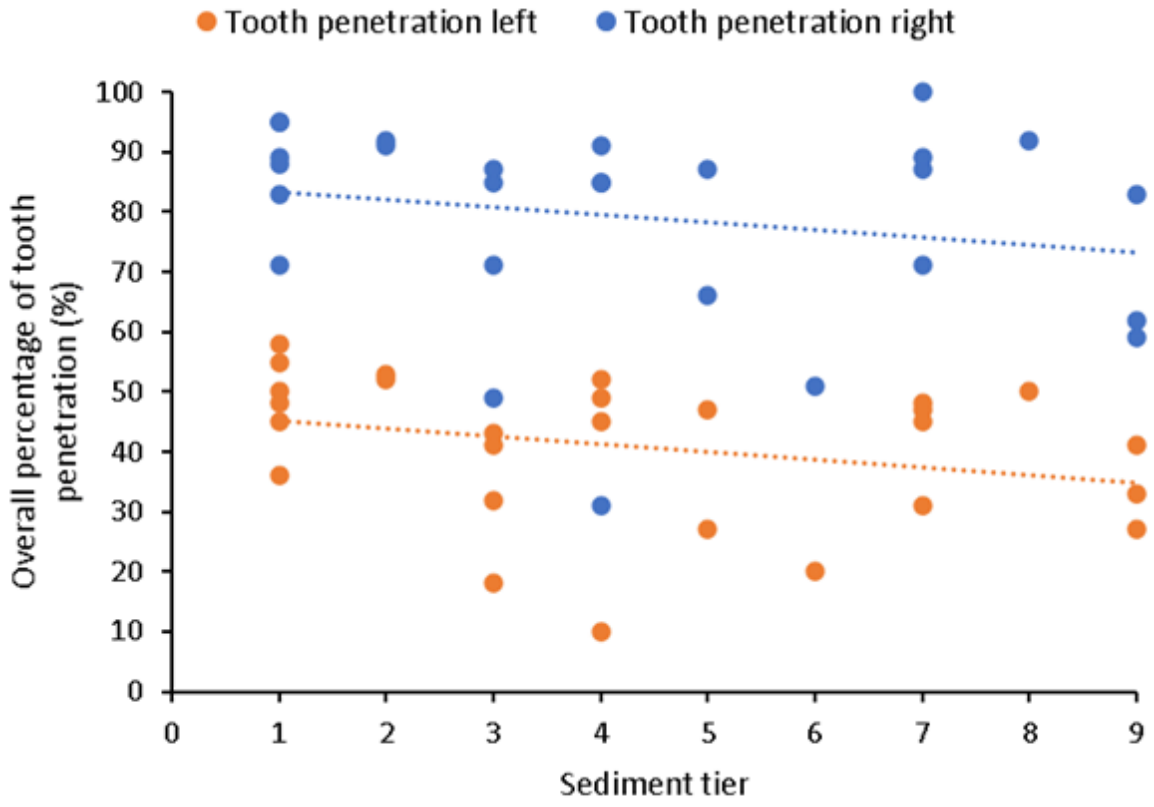


Figure 28: A graph showing tooth penetration, defined by a rough percentage how much of each tooth was buried in the sediment over the course of the dredge. Two individual sets of teeth were visible throughout the videos, separated on the graph by their orientation to the recording camera. The tooth left from the left hand side king scallop dredge was longer (110 mm) than the tooth length from the right hand side queen scallop dredge (60 mm). Linear regression trend lines are present in each graph. R^2 values are as follows: 0.0533 for A, 0.0436 for left penetration of graph B and 0.0853 for right penetration.

Research priorities for the new contract 2020-2025

Following the award of a new 5 year contract for provision of fisheries science and advice to the Isle of Man Government, Bangor University have put together a 5 year work plan that addresses the key themes and objectives outlined within the tender and DEFA's Future Fisheries Strategy document. The work packages (WP) from that science research plan will be presented here and are split into mobile gear fisheries and static gear fisheries.

Mobile-gear Fisheries

WP1.
Scientific Scallop Surveys

WP1 A long time-series of scientific survey data exists for scallops, from 1992—to date.

WP1 'Scientific Scallop Surveys' continues this long-term data collection via a 12 day scallop survey planned annually onboard the RV Prince Madog. A standardised scallop survey protocol is used.

Outputs from WP1 include survey analysis, stock advice, and recommendations provided to DEFA and the SMB in advance of the king and queen scallop fishing seasons.

