Isle of Man King Scallop 2024 Stock Survey Report

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Fisheries Report

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1. Fishery Management:

A fishery for king scallops, *Pecten maximus*, has been prosecuted in and around the Isle of Man's territorial waters since 1937 and developed rapidly in the 1960s as more and larger boats joined the fishery (Duncan et al., 2016). The Isle of Man king scallop fishery is seasonal, occurring from 1st November to 31st May by vessels using toothed, Newhaven dredges. Management of the fishery differs between an inner 0 to 3 NM zone, and an outer 3 to 12 NM zone, with more stringent regulations in the inner zone.

A joint consultation with the Isle of Man Scallop Management Board (SMB) on a long-term management plan (LTMP) for the king scallop fishery was launched in August 2021. Following the consultation, DEFA, Bangor University and the SMB worked collaboratively to develop a LTMP for the Isle of Man king scallop fishery which was approved by DEFA in April 2022 (LTMP 2022). As part of the LTMP a range of short-term objectives were outlined and subsequently introduced by DEFA through a number of policies. These polices included a Capacity Reduction Programme (whereby vessel numbers were reduced in line with a qualifying track record), termination of 'Grandfather Rights' (to be phased out by 2024), technical changes to dredges and tow-bars (introduced 2022/23 fishing season) and the implementation of a Research Contribution Scheme to fund industry-led science.

During the 2023/2024 season a total of 53 eligible vessels from the Isle of Man, Wales, Scotland, England and Northern Ireland were licenced to fish for king scallops within Isle of Man territorial waters 3- 12 nm zone. Of these 53 vessels, 30 were also eligible to fish for king scallops within the 0-3 nm zone. For the 2023/2024 fishing season, the management measures that applied to the fishery included (Table 1):

Table 1: Current management measures for the Isle of Man king scallop dredge fishery (as for 2023/2024 fishing season)

Management measure	Applicable zone
Total allowable catch of 2179 t	0 to 12 nm zone
Daily catch limit of 800 - 900 kg per vessel (varied in season)	0 to 12 nm zone
Closed areas (temporary and permanent)	0 to 12 nm zone
Minimum landing size (110 mm)	0 to 12 nm zone
Closed season (01/06 to 31/10)	0 to 12 nm zone
Curfew (18:00 to 06:00)	0 to 12 nm zone
Christmas break 21st Dec 2023 to 2nd Jan 2024 (incl.)	0 to 12 nm zone
VMS required for all vessels	0 to 12 nm zone
Submission of EU logbook	0 to 12 nm zone
Submission of IoM daily catch return	0 to 12 nm zone
Bycatch of queen scallops permitted (up to 10% of trip weight)	0 to 12 nm zone
Maximum 10 dredges	0 to 3 nm zone
Maximum 12 dredges	3 to 12 nm zone
Maximum of 8 teeth per dredge	0 to 12 nm zone
Minimum tooth spacing of 85 mm	0 to 12 nm zone
Maximum tow bar diameter of 185 mm	0 to 12 nm zone
Maximum tow bar length of 5.5 m	0 to 12 nm zone
Minimum belly ring internal diameter 75 mm	0 to 12 nm zone
Minimum dredge net mesh of 100 mm	0 to 12 nm zone
Under 221 kW (except Grandfather Rights)	0 to 12 nm zone
≤ 15.24 m vessel registered length	0 to 3 nm zone
French dredge prohibited	0 to 12 nm zone

These management measures were implemented under the Fisheries Act 2012, various secondary legislation, and through restrictive licencing conditions.

Of the 53 vessels eligible for a licence to fish for king scallops during the 2023/24 fishing season 44 vessels reported landings of king scallops from within Isle of Man territorial waters. The TAC for 2023/2024 was 2179 t of which 1960 t was landed (~ 90 %).

2. Annual (Calendar Year) Landings and Fishing Effort

2.1: Irish Sea

Annual landings (i.e. calendar year; January – December) of king scallops from the Irish Sea (Area VIIa) over the period 1950 – 2020 are shown in Figure 1 (ICES 2023a,b). Landings increased rapidly after 2006, peaking in 2016 at > 11000 t. Part of this step change in landings is attributed to the introduction of Buyers and Sellers regulations (RBS) in 2006 in the UK (Isle of Man then also introduced RBS in 2011). In the early part of the Irish Sea fishery (1950 – 1975), boats from the Isle of Man took the majority of the catch (80%). However, between 2006 and 2020 the average annual Manx share of landings declined to around 22%, with boats from the United Kingdom (Scotland, England, Wales and Northern Ireland) landing around 64% (the remainder was taken by vessels from Belgium and the Republic of Ireland). Several management measures are implemented within Area VIIa i.e. a closed season for *P. maximus,* which runs from 1st June to 31st October (inclusive) and a Minimum Landing Size of 110 mm shell length. Despite these measures the quantity of landings from the Irish Sea (VIIa) for the decade 2008 – 2018 was unprecedented in comparison to landings recorded in any other decade of the time series (Figure 1), and of concern given the general lack of knowledge and management of the stock at these high fishing levels (Duncan et al., 2016). Landings since 2016 have followed a downward trend, with a slight increase in the most recent year of data available (i.e. 2020). There is a lag on the data available from ICES and currently 2020 is the last year of data downloadable for king scallops in Area VIIa.

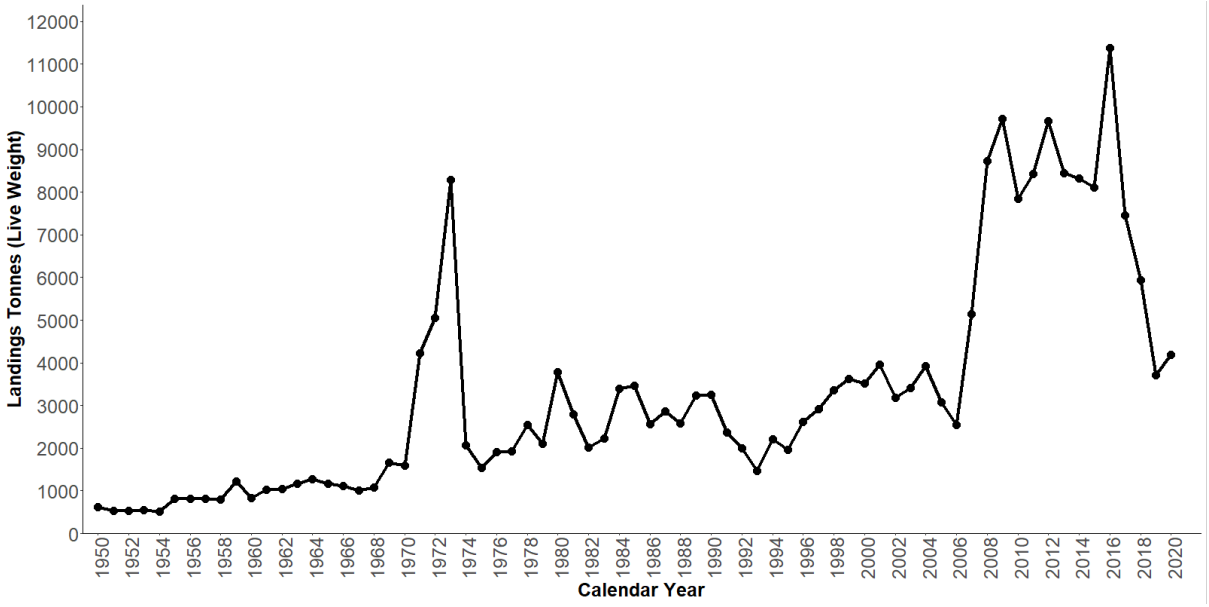

Figure 1: Annual King Scallop landings (t) from ICES Area VIIa for 1950 to 2020 using scallop landings from species Great Atlantic Scallop (SCE) and Scallop Nie (not included elsewhere) (ICES 2023a; ICES 2023b).

2.2: ICES Rectangles 36E5, 37E5 and 38E5

The annual landings (i.e. calendar year; January – December) of king scallops from the ICES Rectangles 36E5, 37E5 and 38E5, which cover the main extent of Isle of Man territorial waters, show a similar pattern of landings to those from the wider Irish Sea (Area VIIa) over the period 1992 – 2023 (Figure

2). Landings increased rapidly from 2006 to 2009 almost doubling during that period from 2111t to 3971t. Annual landings continued to increase after 2009, with an annual average of 4020t from 2010 – 2015 and a peak in 2016 of 5714t. Landings from ICES Rectangles 36E5, 37E5 and 38E5 decreased in 2017, 2018, 2019 and 2020 with slight increases to ~ 2200t for 2021 and 2022 and a further increase to~ 2900t in 2023. These reductions in landings followed the introduction of TACs within Isle of Man territorial waters in 2017/2018. TACs are not the only factor that may have influenced the reduction in landings. Stock decline could also be a contributing factor and in more recent years Brexit and Coronavirus may have also had an impact (Figure 2).

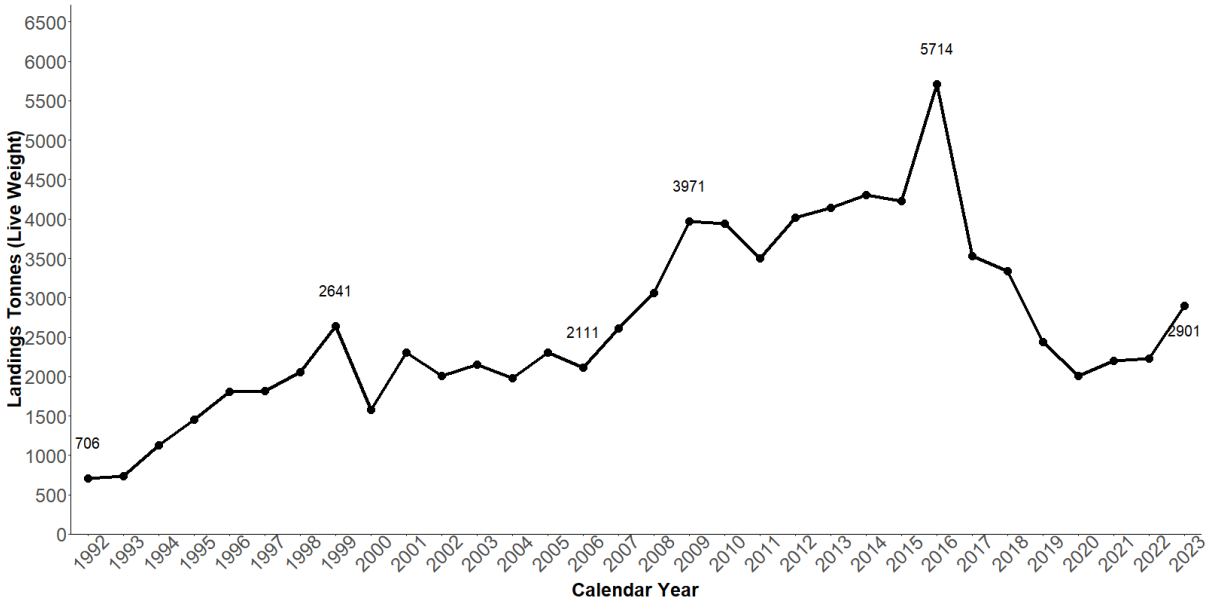

Figure 2: Annual (calendar year) King Scallop landings (t) from ICES Rectangles 36E5, 37E5 and 38E5 from 1992 to 2023 (Source: Logbook data DEFA, Marine Scotland, MMO and IFISH 2). For information the landings (t) values from key years are annotated on the graph.

3. Seasonal Landings and Fishing Effort

3.1: ICES Rectangles 36E5, 37E5 and 38E5

Seasonal landings of king scallops (i.e. covering the king scallop fishing season which runs from 1st November Year^{n} – 31st May Year^{n+1}) from ICES statistical rectangles 36E5, 37E5 and 38E5 show a similar pattern to annual data. Landings peaked in the 2016/2017 season at 5129 t. Following the introduction of TACs in Isle of Man territorial waters there were annual declines in landings from 2017/2018 to 2019/2020 (low of 1939 t in the 2019/2020 season). The TAC set for Isle of Man waters was 2049t for 2019/2020 to 2022/2023 rising to 2179t in 2023/2024. Landings from these three ICES Rectangles were relatively stable from 2019/2020 to 2021/2022, averaging around 2100t. There has subsequently been an increase in landings from these area in 2022/2023 and 2023/2024 averaging around 2750 t (Figure 3). *Note: these ICES Rectangles cover an area greater than the Isle of Man territorial waters.*

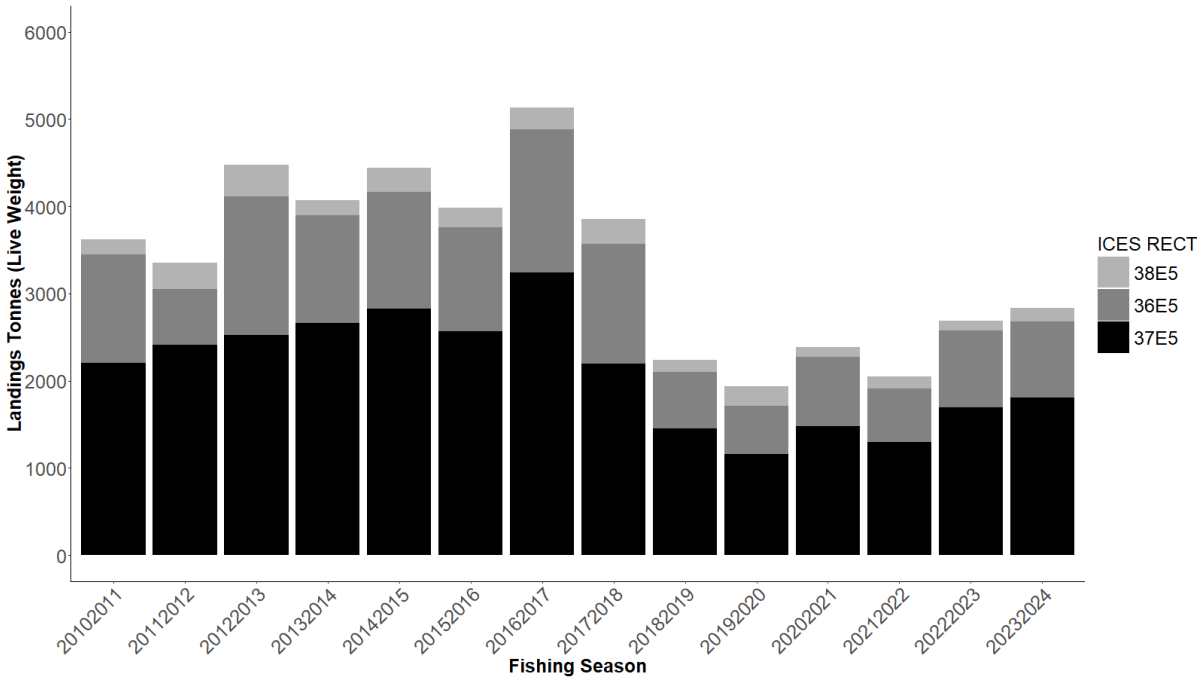

Figure 3: Seasonal landings (t) of king scallops from ICES Rectangles 36E5, 37E5 and 38E5 for the seasons 2010/2011 to 2023/2024. Data source: EU Logbooks downloaded through IFISH2. (NB. these data include ALL vessels fishing for king scallops (except vessels from Ireland for which we do not receive EU logbook data) and not only those vessels that are currently licenced to fish for king scallops within Isle of Man territorial waters).

3.2: Isle of Man Territorial Waters

A requirement of the king 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 reporting requirement is managed by the Isle of Man Department of Environment, Food and Agriculture (DEFA) and provides near real-time fisheries-dependent data from the fishery for the purpose of monitoring TACs and catch rates, etc. at the level of Irish Sea (IS) boxes (Figure 4). IS boxes are used rather than ICES Rectangles as they have a finer spatial resolution and largely align with the main fishing grounds. The spatial location of landings varies annually and often reflects densities. The data from the 2023/2024 fishing season are displayed in Figure 5. The largest proportion of landings for the 2023/2024 fishing season came from IS15: East of Douglas (EDG).

