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Annual Fisheries Science Report

2021

Sustainable Fisheries and Aquaculture Group

School of Ocean Sciences

Annual Report for 2021
(Report No. 7)

Isle of Man Fisheries Science

Sustainable Fisheries and Aquaculture Group
Bangor University

PRIFYSGOL BANGOR UNIVERSITY

Isle of Man Government
Reiltys Ellan Vannin

Review of 2021 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.

During 2021 Bangor University staff, working with DEFA and the Manx fishing industry, have been busy implementing our plan for the new science contract (September 2020- August 2025). Our contract to provide fisheries science advice to the Isle of Man government relies on the embedding of University staff within DEFA's St John's offices. In last year's report we indicated that Dr Jack Emmerson was moving on from employment with Bangor to the position of Sea Fisheries Policy Manager with DEFA. We have been very fortunate to secure the employment of Dr Matt Coleman who joined the Bangor University team on the 1st of July 2021, and moved to the Isle of Man in August. Matt will work closely with Dr Isobel Bloor on all aspects of Isle of Man fisheries, but with a particular focus on static gear, providing scientific advice for sustainable management of crab, lobster, and whelk fisheries. Since graduating from Bangor University in 2013 with a Masters in Marine Biology, Matt has gained highly valuable experience over 7 years working as a fisheries scientist for Orkney Sustainable Fisheries . He brings experience working on the crab and lobster fisheries in Orkney and specifically on lobster reproductive biology and sustainable regional management.

One of the challenges of the 2020-2025 contract is to bring the static gear sector to the same level of data acquisition as achieved already with King and Queen scallops. Whelk, crab and lobster are valuable fisheries and in many ways the Isle of Man is at the forefront of measures to implement sustainable management. However to provide effective management, it is imperative that DEFA receive spatially explicit data on catch and effort across the three target fisheries. The benefits to understanding of stock status, and the drivers of stock dynamics, using spatially explicit data collected by industry were demonstrated through work led by Jack Emmerson and submitted this year to the journal 'ICES Journal of Marine Science'. We are well on our way to being able to collect such data with the implementation of iVMS on <12m vessels.

In addition to the utilisation of fishery-dependent data , we have also begun assessing the use of innovative fishery-independent surveys using for example beam trawl surveys for brown crab and BRUVs (Baited Remote Underwater Video) for whelk and lobster. This latter approach is one technique being assessed by our PhD student, Matt Garratt, whose work on whelk survey methodologies is summarised in this report (see P 29-30). We are also making use of external collaborations with a number of different partners to extend our work in this area. In the summer this year we learnt we were successful in a funding bid with Dr Mike Bell at Heriot Watt University through the Seafood Innovation Fund: 'Use of underwater video and machine learning for monitoring of lobster stocks.' This work is ongoing and is allowing us to explore with our collaborators the usefulness of underwater video in Isle of Man waters, combined with Artificial Intelligence technologies as a tool to monitor lobster stocks.

The work referred to above, on static gear, complements our established procedures with the King and Queen scallop fisheries. Our advice to the Scallop Management Board increasingly takes a spatially explicit approach based on the established Prince Madog surveys and those now undertaken by industry. Full details of the output of these surveys and the resulting management advice for both Queen and King scallops are given in this report. The surveys and subsequent analyses are allowing the rotational closure of relatively small areas of the Territorial Sea. We are seeing the fruits of this in good recruitment and ongrowth in closed or regulated areas, which are being opened to the fishery at the appropriate time to maximise fishing efficiency and minimise impact on the sea bed.

Looking forward to 2022 we anticipate a continuing productive relationship with the Manx fishing industry as we work toward productive and sustainable fisheries.

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Annual scallop surveys (2021)

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Scallop research and science for Isle of Man stocks is well developed and these fisheries are considered data rich. In recent years changes to the way these fisheries are managed, which include managing at a finer spatial resolution, have however required additional finer resolution survey data to be acquired. As such in 2019 a new fine scale survey which is industry led was established. This enables ground specific trends to be more accurately assessed and managed. As such, there are currently two annual scallop surveys undertaken within the Isle of Man's territorial waters:

1. **Long-term, medium resolution, fixed site survey:** This survey has been undertaken since 1992 and incorporates both king and queen scallops. It is a medium resolution survey (~ 3nm between survey sites), conducted at fixed survey stations. In 2021 the survey was undertaken between 8th and 15th April 2021 with a total of 64 stations surveyed. The standard survey gear comprises of a set of four Newhaven dredges: two with 80 mm ring diameter and 9 teeth of 110 mm [king dredges] and two with 60 mm ring diameter and 10 teeth of 60 mm [queen dredges]. At each station the dredges are towed at 2.6 knots for 20 minutes with the direction of the tow dependent on tidal state and current condition. For each tow the total biomass of king and queen scallops per dredge is recorded and a subsample of 90 queen scallops and 90 king scallops from each dredge are then weighed and measured (king scallops are also aged). Further details of the standardised methodology used are

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2. Short-term, fine resolution, random stratified survey: This survey has been undertaken since 2019 (i.e. 2021 is Year 3 of the survey). The survey, which incorporates both king and queen scallops, is currently completed on two industry fishing vessels (F.V. Benolas and F.V. Sarah Lena) and sampling is coordinated by the MFPO with scientific support from Bangor University. It is a fine resolution survey (survey cells: 1 min (longitude) x 0.5 min (latitude)). In 2021 the survey was undertaken between 11th and 17th May 2021 at five scallop fishing grounds: Targets (TAR), East of Douglas (EDG), Chickens (CHI), East Coast (ECO) and Bradda (BRA = 2 days). For financial reasons surveying of the fishing grounds at Point of Ayre (POA) and Maughold (MGH) were not undertaken in 2021. Each vessel towed a 'standard survey dredge bar' with four dredges, two King and two Queen dredges interspersed along the bar and a 'juvenile survey dredge bar' of the same design but using Queen dredges with 17 teeth with a smaller mesh. These dredges are designed to enable smaller queen scallops to be sampled. Survey cells were sampled randomly within each ground strata (strata were defined predominately by depth) with approximately equal effort to ensure relatively even distribution of survey effort across the entire fished ground (Figure 2). Within each survey cell a 10 minute tow was undertaken at ~ 2.5 knots. The catch from each dredge was counted and a subsample of up to ~ 90 kings and 90 queens were measured. Further details of the standardised methodology used are provided within the annual survey reports.

Reports analysing data from both surveys were prepared in collaboration with the MFPO for each scallop species and presented to the scallop management board (SMB) for discussion of the results.

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

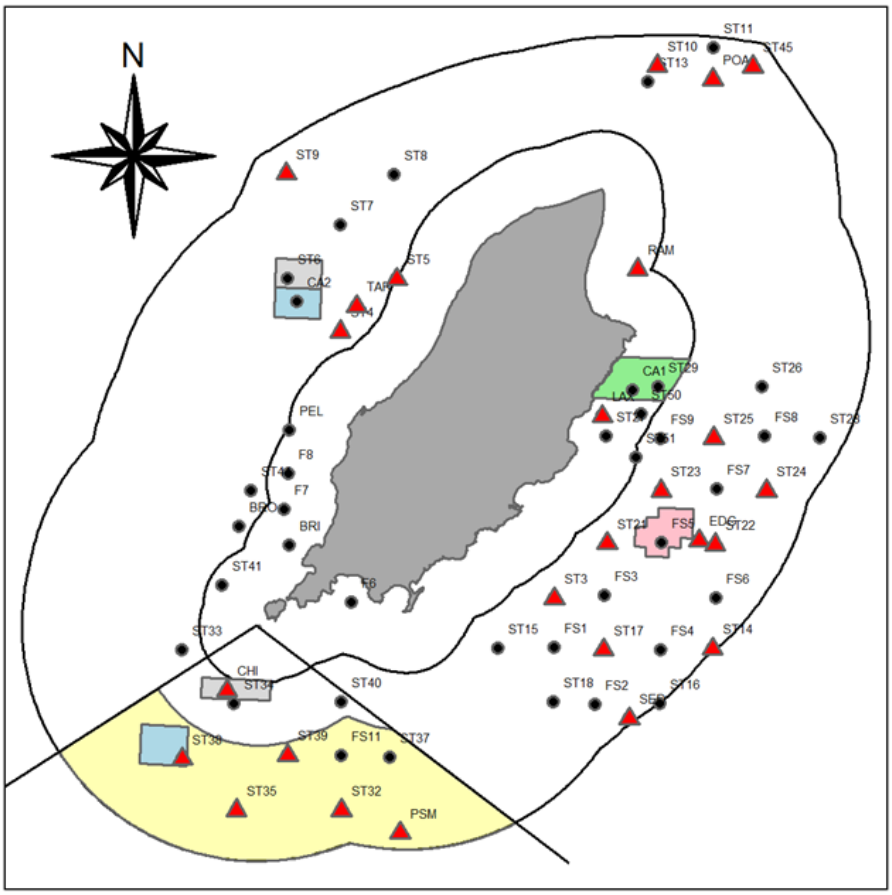


Figure 1: A map showing the location of fixed stations surveyed by the R.V. Prince Madog in 2021 (red triangles = Stations used in stock assessment; black circles = Additional survey stations). During the 2020 queen scallop fishing season light grey boxes indicate areas with restricted management; light blue boxes indicate closed areas, light green box indicates the experimental research area at East Douglas closed for 3 years to allow recovery, the pink box indicates a previous hotspot area of queen scallops in 2019 and the yellow box indicates the area within which dredging for queen scallops is permitted.

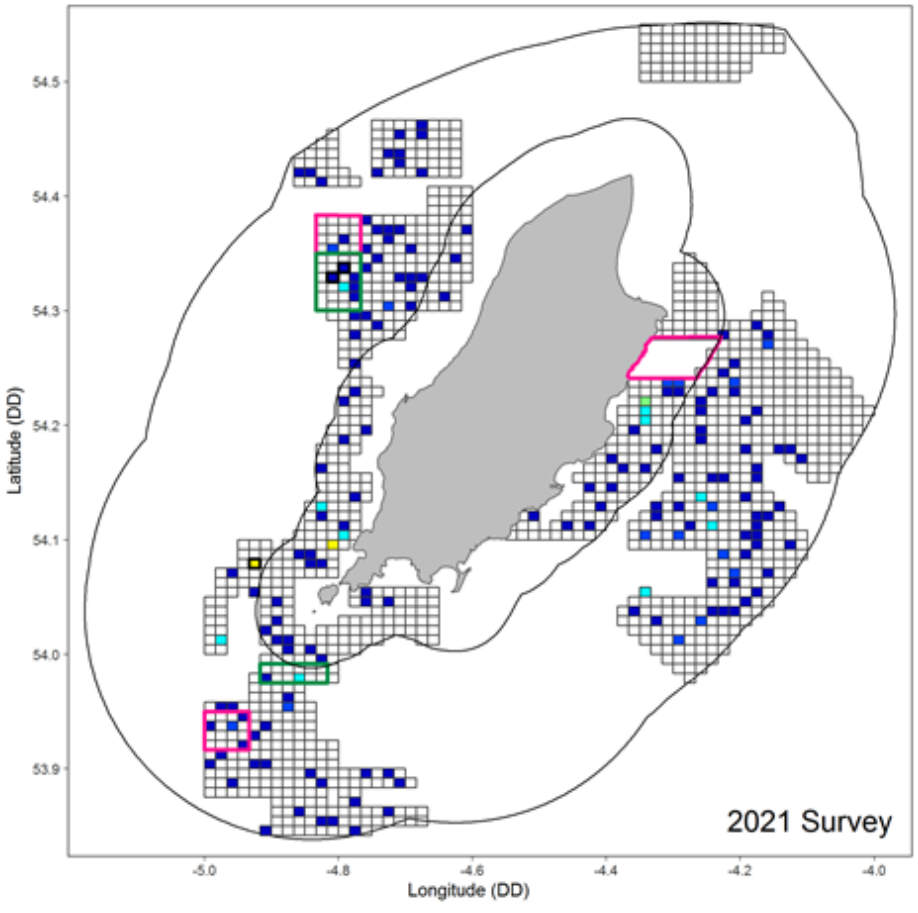


Figure 2: A map showing the survey grid for the fine-scale random stratified scallop survey undertaken by industry vessels. Coloured cells show the locations of randomly selected cells for surveying in 2021. Survey grounds in the north (Point of Ayre) and the north-east (Maughold) were omitted from the 2021 survey due to limited survey time. The green boxes indicate restricted access areas during the current queen scallop fishing season (i.e. 2021) and the pink boxes indicate areas currently closed for queen scallop fishing in 2021.

Prince Madog Survey Results (2021): Queen scallops

The results from the Prince Madog survey enable territorial sea trends to be assessed and the long term nature of the data means that they are sufficient for undertaking stock assessments. The key results and analysis from this survey are presented below. The mean densities (scallops per 100 m^2) of queen scallops from queen scallop dredges for all stations surveyed in 2021 are displayed in Figure 3. The four survey sites with the highest densities are CHI and ST 38 (south coast) and CA2 and ST6 (west Coast) which are all located in closed or restricted access areas (Figure 1). These stations all have densities ranging between 44 – 139 scallops per 100 m^2.

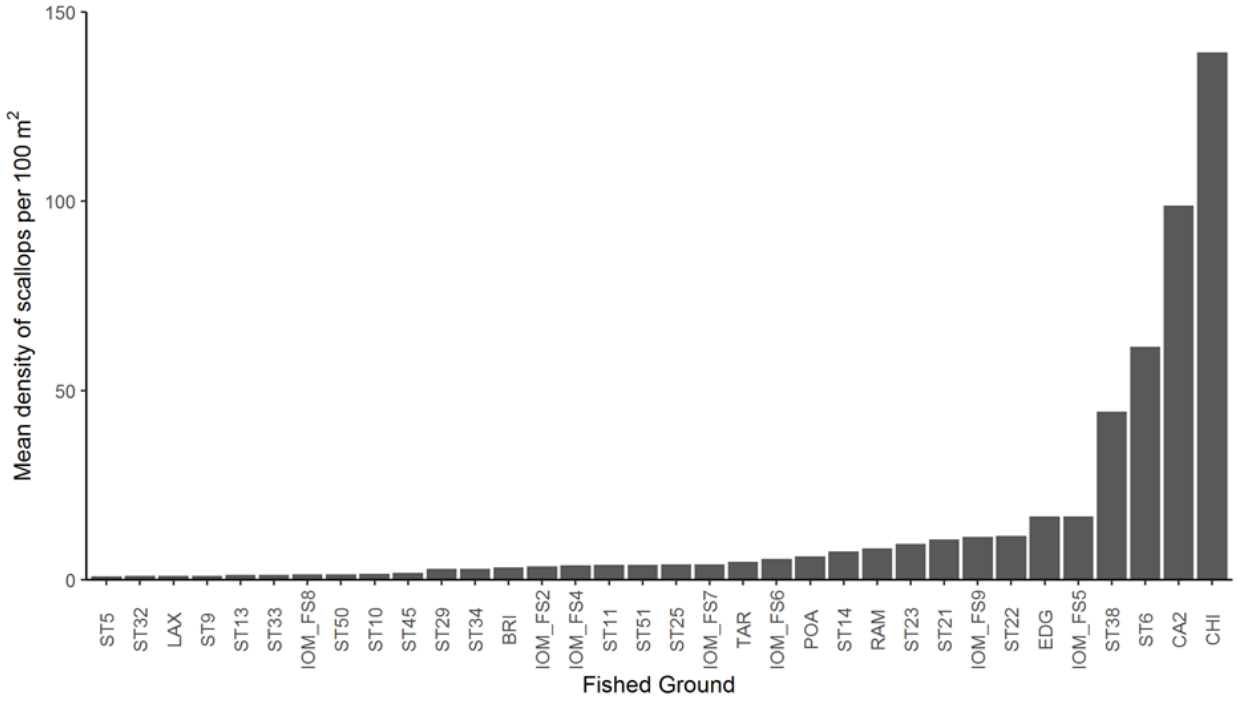


Figure 3 Average survey density (scallops per 100m^2) of queen Scallops from queen scallop dredges from all sites surveyed during the 2021 Prince Madog survey. For plotting purposes sites where QSC density was > 0.45 scallops per 100 m^2 are not displayed. CA2 = an additional site surveyed within the 2020 closed area at TAR.

Stations that have been sampled over at least two years and at which queen scallops are present (3, 4, 5, 9, 10, 14, 17, 20, 21, 22, 23, 24, 25, 32, 35, 36, 38, 39 and 45), in addition to the standard historical queen scallop survey stations (CHI, EDG, LAX, POA, PSM, RAM, SED and TAR), were included in the 2021 stock assessment for Isle of Man territorial waters (Figure 1).

The difference in mean survey densities (scallops per 100 m^2) of queen scallops from queen scallop dredges between 2019 and 2021 (survey cancelled in 2020 due to CV-19) are displayed for all stations used in the stock assessment in Figure 4. The highest density difference is in the south of the Island where densities have increased at CHI and ST38 by 131 and 40 scallops per 100 m^2 respectively (these sites are both located within managed areas (Restricted Access and Closed)). It should also be noted as seen in Figure 3, that two other stations that are not traditionally included in the stock assessment analysis (ST6 and CA2), but are located within managed areas (Restricted Access and Closed) also have very high densities of queen scallops.

The abundance index (derived from the survey data using the geometric mean of queen scallop densities) for recruits (scallops < 55 mm) had a general declining trend from 2009 to 2019 with slight increases observed in 2012, 2014 and 2018. The data for 2021, although still well below the long-term mean (~69), is the highest recorded for recruits since 2016 (Figure 5).

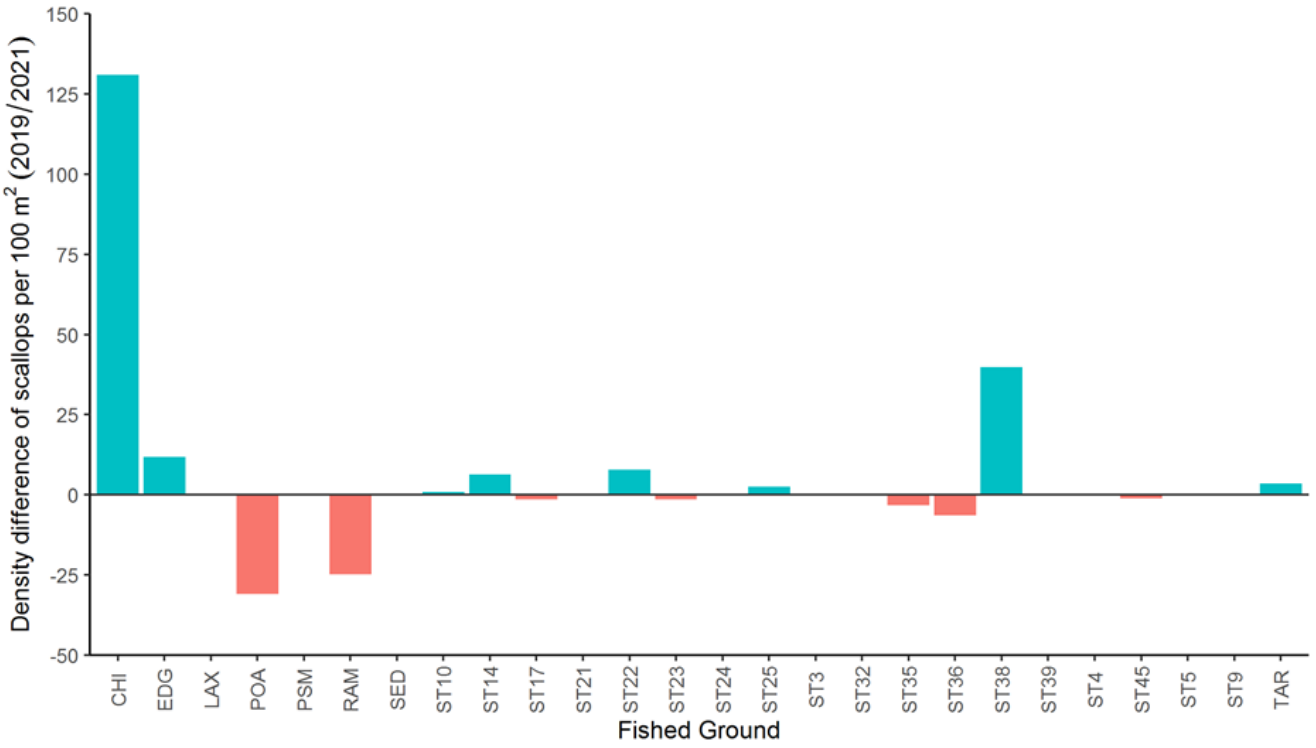


Figure 4 Difference in average survey density (scallops per 100 m^2) of queen scallops from queen scallop dredges between 2019 and 2021 (no survey in 2020 due to CV-19). Red bars indicate decreases in scallop density from 2019 to 2021 and turquoise bars indicate increases in scallop density from 2019 to 2021.