WP2.
Industry Scallop Surveys

WP2 There is an ongoing effort for assessment and management of scallop fisheries at a finer spatial scale (i.e. individual fishing grounds). This can only be achieved with a higher resolution survey and industry assistance

A fine scale scallop survey, that also targets juveniles and queen scallops, was designed by Bangor University in 2019 and implemented by the MFPO.

In the short-term, the data provides relative assessments year-on-year. In the long-term, we can adapt our current stock assessment models to include this additional industry data.

WP3.
Stock Assessment

WP3 Quantitative stock assessment for queen scallops has been undertaken for the IOM since 2012.

For king scallops, we are working with colleagues at Bangor University and within the ICES Working Group on Scallops to develop appropriate stock assessment models (length and age based).

We are also taking a lead role in developing stock assessments at the scale of the North Irish Sea (biological stock unit) through the ICES Working Group.

WP4 Long-term fisheries management plans (LTMPs) for king and queen scallop fisheries are essential to avoid short-term reactionary management that can potentially impact on the longer-term sustainable approaches to fisheries management.

LTMPs will be underpinned by science and highlight the biological, ecosystem, and socio-economic objectives of the fishery. They will include harvest control rules (HCRs) and biological reference points.

Collaborative work on a LTMP for king scallops is underway between Bangor, DEFA, and the SMB.

WP5 In line with the development of LTMPs (above) for king scallops, DEFA plans to consult on the current and future measures for the king scallop fishery.

The outputs from this area of work will support the consultation process by undertaking impact assessment, evidence based reports, and other relevant specific analyses.

WP6 Bottom gear are widely known to have a detrimental effect on the seabed and associated marine organisms, thus impacting the wider ecosystem, if the intensity of effort exceeds the capacity of the environment to recover.

The current status of the habitat types found within IOM waters will be quantified using the relative benthic status (RBS) approach.

RBS provides a measure of the benthic impact of fishing using information on fishing intensity, benthic depletion rate, habitat type and benthic community recovery rate.

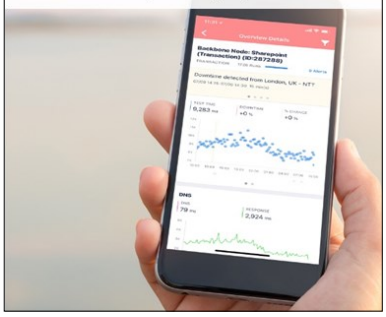
WP7 Long-term closures have proved successful for scallop fisheries. WP7 builds on this success by working with industry and DEFA to develop a standardised implementation and monitoring programme for closed areas.

The research will also look at standardised protocols for re-opening closed areas and monitoring activity within these newly opened areas.

The research will use methods for non-destructive sampling (i.e. cameras) for scallop biomass within closed/protected areas to feed into stock assessment & management.

Static-gear Fisheries

WP1.
Common reporting system

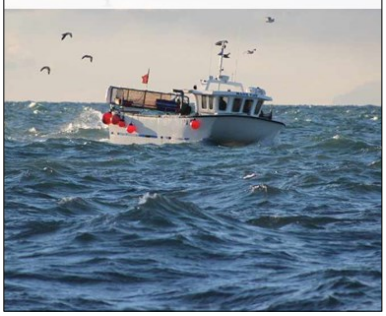


WP1 At present, reporting requirements for catch and effort into the pot fisheries vary by vessel length (under-10, 10-12, over-12).

Significant data gaps exist in certain areas (e.g. number of pots lifted and catch retained by visiting vessels over-10 m within IOM waters specifically).

Bringing all static-gear reporting under a single system, as with scallop fisheries, is a priority.

WP2.
Data feedback

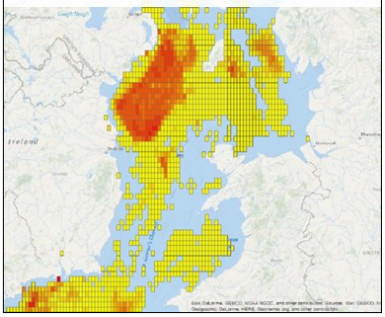


WP2 Feeding information back to industry via co-management boards and working groups has shown to be useful for building trust and understanding between science, industry, and Government.

The data collected as part of WP1 will be fed back to industry in a similar way, and show how and why the data is used.

We will necessarily present data in a way that protects commercially sensitive and private data.

WP3.
Spatial Analysis (iVMS)



WP3 At present, only >12 m vessels are required to have a VMS unit, unless they are fishing for scallops / queenies. Inshore VMS (iVMS) is being developed in the UK.