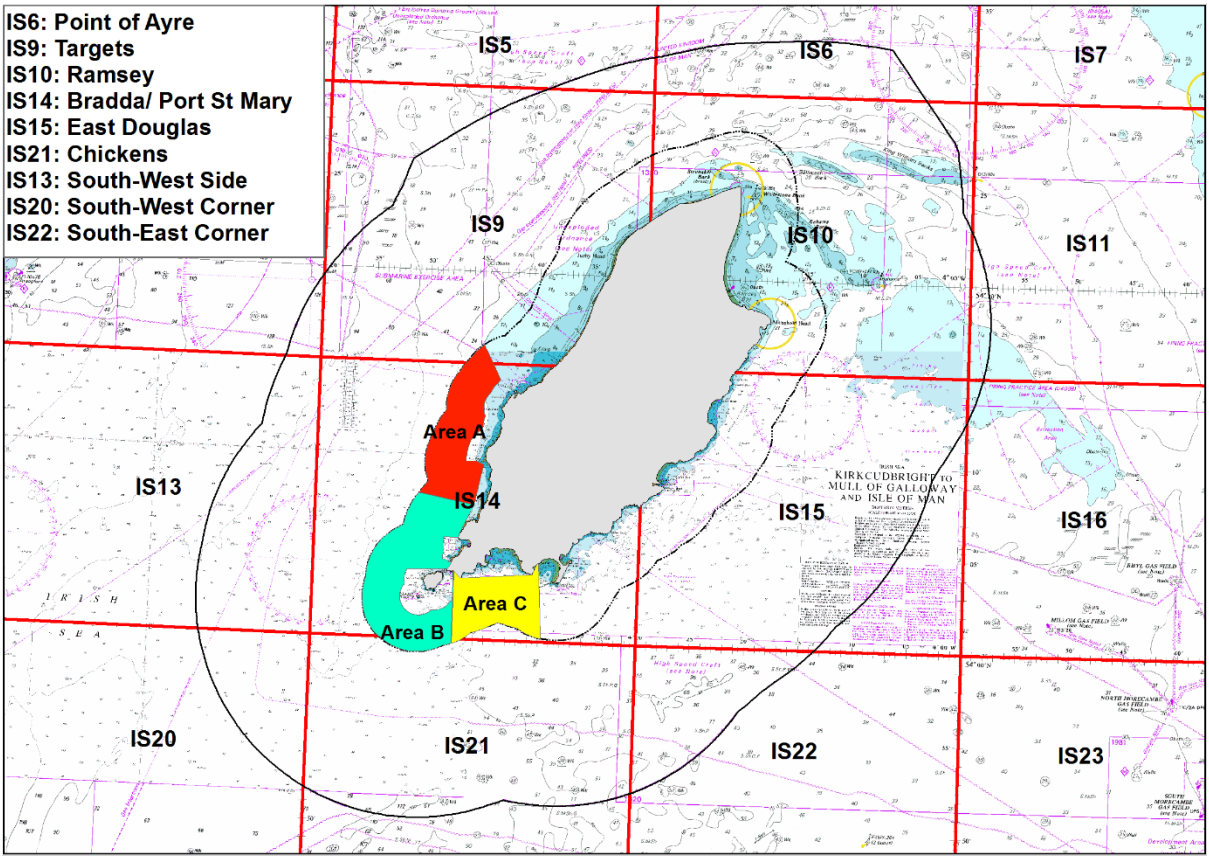

Figure 4: Map showing location of Irish Sea Boxes which are used to define fishing areas in the Nest Forms Landings Data. The fishing grounds delineated within each IS box are listed on the map. In addition, Subzones for reporting fishing within 3 subzones within the 0-3 nm limit are also shown (Area A = West Coast, Area B = Bradda/Calf and Area C = Port St Mary).

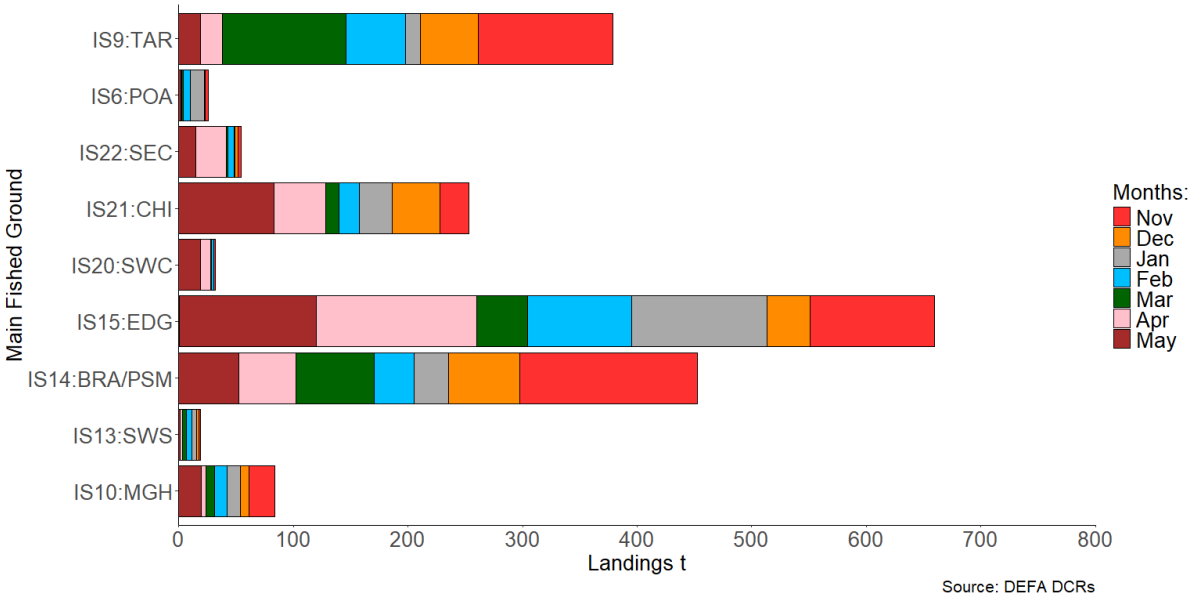

Figure 5: Scallop (SCE) Landings (t) reported by main fished ground (IS Box) and separated by colour for each month to show the spatial and temporal pattern of landings for the 2023/2024 king scallop fishing season. The main fishing grounds are covered by IS9 TAR = Targets, IS6 POA = Point of Ayre, IS21 CHI = Chickens, IS15 EDG = East of Douglas, IS14 BRA/PSM = Bradda and Port St Mary and the remaining smaller fishable areas are covered by IS20 SWC = South West Corner, IS22 SEC = South East Corner, IS13 SWS = South West Side, IS10 MGH = Maughold.

A comparison of average LPUE (kg per hour fished per dredge) at each of the main fished grounds is displayed below for the 2017/18, 2018/19, 2019/20, 2020/21, 2021/21, 2022/23 (grey) and 2023/24

(green) seasons by fished week. In 2023/2024 the LPUE at all grounds (except Ramsey – IS10: RAM) was towards the higher end of the range for historic LPUE trends for these grounds (2017/2018 – 2022/2023) (Figure 6).

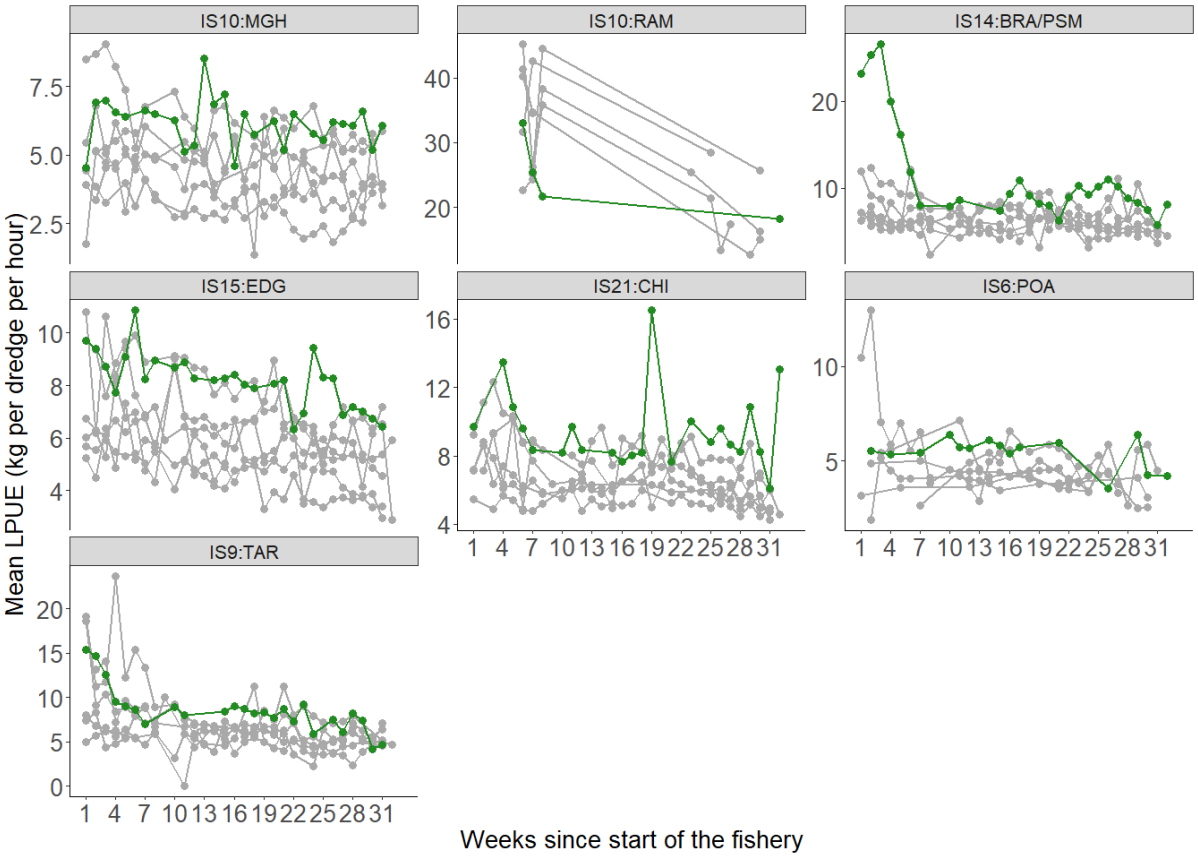

Figure 6: LPUE (kg per hour fished per dredge) displayed by main fished ground for current (2023/2024 (green)) and historic (2017/2018 – 2022/2023 (grey)) seasons. Note the different scales on the Y-axis (LPUE), in addition the fishery closed for Christmas around Week 9 in all seasons

4. Scallop Surveys:

There are currently two annual scallop surveys undertaken within the Isle of Man's territorial waters:

Long-term, medium resolution, fixed site survey: This survey has been undertaken since 1992 and is currently completed on the R.V. Prince Madog. It is a medium resolution survey (~ 3nm between survey sites), conducted at fixed survey stations. There is a long-term data set associated with this survey which enables stock assessment to be undertaken along with provision of a time series for calculation of the ICES Category 3 data-limited approach to TAC calculation (i.e. survey-based methods approach). Unfortunately, due to the Coronavirus restrictions in place in both the IoM and the UK this survey could not be completed in April 2020. This survey is subsequently referred to in this report as the 'Prince Madog survey'.

Short-term, fine resolution, random stratified survey: This is a new survey that was undertaken for the first time in June 2019. It is currently completed on two industry fishing vessels and sampling is coordinated by the Manx Fish Producers' Organisation (MFPO) with scientific support from Bangor University. It is a fine resolution survey (survey cells: 1 min (longitude) x 0.5 min (latitude)), this is approximately 1km x 1km (or ~0.53 nautical miles). This survey was able to be completed by local industry in 2020 in line with the Coronavirus restrictions and social distancing regulations. Due to

funding constraints not all grounds have been surveyed in all years. This survey is subsequently referred to in this report as the 'Industry survey'.

In line with recommendations developed with the scallop management board (SMB), the long-term survey data from the Prince Madog survey has been used to support the calculation of the 'ICES Category 3 data limited' approach to estimating annual total allowable catch (TAC). This approach requires a minimum time series of data of five years with the survey indices of the two most recent survey years summed and then divided by the sum of the survey indices from the three years prior. This ratio is then used to adjust the previous year's TAC up or down by a maximum of 20%. The five-year time series of data is important in this calculation as stocks can be variable in any year and comparing one year against another doesn't incorporate trends in the data.

4.2: Prince Madog Annual Spring Survey:

4.2.1 Survey Methods:

Spring surveys of the Isle of Man's scallop populations have been undertaken annually since 1992 (Beukers-Stewart et al., 2003). The 2024 spring scallop survey was undertaken by the R.V. Prince Madog over 7 days from 8th – 14th April 2024. A total of 35 survey stations were sampled (Figure 7); this was lower than usual due to adverse weather conditions during the survey period which limited the number of viable surveying days. 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 55 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 is recorded by dredge and a subsample of 90 queen scallops and 90 king scallops from each dredge are then weighed and measured (king scallops are also aged).

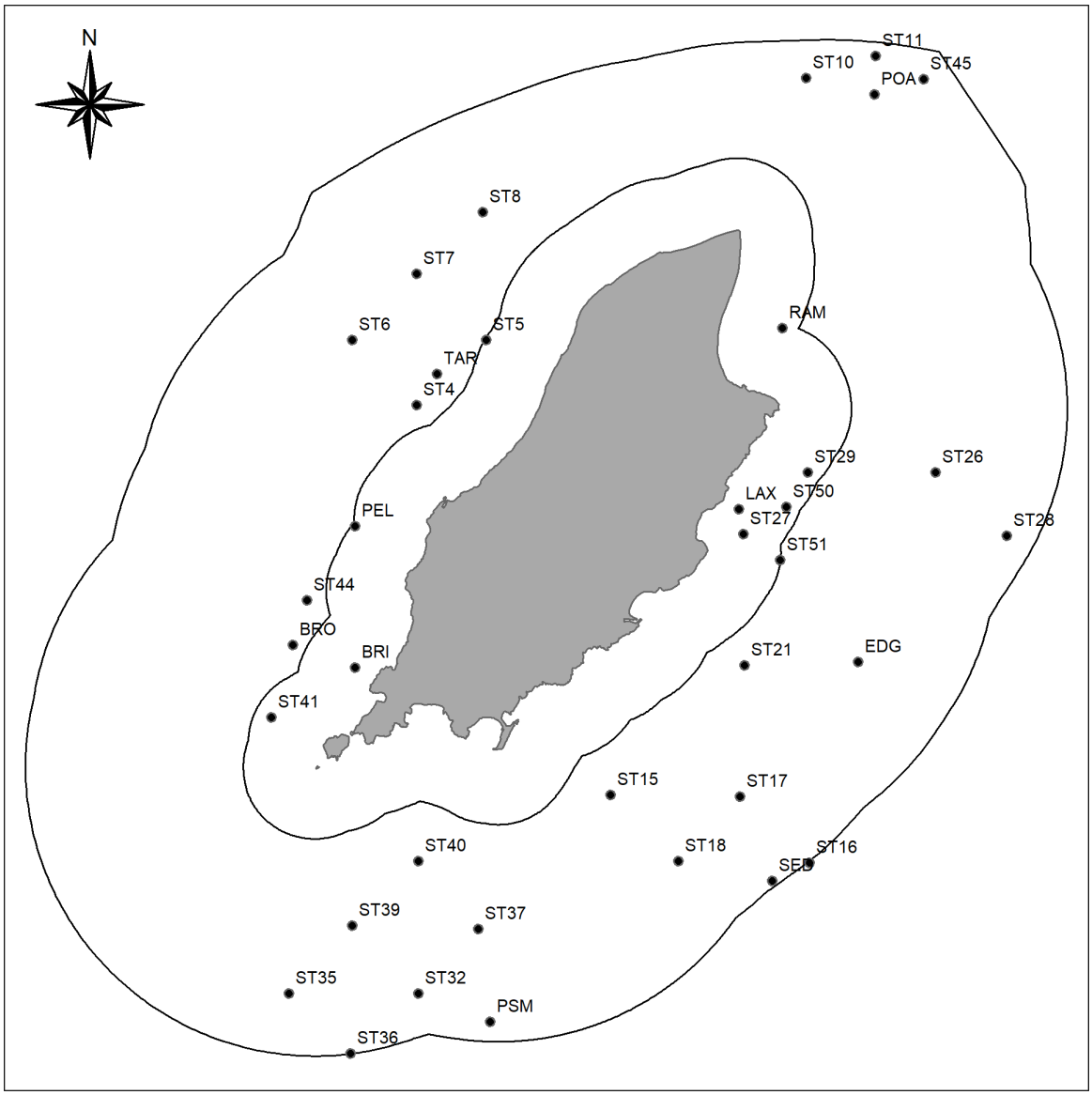

Figure 7: A map showing the location of all 2024 survey stations. Historical stations (i.e. those sampled from 1992) all have three letters (i.e. EDG, SED) while stations added from 2012 onwards are all labelled ST with a number (i.e. ST21, ST50). Fisher-suggested stations (labelled F with a number (i.e. F6, F8)) were added in 2016 and finer resolution stations added in 2021 following discussions with the MFPO are labelled FS with a number (i.e. FS2, FS11).