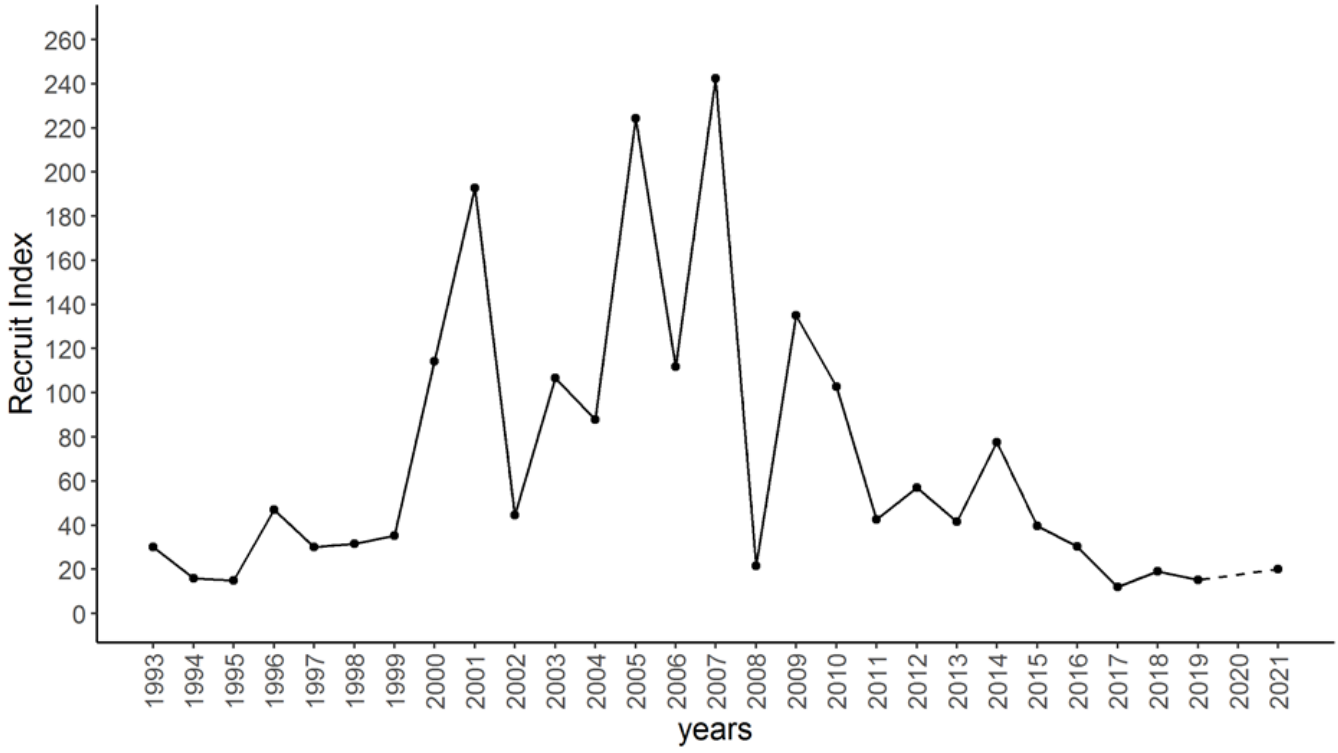


Figure 5 Abundance index (based on geometric mean) for recruits (under 55 mm) used in the catch survey analysis model. This is calculated using data from only the stations used in the stock assessment model. In order to calculate the geometric mean 0.01 was added to each site in order to account for zero data values. Dashed line represents missing values

Prince Madog Survey Results (2021): QSC Cont...

The abundance index for post-recruits (scallops ≥ 55 mm) had an increasing trend from 2007 to 2010, reaching the highest levels on record in 2010. From 2011 to 2019 there has been a declining trend in post-recruit abundance (slight increase observed in 2011), returning to a similar level to that recorded prior to 2007. The data for 2021, although still well below the long-term mean (~399), is the highest recorded for post-recruits since 2017 (Figure 6).

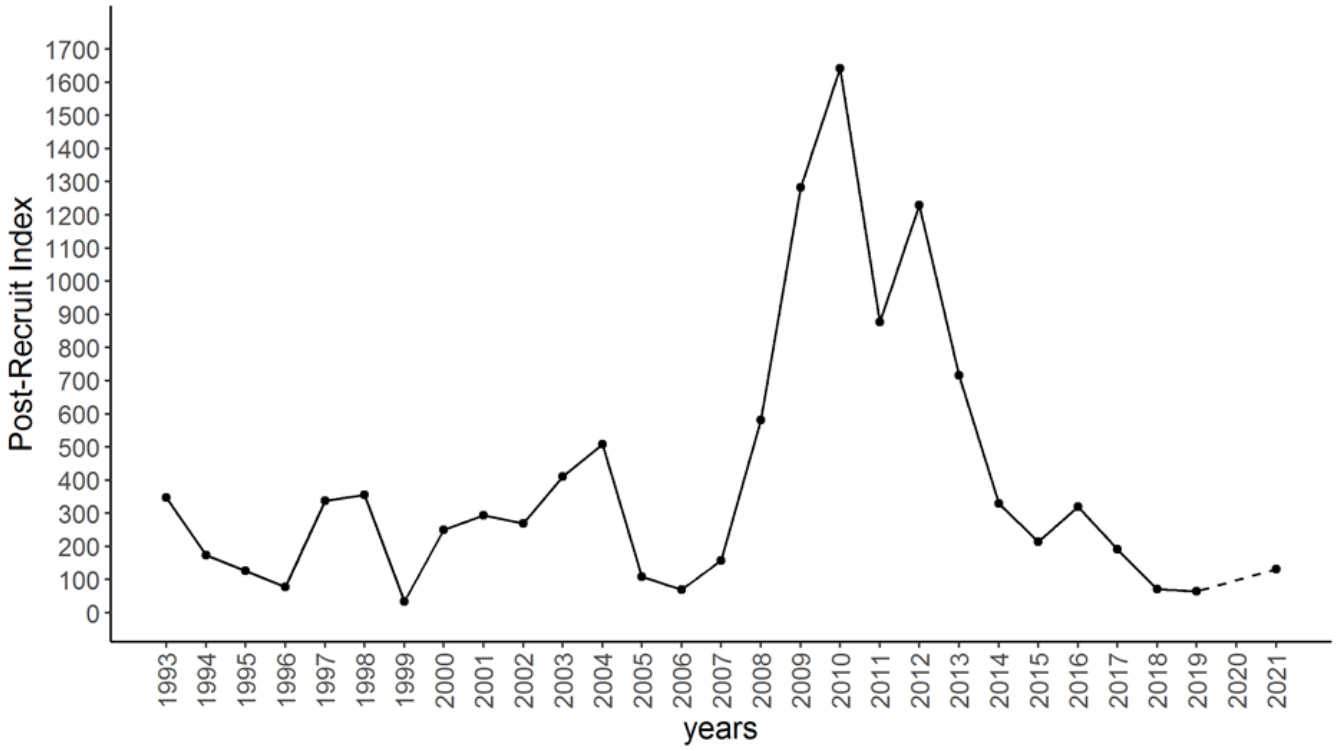


Figure 6. Abundance index (based on geometric mean) for post-recruits (over 55 mm) used in the catch survey analysis model. This is calculated using data from only the stations used in the stock assessment model. In order to calculate the geometric mean 0.01 was added to each site in order to account for zero data values. Dashed line represents missing values.

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

Bloor, I.S.M. and Jenkins, S.R. (2021). Isle of Man Queen Scallop: 2021 Stock Survey Report . Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report. pp. 39.

Industry Survey Results (2021): Queen scallops

The results from the Industry led survey enable ground specific trends to be assessed and the finer scale of the data also enables better demarcation of potential closed or restricted areas to protect high densities of queen scallops under MLS where appropriate.

The Queen scallop densities from the industry survey are shown in Figure 7. Overall data for Isle of Man territorial waters indicates that the survey index has decreased for both post-recruits (over 55 mm) from **5.83 in 2020 to 1.84 in 2021** and recruits (under 55 mm) **from 0.55 in 2020 to 0.11 in 2021**.

In 2019 a recruitment peak (i.e. new recruits ~ 25-45 mm or 1 year olds) can be seen (Figure 8). This peak was focused in two key areas at Chickens and Targets which were protected by closures. By 2020/2021 this peak had grown into the fishery. However, **no new recruitment peak is present in 2021** (Figure 8). This is an important consideration when looking at sustainable management over a > 1 year period.

For **TAR**, which supported the largest quantity of landings from 2020 (301 t), the survey index has decreased for both post-recruits (over 55 mm) from **7.05 in 2020 to 4.84 in 2021** and recruits (under 55 mm) **from 1.62 in 2020 to 0.36 in 2021**.

The survey index for the managed areas at TAR (closed area [southern box] and restricted area [northern box] combined), which was closed in 2018 and 2019 to protect high densities of recruit scallops (king and queen), increased significantly for post-recruits for 2020 and 2021 (0.80 in 2019 to 54.60 and 51.10 in 2020 and 2021 respectively) and decreased for recruits (27.7 in 2019 to 23.6 in 2020 to 7.95 in 2021). 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 and 2020 seasons by full closed or restricted access.

The data indicate that there are high densities of queen scallops ≥ 55 mm in both the closed and restricted area with little new recruitment evident (i.e. queen scallops ≤ 55 mm). For the 2021 fishing season it would therefore be appropriate to open both boxes to fishing. It is noted that some form of managed opening (voluntary or statutory) for this high density area should be considered to avoid over fishing within the area.

For **CHI**, which supported the second largest landings in 2020 (214 t), the survey index has decreased for both post-recruits (over 55 mm) from **3.43 in 2020 to 0.63 in 2021** and recruits (under 55 mm) **from 1.66 in 2020 to 0.10 in 2021**.

The survey index within the area with restricted access during the 2020 fishing season, where access was restricted to prevent over fishing within this high density area, saw a continued increase for post-recruits (**71.20 in 2020 to 266.00 in 2021**) and a continued decrease for recruits (**6.24 in 2020 to 0.27 in 2021**). The shift in abundance indices for recruits and post-recruits is a result of growth within the cohort identified in the 2019 and 2020 surveys, which was protected during the 2019 season by a closure and the 2020 season through restricted access (*note: the highest recorded densities from the industry survey were recorded for post-recruits in a closed area targeted tow: 357 queenies per 100 m^2*). The continued high density of post-recruit density in the restricted area would indicate that for queen scallops the area should be open for fishing during the 2021 fishing season. It is noted that some form of managed opening (voluntary or statutory) for this high density area should be considered to avoid over fishing within the area.

Industry Survey Results (2021): Queen scallops (Cont...)

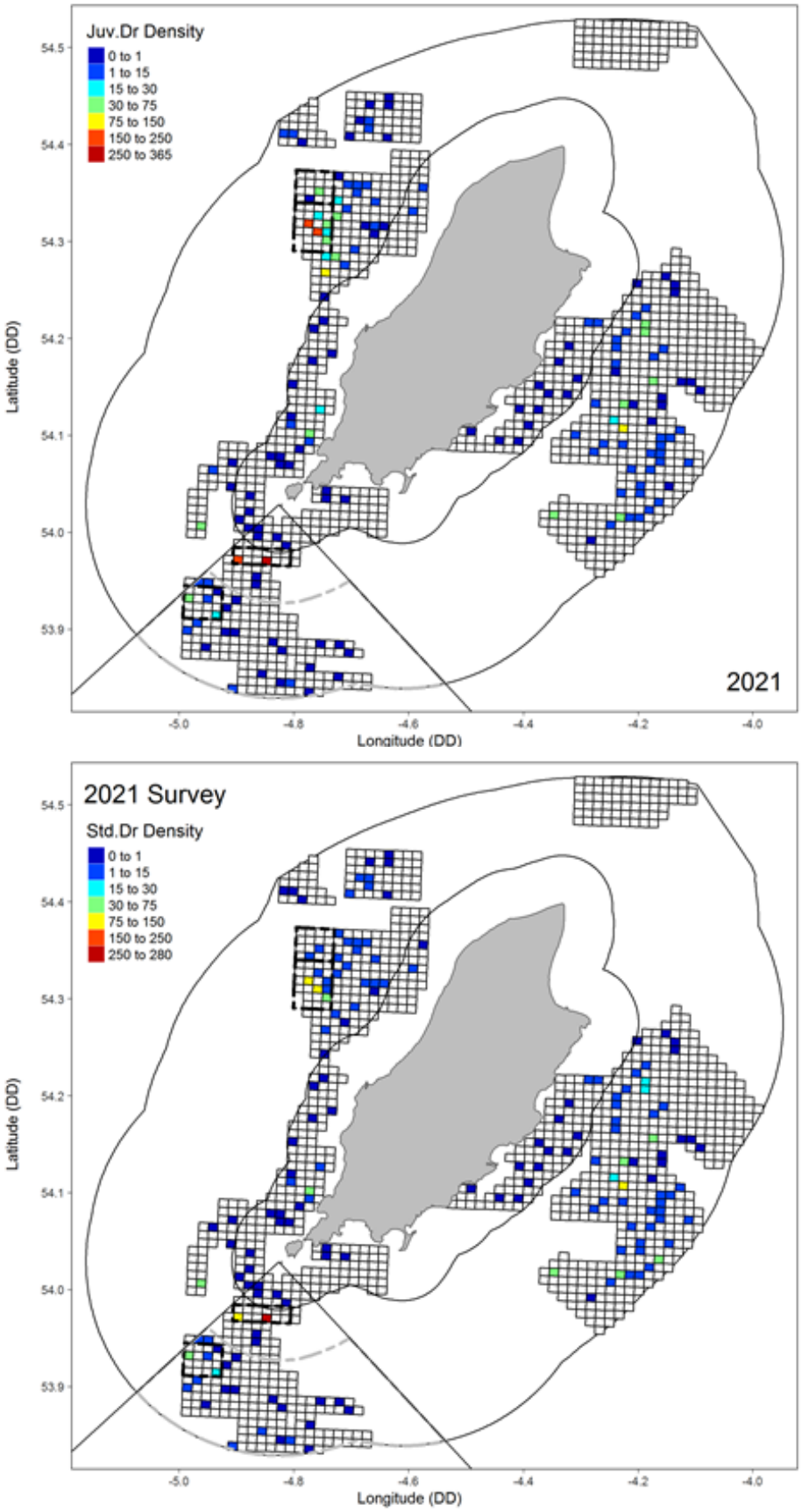


Figure 7 Maps illustrating the survey densities for queen scallops from under MLS (TOP) and over MLS (BOTTOM) for 2021. Point of Ayre in the north of the TS and Maughold in the north-east of the TS were not surveyed in 2021 due to limited survey time. The black borders indicate cells that were part of an additional targeted survey and are not included in the main analysis for the TS, or for individual fishing areas.

For **EDG**, which had landings of only 137 t during the 2020 fishing season and was closed to fishing before the end of the season, both the post-recruit (**6.74 for 2020 and 1.89 for 2021**) and recruit index (**0.20 for 2020 and 0.07 for 2021**) declined.

Given the reduction in post-recruit and recruit densities following removal of only ~ 137 t in 2020 and the closure of the EDG ground towards the end of the 2020 fishing season due to declining LPUE it is recommended that a lower amount is harvested from this fishing ground during the 2021 fishing season and that LPUE for this ground is closely monitored against the set thresholds to limit any further significant decline across the entire fishing ground.

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), there was an increase in the post-recruit index (0.55 in 2020 to 2.25 in 2021) and a decrease in the recruit index (0.69 in 2020 to 0.34 in 2021). 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.

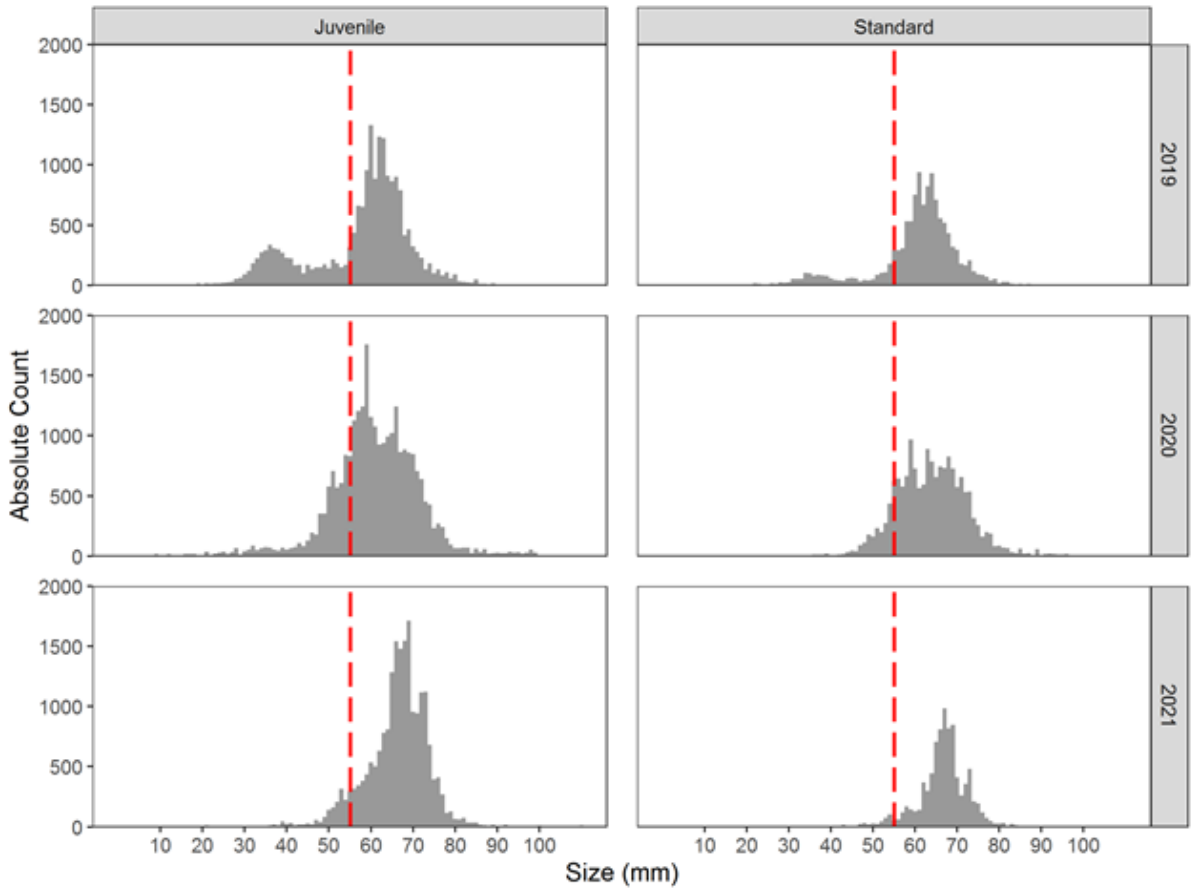


Figure 8 Size frequency distribution of absolute counts of queen scallops displayed by survey year and survey dredge type (red dotted line indicates the MLS of 55 mm). Targeted survey cells excluded. The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions. Note the new recruitment peak (i.e. queenies of ~ 25 – 45 mm) in 2019 indicating new recruitment coming through from that year (i.e. these queen scallops are 1 year old). No recruitment peak was observed in 2020 and 2021.