Spatial information is essential for good fisheries science, marine spatial planning, and also for monitoring, control and surveillance (MCS). This is particularly true for spatial management tools in static gear fisheries, for mapping activity within MNRs, and areas designated for other uses such as wind farms.

WP4.
Fisheries-independent surveys

WP4 Unlike the 30 year time series of scientific data for scallops, there is no survey for crab, lobster or whelk. However, we have a PhD student starting April 2021 to research this area specifically for the whelk fishery.

It is important to stress that methods for conducting these surveys (e.g. underwater video) are experimental, and validation will be required before use in stock assessments. There are no blueprints to adopt from elsewhere in Europe for these species.

WP5.
Juvenile & Recruit Survey

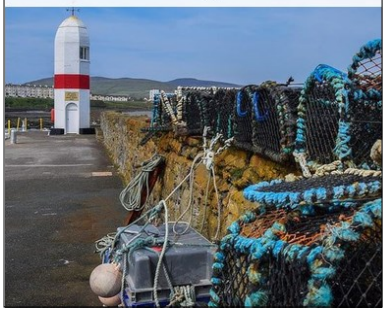
WP5 Similar to WP4, but with an emphasis on monitoring small 'juvenile' animals of the population. It is important to develop a long-term stock forecast model for fisheries management, and juvenile surveys can help model likely scenarios 3-5 years into the future. Again this is experimental science, be we hope to trial and adopt a number of methods that have been used previously.

WP6.
Mark-recapture / tagging

WP6 The Isle of Man crab fishery may target only part of a wider stock unit in the Northern Irish Sea, or further. Together with colleagues in Northern Ireland and Wales, we will design and undertake a mark-recapture experiment to establish edible crab movements in the region.

North Sea and West of Scotland dafa show that edible crab undertake migrations of 100s of kilometres. Information for the N.Irish Sea is missing, but is essential for stock assessments going forward.

WP7.
Alternative management models



WP7 An area of research that may arise as a result of the Crab and Lobster consultation is alternative approaches to management, such as territorial-user-rights.

Alternative management models, other than the present (restricted) open access fishery, may be able to deliver enhanced environmental and economic benefits in pot fisheries.

We are prepared to help identify and evaluate the efficacy of these models if they are adopted by industry.

WP8.
Nephrops scoping project

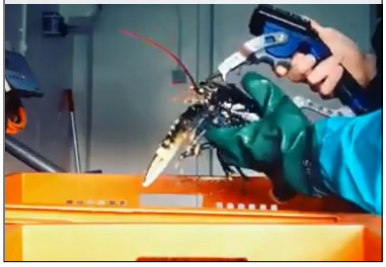
WP8 *Nephrops* are an EU/UK quota species, and are found in abundance in Isle of Man waters. Diversification into this fishery, particularly as a result of UK (and possibly IOM) quota-share uplift as a result of Brexit, presents an opportunity for diversification. Certain areas of the territorial sea may support a creel fishery for *Nephrops* as opposed to trawling. Creels can offer several advantages compared to trawling, such as higher value products and less benthic impact. We can support any effort to establish such a fishery with scientific support.

WP9.
Trap survey / reference fleet

WP9 A trap-based survey programme will need to be established for all 3 fisheries (crab, lobster and whelk) in order to help validate results from WP4. Designing and developing this survey will require close collaboration and commitment from industry. The survey will be standardised, so far as practically possible, to improve the scientific validity of the results.

The trap survey will require onboard observers, or a system of landing sub-samples for robust and high-resolution data.

WP10.
Catch sampling



WP10 is a continuation of previous monitoring and data collection at processors and on the quayside. It will tie in closely with WP9. A programme of regularly monitoring landed animals is important for monitoring the condition and population structure of the stocks. It could also help inform and develop 'code of conduct' to help industry achieve higher prices. There is scope to develop and trial electronic solutions that automate the data collection process, e.g. using cameras and AI to identify and measure animals.

During 2020 the Isle of Man research team (staff and students) have communicated the findings of the scientific work undertaken to interested stakeholders. These communications include advisory reports to the Isle of Man Government and during attendance at national and international committees, working groups and meetings.