4.2.2 Size Frequency:

Frequency-density plots of king scallop size data are presented for the 2024 survey in Figure 8 from samples measured at ten historical stock assessment stations (POA, LAX, EDG, SED, PSM, CHI, BRI, BRO, PEL and TAR; data from all dredges combined). In 2024 the size range of scallops from the survey indicates that the first significant peak in the data is around 95-100 mm with a second overlapping peak around 110-115 mm (these reflect king scallops that are already at MLS or that would be expected to grow into the fishery during the 2024/2025 fishing season) (Figure 8).

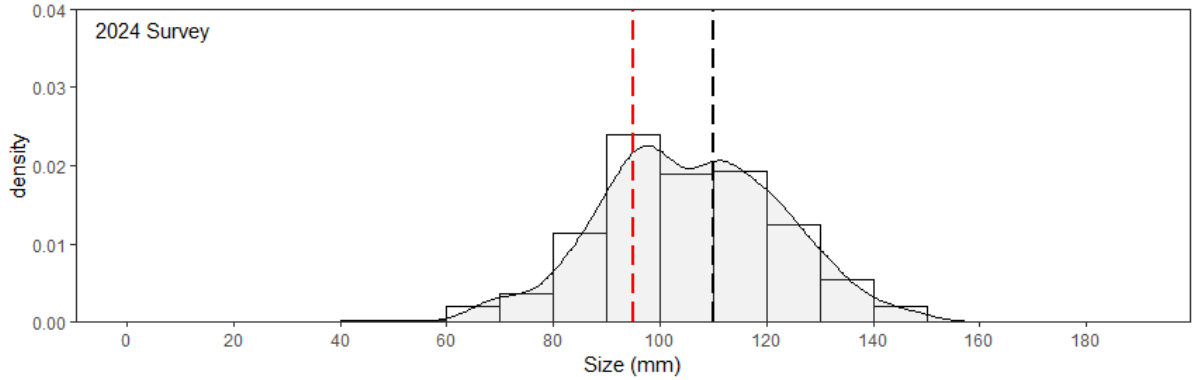

Figure 8: King scallop size frequency-density plot for 2024. Black dashed line indicates MLS (110 mm) and the red dashed line indicates the estimated MLS cut-off width (95 mm) for the territorial sea (i.e. the size at which scallops sampled in April Year^{0} will typically have reached MLS by 31st May Year^{+1}). Data from historical stations (no RAM) and includes data from both king and queen scallop dredges.

4.2.3 Density Estimates:

The average survey density of king scallops captured in queen scallop dredges (of all sizes caught) per 100 m^2 around the Isle of Man for the 2024 survey is displayed in Figure 9 for all survey stations. In 2024 the two highest density stations TAR, ST27 (≥ 8 kings scallops per 100 m^2) are on the West and East coast respectively, indicating a spread among fishing grounds (Figure 9).

The difference in mean survey density (scallops per 100 m^2) of king scallops from queen scallop dredges between 2023 and 2024 is displayed for all survey stations sampled in both years (Figure 10). This indicates positive increases between 2023 and 2024 in total scallop density at 24 stations and decreases at 11 stations (the historical station at CHI was not surveyed in 2024).

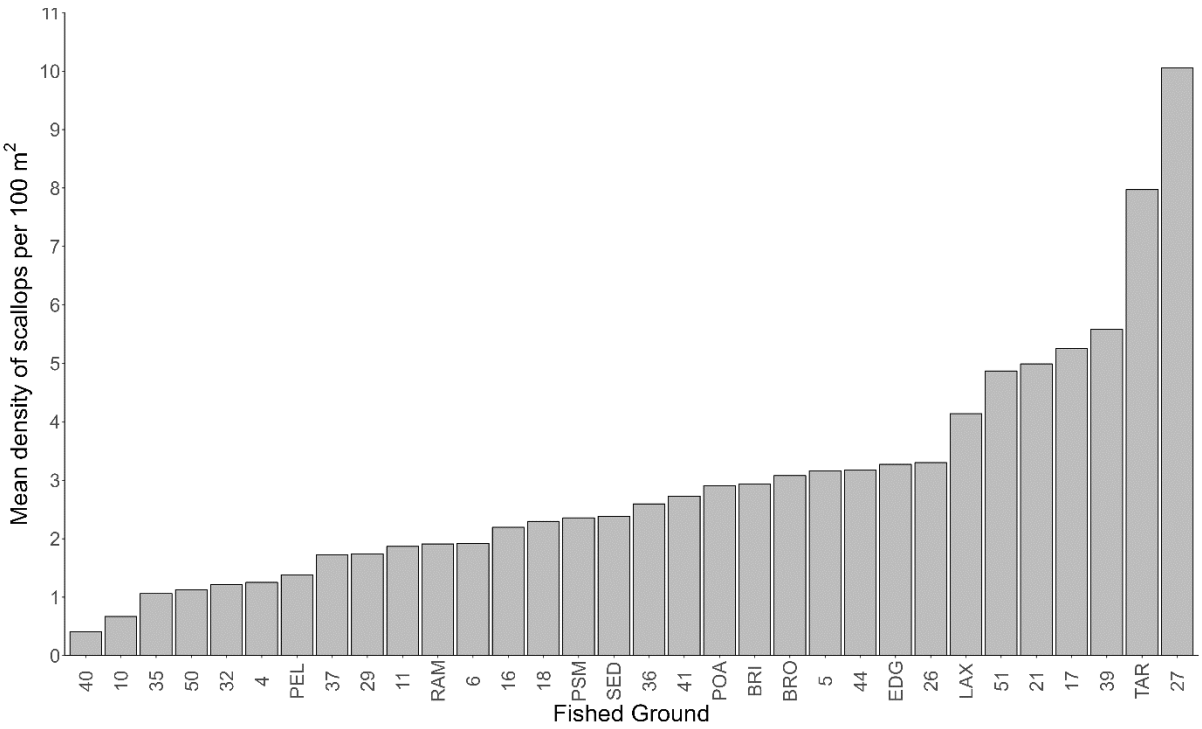

Figure 9: Survey densities (king scallops per 100 m^2) displayed by survey station for spring 2024 survey (average of queen scallop dredge data). Only sites with densities ≥ 0.25 king scallops per 100 m^2 are displayed.

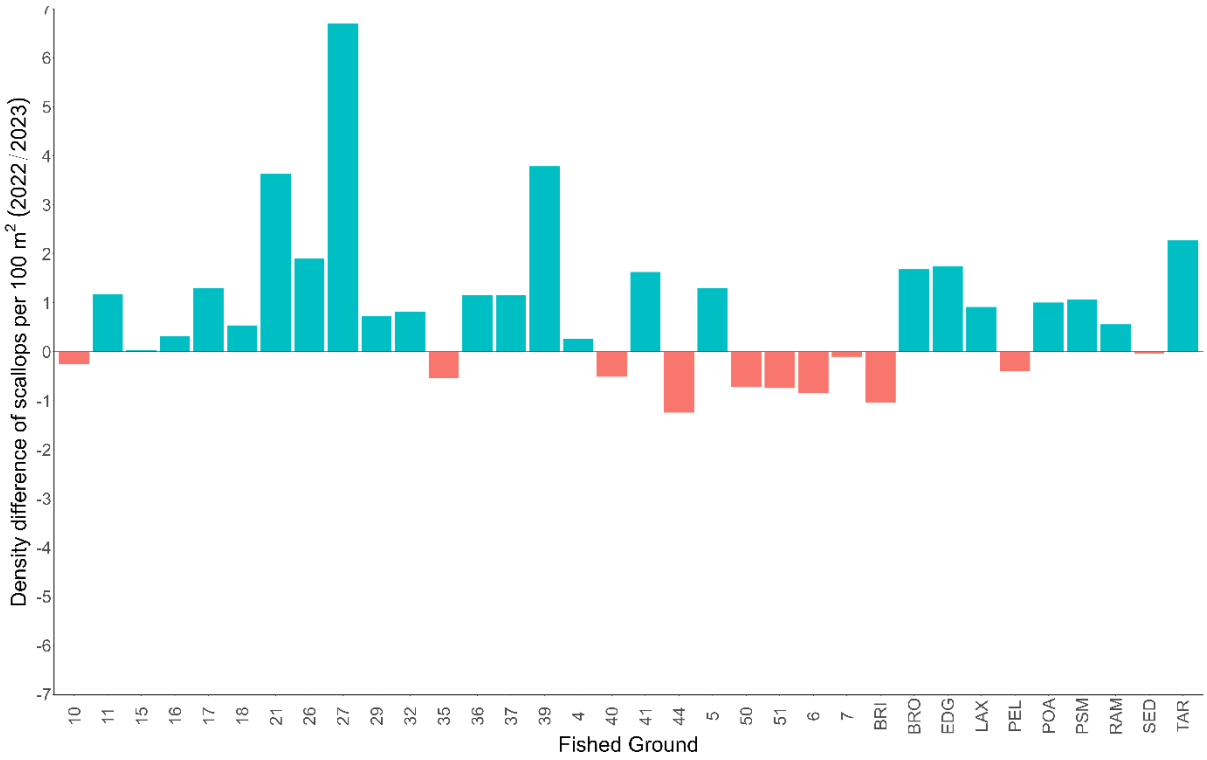

Figure 10: Difference in average survey density (scallops per 100 m²) of king scallops between 2023 and 2024 from queen scallop dredges for all survey stations sampled in both years (red bars indicate a reduction in scallop densities and green bars indicate an increase in scallop density from 2023 to 2024).

Despite positive increases in seven out of the ten historical stations surveyed in 2024 compared to 2023, the data need to be considered in the wider context of the time series. Figure 11 and Figure 12 indicate the density of king scallops per 100 m^2 for each of the eleven historical stations from 1992 to 2024. These longer-term data show a largely positive trend for 2024 with a number of stations at the upper range of historical densities (e.g. EDG, PSM, LAX, PEL, BRO and SED) (Figure 11 and Figure 12). The 2024 density at TAR, which is a site that has previously had very high densities, is at the upper end of the general densities for this site, but below the very high density years. ***Note no data for CHI in 2024***.

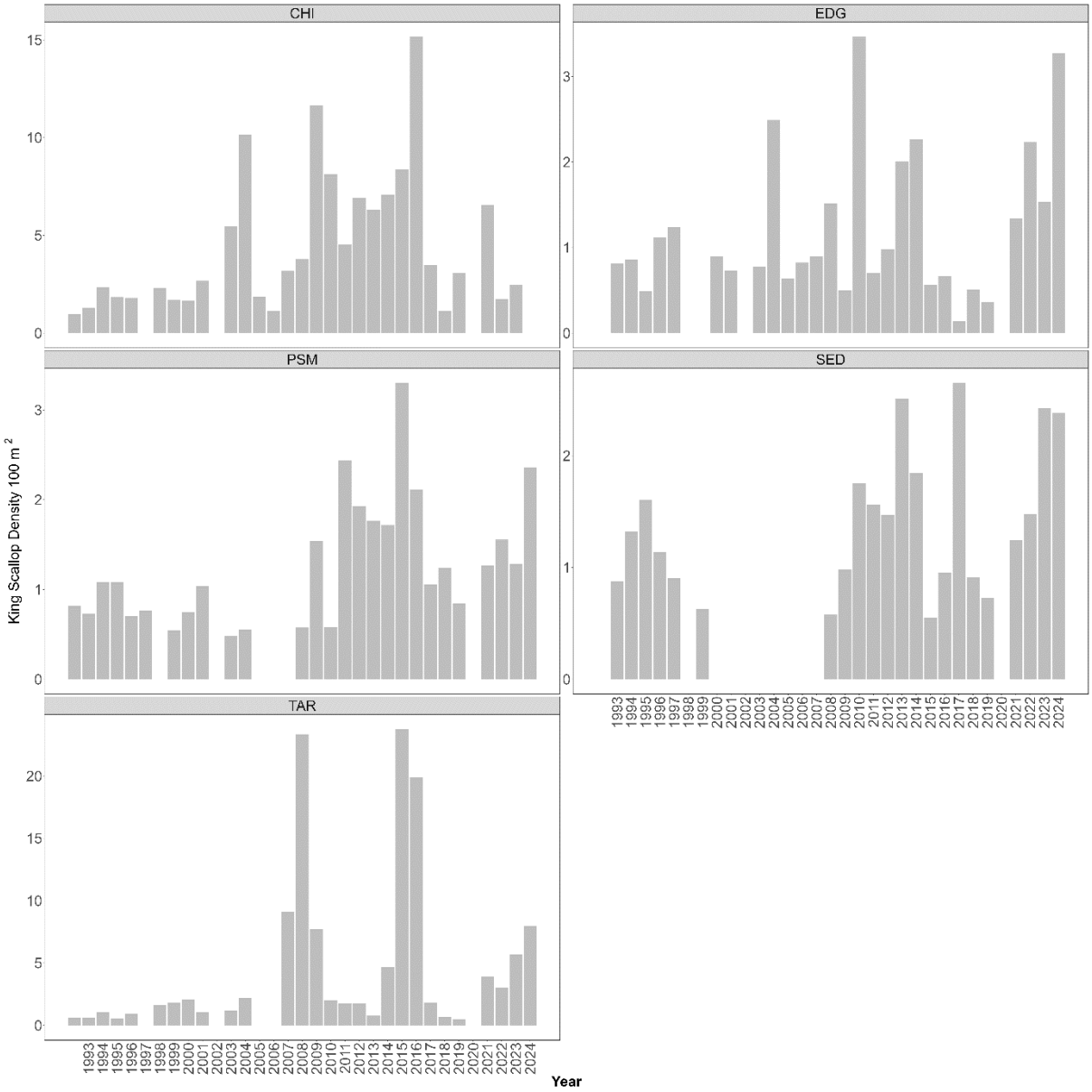

Figure 11: Density of king scallops (scallops per 100 m^2) at historical stations from 1992 to 2024 for the Prince Madog survey. Blank spaces indicate years with no survey data. Sites include CHI, EDG, PSM, RAM, SED and TAR

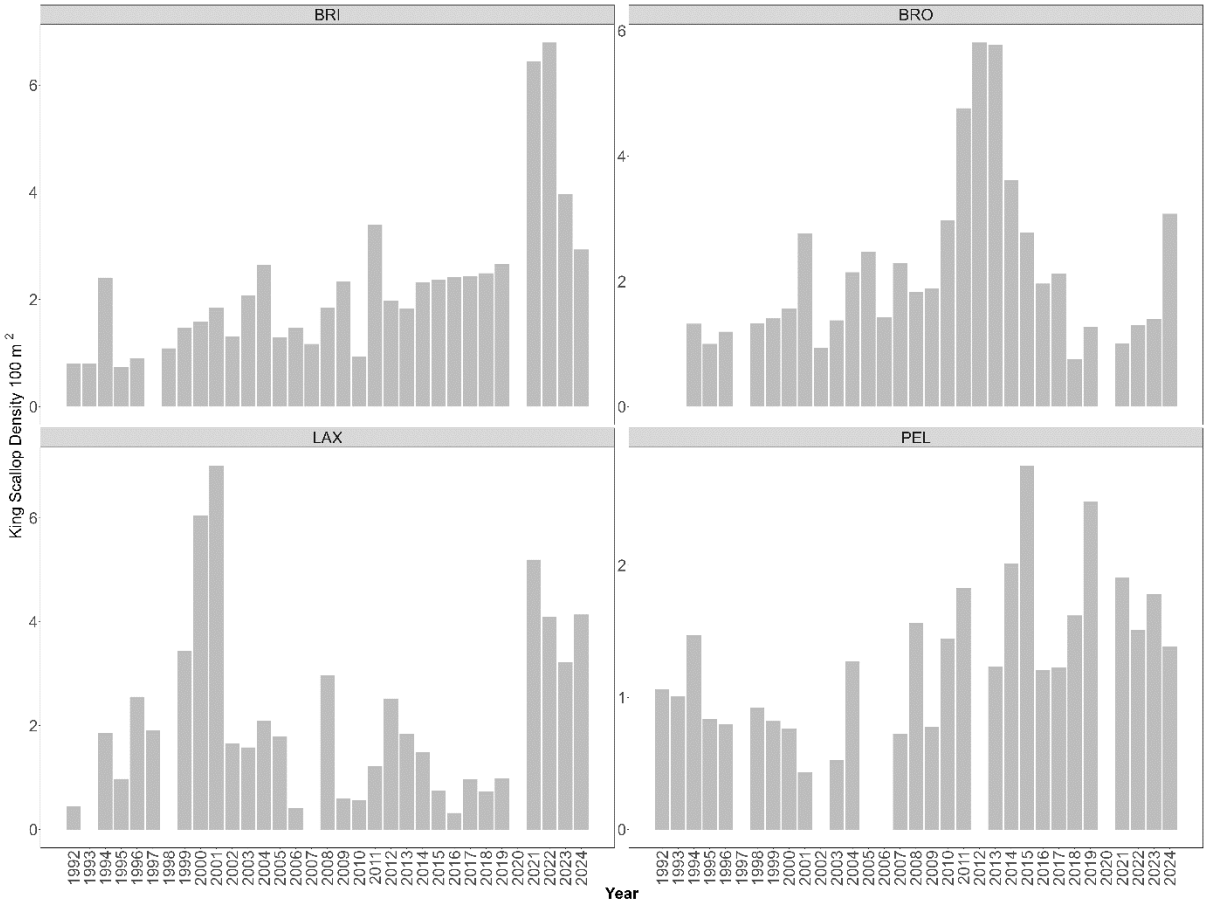

Figure 12: Density of king scallops (scallops per 100 m2) at historical stations from 1992 to 2024 for the Prince Madog survey. Blank spaces indicate years with no survey data. Sites include BRI, BRO, LAX and PEL.