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

Bloor, I.S.M. and Jenkins, S.R. (2021). Isle of Man Queen Scallop: 2021 Stock Survey Report . Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report. pp. 39.

Queen Scallop Stock Advice (2021)

The advice below was provided by Bangor University to the Scallop Management Board for consideration for management of the 2021 queen scallop fishing season.

A total allowable catch (TAC) for the 2021 fishing season was not calculated using the ICES Category 3 data limited approach due to the year of missing data in the long-term survey abundance index for 2020. Within the territorial waters there were four temporary managed areas for queen scallops during the 2020 fishing season, for which access has been restricted or prohibited over the last two fishing seasons. These areas, located at CHI and TAR, have the highest densities of post-recruit queen scallops recorded in the 2021 surveys.

Recommendations for the management approach for the 2021 queen scallop fishing season were presented to the SMB as follows:

- A precautionary management approach should be considered due to the lack of a TAC calculation and indications of continued low biomass and decreases in the industry survey index for both recruits and post-recruits at the scale of the Isle of Man territorial waters.

- Starting TAC to remain at 2020 fishing levels for the trawl fishery (i.e. 647 t) with the flexibility of decrease or increase depending on the monitoring of high density areas.

- Restricted access and management of the two high density fishing areas at Chickens and Targets that were defined as newly opened areas in 2020. With monitoring of LPUE and fishing intensity (swept area) to ensure that overfishing of these spatially discrete areas does not occur.

- Regular monitoring and triggered reviews of all fishing areas throughout the fishing season in terms of LPUE thresholds that were established for 2020 and total catch.

- Temporary closed areas implemented to protect any high densities of recruits identifies in the survey (i.e. CHI and TAR).

- Closure of POA: The fishing ground was closed during the 2020 fishing season due to low LPUE and the scientific survey data indicates a further reduction in queen scallop density in 2021.

- Closure of the dredge box: LPUE from dredge vessels within the dredge box has been declining annually since 2014 with the lowest value recorded in 2020 and only 1 of the 5 licenced vessels fishing. The current survey data from both the scientific and industry survey in the dredge box indicate lower densities (except for the closed area represented by ST38) for 2021 compared to 2020 and thus a closure for both net and dredge boats is recommended in order to enable stock recovery within this area.

Queen Scallop Trawl Fishery Update (2021)

A requirement of the queen scallop fishing licence In the Isle of Man is that Daily Catch Return forms (DCRs) are submitted through an electronic App by midnight on the day of fishing. This provides almost real-time fisheries dependent data for the fishery for monitoring total allowable catches (TACs) and catch rates (i.e. landings per unit effort [LPUE]) and the ability to modify management at a fine spatial resolution within the fishing season.

The 2021 Isle of Man queen scallop fishery had a TAC of 851.3 t. The TAC was fished by two separate metiers: Trawl fishery (32 eligible vessels) and dredge fishery (5 eligible vessels).

The trawl fishery had an initial sub TAC of 661.7 t (increased to 793 t during Week 11 of the trawl fishery for socio-economic reasons) and opened on 1st July 2021 and closed on 27th September 2021. For the trawl fishery a weekly catch limit of 3150 kg was implemented for Weeks 1-5. For socio-economic reasons, from Week 6 of the fishery the weekly catch limit was increased to 4550 kg per vessel which was then decreased to 3640 kg from Week 12 (a voluntary reduced catch limit of 3150 kg was then established by industry for Week 13 to limit any TAC overshoot). Total reported landings for the trawl fishery during the 2021 fishing season were ~ 818.36 t with 24 unique vessels reporting landings. The majority of landings came from Chickens and Targets (Table 1). For 2021 there were no additional trawl landings from the Ramsey Bay permit only fishery which operates under a separate TAC (i.e. 0 t landed) and the dredge fishery, which is open in October and operates exclusively within a set dredge area at Chickens, also reported no landings for 2021 (i.e. 0 t).

Table 1: Landings by ground for the 2021 queen scallop fishery (trawl and dredge)

Area	Landings (t)
IS21: Chickens	517.9
IS9: Targets	264.6
IS10: Maughold	17.6
IS15: East Douglas	16.7
IS14: BRA/PSM	1.5

Weekly LPUE, standardised to 35 kg bags per hour fished per 10 fathoms of net, are displayed for each of the main fishing grounds in Figure 9. Chickens (IS21) and Targets (IS 9) had the highest LPUE across the season within the newly opened restricted area (median weekly LPUE values of ~ 10 – 20 for CHI and 9 – 26 for TAR). The mean weekly LPUE for all other grounds (EDG, BRA, PSM and MGH) was typically below 5 bags (35 kg) per hour fished per 10 fathom of net (Figure 9).

Seasonal landings per unit effort, standardised to 35 kg bags per hour fished per 10 fathoms of net, is displayed for each fishing season from 2014 to 2021 in Figure 10. The boxplot indicates that with the exception of 2015, the median LPUE for the 2021 fishery was higher than all other years for this period (Figure 6). Fishing within the high density newly opened restricted access areas at Chickens and Targets largely contributed to the increase in median LPUE for 2021 (Figure 10).

Queen Scallop Trawl Fishery Update (2021) (Cont…)

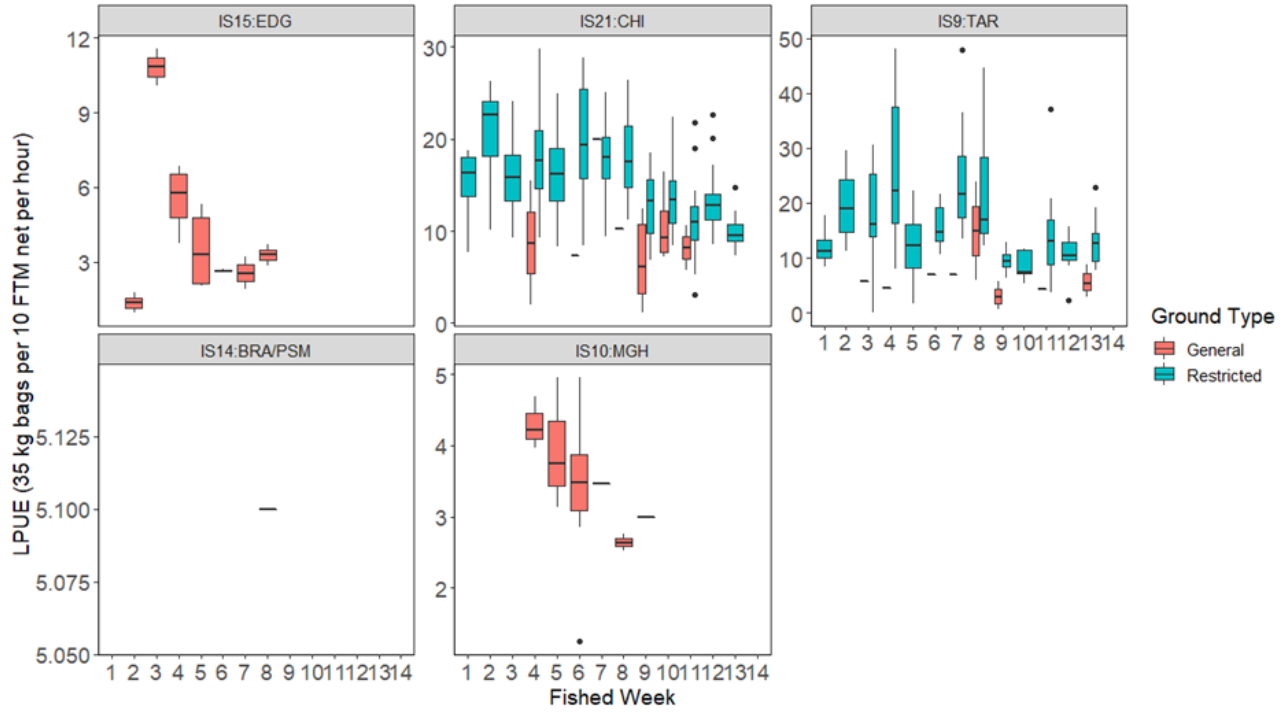


Figure 9 A boxplot of queen scallop trawl LPUE (35 kg bags per hour fished per 10 fathom of net) for the 2021 queen scallop trawl fishing season displayed by week and main fished ground. For TAR and CHI fishing grounds the vessel trips are split further into the general fishing area and the newly opened restricted fishing areas. Note: Different scales on Y-axes.

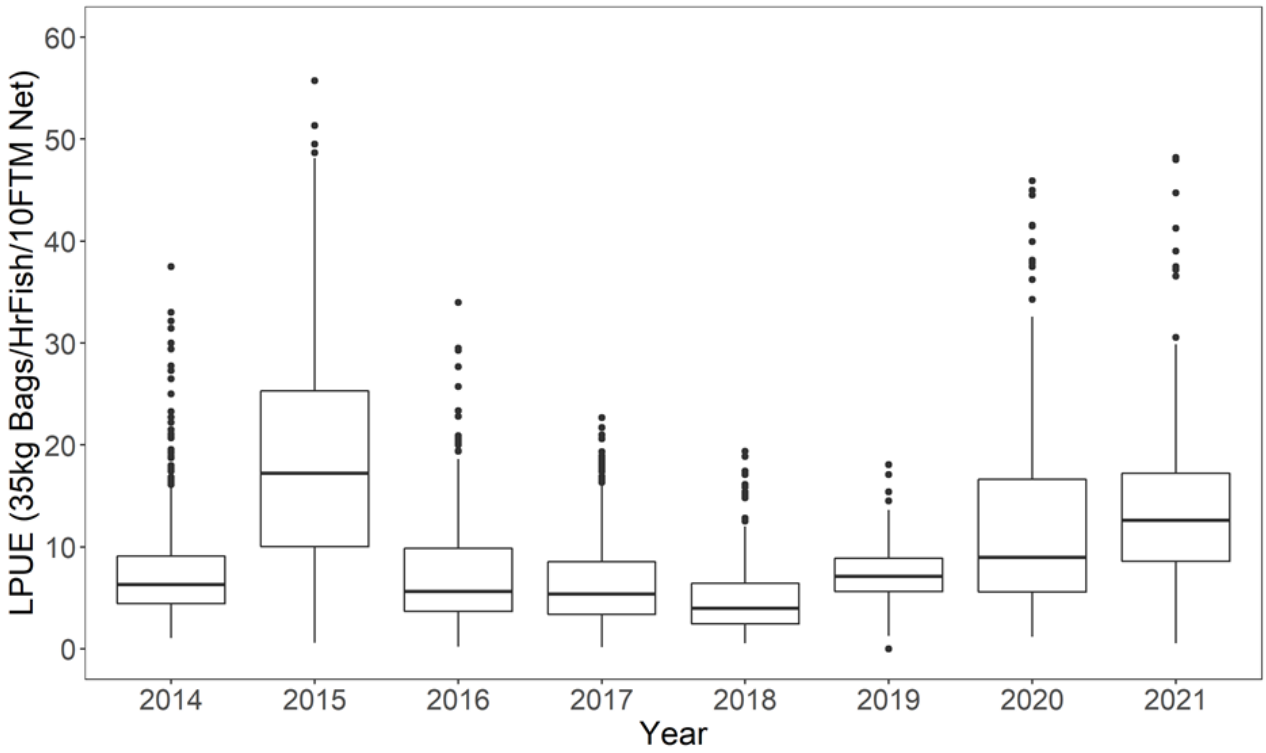


Figure 10 A boxplot of queen scallop trawl LPUE (35 kg bags per hour fished per 10 fathom of net) for all vessel trips by fishing season

When the data are displayed by fishing ground and season, the median LPUE at Targets was the second highest recorded in the eight year period while that at Chickens was the third highest. However in contrast LPUE at the East Douglas ground was low. In fact within season monitoring led to the ground being closed out to the 6 nm limit mid-season due to substantial declines in LPUE . There was no fishing at Point of Ayre or Ramsey Bay during the 2021 season (Figure 11).

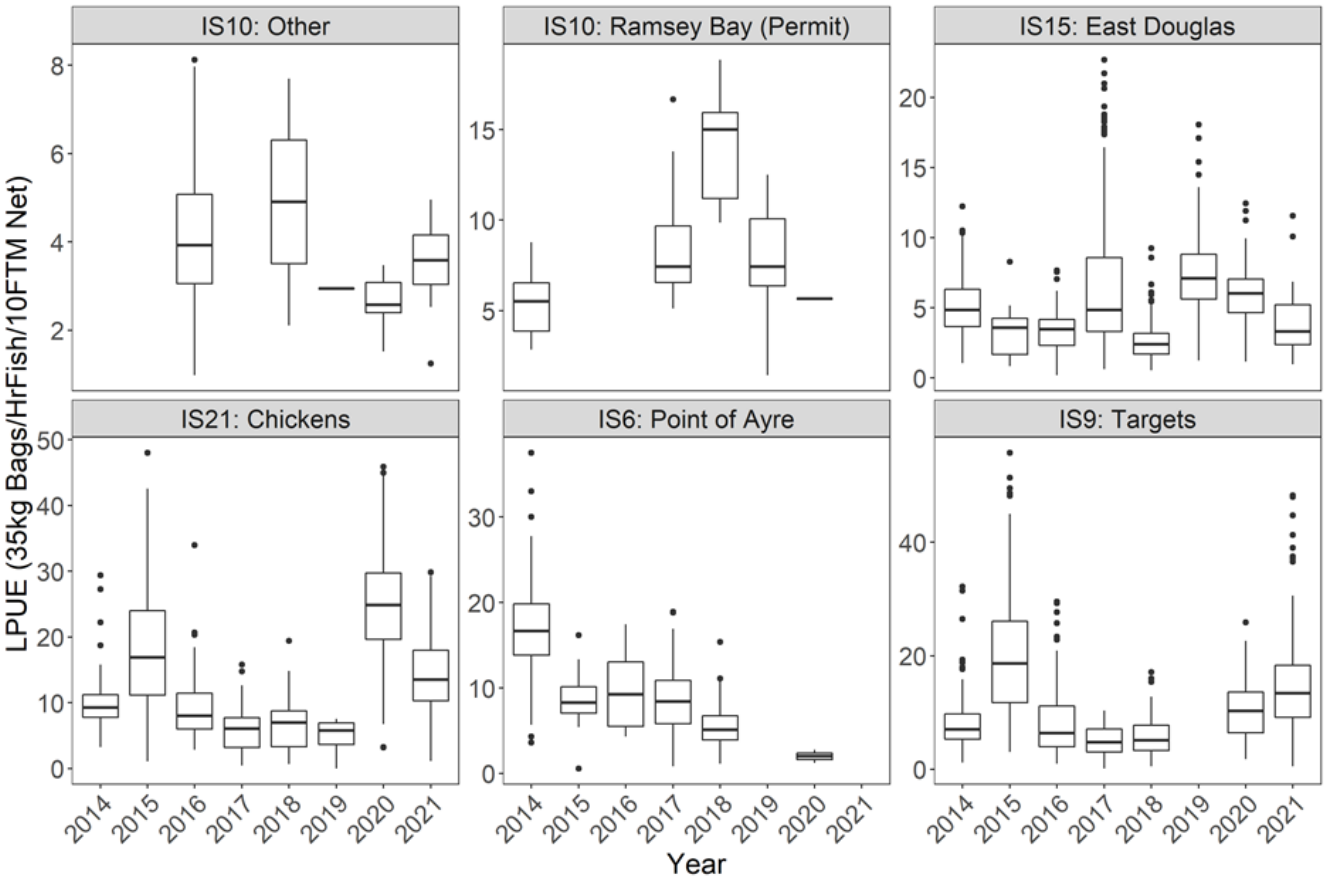


Figure 11 A boxplot of queen scallop trawl LPUE (35 kg bags per hour fished per 10 fathom of net) for all vessel trips by season and split by fishing ground from 2014 to 2021.

Queen Scallop Dredge Fishery Update (2021)

The dredge fishery had a sub TAC of ~58.3 t and opened on 1st October 2021. For the dredge fishery each eligible vessel was allocated an individual quota of 11,660 kg which could be fished during the season as and when suited the vessel. However none of the 5 licenced vessels reporting landings. Prior to 2021, LPUE for the dredge fishery had seen annual declines in LPUE with the lowest value (based on a single trip) recorded in 2020 (Figure 12).

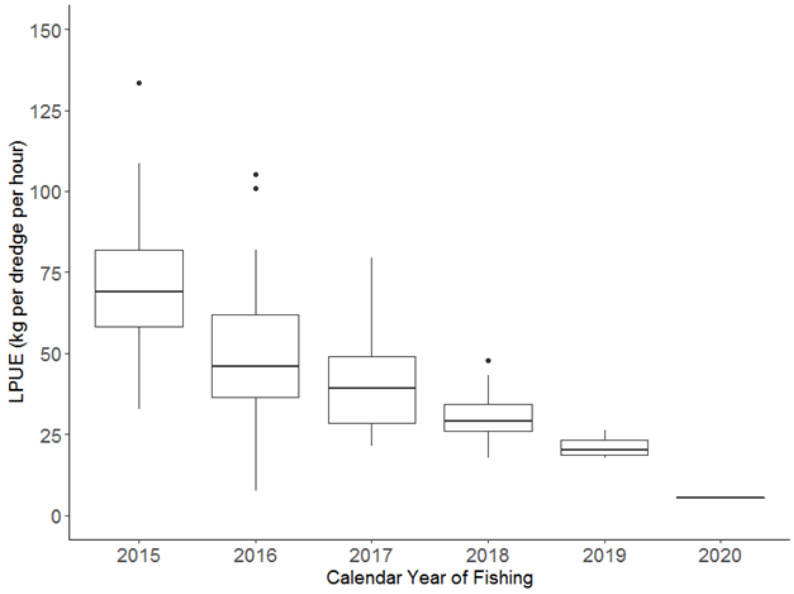


Figure 12 LPUE standardised to kg per dredge per hour for dredge vessels participating in the Isle of Man queen scallop dredge fishery which occurs within the dredge box located within the CHI fishing ground from 2015 to 2020 (note no landings reported in 2021).

Review: King Scallop Fishery (2020/2021)

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. Just as in the Queen scallop fishery these analyses, which are provided on a weekly basis, enable the SMB and DEFA to respond rapidly to conditions in the fishery as they occur.

The fishery opened on Sunday 1st November 2020 and closed on 31st May 2021. The total allowable catch (TAC) for the 2020/2021 Isle of Man king scallop fishery was 2049t. This was equal to the TAC set for the 2019/2020 fishing season. Total reported landings for the Isle of Man king scallop fishery during the 2020/2021 season were ~ 1727t with 64 unique vessels reporting landings. This was the same number of unique vessels as in the previous season (2019/20120).

Landings are reported below by IS Box which represents the Main Fished Ground (Figure 13). The main fishing grounds are Targets in IS9, Chickens in IS21, Bradda/Port St Mary in IS14, East Douglas in IS15, Maghould in IS10 and Point of Ayre in IS6. For the 2020/2021 fishing season East of Douglas (IS15: EDG) had by far the most landings. The fill colour of each bar shows which month landings are from enabling temporal changes in the spatial distribution of landings through the season to be detected.