Government Reports:

- Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). Queen Scallop: 2020 Industry Survey Analysis. Bangor University and Manx Fish Producer Organisation Combined Report for the Scallop Management Board. Bangor University. pp. 30.
- Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). King Scallop: 2020 Industry Survey Analysis. Bangor University and Manx Fish Producer Organisation Combined Report for the Scallop Management Board. Bangor University. pp. 38.
- Garratt, M. J., Dempster, N. C., Bloor, I. S. M., Emmerson, J. A. and Jenkins, S. R. (2020). Benthic Habitat Mapping: Ramsey Bay Marine Nature Reserve. SFAG Report No.6, Bangor University. pp 45
- Garratt, M. J., May, L., Bloor, I. S. M., Emmerson, J. A. and Jenkins, S. R. (2020). Benthic Habitat Mapping: Baie ny Carrickey Marine Nature Reserve. SAFG Report No.7, Bangor University. pp 38.
- Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). Queen Scallop: 2020 Industry Survey Analysis. SFAG Report No.8, pp. 26
- Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2020). King Scallop: 2020 Industry Survey Analysis. SFAG Report No.9, pp. 37.
- Garratt, M. J., Allison, C., Bloor, I. S. M., Emmerson, J. A. and Jenkins, S. R. (2020). Benthic Habitat Mapping: Niarbyl Bay Marine Nature Reserve. SFAG Report No. 10, Bangor University. pp. 22.
- Garratt, M. J., Allison, C., Bloor, I. S. M., Emmerson, J. A. and Jenkins, S. R. (2020). Benthic Habitat Mapping: Laxey Bay Marine Nature Reserve. SFAG Report No. 11, Bangor University. pp. 18.
- Garratt, M.J., Bloor, I.S.M., Emmerson, J.A., Duncan, P. and Jenkins, S.R. (2020). East of Douglas Experimental Research Area: Three-Year Review. SFAG Report No. 12, Bangor University. pp. 16.
- Emmerson, J. A., Bloor, I.S.M, Jenkins, S.R. (2020) An overview of the crab and lobster fishery in the Isle of Man territorial sea; catch & effort trends, licencing, and latency. SFAG Report No. IOM 1, Bangor University. pp. 9.
- Emmerson, J. A. (2020 Minimum Conservation Reference Size (MCRS) changes in the lobster (H. gammarus) fishery; expected short-term costs and long-term benefits. Evidence to support the crab and lobster consultation (2020). SFAG No. IOM 2, Bangor University. pp. 8.
- Garratt, M.J., Emmerson, J.A., Duncan, P., Bloor, I.S.M. and Jenkins, S.R. (2020). Size at onset of maturity (SOM) of European lobster (H. gammarus), Isle of Man. SFAG Report No. IOM 3, Bangor University. pp. 15.
- Emmerson, J. A. (2020) A 5-year scientific research plan for the Isle of Man crab and lobster fishery (2020-2025). Sustainable Fisheries and Aquaculture Group Report No. IOM 4, Bangor University. pp. 19.
- Emmerson, J. A. (2020) Enhanced Electronic Reporting System (EEERs) in the Isle of Man static-gear fisheries; observations, insight and recommendations from a 12-month trial within the Edible crab fishery 2018/2019. Fisheries and Conservation Report No. IOM 5, Bangor University.

Meetings and Committees:

- International Council for Exploration of the Seas (ICES) Workshop on Scallop Ageing. Marine Scotland, Aberdeen, 10^{h} – 12^{th} March 2020 (Attended by Dr. Isobel Bloor).
- International Council for Exploration of the Seas (ICES) Working Group on Scallop Stock Assessment, Virtual via Video Conference, 5^{h} – 9^{th} October 2020 (Attended by Dr. Isobel Bloor).
- International Council for Exploration of the Seas (ICES) Working Group on the Biology and Life History of Crabs, Virtual via Video Conference, 10^{h} – 12^{th} October 2020 (Attended by Jack Emmerson).
- International Council for Exploration of the Seas (ICES) Working Group on Scallop Stock Assessment, Subgroup meeting North Irish Sea Stock Assessment for King Scallops. Virtual via Video Conference, 8th December 2020 (Attended and Chaired by Dr. Isobel Bloor).
- International Council for Exploration of the Seas (ICES) Working Group on Scallop Stock Assessment, Subgroup meeting Queen Scallops. Virtual via Video Conference, 8th December 2020 (Attended by Dr. Isobel Bloor).
- Association of Inshore Fisheries and Conservation Authorities whelk working group meeting. Virtual via video conference. 11th June 2020 (Attended by Jack Emmerson).
- Wildlife committee meeting, Thursday 22nd October 2020, Thie Slieau Whallian, DEFA. (Attended by Dr. Isobel Bloor)
- Scallop Management Board meeting, Virtual via Video Conference, Friday 5th June 2020, (Attended by Dr. Isobel Bloor).
- Scallop Management Board meeting, Virtual via Video Conference, Tuesday 8th September 2020 (Attended by Dr. Isobel Bloor).