4.2.4 Survey Abundance Indices:

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; Figure 7) only 10 standard historical scallop survey stations (BRI, BRO, CHI, EDG, LAX, PEL, POA, PSM, SED and TAR), are 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.

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. However, the arithmetic mean has also been calculated 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.

4.2.4.1 Recruits:

Overall stock trends for recruits can be observed using the recruit abundance index calculated using the geometric mean (solid line; Figure 13). The recruit index (geometric mean) had previously peaked in 2014 (66) with subsequent year on year reductions until it reached a time-series low in 2018 (6). From 2019 to 2022 there were annual increases in the abundance of recruits for the first time since 2014 followed by a slight decline in 2023 (solid line; Figure 13). However, recruit abundance in 2024 is the highest value recorded in the 33 year time series (91).

Cyclical spatially specific recruitment events can be observed using the recruit abundance index calculated using the arithmetic mean (dashed line; Figure 13) 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).

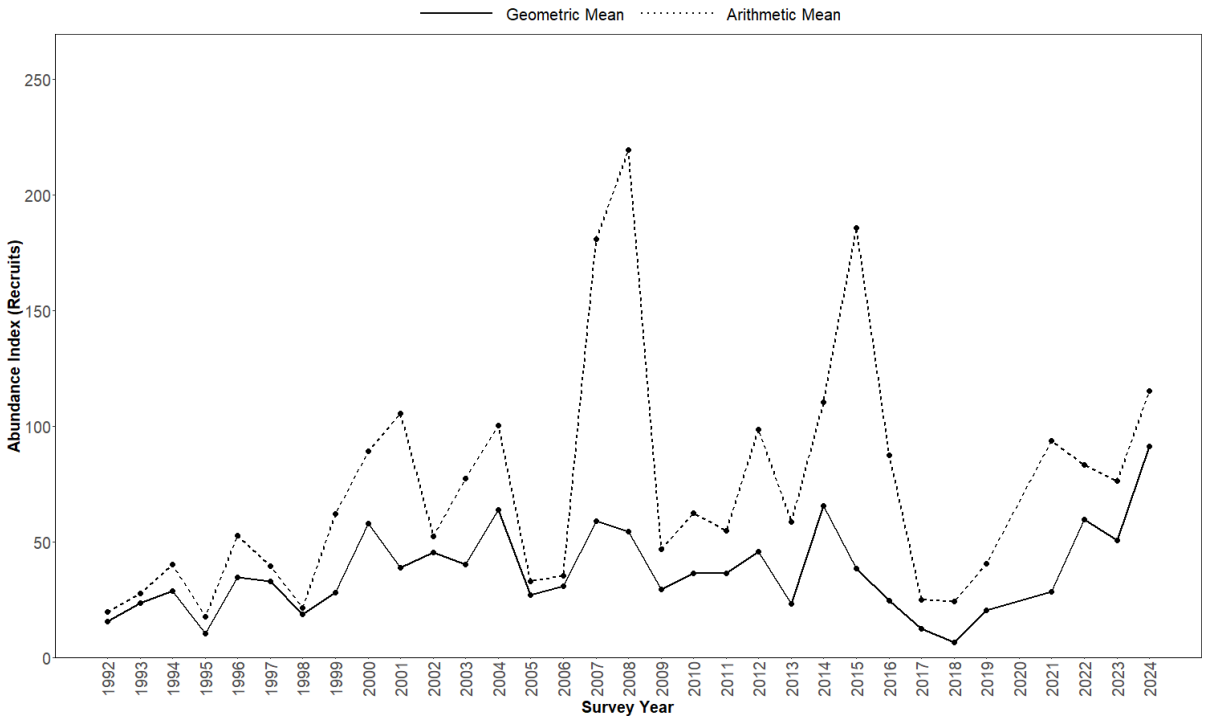

Figure 13: Recruit abundance index (scallops < 95 mm). Calculated based on length-based data where recruits were categorised as scallops under 95 mm at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. final day of 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 and utilises data from the 10 historical stations listed in the report.

4.2.4.2 Post-Recruits:

Overall stock trends for post recruits can be observed using the abundance index calculated using the geometric mean (solid line; Figure 14) which shows a general increasing trend in the mean abundance of post recruits (scallops ≥ 95 mm) from 1992 to 2015 (2015 is the 2nd highest value (186) in the time series). This was followed by four years of decreasing values before increasing again in 2021, 2023 and 2024 (slight decrease in 2022). Post-recruit abundance in 2024 is the highest value recorded in the 33 year time series (206).

The post recruit abundance index calculated using the arithmetic mean (dashed line; Figure 14) which does not down-weight isolated high-density patches of scallops shows peaks in 2009 and 2016 which tally with large recruitment events observed in the recruit index the year before.

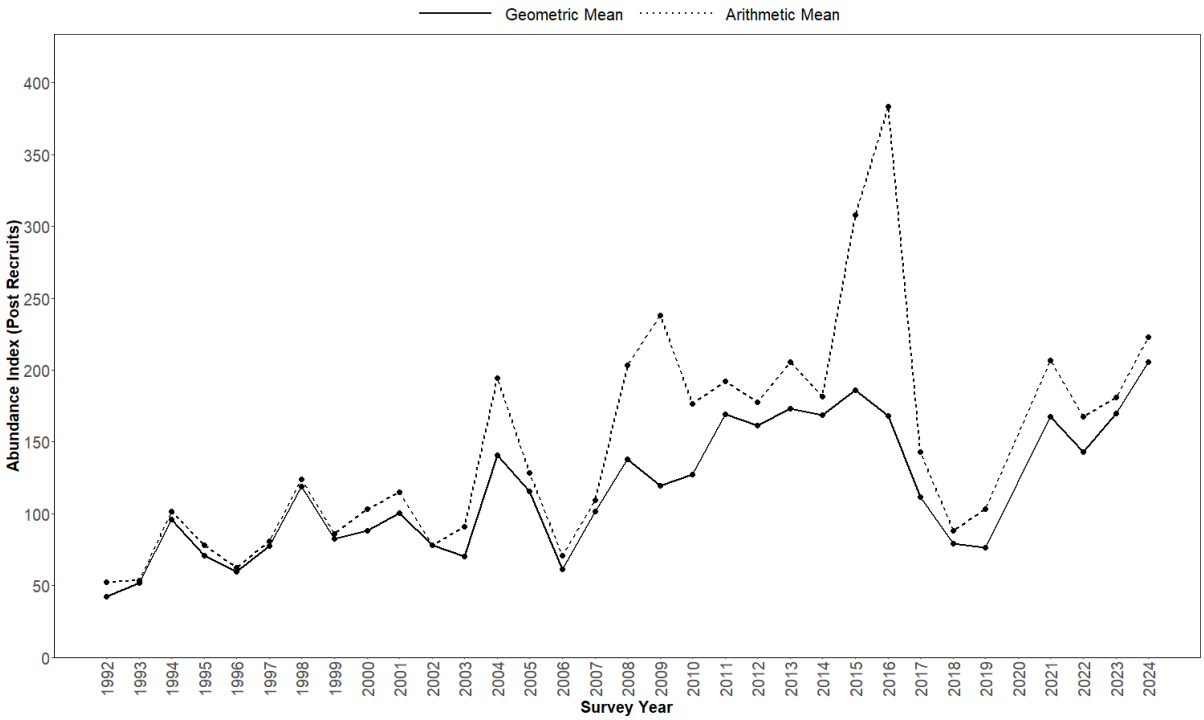

Figure 14: Post recruit abundance index (scallops ≥ 95 mm). Calculated based on length-based data where post recruits were categorised as scallops 95 mm or above at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. 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 and utilises data from the 10 historical stations listed in the report.

4.3: Industry Spring Scallop Survey:

4.3.1 Survey Methods:

A survey for king and queen scallops was undertaken onboard two industry vessels (F.V. Benolas and F.V. Our Sarah Jane) from 24nd May - 6th June 2024. The survey was undertaken at all of the main king scallop fishing grounds (Table 2):

Table 2: Grounds surveyed during the 2024 industry scallop survey and number of survey days detailed

Ground	Survey Tows	Zone
Targets (TAR)	41	3-12 nm
Chickens (CHI)	37	3-12 nm
East of Douglas (EDG)	96	3-12 nm
Bradda (BRA)	53	0-12 nm
Point of Ayre (POA)	10	3-12 nm
Maughold (MGH)	5	0-3 nm
East Coast (ECO)	20	0-3 nm
East of Douglas Experimental Research Area (EDG ERA)	56	0-3 nm

Survey areas were split into a fixed grid with a resolution of 1 min (longitude) x 0.5 min (latitude). 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. Within each survey cell a 10-minute tow was undertaken at ~ 2.5 knots. Each vessel towed a 'standard survey dredge bar' with four dredges, two King and two Queen dredges

interspersed along the bar (Queen dredges had 10 teeth) and a 'juvenile survey dredge bar'. This is of the same design but uses Queen dredges with 17 teeth with a mesh (60 mm) attached internally that when stretched into a fixed position results in a maximum mesh size of 38 mm. The catch from each dredge was counted and a subsample of up to ~ 90 kings and 90 queens were measured.

Data cleaning: During 'data cleaning' any scallops in the subsample that were recorded as queen scallops over 100 mm were assumed to be king scallop recorded as the wrong species and the data adjusted accordingly. Discrepancies between the number reported on the tow sheet and the number sampled (where the whole dredge catch were measured) were altered to reflect the number measured.

Data analysis: The geometric mean was used for data analysis due to the skewed (non-normal) distribution of the density data. Recruits (i.e. < 95 mm) were estimated using the data from standard queen and juvenile queen dredges whilst post-recruits (i.e. > 95 mm) were estimated using data from the standard king and standard queen dredges due to differences in the size selectivity of the dredges. In addition, for the first time the survey index for the whole TS from the industry survey data was standardised using a spatio-temporal model in R using the sdmTMB package (Anderson et al., 2024). In previous years the analysis for the overall TS has been restricted to the inclusion of data from CHI, EDG and TAR only as these were the grounds that had been surveyed in every year. By using a spatio-temporal model to standardise the survey index it has been possible to include the data from all survey grounds. The model used data from standard queen dredges for all sizes (i.e. not split into recruits and post-recruits).

Survey timing: It should be noted that the industry survey has taken place at slightly different times of the year since it started in 2019 (2019 – June; 2020 and 2022 -April; 2021 and 2024 – May; 2023 - May/June). Size data is presented here as a snap shot at the time of the survey and the data has not been adjusted for size increase due to growth between these periods due to the spatial-temporal complexity and uncertainty associated with scallop growth. However, a 95 mm cut off point for recruits has been used for the analysis to indicate the maximum size at which scallops on average caught in spring/summer could potentially grow to 110 mm during the king scallop fishing season.

Data legend scales: Please note that the scales for each data subsection (i.e. TS, TAR, CHI, EDG, TAR, ECO, BRA etc.) differ among grounds and represent the range of density values within that dataset. The scales are consistent within each ground such that the same scale is used to represent recruit and post-recruit data.

4.3.2: Results:

The following sections show survey densities of under 95mm king scallops (based on data from juvenile and standard queen scallop dredges) and over 95mm king scallops (based on data from standard king and standard queen scallop dredges) for the years in which the industry survey has taken place. Initially data are presented for the whole Territorial Sea, and then ground by ground. In addition frequency histograms are presented to show the size distribution of sampled scallops.

Analysis of data for recruits and post-recruits for each ground uses data from different gear types. The standard king scallop dredges do not sample scallops under 95 mm (i.e. recruits) as efficiently as either the juvenile or standard queen scallop dredges. As such, the combined data from the juvenile and standard queen dredges is used to generate the survey index for recruits whilst for the post-recruit index data combined from the standard king and queen dredges are used.

For the analysis at the whole TS level, in order to standardise the survey index a spatiotemporal Generalised Linear Mixed Effect Model (GLMM) was fitted using the sdmTMB package (Anderson et al.,2024) in R. The model was fitted with a tweedie distribution and a log link with year used as the temporal component. The formula used was:

$$density\ (kg\ km^2 \sim s(Depth, k\ =\ 5)\ +\ 0\ +\ as.factor(year)$$

The index was calculated using density of scallop biomass, and includes all scallop sizes (i.e. it is not divided into recruits and post recruits). Here individual scallops were converted from length to weight using a formula which was tested for spatial, annual and seasonal effects.

4.3.2.1 Territorial Sea

The size distribution of individuals from all three dredge types (Juvenile Queen, Standard King and Standard Queen) for the 2024 survey is shown in Figure 15. The juvenile and standard queen dredges both show a recruitment peak at around 50 mm.

Figure 16 shows the densities of under 95mm (left) and over 95mm (right) king scallop densities for the 2024 survey (using the geometric mean).
The standardised index produced for the whole TS using the sdmTMB model indicates an increase in the survey index for 2024, which is currently the highest value in the six year time series (Figure 17).