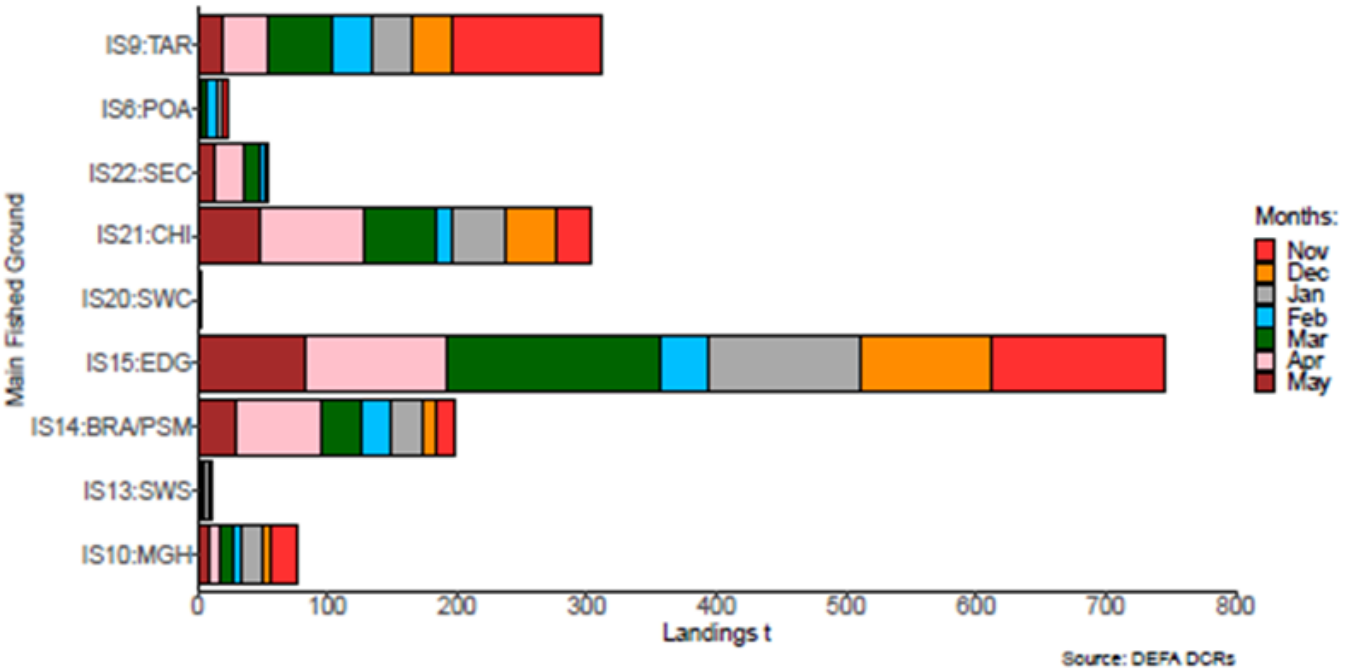


Figure 13 King scallop landings (t) from Isle of Man territorial waters displayed by main fished ground and month for the 2020/2021 fishing season.

The Daily catch limit for the 2020/2021 Isle of Man king scallop dredge fishing season within the 0- 12 nm limit was **700 kg** per vessel. At the start of the fishing season (November 2020) ~ 65 % of vessel trips were meeting the DCL (i.e. landing around 700 kg) whilst at the end of the fishing season (May 2021) this had reduced to ~ 41 % of vessel trips.

The 2020/21 average LPUE (**kg per hour fished per dredge**) at each of the main fished grounds is displayed in Figure 14 (green line) with comparisons for 2017/18, 2018/19 and 2019/20 (grey lines) by fished week. For 2020/2021 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 2020/2021 the LPUE at all other grounds ranged between 0 and 15 kg/Dr/HrF. The LPUE at IS10 MGH, IS15 EDG and IS21 CHI were all within the top range of LPUE for these grounds over the last three fishing seasons. IS14 BRA/PSM, IS4 POA and IS9 TAR were all around average LPUE compared with previous seasons.

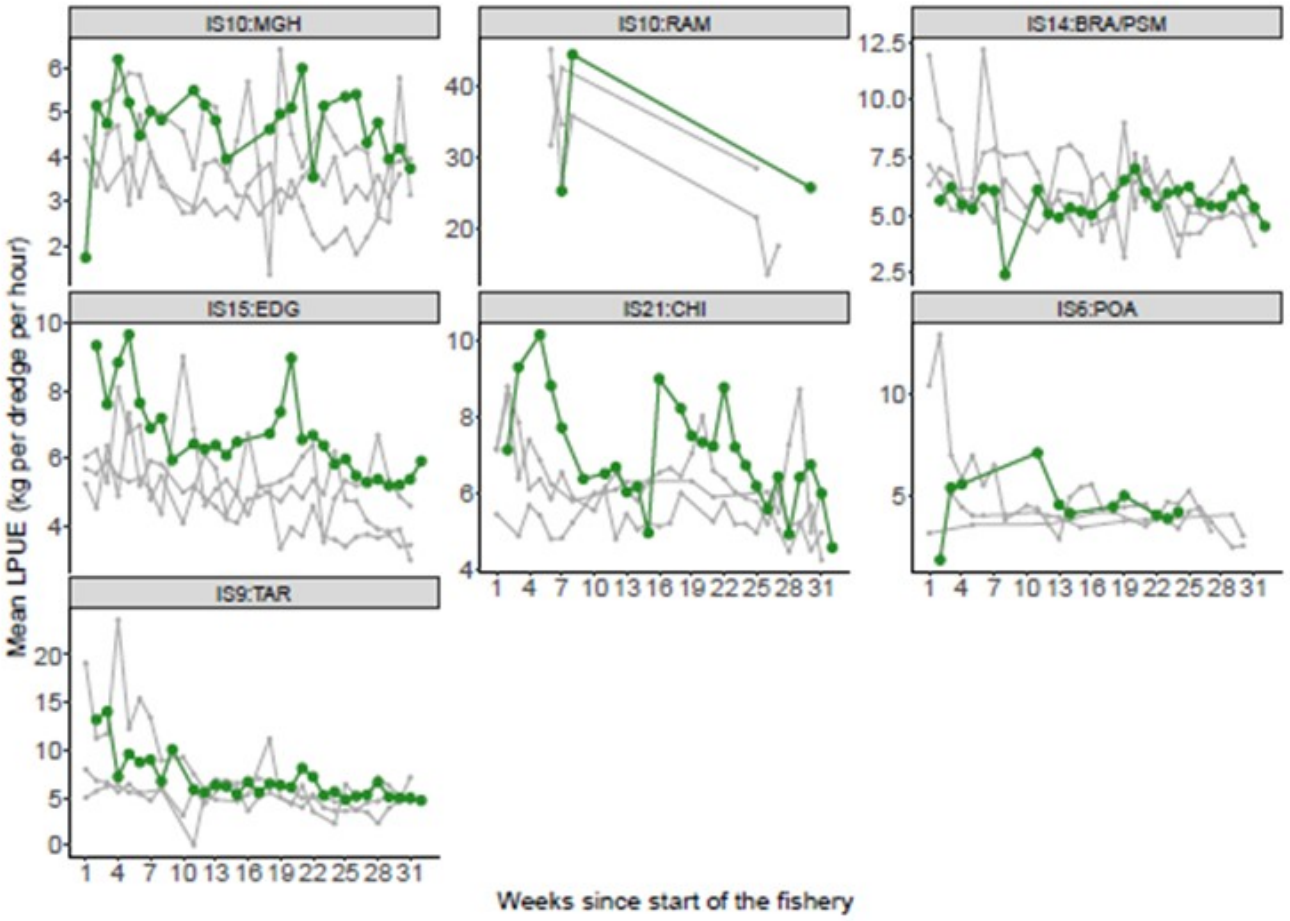
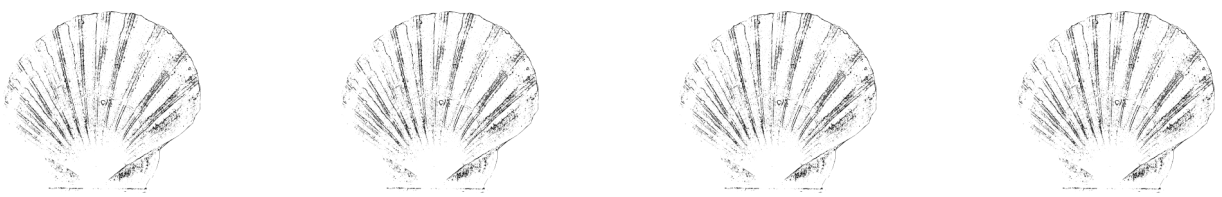


Figure 14 King scallop LPUE (kg per dredge per hour) for the 2020/2021 (green) and historic (grey) fishing seasons.



Prince Madog Survey Results (2021): King scallops

As for queen scallops, the results for king scallops from the Prince Madog survey enable territorial sea trends to be assessed and the long term nature of the data means that they are sufficient for undertaking stock assessments. The average survey density of king scallops (of all sizes caught) per 100 m^2 around the Isle of Man for the 2021 survey is displayed in Figure 15 for all survey stations. In 2021 the fishing grounds in the inshore east coast and to the south of the Island (ST27 and CHI) had the highest densities of king scallops per 100 m^2 (~7.3 and 6.6 king scallops per 100 m^2 respectively) (Figure 15).

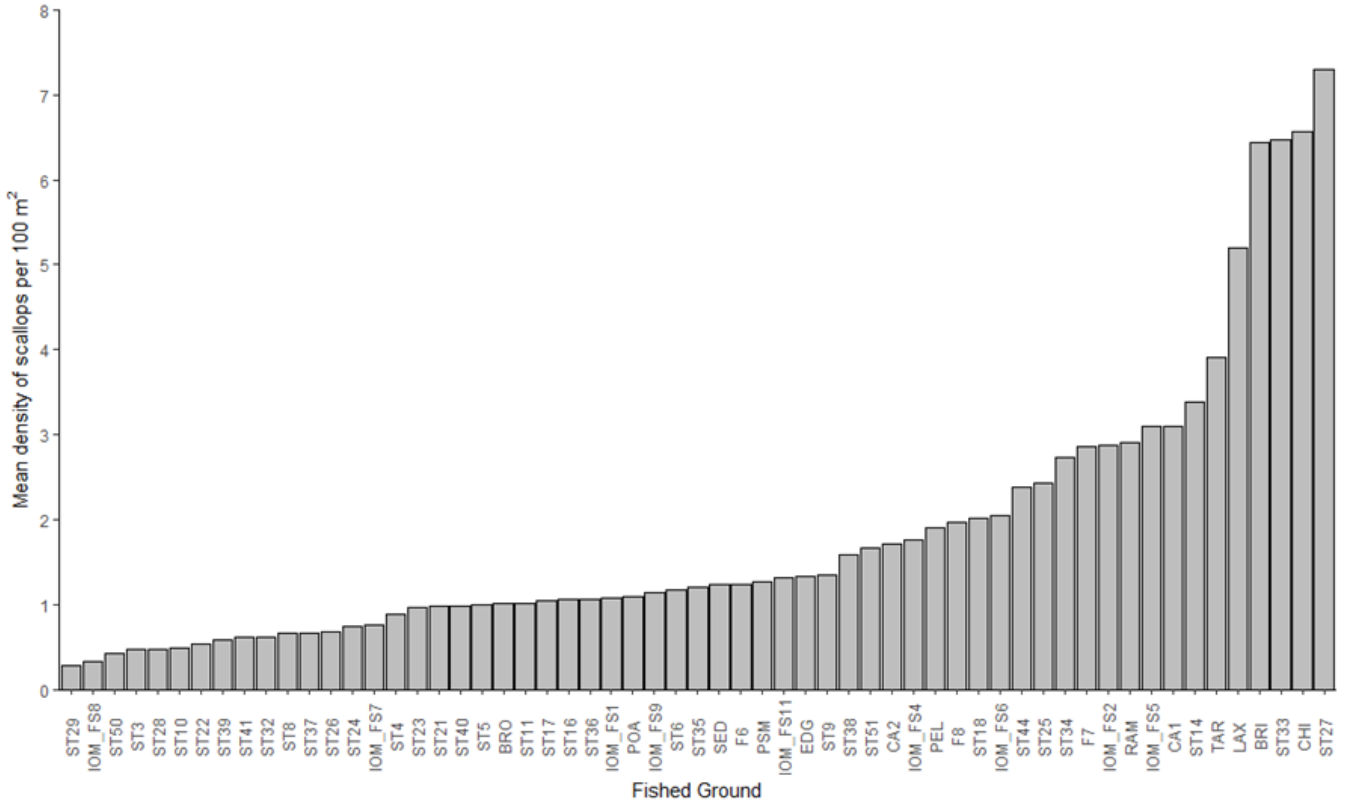


Figure 15 Survey densities (king scallops per 100 m^2) displayed by survey station for spring 2021 survey (average of queen scallop dredge data).

The difference in mean survey density (scallops per 100 m^2) of king scallops from queen scallop dredges between 2019 and 2021 (no survey data for 2020) is displayed for all survey stations sampled in both years (Figure 16). This indicates positive increases between 2019 and 2021 in total scallop density at 28 of the 51 historical stations, but decreases in 21.

Although the extent and number of survey stations has been increased since 2013 (Bloor & Kaiser, 2017) (recently introduced stations are represented by either just a number e.g. 46 or a number prefixed with an F e.g. F12) only 10 standard historical scallop survey stations (BRI, BRO, CHI, EDG, LAX, PEL, POA, PSM, SED and TAR), were included in the current survey abundance index assessments as these reflect the extent of the main, persistent king scallop beds within the Isle of Man's territorial sea. The eleventh historical station RAM was excluded from the abundance indices presented here as it is managed and assessed separately from the rest of the territorial sea scallop fishery.

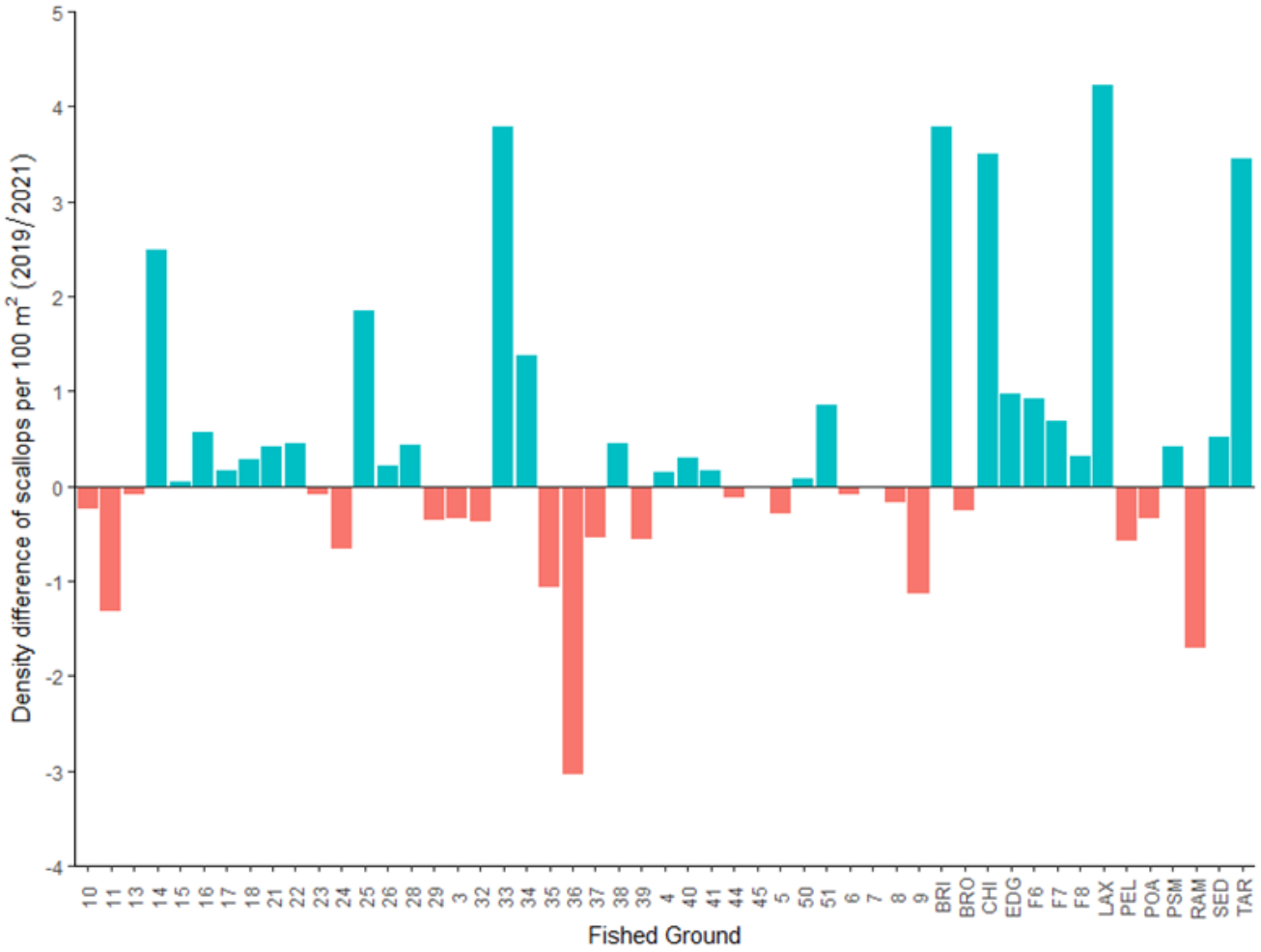


Figure 16 Difference in average survey density (scallops per 100 m^2) of king scallops between 2019 and 2021 (no survey data for 2020) from queen scallop dredges for all survey stations sampled in both years (red bars indicate a reduction in scallop densities and green bars indicate an increase in scallop density from 2019 to 2021).

The geometric mean of king scallop density was calculated across survey stations using data from **only** queen scallop dredges to derive the abundance indices. *Data from only queen scallop dredge types was used as the number of king scallops was generally higher in the queen scallop dredges across all length categories.* The use of the geometric mean to look at general stock trends across the territorial sea is precautionary and necessary to obtain meaningful stock assessment results. A failure to use the geometric mean, which down-weights isolated high-density patches of scallops, would increase the risk of over- estimating population size (Hutchings, 1996) and would provide a misleading over-optimistic estimate of scallop abundance. The arithmetic mean has also been calculated though and is presented along with the geometric mean as it allows the high levels of cyclical recruitment that occurs at specific sites around the territorial sea (in particular Chickens and Targets) to be highlighted as stock management might differ in these 'bumper' years.

Length data is currently used for the king scallop abundance index as the measurement method is considered more robust than for Age data and a greater degree of variance within the population is included (i.e. age data could typically have a length variance of ~50 -115 mm for Age 2 scallops). The length based abundance index splits the data into recruits (scallops < 95 mm) and post-recruits (scallops ≥ 95 mm). A cut off point of 95 mm has been used for recruits as this is the average size at which scallops across the extent of the territorial sea would potentially grow into the fishery by the end of the following king scallop fishing season (i.e. 31st May). Growth rates do however differ quite significantly around the Island and this single cut off value is not representative of that.

Prince Madog Survey Results (2021): King Scallops(Cont..)

Overall stock trends for recruits can be observed using the recruit abundance index calculated using the geometric mean (solid line; Figure 17) which shows a general increasing trend in the mean abundance of recruits (scallops < 95 mm) from 1992 to 2007 and a general decreasing trend from 2007 to 2021. The recruit index (geometric mean) peaked in 2014 with subsequent year on year reductions until 2018. However, the most recent years (2019 and 2021) both show increases in the abundance of recruits for the first time since 2014 (solid line; Figure 17).

Cyclical spatially specific recruitment events can be observed using the recruit abundance index calculated using the arithmetic mean (dashed line; Figure 17) which does not down-weight isolated high-density patches of scallops. Whilst the use of this index for stock assessment would cause an over-estimation of stock abundance it is useful for observing spatially specific recruitment events which may need to be managed independent of the remaining stock. This index shows peaks in 2007/2008 and in 2015 which tally with large recruitment events at both Chickens (south coast) and Targets (west coast). Both of these recruitment events supported high density fisheries of post-recruits on the west coast of the Island in the subsequent year (i.e. November 2009 and November 2016).