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Grants & Funding:

- A new 5 year contract awarded to Bangor University to provide scientific research and advice to DEFA on Isle of Man commercial Sea Fisheries (1st September 2020—31st August 2025)
- Global Wales International Research Mobility Fund: Travel award to support a 2 week research trip to Professor Stokesbury's laboratory at the School for Marine Science & Technology at the University of Massachusetts, Dartmouth, USA. The topic of the proposed activity is "Stock assessment, ecosystem based fisheries management and the impacts of marine renewables on commercial shellfish fisheries—Dr Isobel Bloor (Awarded November 2019, travel to be undertaken during 2021).
- PhD Studentship funding for Matthew Garratt for research through Bangor University on commercial sea fisheries in the Isle of Man. Student Awards. Isle of Man Government Department for Education, Sport and Culture (Awarded 2020 for start in 2021).

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Theses:

- Boyle, C. (2020). Using fine-scale industry data to manage queen scallop (*Aequipecten opercularis*) fisheries in the Isle of Man. MSc thesis, Bangor University.

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Bangor University has undertaken research for the Isle of Man's Department of Environment, Food and Agriculture since 2007. The research focuses on achieving sustainable and economically viable fisheries within an ecosystem context. We are assessing scallop, crustacean and mollusc stocks and quantifying bycatch, as well as focusing on the ecosystem through habitat surveys and studies examining the impacts of different fishing gears. We also use state of the art techniques utilising fishery-dependent data to understand how the Island's scallop fisheries are exploited and how their management can be improved.

The work is funded by the Isle of Man's Department of Environment, Food and Agriculture

Professor Stuart Jenkins:

I graduated in Zoology from Cambridge University in 1990 and undertook my PhD at Port Erin Marine Laboratory between 1991 and 1995. I remained at Port Erin for a further 6 years, working first on intertidal rocky shores and then with Dr Andy Brand and colleagues at Seafish, examining the effect of scallop dredging on the wider marine ecosystem. In 2001 I moved to Plymouth to the Marine Biological Association where I developed a research group in coastal ecology and in 2007 moved to the School of Ocean Sciences, Bangor University. My research interests are varied, addressing questions in both fundamental and applied ecology. I have particular interests in recruitment dynamics, non-native species, the role of key species over large geographic scales and effective management of marine resources.

Dr Isobel Bloor:

After graduating from Queen Mary's University of London with an MSc in Marine Ecology and Environmental management, I worked as a marine ecologist at a small independent marine consultancy managing the impacts of marine related projects. I then worked on a cross-Channel EU project on cephalopod ecology and completed my PhD in conjunction with the Marine Biological Association and the Marine Institute, University of Plymouth on Cephalopod ecology, movement and behaviour. My research has been predominately fisheries and field-work based working directly with inshore potting fishermen, undertaking acoustic and data storage tagging studies and completing *in situ* scuba surveys of spawning grounds. I also have experience in developing presence-only and presence-absence species distribution models. My current role as a postdoctoral fisheries scientist on the Isle of Man involves developing and undertaking stock assessments and providing the science necessary to assist the government in managing all their commercial fisheries.

Jack Emmerson:

I am a fisheries scientist focussing principally on the interaction between commercial static-gear fisheries in the Irish Sea and the biology of the shellfish resources they depend upon. I gained my BSc and MSc degrees at York University and have worked as a shellfish research scientist for the Holderness Fishing Industry Group, Orkney Sustainable Fisheries and the Cardigan Bay Fisherman's Society. I am part of the Fisheries and Conservation Science group at Bangor University and am based on the Isle of Man within the Department for Environment, Food & Agriculture. I am leading on research related to the biology and life-history of lobster (*H. gammarus*), edible crab (*C. pagurus*) and whelk (*B. undatum*) and am contracted to supply evidence to inform sustainable management of static-gear fisheries within the Isle of Man territorial waters, whilst working towards a part-time PhD "*Sustainable static-gear fisheries in the Irish Sea*".

Matthew Garratt:

I graduated from Bangor University in 2017 with a BSc in Ocean Science before completing an MSc in Marine Environmental Protection the following year. I then began a 3-month work placement on the Isle of Man based at DEFA as a research assistant for Bangor University. Following this period I was contracted by DEFA to continue this work part-time, and have been tasked with a variety of projects, including benthic habitat mapping, closed area assessments and lobster size-at-maturity analysis. I have also assisted on a number of offshore surveys, including the annual Prince Madog cruise. With the valuable experience that I have gained at DEFA I hope to pursue a career in fisheries science.