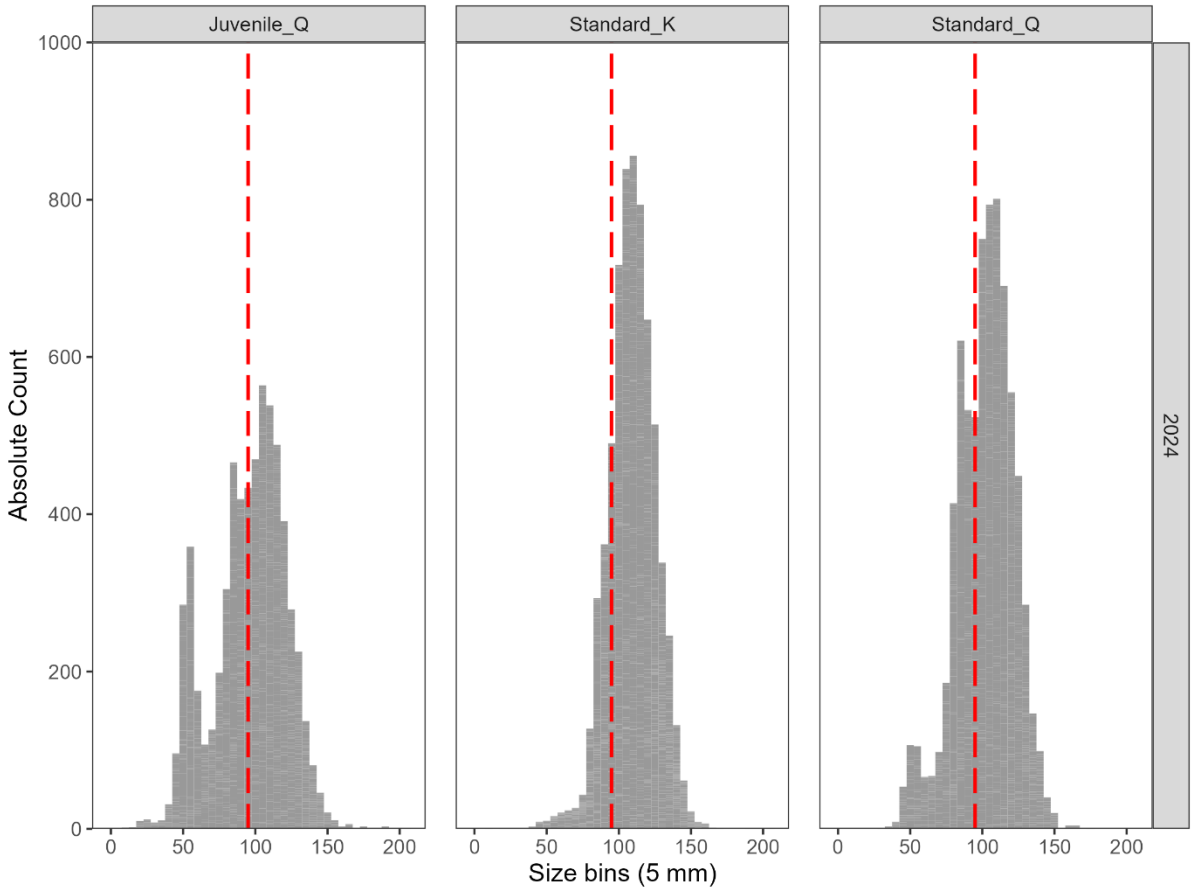

Figure 15: Size frequency of absolute counts of king scallops for the territorial sea (all survey cells and grounds) displayed for 2024 by survey dredge type (red dotted line indicates the estimated recruit cut-off of 95 mm). The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions.

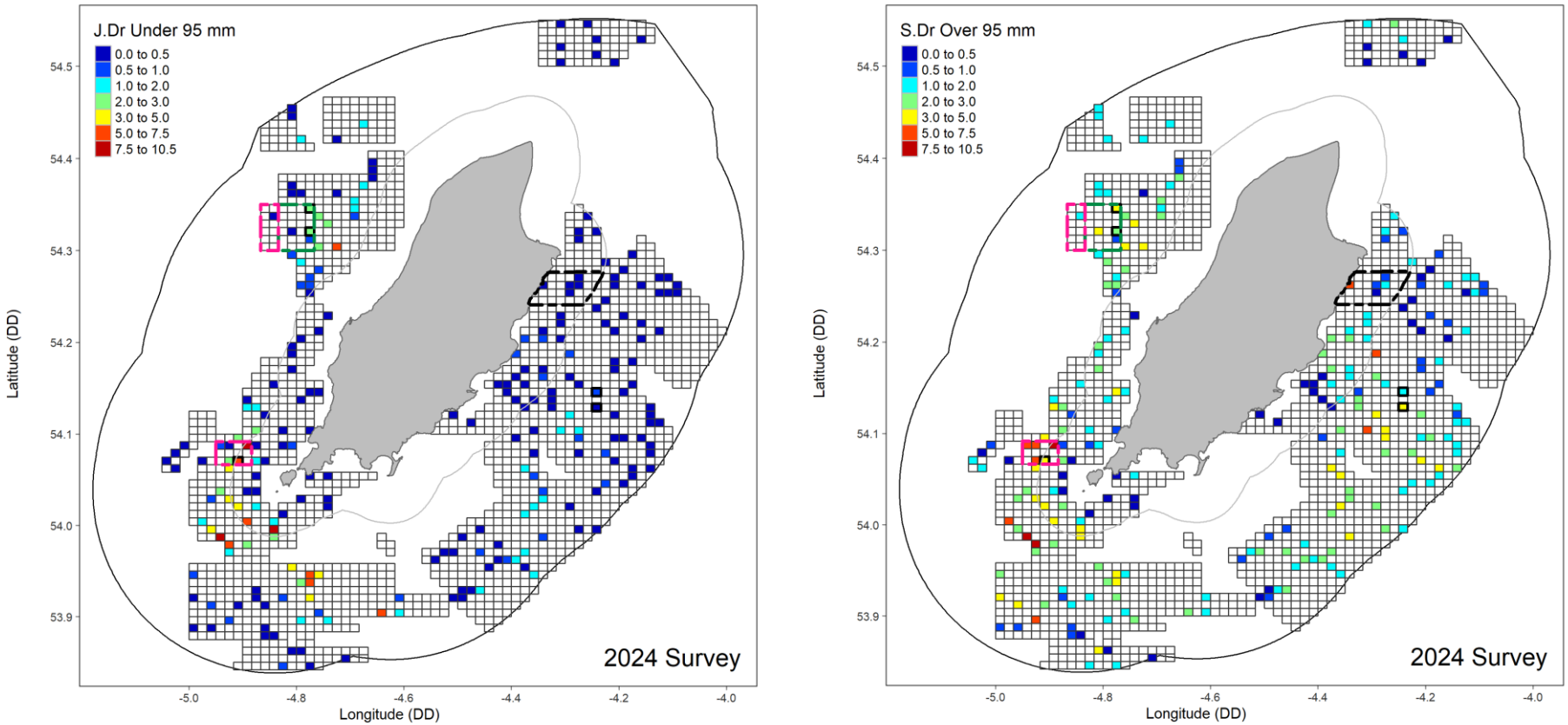

Figure 16: 2024 Survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen dredges (left) and over 95 mm from standard king and standard queen scallop dredges (right). Green box indicates restricted access during the 2023/2024 king scallop fishing season and pink boxes indicate 2023/2024 king scallop closed areas. Black box indicates the East of Douglas Experimental Research Area. Black cell borders indicate cells that were targeted during the survey.

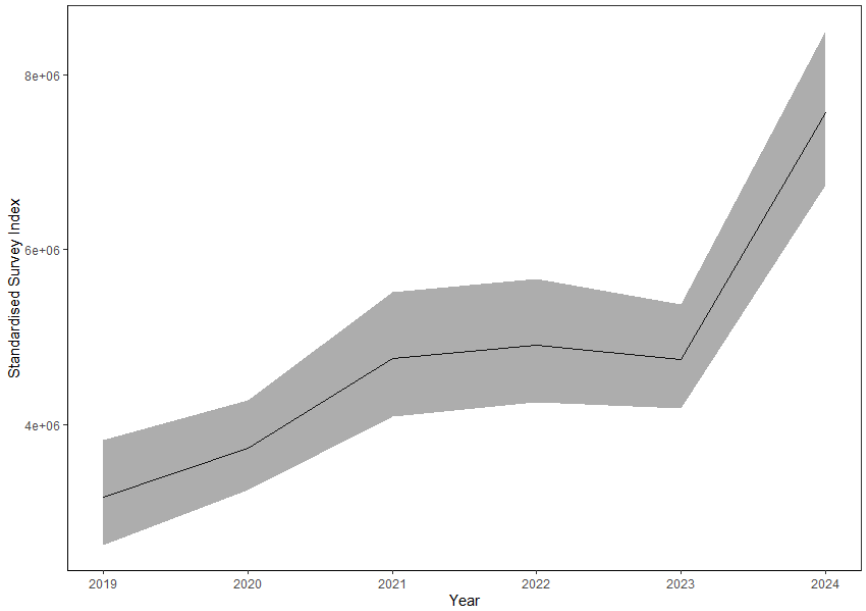

Figure 17: Standardised survey index for king scallops within Isle of Man Territorial Waters (2019 – 2024). Black line indicates the mean values and the grey shaded areas indicate the upper and lower boundaries. Using data from standard queen scallop dredges only (scallops of all sizes).

4.3.3 Fishing Grounds (3- 12 nm)

4.3.3.1 Targets

Spatial plots of the survey data from the four most recent survey years (2021 – 2024) are presented for TAR for both recruits (under 95 mm) in Figure 18 and post-recruits (over 95 mm) in Figure 19. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 recruits (bottom right; Figure 18) there is a collection of survey cells extending east from the edge of the previous restricted area with densities between 2-7.5 scallops per 100m^2 (very high densities for recruits). The highest densities of post-recruits at TAR in 2024 were also located in a similar area with densities between 2-5 scallops per 100m^2 (bottom right; Figure 19 & Figure 20).

The data from TAR indicates that for post-recruits (over 95 mm) the survey index was relatively constant from 2020 to 2023 i.e. 0.84 to 0.78 and then almost doubled in 2024 to 1.54 (highest in six-year time series) (Table 3). For recruits (under 95 mm) the survey index in 2024 is also the highest recorded for this ground in the six-year time series (2024 is 0.58) (Table 3).

The size frequency histogram for 2024 (Figure 21) also shows that there is good levels of recruitment across a relatively wide range of sizes (pre-recruits and recruits; 40-95 mm) detected by the juvenile queen scallop dredges, which with good management, will be due to recruit to the fishing ground in across the next 1-3 years.

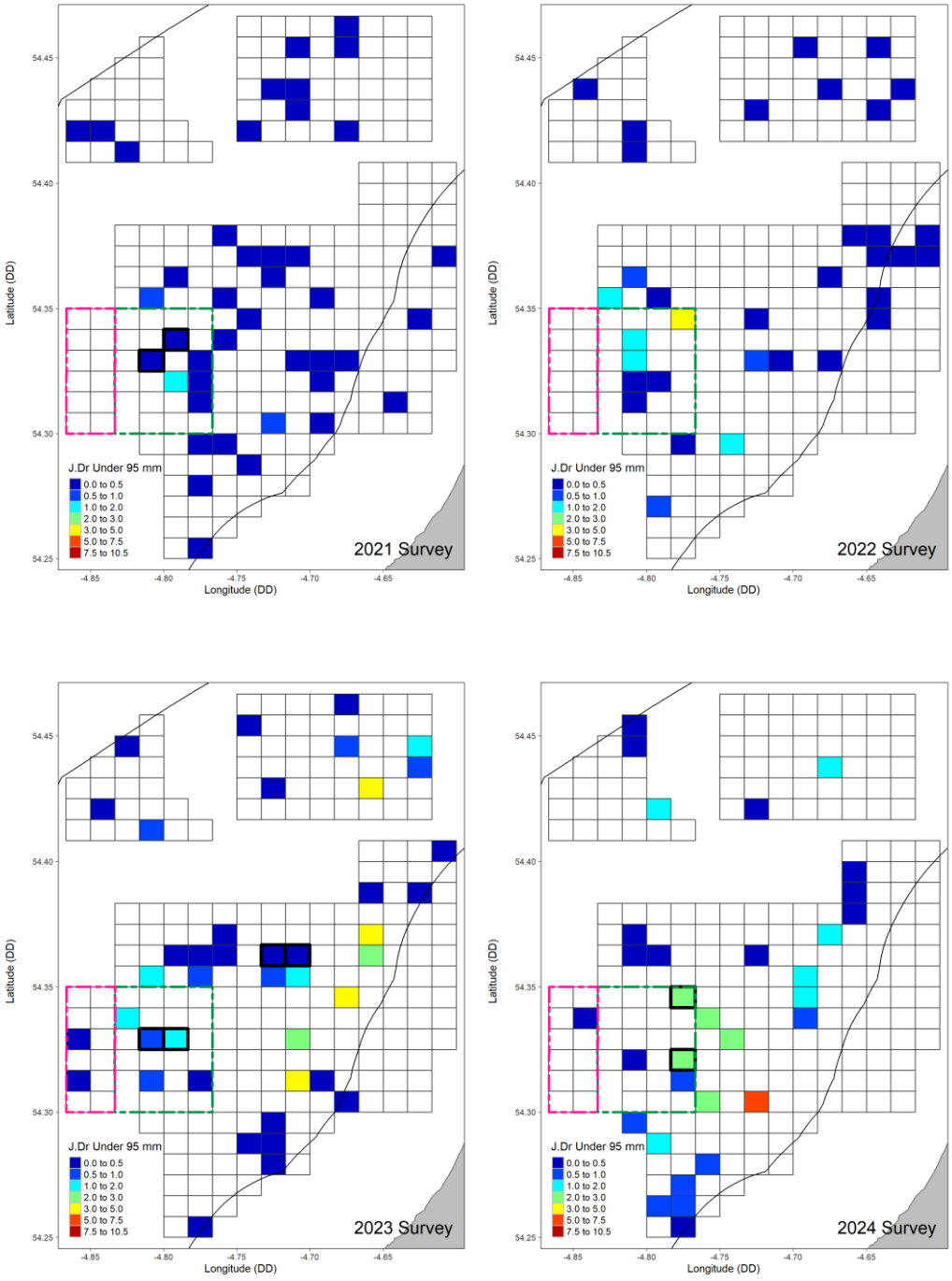

Figure 18: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2021 (top left), 2022 (top right), 2023 (bottom left) and 2024 (bottom right) at Targets (West coast). The green box indicates a restricted access area and the pink box indicates a closed area during the 2023/2024 king scallop fishing season. Black borders indicate cells that were specifically targeted during the survey.

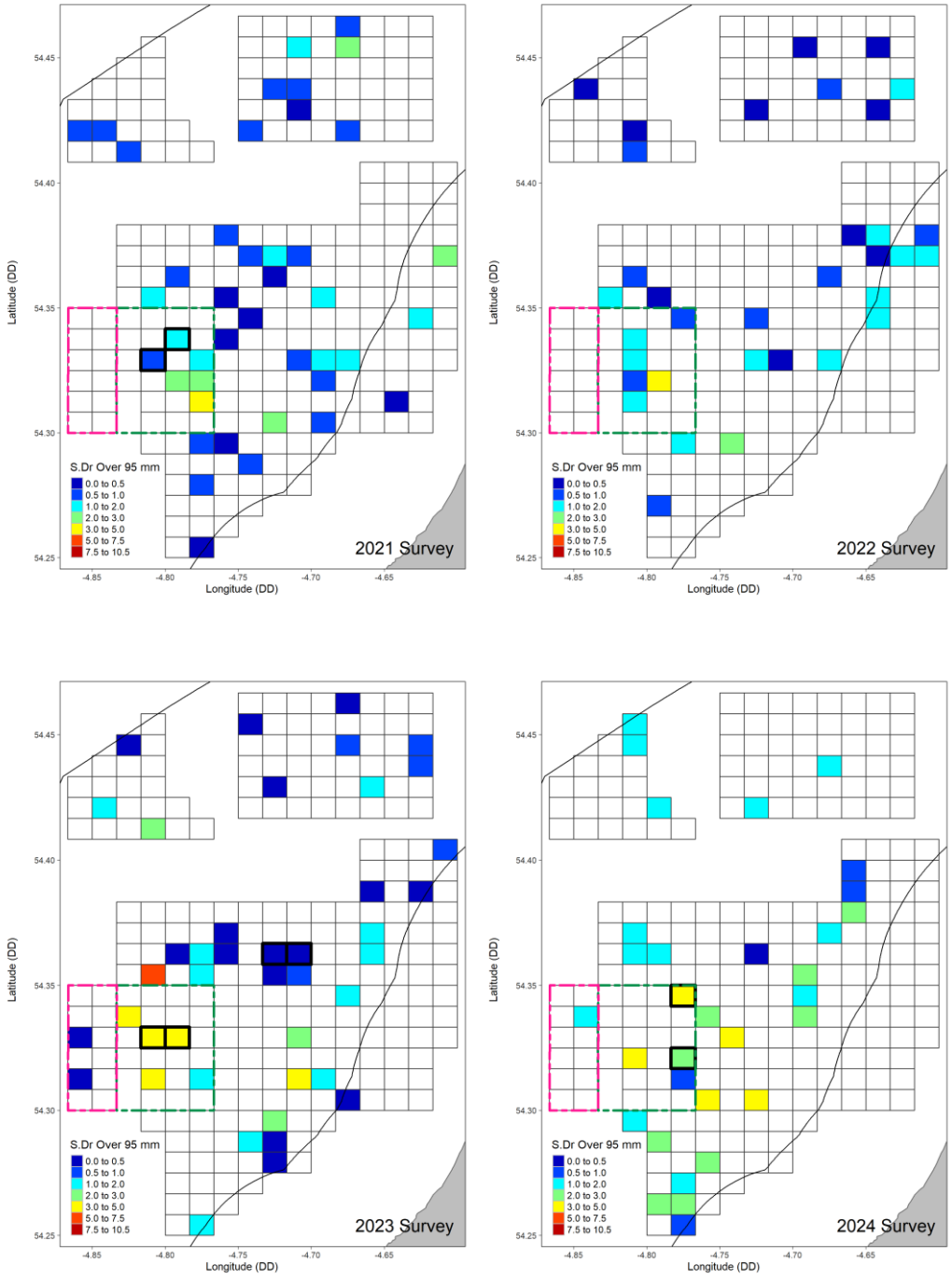

Figure 19: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard king and standard queen scallop dredges for 2021 (top left), 2022 (top right), 2023 (bottom left) and 2024 (bottom right) at Targets (West coast). The green box indicates a restricted access area and the pink box indicates a closed area during the 2023/2024 king scallop fishing season. Black borders indicate cells that were specifically targeted during the survey.