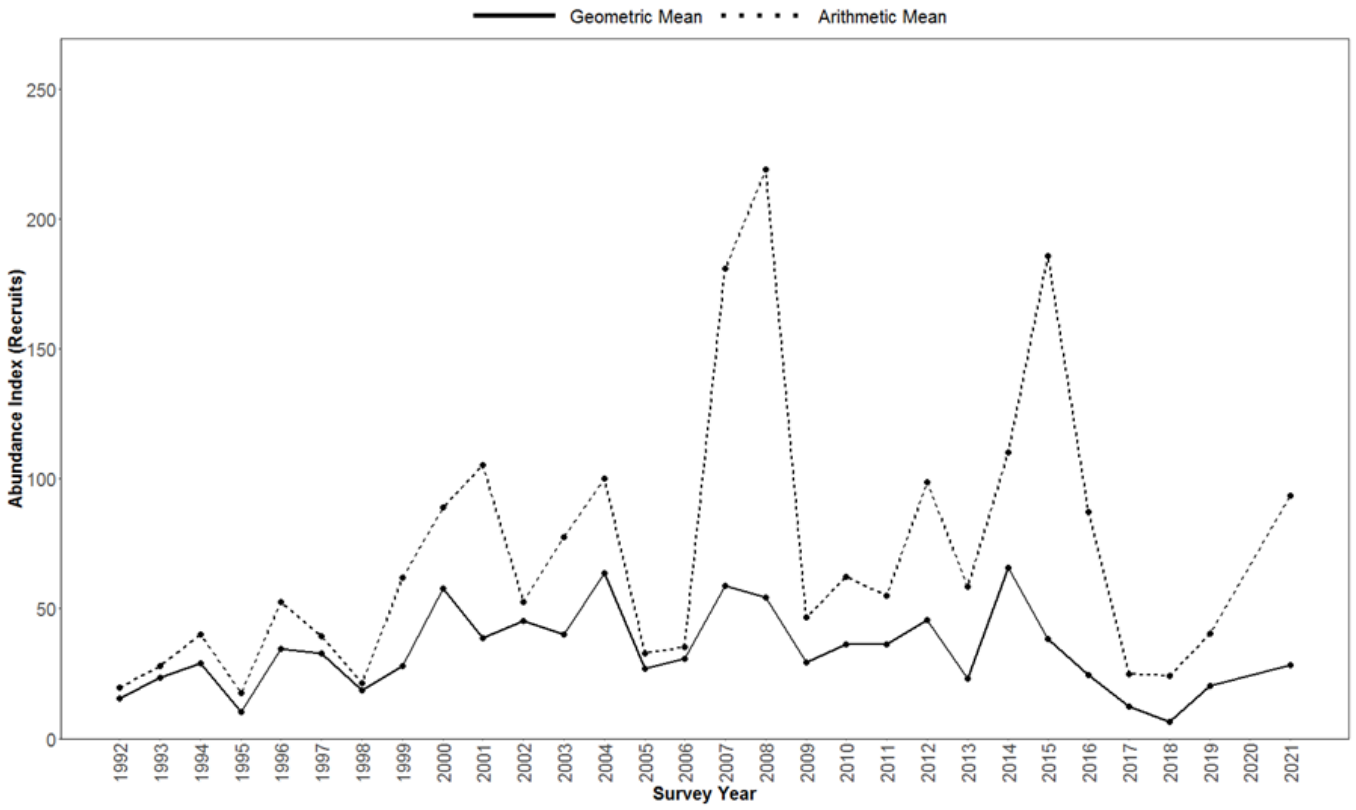


Figure 17 Recruit abundance index (scallops < 95 mm). Calculated based on length-based data where recruits were categorised as scallops under 95 mm at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. final day of the following season). The index is displayed using calculation of both the Geometric mean (solid line) for general stock trends and the Arithmetic mean (dashed line) for spatially specific cyclical recruitment events. The data is sourced from the April scallop survey using data from queen scallop dredges only.

Overall stock trends for post recruits can be observed using the abundance index calculated using the geometric mean (solid line; Figure 18) which shows a general increasing trend in the mean abundance of post recruits (scallops ≥ 95 mm) from 1992 to 2015 (reaching the highest level on record in 2015), followed by three years of decreasing values before an increase in the most recent year (2021).

Cyclical spatially specific recruitment events can be observed using the recruit abundance index calculated using the arithmetic mean (dashed line; Figure 18) which does not down-weight isolated high-density patches of scallops. Whilst the use of this index for stock assessment would cause an over-estimation of stock abundance it is useful for observing spatially specific recruitment events which may need to be managed independent of the remaining stock. This index shows peaks in post-recruits 2009 and 2016 which tally with large recruitment events observed in the recruit index the year before.

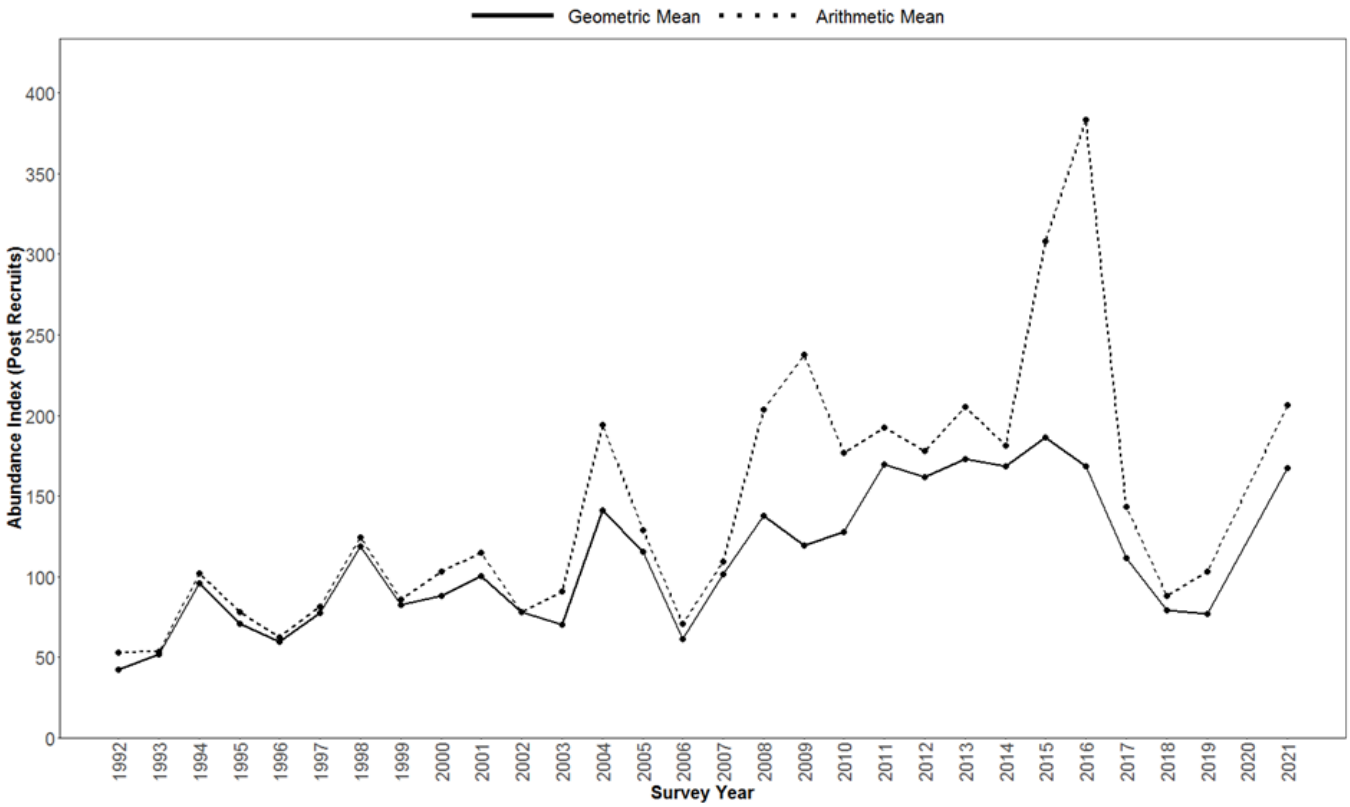


Figure 18 Post recruit abundance index (scallops ≥ 95 mm). Calculated based on length-based data where post recruits were categorised as scallops 95 mm or above at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. final day of the current season). The index is displayed using calculation of both the Geometric mean (solid line) for general stock trends and the Arithmetic mean (dashed line) for spatially specific cyclical recruitment events. The data is sourced from the April scallop survey using data from queen scallop dredges only.

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

Bloor, I.S.M. and Jenkins, S.R. (2021). Isle of Man King Scallop 2021 Stock Survey Report. Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report pp. 45.

Industry Survey Results (2021): King scallop

As with the queen scallop data the king scallop industry survey data are used to assess trends at the ground specific level and for demarking closed or restricted areas with high densities of king scallops under MLS where appropriate.

Within the territorial sea there has been an overall increase in the abundance index (geometric mean) from 2020 to 2021 from the industry survey for both post-recruits and recruits when combining the three grounds, EDG, TAR and CHI (Figure 20; TS). This follows 1727 t of landings reported for the whole territorial sea area during the 2020/2021 fishing season.

Of the three grounds surveyed in 2021 by the industry survey within the 3-12 nm limit (EDG, CHI and TAR), two (CHI and EDG) have seen increases in the post-recruit abundance for 2021, while the third, TAR shows no change. In terms of recruits both CHI and EDG recorded increases in abundance from 2020, while TAR showed a decline. EDG has the highest post-recruit and recruit index value for 2021 (although the current restricted area at CHI and closed area at TAR both have higher localised densities of post-recruits) (Figure 20).

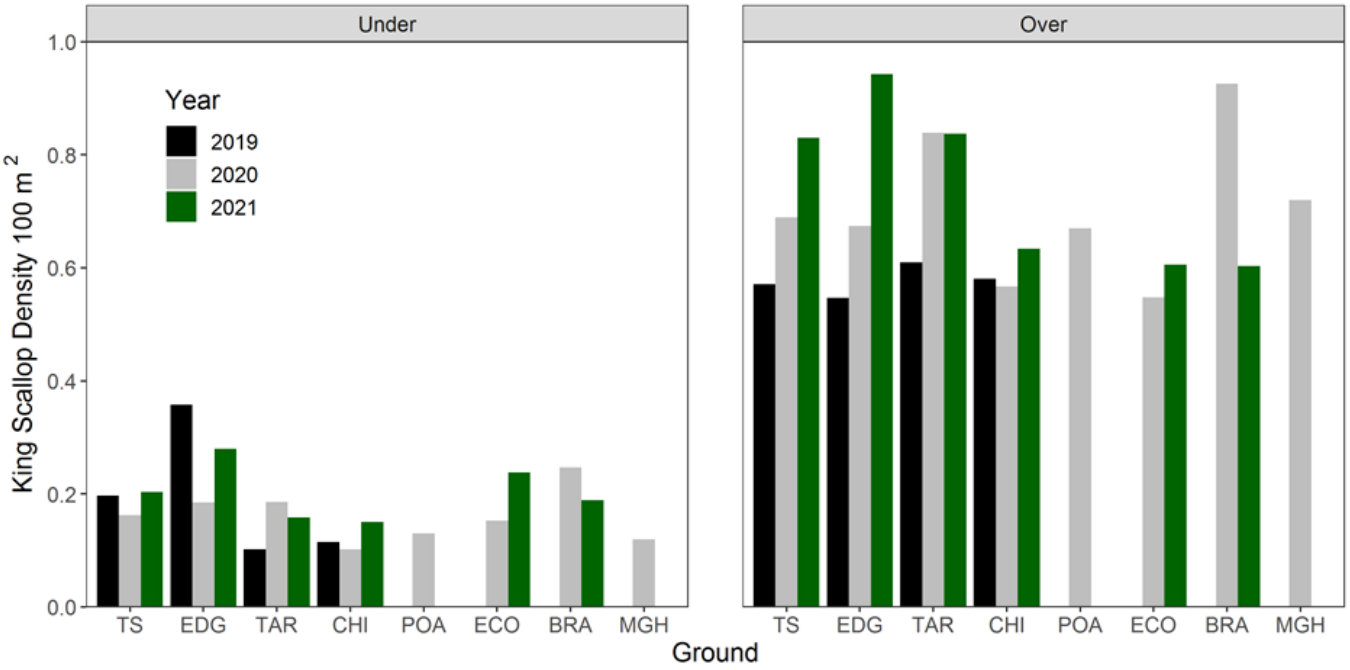
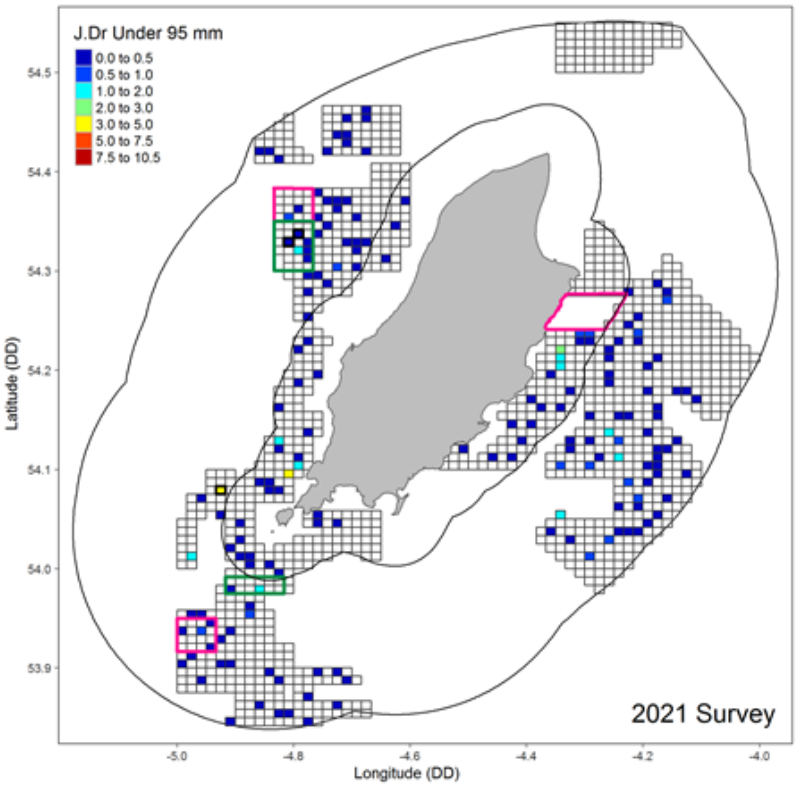


Figure 19 Comparison of king scallop abundance indices (geometric mean) (over and under 95 mm) by year and by ground for the industry survey



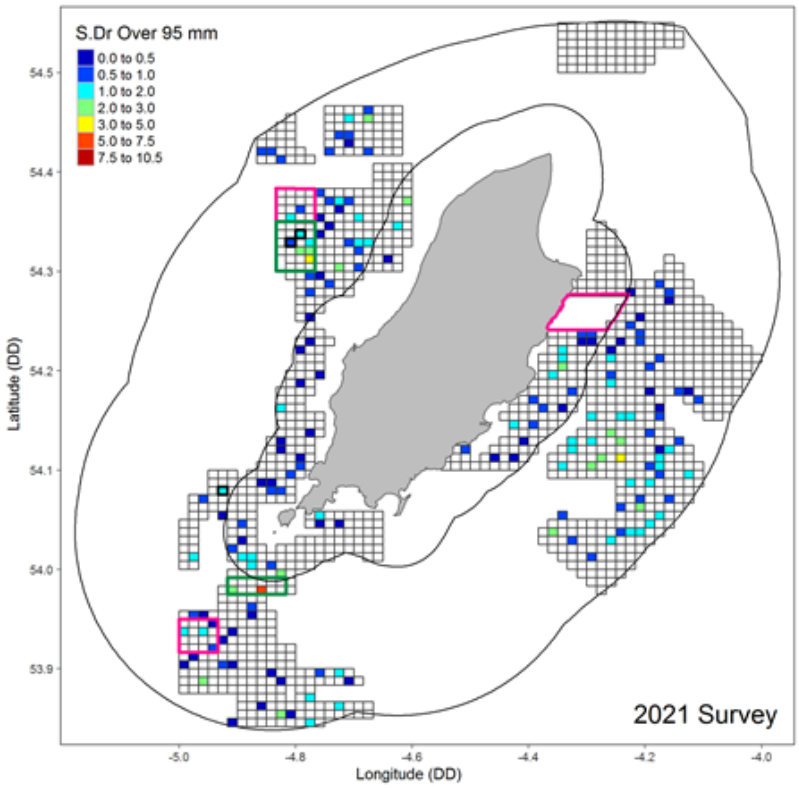


Figure 20 Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm (top) and over 95 mm (bottom) from standard king and standard queen scallop dredges for 2021. The 3-12 nm Point of Ayre (north) and the 0-3 nm Maughold (north-east) were omitted from the survey in 2021 due to limited survey time. The green boxes indicate restricted access areas during the 2021 queen scallop fishing season and the pink boxes indicate areas closed for queen scallop fishing in 2021.

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

Bloor, I.S.M. and Jenkins, S.R. (2021). Isle of Man King Scallop 2021 Stock Survey Report. Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report pp. 45.

King Scallop Stock Advice (2021/2022)

The advice below was provided by Bangor University to the Scallop Management Board for consideration for management of the 2021/2022 king scallop fishing season.

A total allowable catch (TAC) for the 2021/2022 fishing season was not calculated using the ICES Category 3 data limited approach due to the year of missing data in the long-term survey abundance index for 2020. It was recommended that the management approach for 2021/2022 king scallop fishery should be precautionary and 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 opened or closed) based on the real-time data collected by the fishery. High density areas within a ground (i.e. TAR or CHI) may require additional management to avoid high fishing intensities leading to excessive fishing mortality and habitat damage.
- **Closed area management:** The continued management of restricted areas 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 2021/2022 king scallop fishery based on the survey data analysis:

⇒ A precautionary management approach should be considered in particular due to the uncertainty in a TAC calculation for 2021/2022 due to missing data in 2020.

⇒ In addition to catch rates, various management measures, including the use of a daily catch limit to ensure the TAC lasts throughout the season, and various logistical issues as a result of BREXIT and Coronavirus restrictions, may have contributed to the under achievement of the TAC in recent seasons. However, it is highlighted that the quantity of removals which have impacted the current survey densities are lower than the TAC limits set for the past two fishing seasons and so a precautionary approach to the setting of the TAC is advised.

⇒ Starting TAC to remain at 2020/2021 fishing levels (i.e. 2049 t) which, if achieved, would already be a 15% increase in landings from 2020/2021 and a 42% increase in landings compared to 2019/2020.

⇒ Flexibility of decrease or increase of the TAC during the fishing season 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.

⇒ Restricted access and management of the two high density fishing areas at Chickens and Targets that are defined as restricted areas during the current queen scallop fishing season.

⇒ Monitoring of landings per unit effort (LPUE) and fishing intensity (swept area) should also be undertaken in managed areas to try and ensure overfishing of these spatially discrete areas does not occur. Both metrics are under development and the relationship between different levels and impacts on the stock will continue to be examined to develop threshold values for management.

⇒ Monthly reviews of the TAC and fishery with consideration of LPUE and fishing intensity within each fishing ground (including combined fishing intensity of king and queen scallop activity).

⇒ Temporary closed areas implemented to protect any high densities of recruits identified in the survey (Bradda (i.e. BRI) and East Coast (i.e. ST27) had the highest densities of recruits in the 2021 industry and scientific surveys and may be suitable areas for consideration).

⇒ Strict monitoring and enforcement of daily catch limits within high density restricted areas should be in place.

East of Douglas Experimental Research Area

5-year review (2017—2021):

Background:

The East of Douglas Experimental Research Area (EDG ERA) was established as an experimental closed area for three years in July 2017. The ERA encompassed a region (~ 24 km^2) agreed with industry (Figure 20) where the queen scallop (*Aequipecten opercularis*) stock had recently declined. Prior to closure, there was little sign of natural improvement in the region over the preceding years (i.e. 0 queen scallops per $100m^2$ in 2014, 2015 and 2016; source: R.V. Prince Madog survey Station 29). The purpose of the EDG ERA was to assess the recovery of a depleted queen scallop ground during a three-year closure to demersal mobile gears. Since 2017, the area has been monitored annually over the three years of closure during autumn (October-November) from the F.P.V. Barrule, including demersal fisheries surveys (beam trawl and dredge) and a drop-down camera habitat survey. Additionally, the annual R.V. Prince Madog dredge survey, which occurs in the spring, has sampled a station within the EDG ERA (Station 29; see Bloor & Jenkins, 2020 for further survey details).

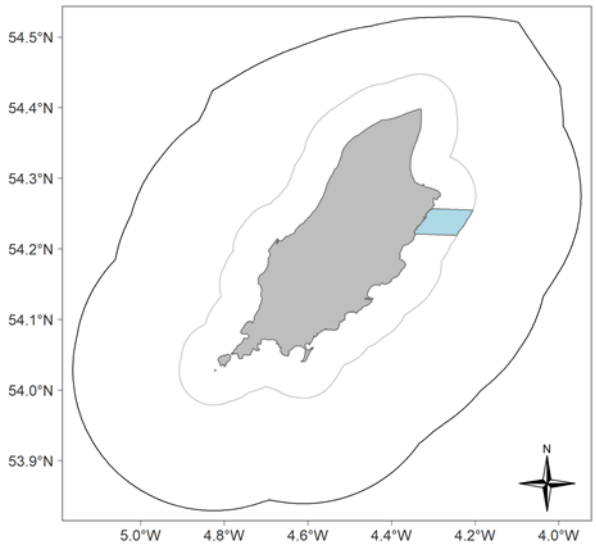


Figure 21 Location of EDG ERA (closed area highlighted in blue) on the east coast of the Isle of Man within the 0-3 nm limit

An initial assessment of the experiment was expected after three years, but it was agreed to extend the trial further; however, due to Corona Virus restrictions and an inability to survey the area in 2020 the area remained closed. A further survey was completed in November 2021 onboard the F.P.V. Barrule, and was considered sufficient to complete the project and report on results, with a view to determination of its longer-term management.

Methods:

The EDG ERA survey design consisted of a grid of 80 sampling stations evenly distributed between four strata (inshore north; offshore north; inshore south and offshore south) to ensure consistent sampling across the entire ERA. The survey work consisted of:

- 16 random stations selected annually for beam trawling in 2017, 2018, 2019 and 2021 (4 stations in each strata)
- 8 fixed transects (A-H) (each transect running through 4 consecutive stations) were dredged in 2018, 2019 and 2021 (2 transects in each strata)
- Drop-down camera work was undertaken in 2018 and 2021 (10 stations in 2018 and 14 in 2021) to assess habitat and sediment

East of Douglas Experimental Research Area (Cont…)

Results:

There has been an increase in the mean density of queen scallop recorded within the EDG ERA over the five years of the closure with the mean density of queen scallops (any size) recorded as 9 ± 1.6 queen scallops per 100m^2 in 2017, 14 ± 2.3 in 2018, 16 ± 1.5 in 2019 and 21 ± 4.7 in 2021 (Figure 22)

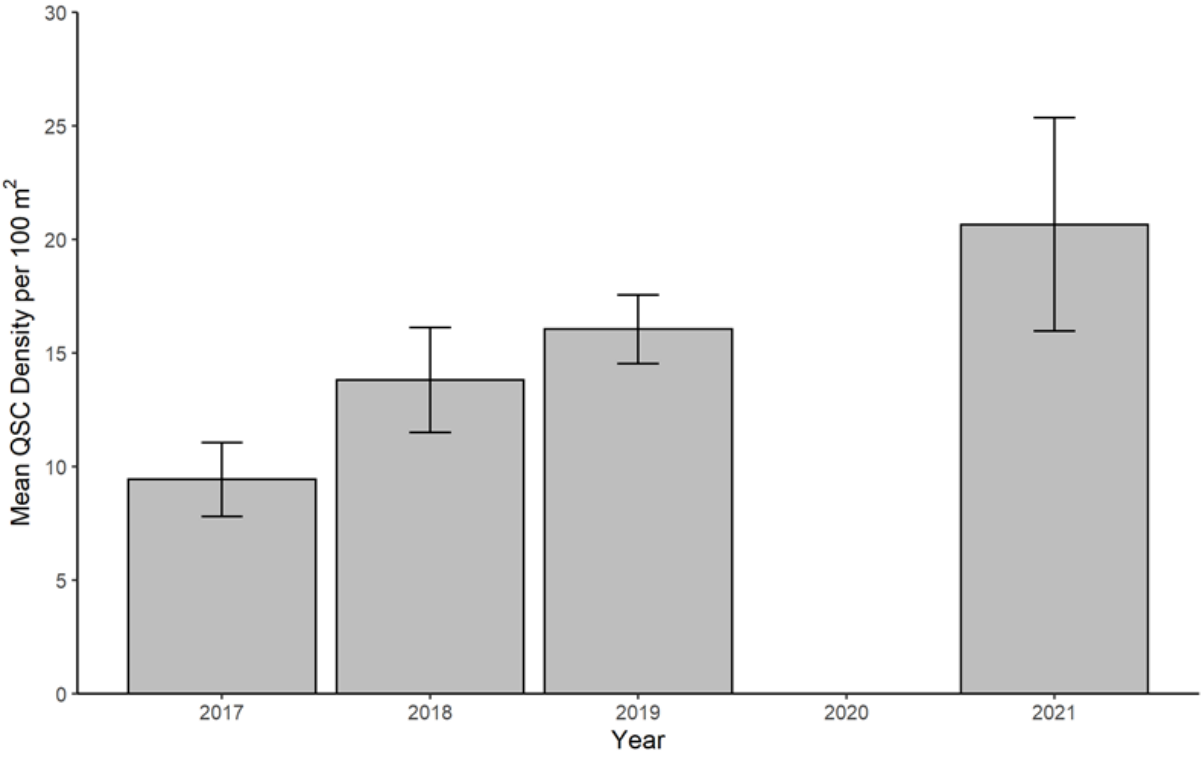


Figure 22 Queen scallop: Mean density (QSC per 100 m^2) by year from 2m beam trawl samples. Note: no survey completed in 2020 due to Corona virus restrictions. Black lines indicate the standard error for each year. Data includes queen scallops across all size s

Spatial variance in queen scallop density across the area is high within years. The 2021 survey recorded the highest station densities of queen scallops over the total survey period (2017 – 2021) at up to 60 queen scallops per 100m^2. For 2021 densities for the whole EDG ERA ranged from 0 – 60 queen scallops per 100m^2, with the highest densities occurring in the Offshore North (NE) and Inshore South (SW) strata of the closure specifically (Figure 23).

In addition to the data collected as part of a targeted survey in the EDG ERA, the annual scallop stock survey, undertaken by the R.V. Prince Madog has a station within the ERA (Station 29) which has been monitored annually since 2012 and has also indicated annual increases in queen scallop densities since the closure in 2017 (Figure 24).

Conclusions:

There have been improvements in queen scallop density across the EDG ERA from 2017 – 2021, assumed to be as a result of restricted fishing, benthic recovery and natural recruitment processes. Within the EDG ERA there were large spatial variations between individual catches (reflected in large standard error bars on plots of mean scallop densities) with discrete patches of high densities. This is

typically a common observation in scallop surveys throughout the territorial sea, and elsewhere and can be partially related to variation in seabed substrate. The highest densities at individual sites occurred in 2021. The EDG ERA has now been closed for five years and will be reviewed by the Isle of Man Scallop Management Board during 2022.

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

Bloor, I.S.M., Garratt, M.J., Coleman, M, Duncan, P.F. and Jenkins, S.R. (2022). East of Douglas Experimental Research Area: Five-Year Review. Sustainable Fisheries and Aquaculture Report (IoM), Bangor University. pp. 1 –13.

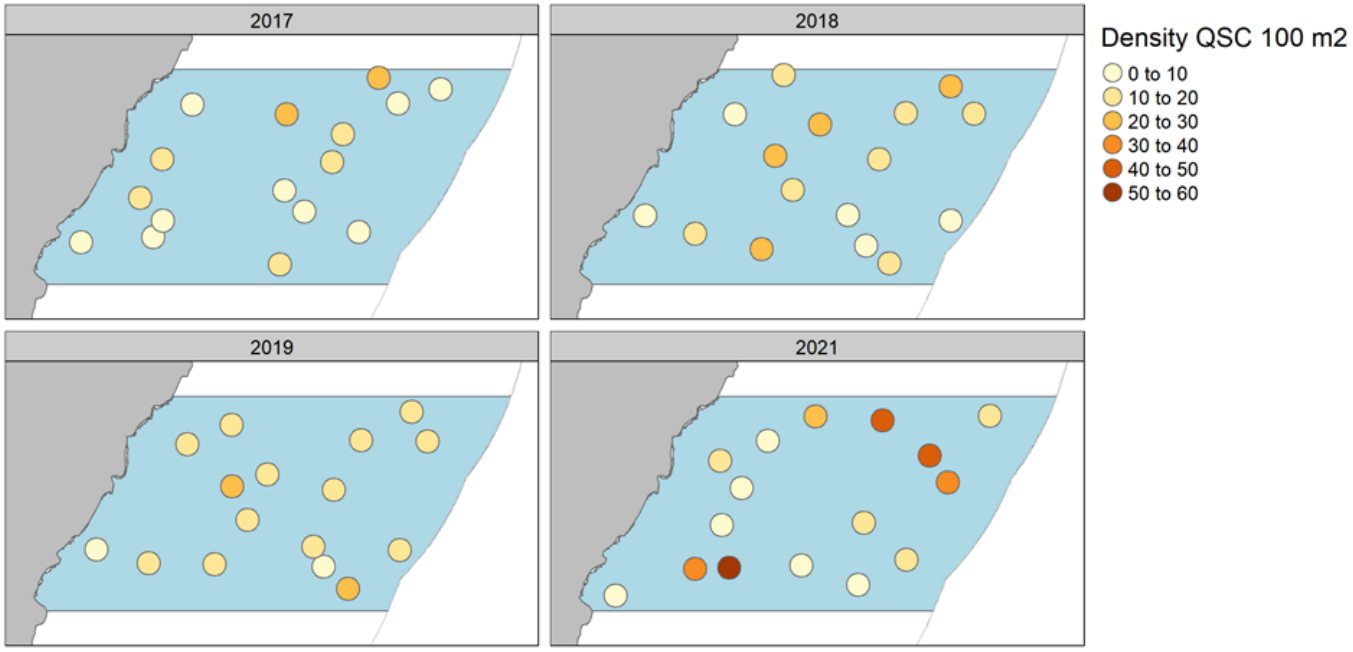


Figure 23 Queen scallop: Spatial variance of density (QSC per 100 m^2) from 2m beam trawl samples displayed by survey station and by year. Note: no survey completed in 2020 due to Corona virus restrictions. Data includes queen scallops across all size ranges. Blue polygon represents the extent of the EDG ERA closed area.

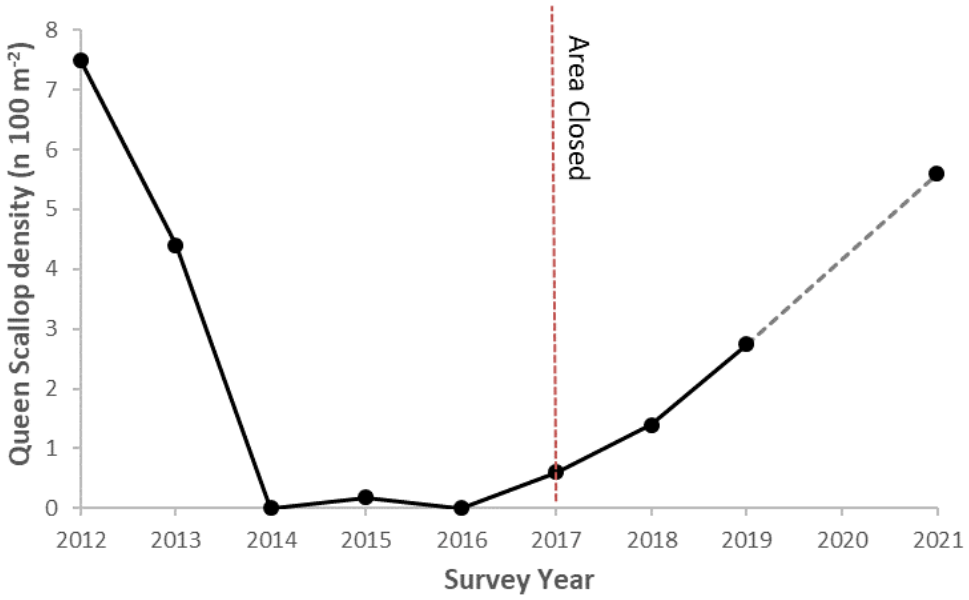


Figure 24 Queen scallop: Mean density (QSC per 100m^2) in EDG ERA from dredge surveys (queen scallops from queen scallop dredges) Source: Prince Madog stock assessment Station 29 which is located within the EDG ERA.

ICES Working Group on Scallop Stock Assessment

4th – 8th October 2021, virtual via video conferencing

Due to the continued travel restrictions associated with the global Covid-19 pandemic the 2021 WGScallop meeting was held virtually using video conferencing for the second year. The meeting, chaired by Lynda Blackadder from Marine Scotland, was opened on 4th October and was attended by 28 participants from 11 countries and 16 institutions.

Figure 25 International delegates at the ICES Working Group meeting held via video conference in October 2021 (Source: Twitter @ ICES_ASC).

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 3rd year. The received data were reviewed and quality checked to enable improvements to the data call to be made. The fisheries data are reported in the WG report and have been used by members of the working group for scallop stock assessments.

Review paper: A paper which reviews dredge efficiency in global scallop fisheries has been drafted by the group with the aim of publishing the manuscript in 2022.

King Scallop Stock Assessment in the northern Irish Sea: The WG formed a subgroup to assess king scallop stock(s) in the northern Irish Sea (around Isle of Man). The WG collated data and are developing a modelled survey index which will be used with fisheries data to assess the stock. The group discussed the merits of using Surplus Production Model in Continuous Time (SPiCT) and this work will continue through the sub group.

The full 2021 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. 2021. Scallop Assessment Working Group (WGSCALLOP). ICES Scientific Reports. 3:114. 106 pp. https://doi.org/10.17895/ices.pub.9561

The next meeting will be hosted by the Marine & Freshwater Research Institute in Iceland from 3rd – 7th October 2022 (this will be a hybrid meeting virtual and in person due to travel restrictions still being in place for some institutions).

Potting Sector fisheries: Crab, Lobster & Whelk

The potting sector of the Isle of Man fishery is dominated by three primary target species; Brown Crab (*Cancer pagurus*), European Lobster (*Homarus gammarus*) and Common whelk (*Buccinum undatum*). These three species face separate challenges and gaps in scientific knowledge to progress towards sustainable management similar to the Isle of Man scallop fisheries. Bangor University continues to work collaboratively with both industry and DEFA to address a number of these knowledge gaps over the course of the current contract.

The necessity of addressing these knowledge gaps is evident in the price of first sale, with static gear target species in 2019 individually at a similar level to Queen Scallops (QSC) (2019 sales : QSC—£0.9million; Whelk—£1.1million; Crab £0.9million). A summary of the current status of these three static gear fisheries is presented along with complimentary research undertaken in 2021.

Common Whelk (*Buccinum* undatum) Fishery update

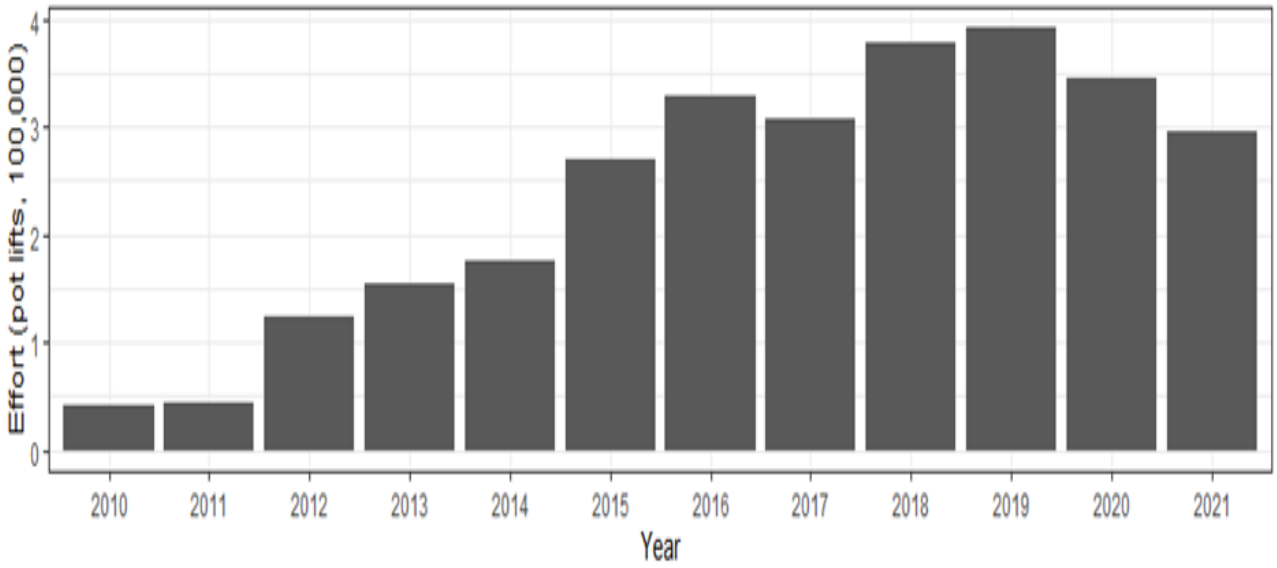
Management of the whelk fishery in the Isle of Man territorial sea is not yet informed by stock assessments and currently there are no fisheries-independent surveys of stock biomass. Additionally, spatial information (VMS or equivalent) is absent for the vast majority of whelk fishing activity (i.e. landings by vessels <12 m length overall). Trends in fisheries-dependent data are therefore presented on a whole territorial sea level.