Table 3: Survey index (geometric mean) of king scallops per 100 m² for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for Targets.

Year	< 95 mm	≥ 95 mm
2019	0.10	0.61
2020	0.19	0.84
2021	0.16	0.84
2022	0.27	0.87
2023	0.38	0.78
2024	0.58	1.54

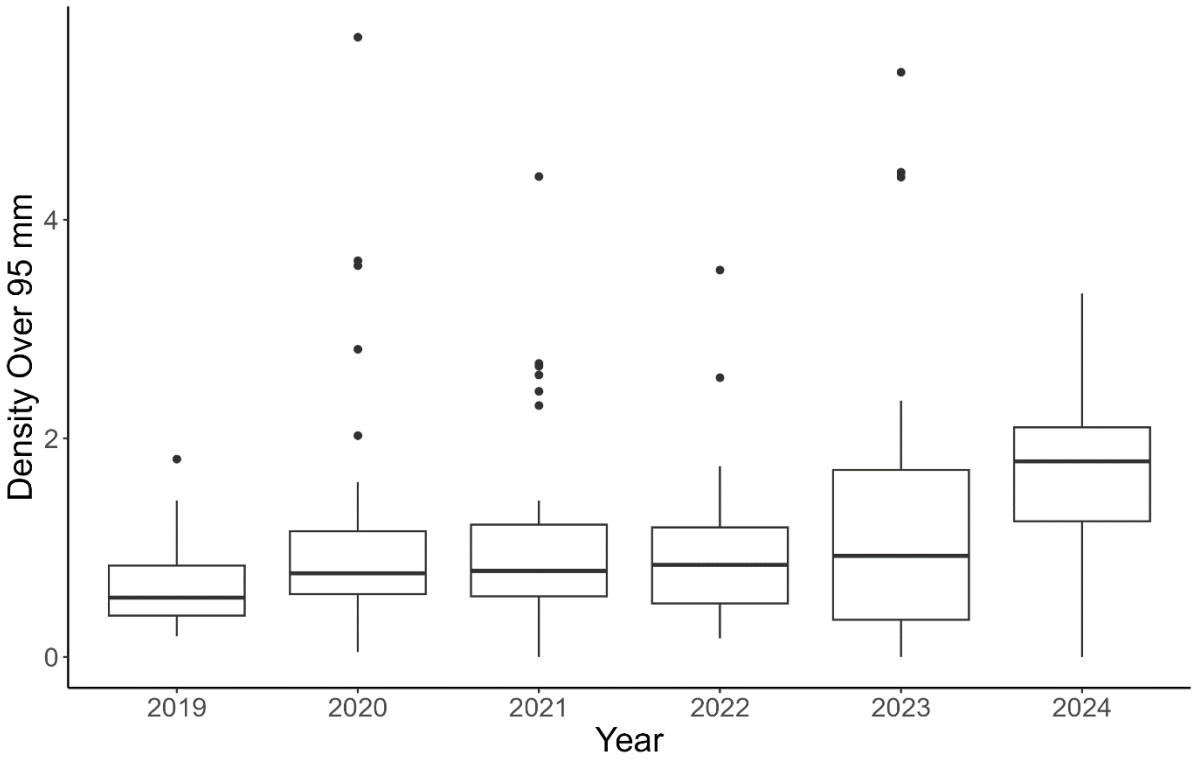

Figure 20: Boxplot showing the density by year of scallops over 95 mm for all sites surveyed at TAR

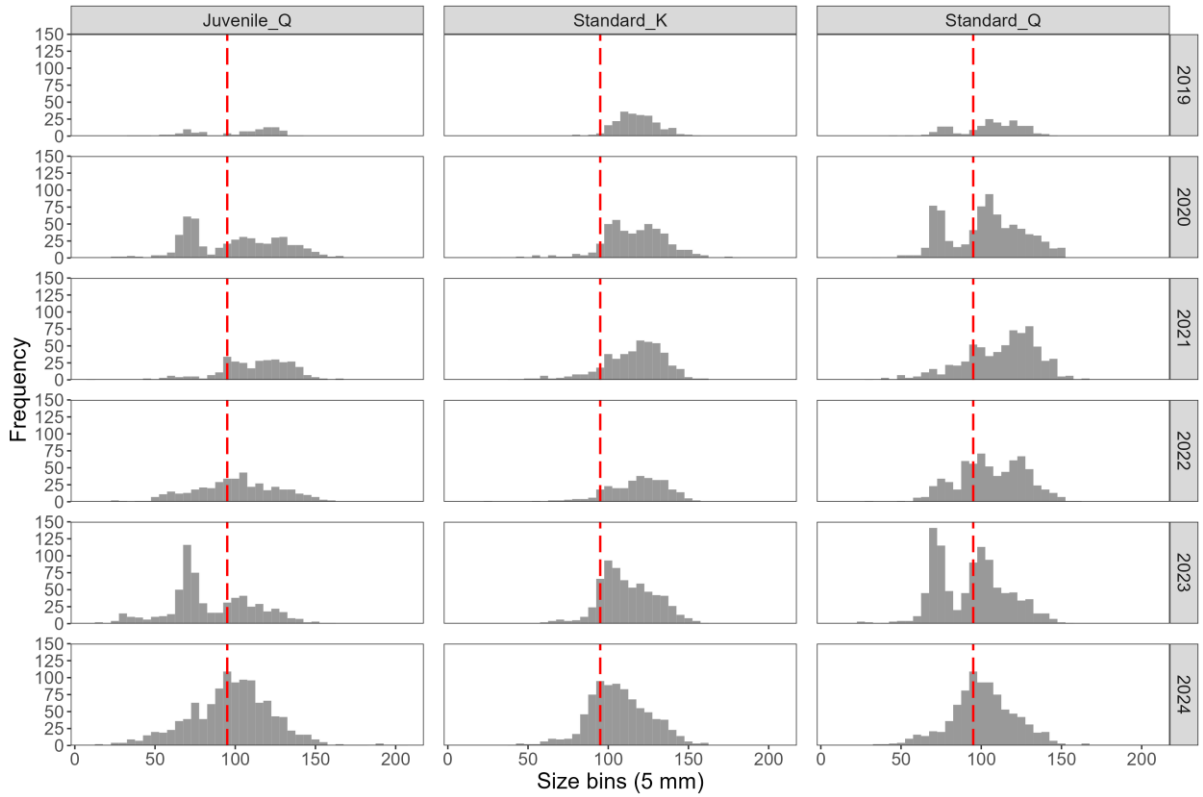

Figure 21: Size frequency of absolute counts of king scallops at Targets displayed by survey year and survey dredge type (red dotted line indicates the estimated recruit cut-off of 95 mm). Targeted survey cells excluded. The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions.

4.3.3.2 Chickens

Spatial plots of the survey data from the four most recent survey years (2021 – 2024) are presented for CHI for both recruits (under 95 mm) in Figure 22 and post-recruits (over 95 mm) in Figure 23. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 recruits (bottom right; Figure 22) there is good recruitment located in the north (up to 8 scallops per 100m^2) and east (up to 6 scallops per 100m^2) of the fishing ground. Densities of post-recruits at CHI in 2024 were higher (up to 8 scallops per 100m^2) than the previous three surveys and were distributed across the majority of the fishing ground (bottom right; Figure 23 & Figure 25).

The data from CHI indicates that for post-recruits (over 95 mm) the survey index was relatively constant from 2019 to 2023 i.e. 0.57 to 0.70 before more than doubling in 2024 (1.80) (Table 4). For recruits (under 95 mm) the survey index has also remained relatively stable from 2019 – 2023 i.e. 3.1 – 0.15 before increasing more than 5x in 2024 to 0.81 (Table 4).

The size frequency histogram for 2024 (Figure 26) also shows that there was a large proportion of pre-recruits (40-60 mm; Figure 24) detected by the survey in the standard and juvenile queen scallop dredges, which with good management, will be due to recruit to the fishing ground in 2-3 years.

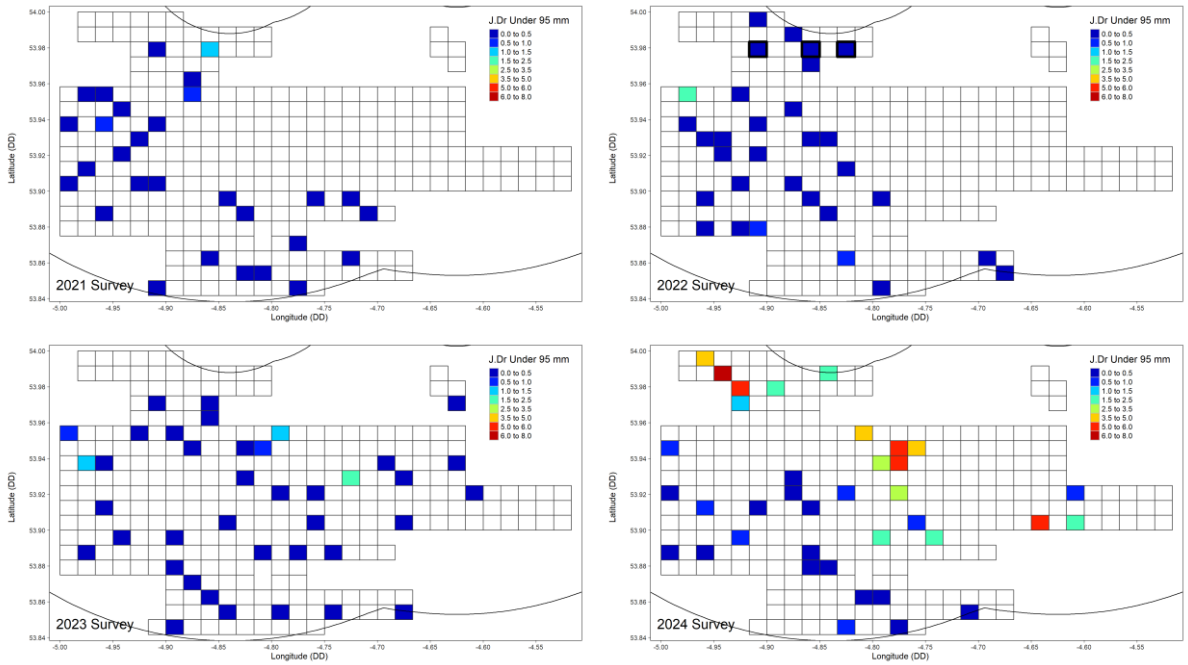

Figure 22: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2021 (top left), 2022 (top right), 2023 (bottom left) and 2024 (bottom right) at Chickens (South coast). Black borders indicate cells that were specifically targeted during the survey.

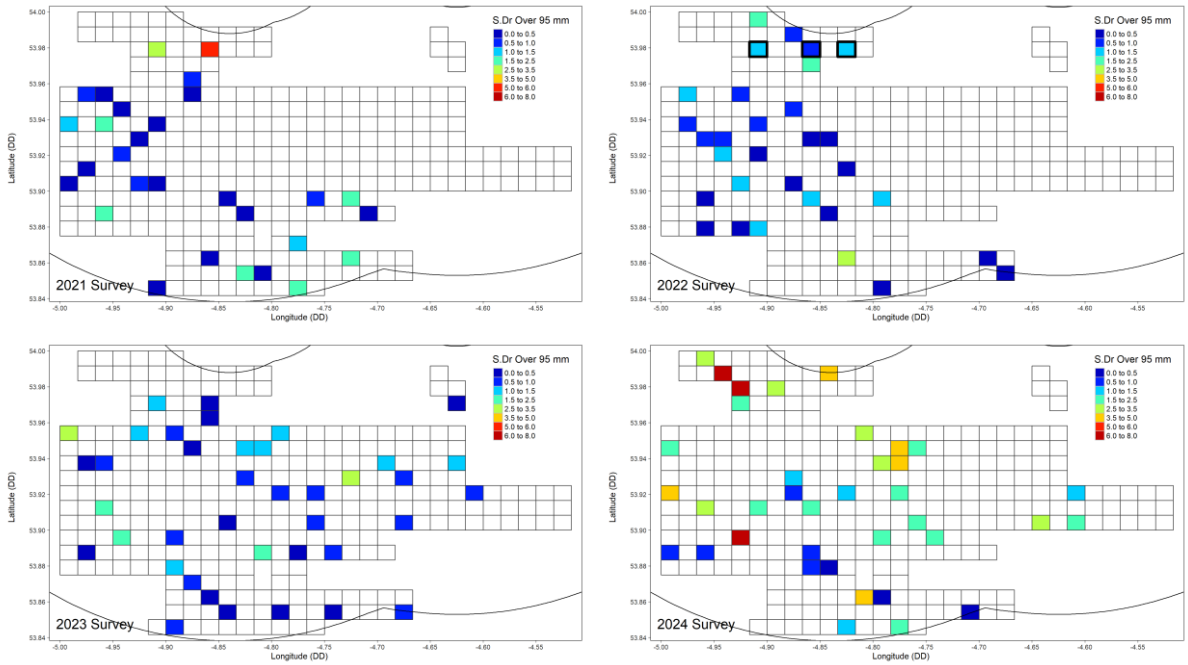

Figure 23: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2021 (top left), 2023 (top right), 2024 (top left) and 2024 (top right) at Chickens (South coast). Black borders indicate cells that were specifically targeted during the survey.

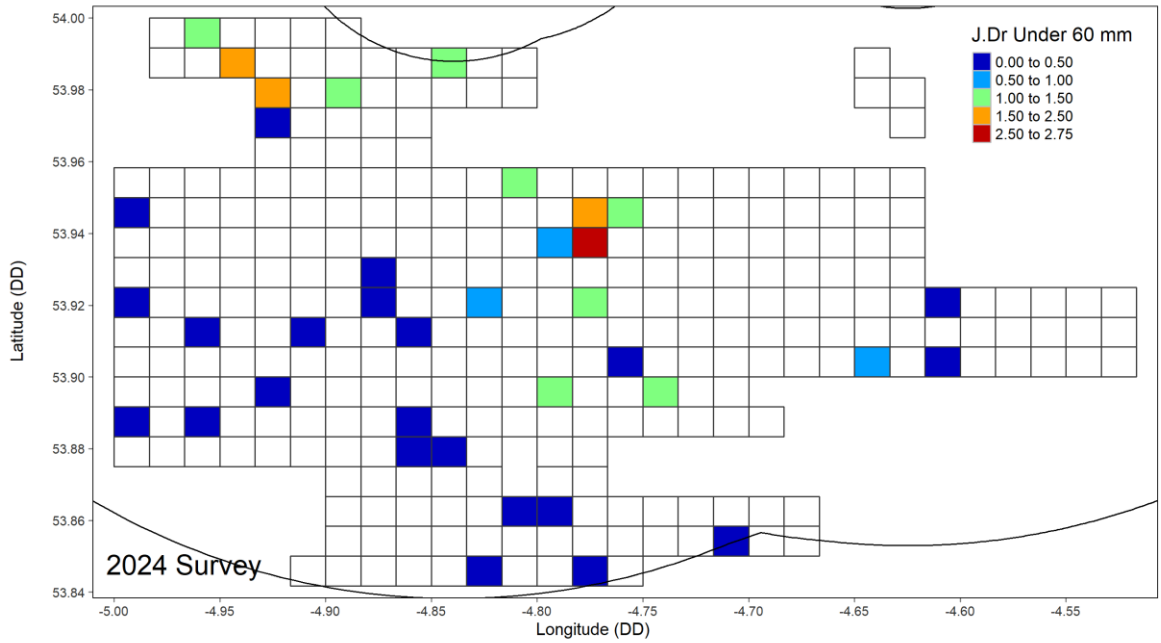

Figure 24: Map illustrating the survey densities (scallops per 100 m^2) for king scallops under 60 mm from juvenile queen and standard queen scallop dredges for 2024 at Chickens (South coast).