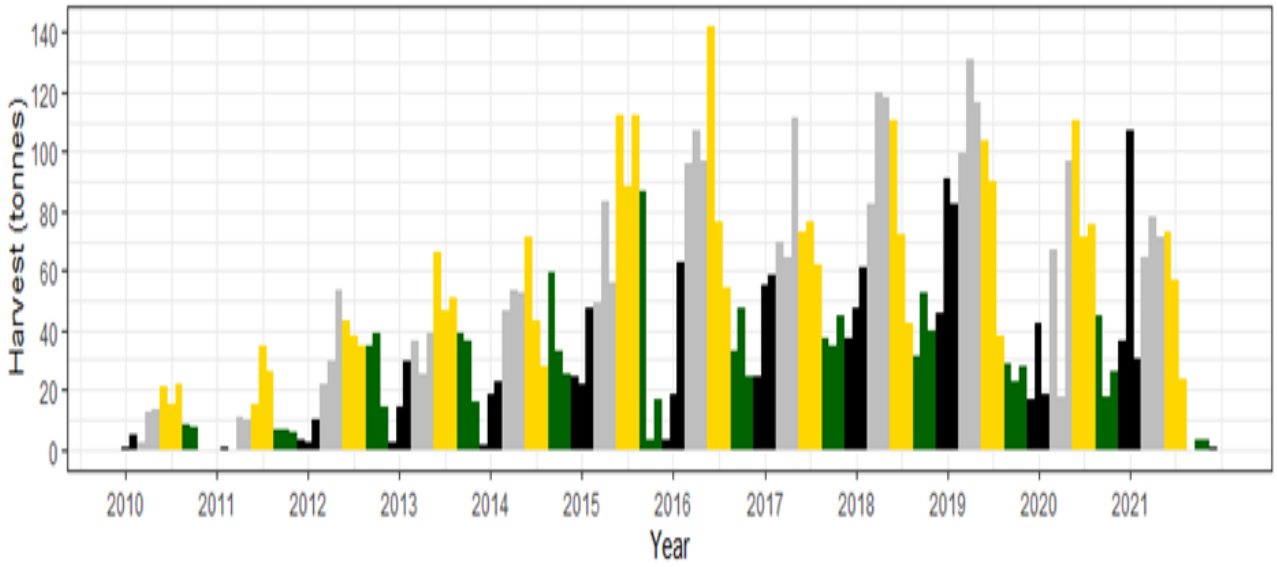
In 2021, the landings of whelk into the Isle of Man was 483 t, a reduction equal to -19% compared to 2020. The total effort by Isle of Man registered vessels was c.290,000 pot-lifts, a reduction equal to -16% compared to 2020 . These effort data illustrate broad scale changes , but can also be used to show that the average Manx whelk vessel lifts approximately 430 pots per day-at-sea.

Figure 26 shows that the usual increase in landings from winter to spring failed to occur in 2021 (and in 2020) probably as a consequence of covid-19 restrictions. 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 2021—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, and 21% lower than in 2020.

The explanation for the decline in LPUE in 2021 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.





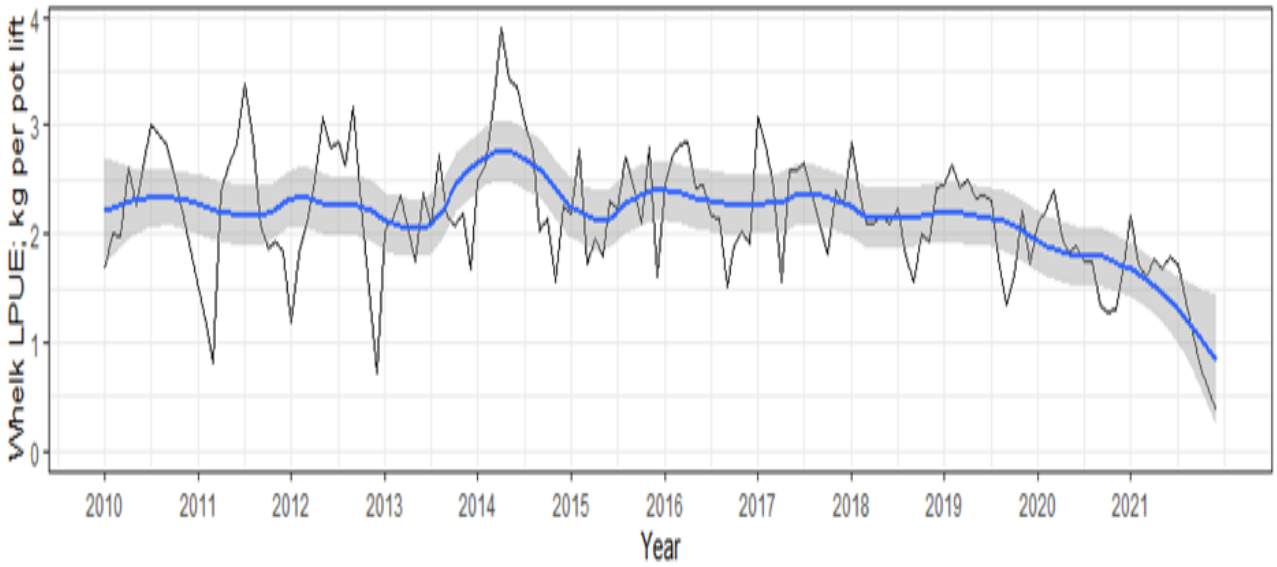


Figure 26. Common Whelk Fishery—Top_ Total Annual pot lifts declared in the Isle of Man Territorial Sea. Middle) Seasonality in total landings for the Isle of Man Territorial sea (Black-winter; grey– Spring; yellow-Summer; green-Autumn. Bottom) Long term whelk landing per unit effort (LPUE) trend from 2010 to 2021.

Whelk Stock Assessment Gear Trials—August/September 2021

A series of surveys were completed in late summer 2021 to trial potential sampling gears for whelk (*Buccinum undatum*) stock assessment surveys. This included commercial whelk pots, BRUVs (baited remote underwater video) and beam trawling (Figure 1). The aim was to compare relative whelk abundance across gear types on the same ground, while avoiding any interactions between the gears.

Figure 27. Sampling gears trialled for whelk stock surveys: commercial whelk pots (left); BRUVs (middle); beam trawl (right).

Sampling took place during neap tides in a whelk fishing area outside Douglas Bay with uniform habitat and minimal variation in depth. Seven survey squares (1km^2 each) were selected randomly from the area with each square split into four quarters and the sampling gears deployed in different quarters within each square.

Whelk pots

Two strings of whelk pots were deployed in each of the seven survey squares, with 10 pots on each string. Strings were standardised by length, pot design and bait used, and were deployed over a 24-hour period (16 – 17 August). CPUE (abundance per pot) and median shell length significantly varied across survey squares, indicating local variation in whelk populations.

BRUVs

BRUVs consisted of lobster pot frames with a bait bag attached to the base of the pot at one end and a GoPro and waterproof light mounted on a piece of wood at the other end of the pot facing towards the bait. The settings of the cameras and lights were consistent across deployments, and bait was standardised in the same manner as the whelk pots. BRUV deployments were completed over four survey days, with four individual BRUVs deployed in each survey square for a period of 2 hours (soak time was limited due to the battery life of the GoPros). Whelk abundance data was collected using still images taken at 5-minute intervals, and three abundance indices calculated for each BRUV: meanN (average of all images), maxN (maximum abundance in one image), and T0 (time of first arrival). Whelk abundance in BRUV images was generally low (mean: 2 per image) and there was no significant variation

in abundance indices across survey squares. Although BRUVs were deployed over a range of tidal conditions, no relationship between abundance indices and tidal variables (tidal coefficient, hours in relation to slack water) was found.

Beam trawl

Beam trawl tows were completed over three survey days, with two tows in each of the seven survey squares. These were standardised by duration (5 minutes) and speed (1 – 1.5 knots) and were executed against the direction of tidal currents to minimise variation in catchability. CPUE was low (1-4 whelks per 100m^2) and did not significantly vary across survey squares. **Median shell length also did not significantly vary** across survey squares but was related to tidal state, with smaller sizes caught during ebb tides than flood tides.

Conclusions

Although spatial variation in whelk abundance was not significant (with the exception of commercial pot strings), there was a general pattern in mean abundance that was consistent across gear types, with higher relative abundance to the west (squares 11, 12, 28, 32) and lower relative abundance to the east (squares 19, 25, 30) (Figure 2). Beam trawling however proved to be a highly inefficient sampling method, with large amounts of substrate and bycatch, and was size-selective towards smaller whelks, with only 13% of individuals of marketable size (≥ 75 mm) in comparison to 42% in whelk pots. It is also noted that longer BRUV soak times are likely to produce clearer results, and therefore work is being done to increase the battery life of the cameras to ~24 hours. Additionally, custom BRUV frames have since been produced allowing the camera to be positioned above the bait bag pointing down to achieve more accurate whelk counts. Work is ongoing to assess the utility of enhanced BRUV methodologies.

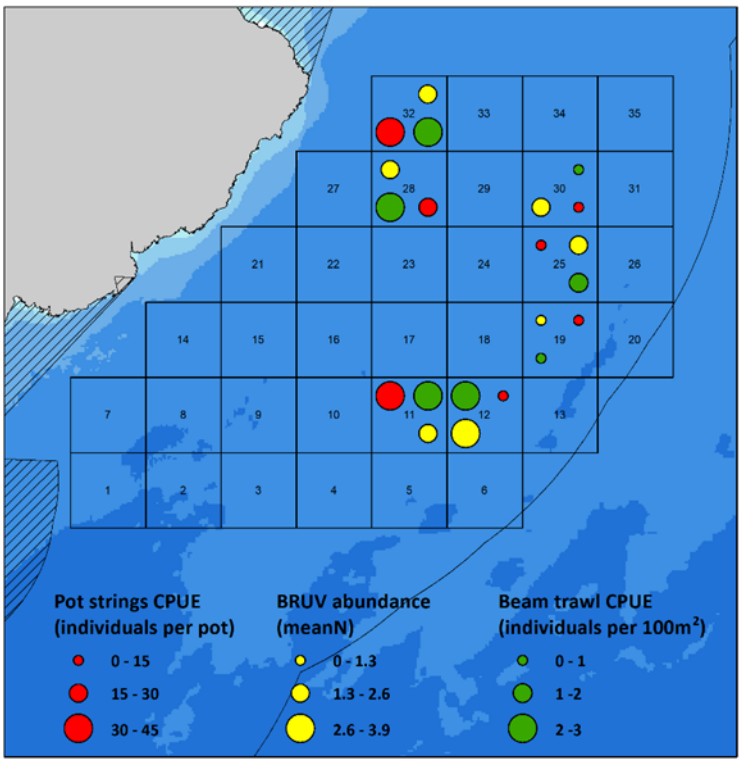


Figure 28. Map of mean whelk abundance indices by gear type. Larger circles indicate higher relative abundance, with different scales for each gear type. The positions of the circles within each square are indicative of where each gear was deployed.

Brown 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) (Figure 29).

In 2021, landings and effort increased to 468 t and 377,000 pot-lifts, equal to an increase of +14% and +13% relative to 2020 respectively. The fishery is historically an autumn fishery. This trend however differed in 2021 with the bulk of landings occurring in summer. There was a slight decline in LPUE versus 2020, continuing the overall declining trend in LPUE seen since 2018. 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). Following the implementation of inshore vessel monitoring systems (iVMS) in 2022 more precise spatial and temporal information can be added to logbook data, increasing our understanding and interpretation of long term trends.

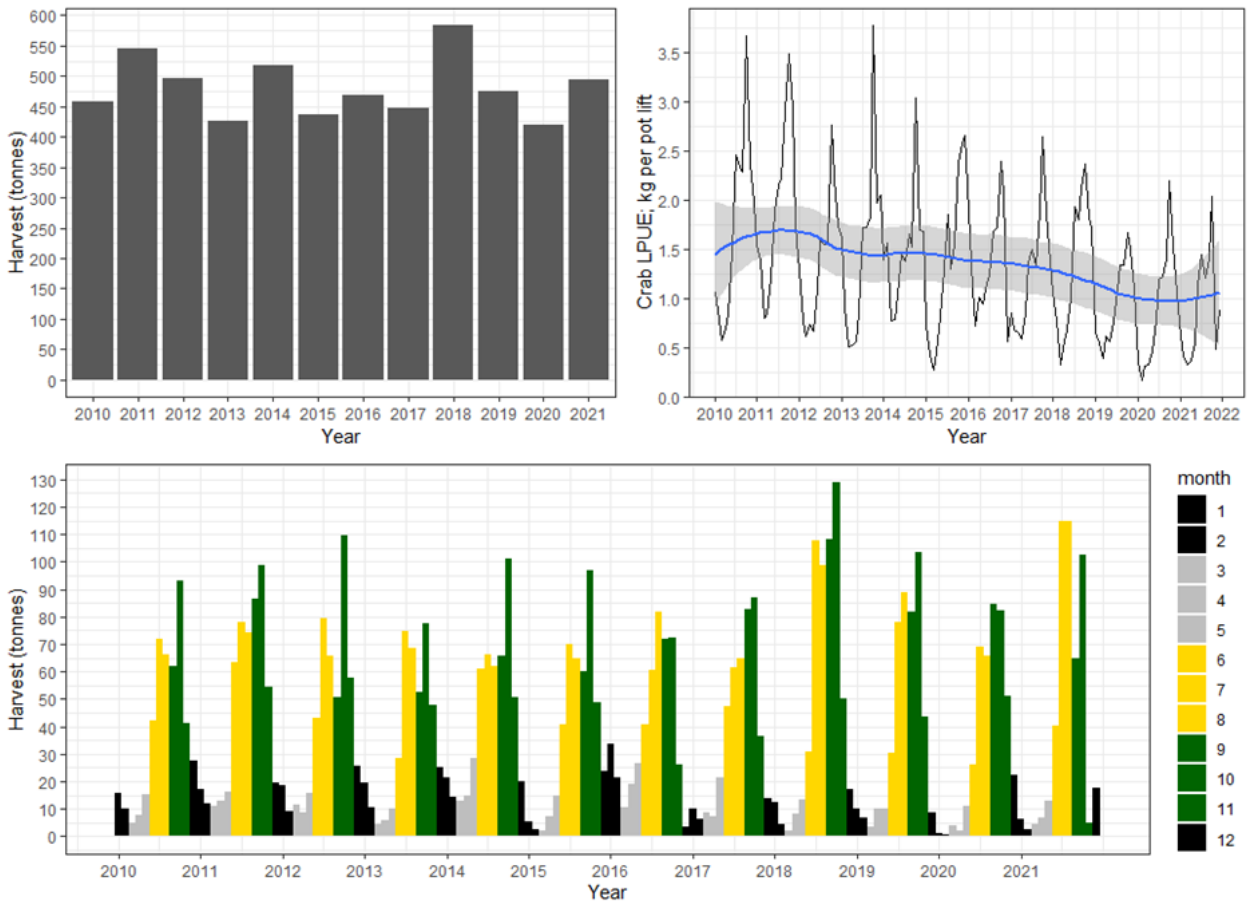


Figure 29. Brown Crab—Top Left) Total Annual landings declared in the Isle of Man Territorial Sea. Top Right) Long term whelk landing per unit effort (LPUE) trend from 2010 to 2021. Bottom) Seasonality in total landings for the Isle of Man Territorial sea (Black-winter; grey– Spring; yellow-Summer; green-Autumn

Use of beam trawl survey (BTS) data as a fishery independent abundance survey in the North West Irish Sea for Edible Crab (*Cancer pagurus*)

Anecdotal evidence of declining catches of edible crab *Cancer pagurus* across the North East Atlantic has been reported by fishers in recent years with this trend now being detected in commercial landings and landing per unit effort (LPUE), including the Isle of Man.

Current assessment techniques however rely heavily on the sampling of commercial landings and/or the interpretation of fishery dependent data to inform stock status. This approach however has pitfalls, inherent to the use of fishery dependent data in isolation, potently failing to detect changes in an already heavily growth overfished stock . In response, additional metrics of fishery independent estimate of fisheries biomass have been sought.

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) have undertaken an annual beam trawl survey (BTS) across the Irish Sea and English Channel from 1993 to present. A by-product of this survey has been to record the abundance, sex and size of *C. pagurus* as a bycatch species. In this instance a subset of this historical data set has been utilized to investigate the use of BTS data as a fishery independent survey method and its capabilities of detecting the trend of *C. pagurus* abundance in the North West Irish Sea. The study area is centralized around the Isle of Man and neighbouring Northern Ireland and Scottish waters (Figure 30). Utilizing a general additive model, trends indicate increasing overall abundance since 1995, with a peak in 2015 followed by a significant rapid decline in the past 5 years (Figure 31), with a similar declining trend detectable in the IOM LPUE time series. Furthermore it highlights distinct spatial clustering of stock biomass in the Irish Sea relative to size.

The identification of these trends and the utilization of such historic data presents a number of opportunities in the management and forecasting of fishery status in future. We plan to extend this work in collaboration with the wider scientific community to better understand these trends and any underlying drivers of *C. pagurus* abundance.

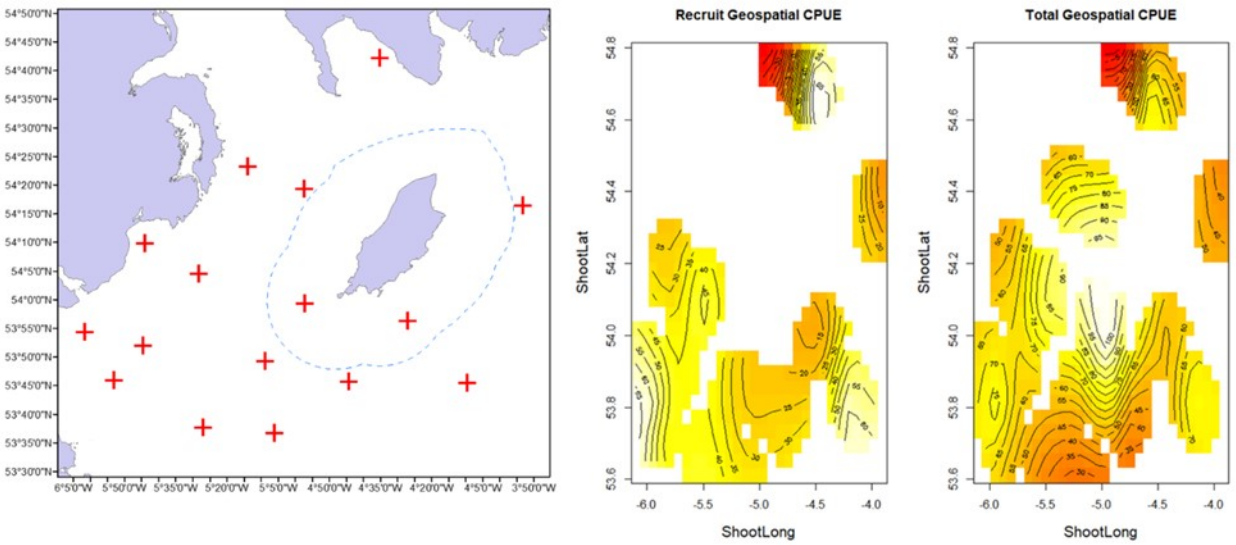


Figure 30. Brown Crab—Left) Distribution of CEFAS beam trawl survey station in the Northern Irish Sea . Right) Spatial distribution of both recruit (<140mm carapace width) and total abundance .

Use of beam trawl survey (BTS) data as a fishery independent abundance survey in the North West Irish Sea for Edible Crab (*Cancer pagurus*) Cont.

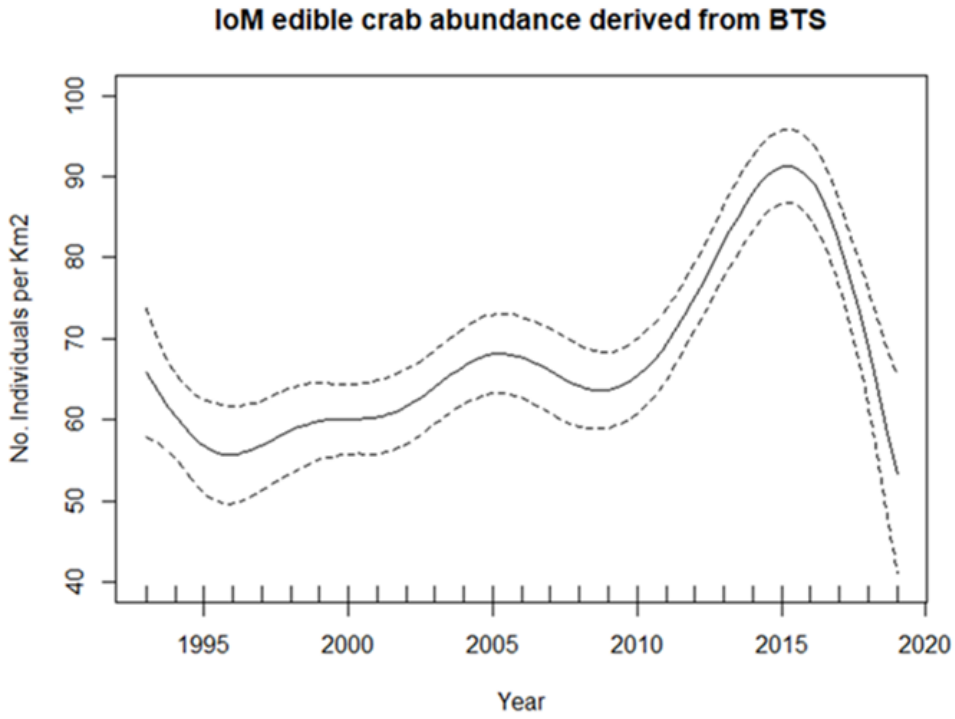


Figure 31. Brown Crab—Fishery independent trend in brown crab abundance derived from Beam trawl data for the North West Irish Sea from 1993 to 2020.