Table 4: Survey index (geometric mean) of king scallops per 100 m^2 for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for Chickens; note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's). Targeted survey cells excluded.

Year	< 95 mm	≥ 95 mm
2019	0.12	0.58
2020	0.10	0.57
2021	0.15	0.63
2022	0.13	0.67
2023	0.14	0.70
2024	0.81	1.80

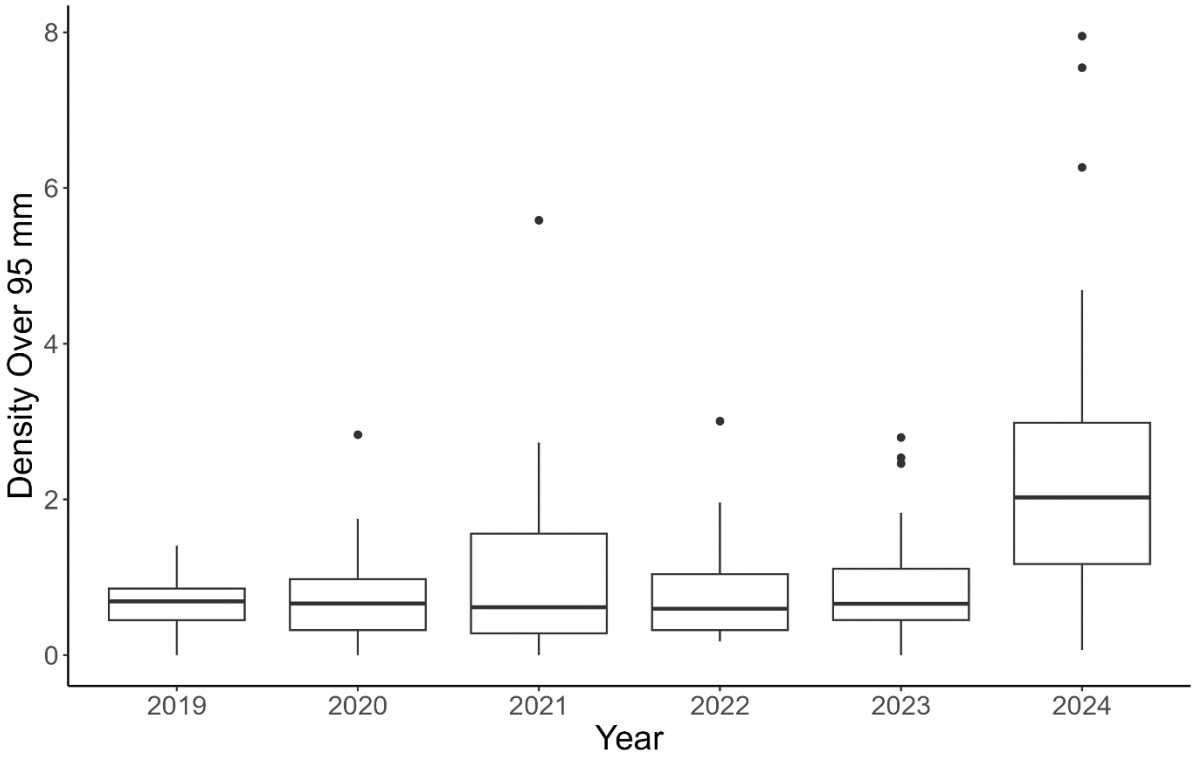

Figure 25: Boxplot showing the density by year of scallops over 95 mm for all sites surveyed at CHI

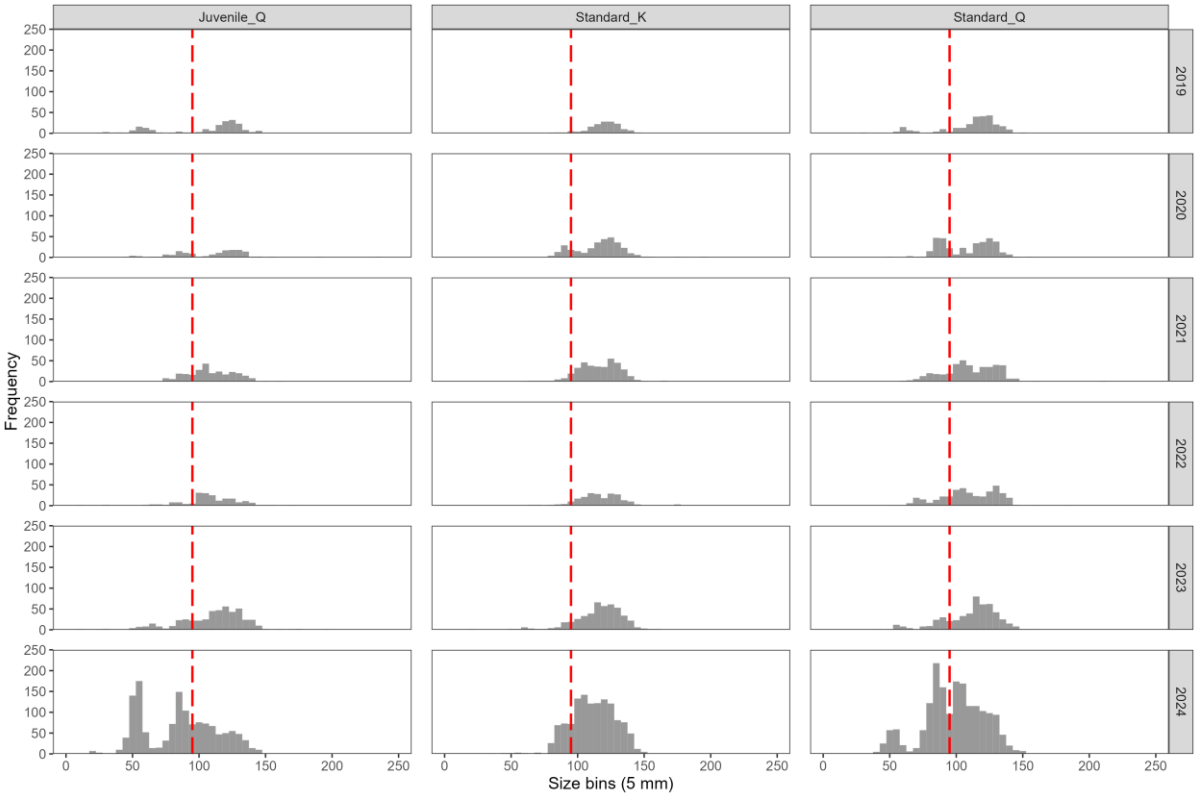

Figure 26: Size frequency of absolute counts of king scallops at Chickens displayed by survey year and survey dredge type (red dotted line indicates the estimated recruit cut-off of 95 mm). Targeted survey cells excluded. The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions.

4.3.3.3 East of Douglas

Spatial plots of the survey data from the four most recent survey years (2021 – 2024) are presented for EDG for both recruits (under 95 mm) in Figure 27 and post-recruits (over 95 mm) in Figure 28. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 recruits (bottom right; Figure 27) there is relatively good recruitment located in central and southern areas of the fishing ground (1-2.5 scallops per 100m^2) [*N.B. The survey extent for this ground was extended southwards in 2024*]. Densities of post-recruits EDG in 2024 were higher (up to 7.5 scallops per 100m^2) than the previous three surveys and were distributed across the central part of the fishing ground (bottom right; Figure 28 & Figure 29).

The data from EDG indicates that for post-recruits (over 95 mm) the survey index ranged from 0.55-0.95 from 2019 to 2023 before increasing to 1.36 in 2024 (Table 5). For recruits (under 95 mm) the survey has fluctuated between 0.15 and 0.36, with a value of 0.26 in 2024 (Table 5).

The size frequency histogram for 2024 (Figure 30) also indicates a proportion of pre-recruits (50-80 mm) detected by the juvenile queen scallop dredges. The survey at EDG has, to date, not detected any large peaks in recruitment, but the 2024 data is on the higher end of recruitment detected for this fishing ground.

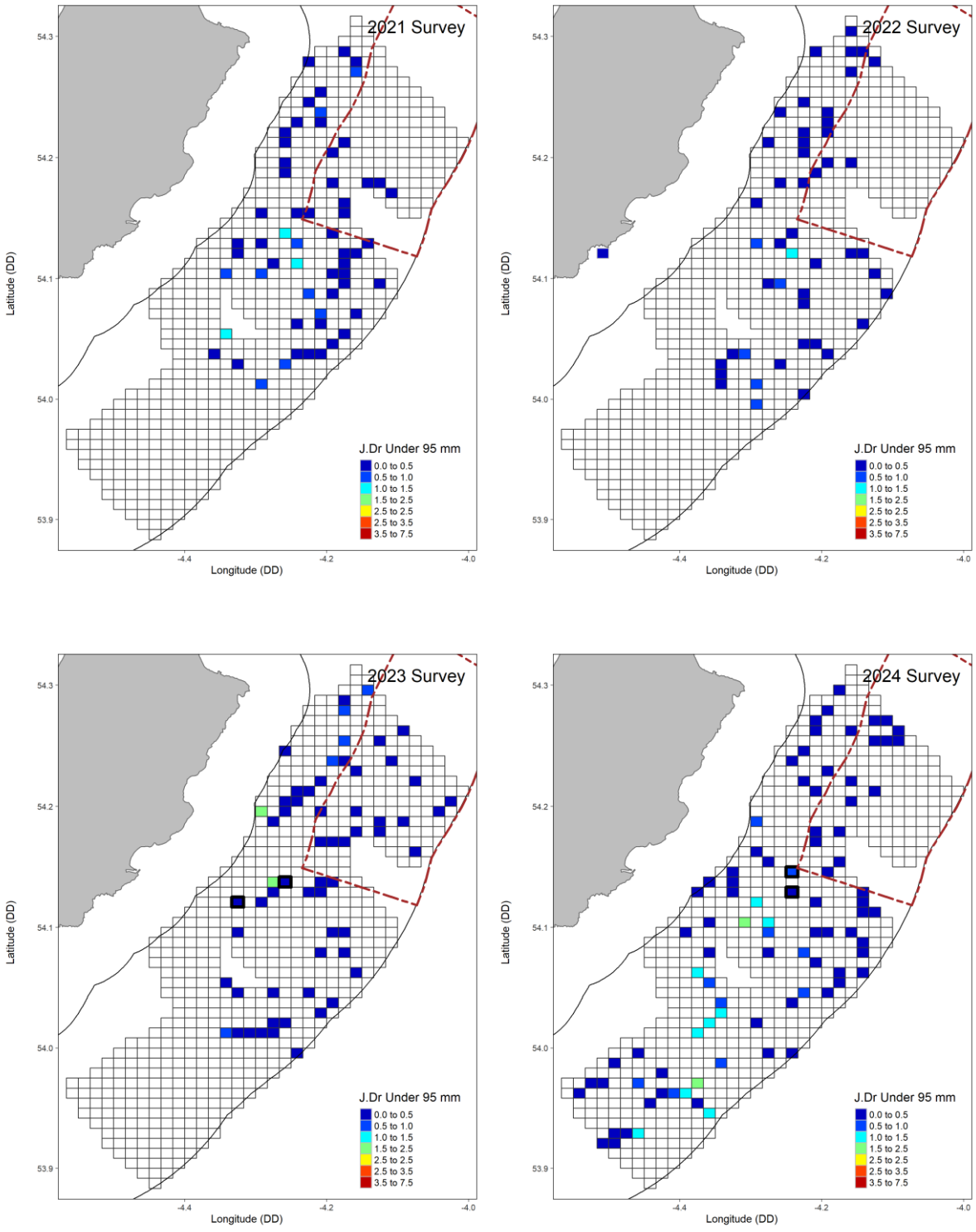

Figure 27: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2021 (top left), 2022 (top right), 2023 (bottom left) and 2024 (bottom right) at East Douglas (East coast). Black borders indicate cells that were specifically targeted during the survey. The brown polygon indicates the Area For Lease for the Ørsted Mooir Vanin wind farm project.

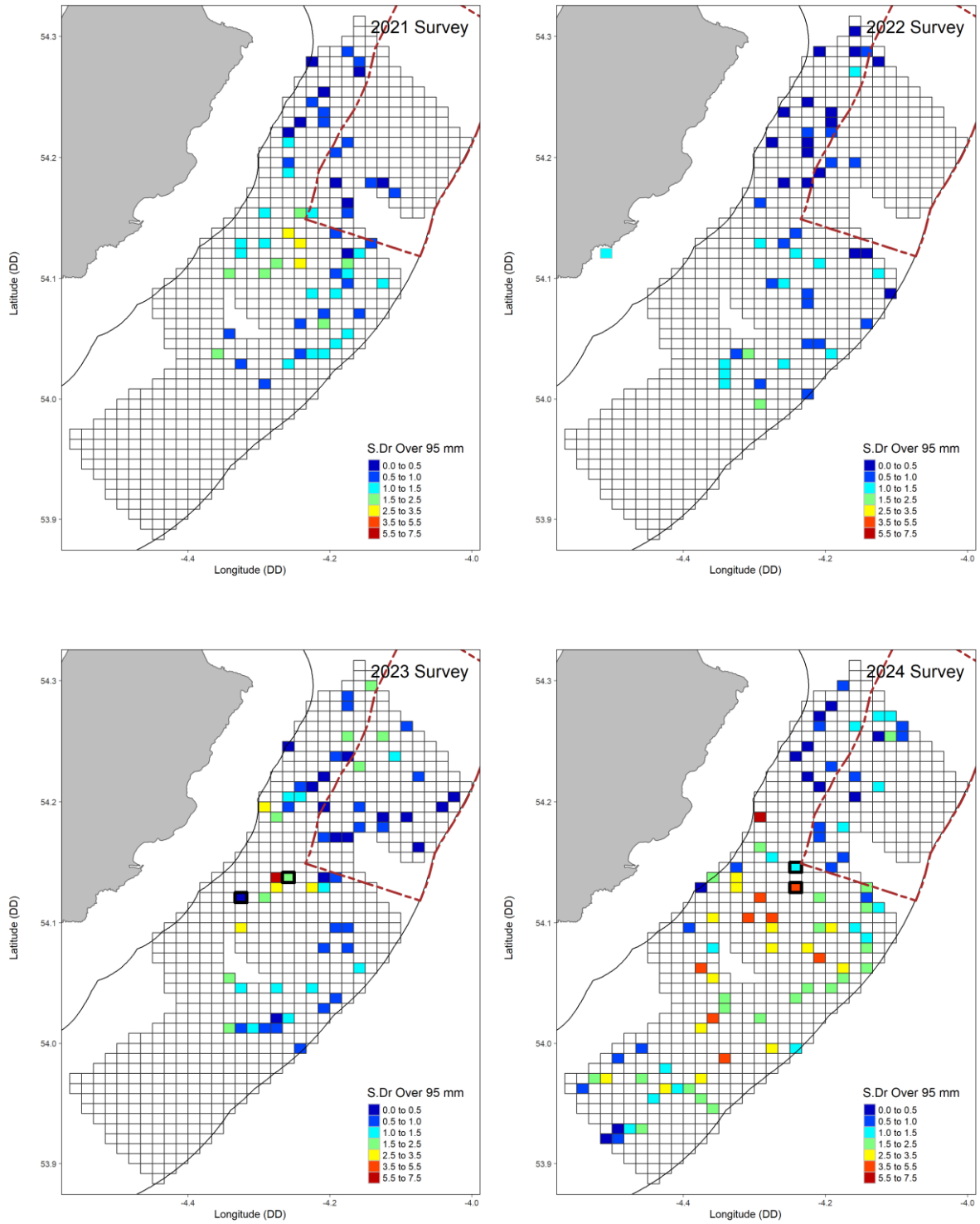

Figure 28: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2021 (top left), 2022 (top right), 2023 (bottom left) and 2024 (bottom right) at East Douglas (East coast). Black borders indicate cells that were specifically targeted during the survey. The brown polygon indicates the Area For Lease for the Ørsted Mooir Vanin wind farm project.