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 from 2007-present (Figure 32).

Landings in 2021 were at a 5 year high, with 51.1 tonnes landed, a 17% increase compared to 2020 and up 3% compared to 2019 (pre pandemic). Effort in the fishery also increased from 235,300 to 273,000 pot lifts, an increase of ~15% compared to 2020. The number of targeted fishing days therefore increased from 1,214 to 1,473 days at sea, equal to an increase of 19% compared to 2020. Annual average landings-per-unit-effort (LPUE) have been generally stable over the period from 2010. 2021 saw this trend continue.

Changes in LPUE in the fishery are difficult to verify from logbook data alone, considering that the lobster and edible crab fishery are reported as a 'mixed' fishery and there are complex capture dynamics associated with lobsters. Following the implementation of inshore vessel monitoring systems (iVMS) in 2022 more precise spatial and temporal information can be added to logbook data, increasing our understanding and interpretation of long-term trends. Bangor University will also look to trial fishery independent methods of assessing abundance to help corroborate patterns in LPUE recorded by the fishery.

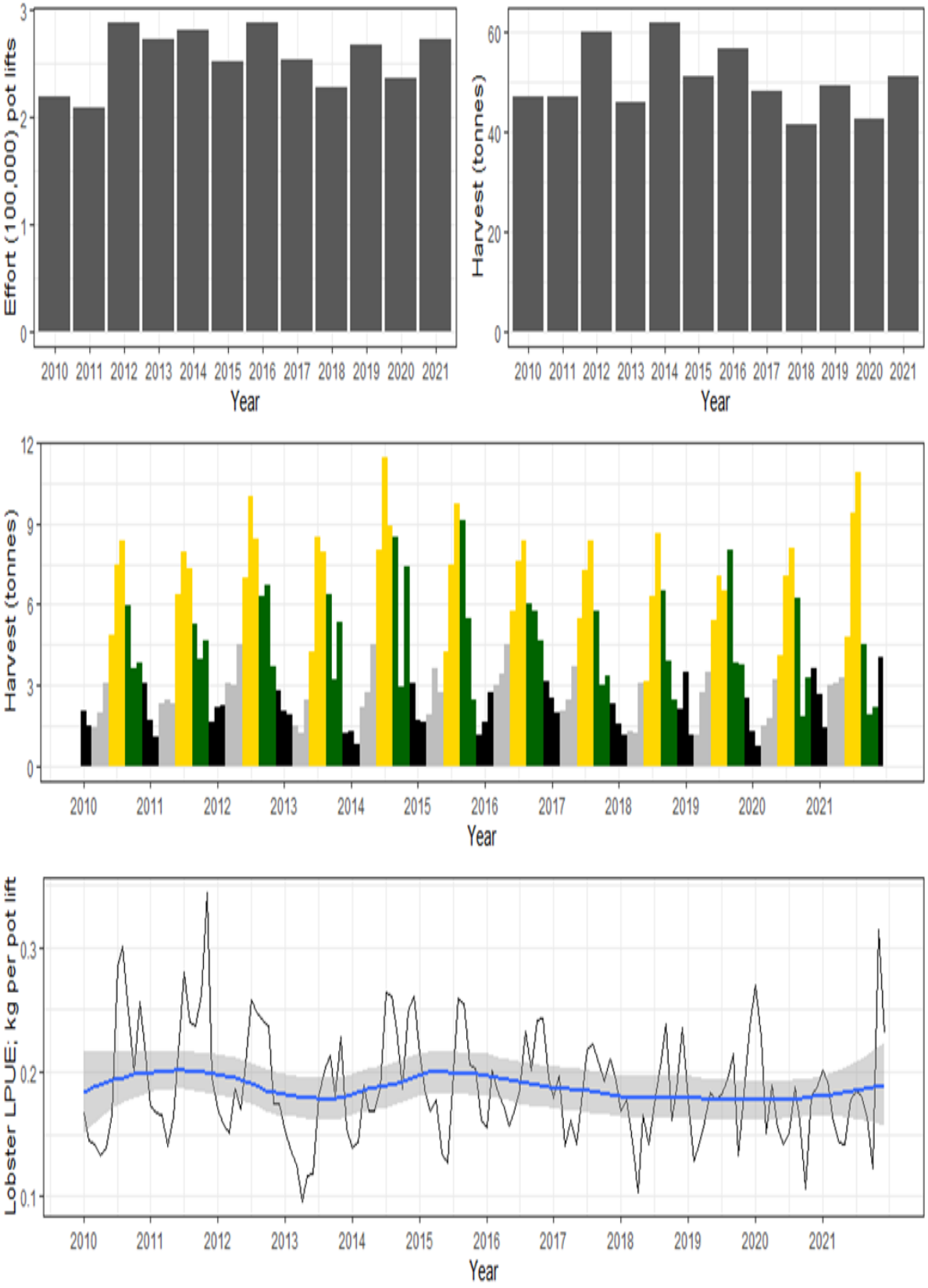


Figure 32. European Lobster—Top lLeft) Total Annual pot lifts (effort) declared in the Isle of Man Territorial Sea targeting lobster Top Right) Annual landings (tonnes) declared in the Isle of Man Territorial Sea. Middle) Seasonality in total landings for the Isle of Man Territorial sea (Black-winter; grey– Spring; yellow-Summer; green-Autumn. Bottom) Long term lobster landing per unit effort (LPUE) trend from 2010 to 2021.

ICES Working Group on crab and Lobster (Nov 2021)

The International council for the exploration of sea crabs and lobster working group met online for the second consecutive year due to Covid-19 restrictions at the time (Fig 33) .

The group brings together crustaceans researchers from Universities and government institutions, providing a platform to share ideas and encourage collaborative working. Each member typically presents ongoing work ranging from crustacean biology, fisheries management and stock assessment techniques. This year saw the Republic of Ireland present ongoing work looking at the utilization of SPiCt modelling to assess brown crab in the Malin Fishery. This presents interesting possibilities for a similar application for the Isle of Man fishery. Bangor University presented two key pieces of work at the meeting. Firstly an overall update on current crustacean stocks in the Isle of Man enabling comparison with other fisheries. Secondly, preliminary work on the utilisation of beam trawl data and the role of environmental drivers was presented. For further information on this work see page 32 .

The establishment of a WGCRAB modelling subgroup was proposed by Bangor University, with this grouping looking to establish a forum in which stock assessment techniques and developments could be shared more regularly than the current annual meeting format. Matthew Coleman – Bangor University and Guillermo Martin (Irish Marine Institute) were appointed joint chairs.

A hybrid in person/virtual meeting was proposed for 2022, with this being held at ICES HQ Copenhagen, Denmark.

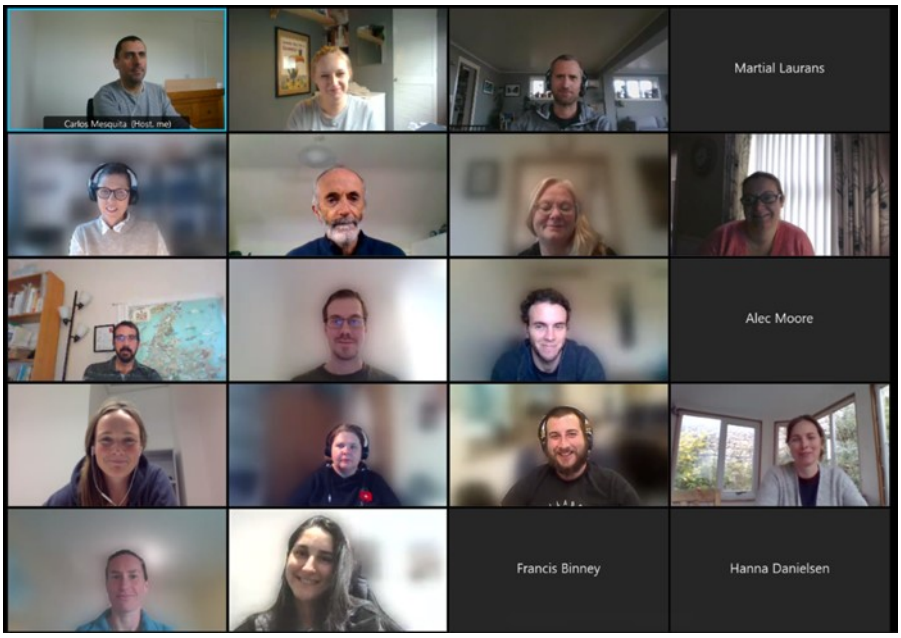


Figure 33. International delegates at the ICES Working Group meeting held via video conference in November 2021.

Habitat Mapping: Marine Nature Reserves

As part of our ongoing investigations of the Isle of Man's seabed habitats, we have undertaken further work to analyse underwater camera footage from two of the island's Marine Nature Reserves, Laxey Bay and Niarbyl Bay. This work adds to our recent standardisation of MNR habitat surveys undertaken by current PhD student Matthew Garratt during 2020. In 2021, Joshin Patel, an MSci student at the School of Ocean Sciences, Bangor University utilised towed sled underwater camera footage from 2016 to take a close look at the distribution of species in relation to habitat type. Joshin analysed over 600 images as well as towed video footage and BRUVs (Baited Remote Underwater Video) in order to construct habitat maps and determine the relationship between habitat type and epifaunal diversity.

Two different approaches were used to create habitat maps, a fully quantitative statistical approach using SIMPROF to distinguish distinct habitats and a more qualitative approach based on the EUNIS (European Union Nature Information System) habitat classification system . The EUNIS approach was by far the more successful and allows understanding of the scale and distribution of different habitats across each MNR (Figure 34).

Understanding the relationship between sediment type and distribution of species can be a powerful tool in conservation and management. There was clear variation in species richness between the two MNR's, with greater epifaunal diversity at Niarbyl. However both MNR's showed the same pattern, with increasing diversity on more mixed and harder sediment types.

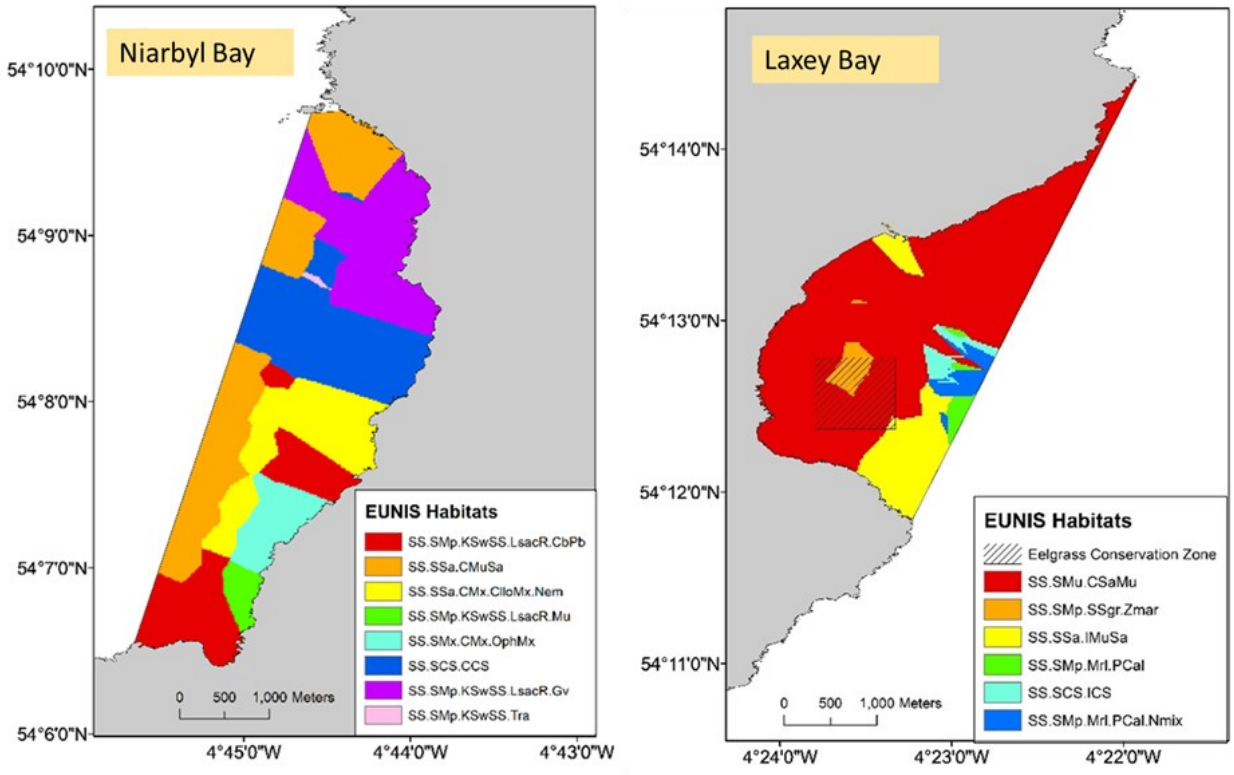


Figure 34 The distribution of EUNIS habitat types in Niarbyl and Laxey Bay MNR's

Research priorities for the 2020-2025 contract

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.

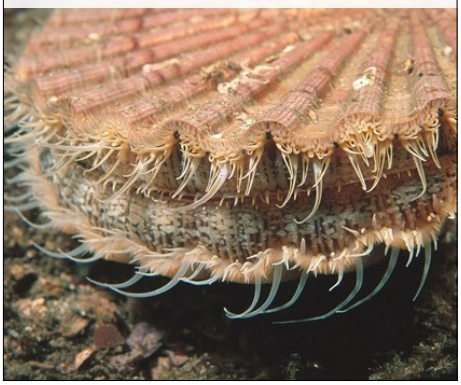
WP2.
Industry Scallop Surveys

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.

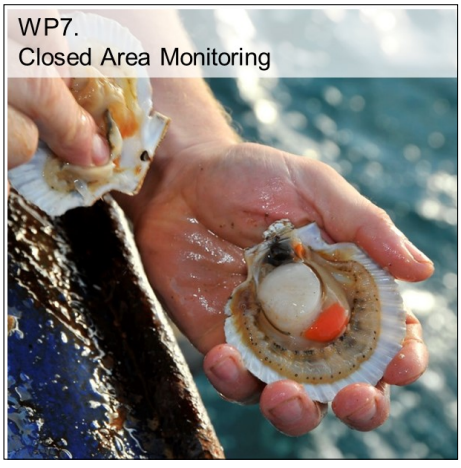
WP5 In line with the development of LTMPs (above) for king scallops, DEFA plans to consult on the current and future measures for the king scallop fishery.

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.



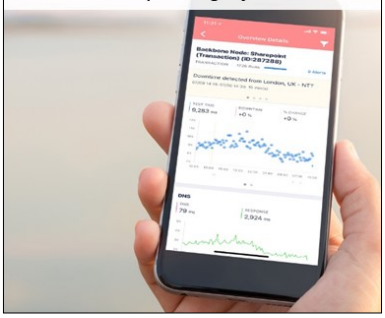
WP7 Long-term closures have proved successful for scallop fisheries. WP7 builds on this success by working with industry and DEFA to develop a standardised implementation and monitoring programme for closed areas.

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.

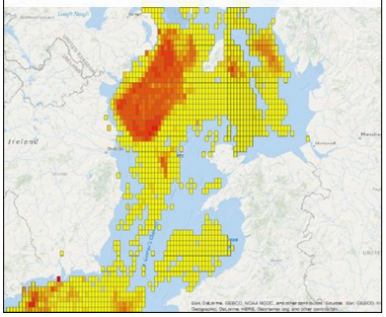
WP2.
Data feedback

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

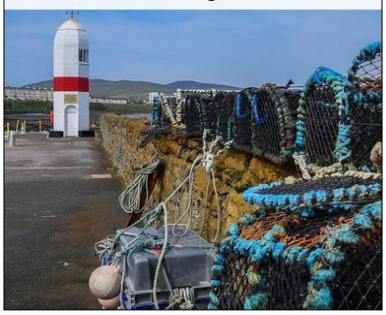
WP5 Similar to WP4, but with an emphasis on monitoring small 'juvenile' animals of the population. It is important to develop a long-term stock forecast model for fisheries management, and juvenile surveys can help model likely scenarios 3-5 years into the future. Again this is experimental science, 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 2021 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. and Jenkins, S.R. (2021). Isle of Man Queen Scallop: 2021 Stock Survey Report . Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report. pp. 39.
- Bloor, I.S.M. and Jenkins, S.R. (2021). Isle of Man King Scallop 2021 Stock Survey Report. Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report pp. 45.
- Bloor, I.S.M., Garratt, M.J., Coleman, M, Duncan, P.F. and Jenkins, S.R. (2022). East of Douglas Experimental Research Area: Five-Year Review. Sustainable Fisheries and Aquaculture Report (IoM), Bangor University. pp. 1 –13.
- Garratt, M. J., Coleman, M. T., Bloor, I. S. M. & Jenkins, S. R. (2022). Evaluation of potential sampling gears for Common whelk (Buccinum undatum) stock assessment surveys. Bangor

Meetings and Committees:

- International Council for Exploration of the Seas (ICES) Working Group on Scallop Stock Assessment. Virtual Meeting, 4th—8th October 2021.
- Scallop Management Board meeting, Virtual via Video Conference, Wednesday 17th February 2021, (Attended by Dr Isobel Bloor).
- Scallop Management Board meeting, Virtual via Video Conference, Wednesday 17th February 2021, (Attended by Dr Isobel Bloor).
- International Council for Exploration of the Seas (ICES) Working Group on Crab and Lobster. Virtual Meeting, 9th—11th November 2021.
- Isle of Man Crab Fisheries Management Advisory Council, Monday 18th November 2021, (Attended by Dr Matthew Coleman)

Theses:

- Emmerson, J. (2021). Towards sustainable fisheries management addressing evidence-gaps in baited-pot fisheries in the Irish Sea. PhD, School of Ocean Sciences, 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

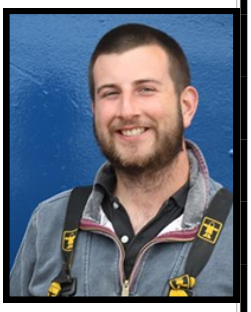
Professor Stuart Jenkins:

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.

Matthew Coleman:



I am fisheries scientist focusing on the management and the interaction of biological characteristics of crustacean stocks in static gear fisheries. I gained a BSc in Zoology from the University of Exeter and a MSc Marine Biology from Bangor University. Following graduation from Bangor University I have worked as a fisheries scientist for Orkney Sustainable Fisheries in Orkney, Scotland for the past 7 years. During my time in Orkney, I undertook a part-time industry funded PhD with Heriot-Watt University focusing on addressing key knowledge gaps on reproductive biology of the European lobster and their incorporation in sustainable regional management, working collaboratively with other researchers from France to Norway. My current role on the Isle of Man focuses on the static gear fisheries providing scientific advice for sustainable management of crab, lobster, and whelk fisheries.

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. In April 2021 I began a PhD with Bangor University focusing on whelk biology and fisheries management in the Isle of Man.