Table 5: Survey index (geometric mean) of king scallops per 100 m² for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for East of Douglas; note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's). Targeted survey cells excluded.

Year	< 95 mm	≥ 95 mm
2019	0.36	0.55
2020	0.19	0.67
2021	0.28	0.95
2022	0.15	0.65
2023	0.18	0.86
2024	0.26	1.36

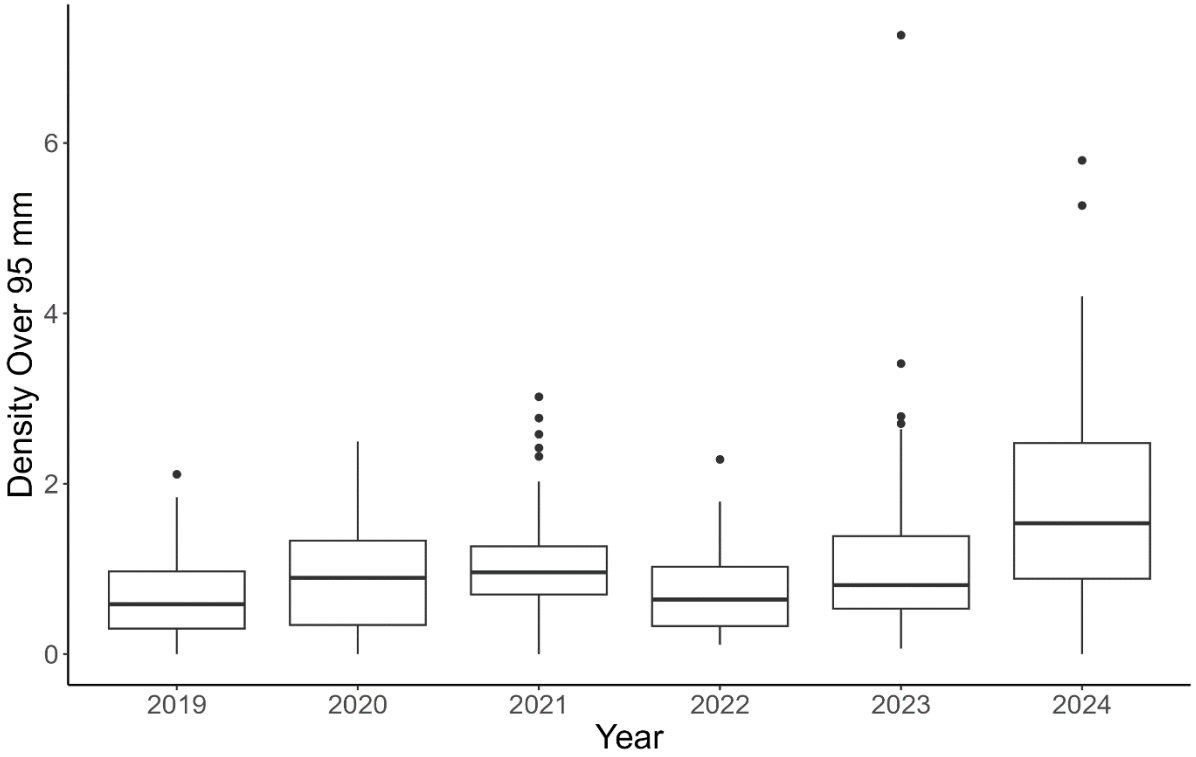

Figure 29: Boxplot showing the density by year of scallops over 95 mm for all sites surveyed at EDG

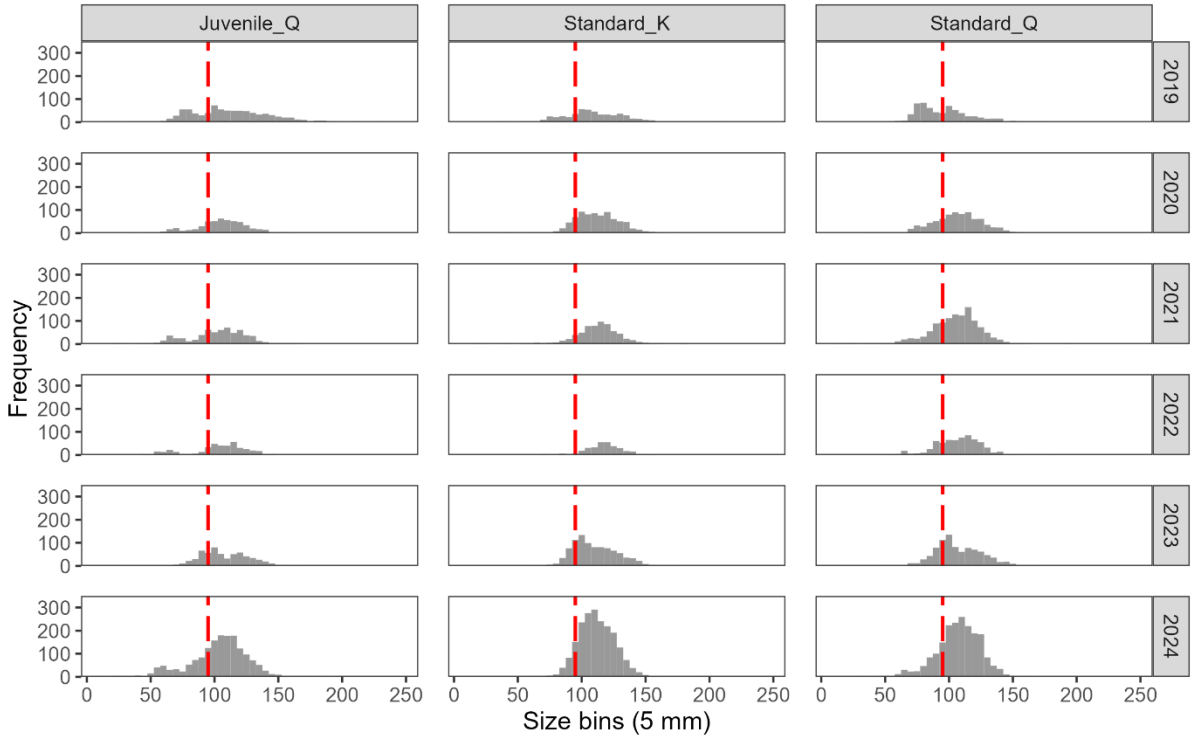

Figure 30: Size frequency of absolute counts of king scallops at East of Douglas displayed by survey year and survey dredge type (red dotted line indicates the estimated recruit cut-off of 95 mm). Targeted survey cells excluded. The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions.

4.3.3.4 Point of Ayre

Spatial plots of the survey data from the three years that this fishing ground has been surveyed (2022-2024) are presented for POA for both recruits (under 95 mm) in Figure 31 and post-recruits (over 95 mm) in Figure 32. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 recruits (bottom; Figure 31), as in all previous survey years, there was very low recruitment detected at this POA (≤ 0.5 scallops per 100m^2). Densities of post-recruits detected at POA in 2024 were also low (up to 2.5 scallops per 100m^2) (bottom; Figure 32).

The data from POA indicates that for post-recruits (over 95 mm) the survey index has been variable ranging from 0.27 to 0.67, with the value for 2024 (0.27) the lowest of the time series (Table 6). For recruits (under 95 mm) the survey index has also been variable ranging from 0.07 to 0.16, with the value for 2024 (0.07) also the lowest of the time series (Table 6).

The size frequency histogram for 2024 (Figure 30) also indicates limited pre-recruits or recruits (40-95 mm) detected in the survey.

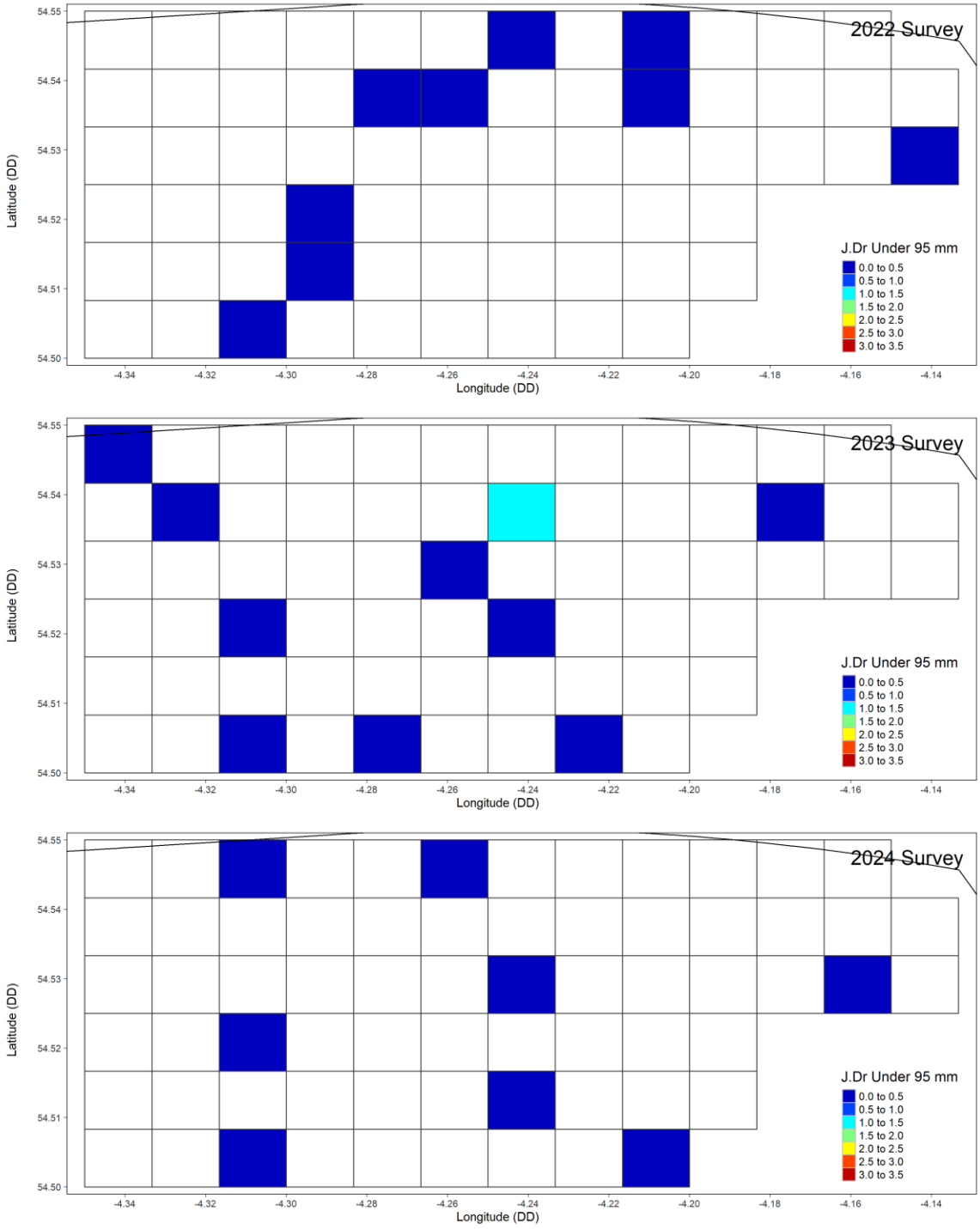

Figure 31: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2022 (top), 2023 (middle) and 2024 (bottom).

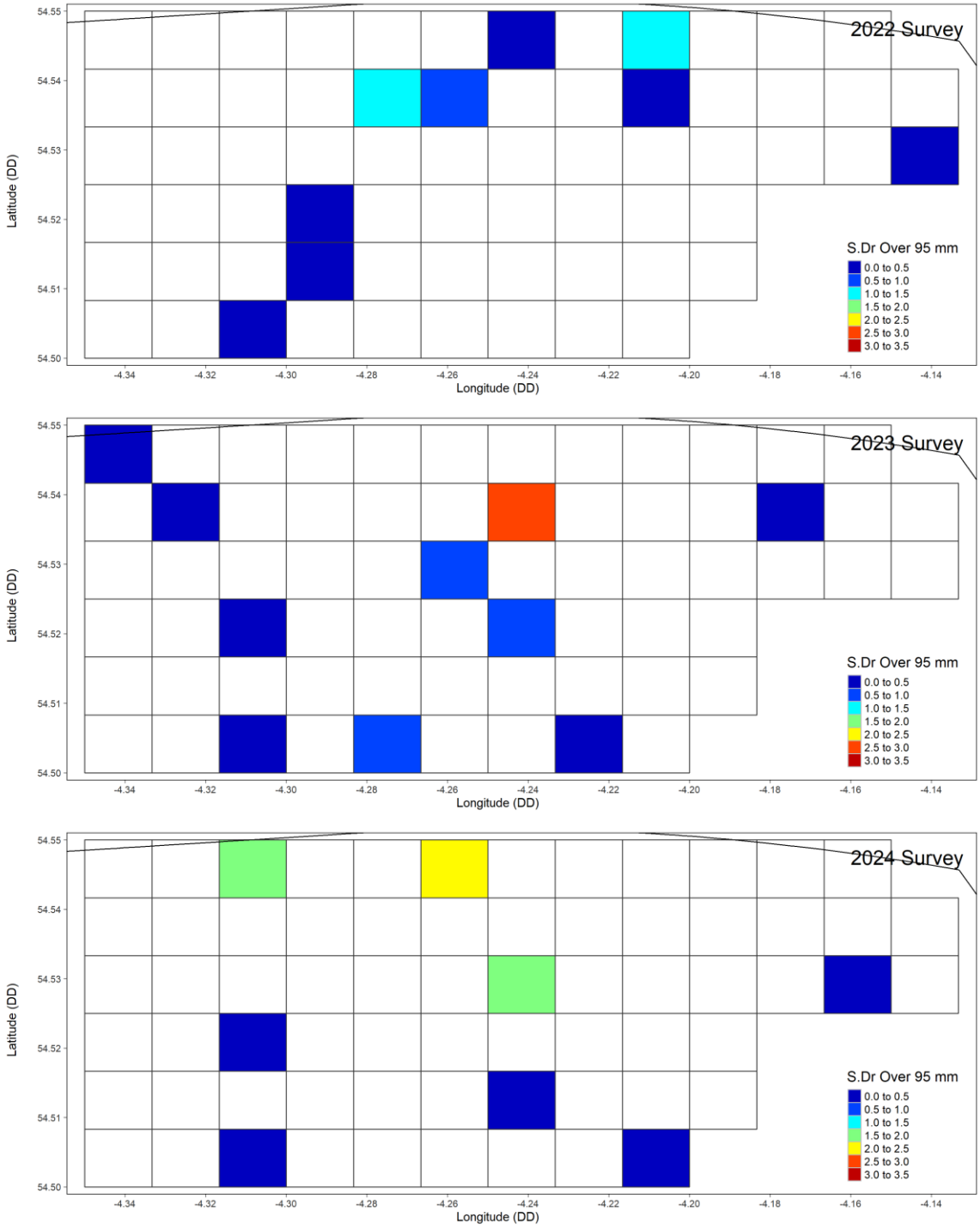

Figure 32: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2022 (top), 2023 (middle) and 2024 (bottom).

Table 6: Survey index (geometric mean) of king scallops per 100 m² for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for Point of Ayre; note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's). Targeted survey cells excluded.

Year	< 95 mm	≥ 95 mm
2019		
2020	0.14	0.67
2021		
2022	0.12	0.28
2023	0.16	0.41
2024	0.07	0.27

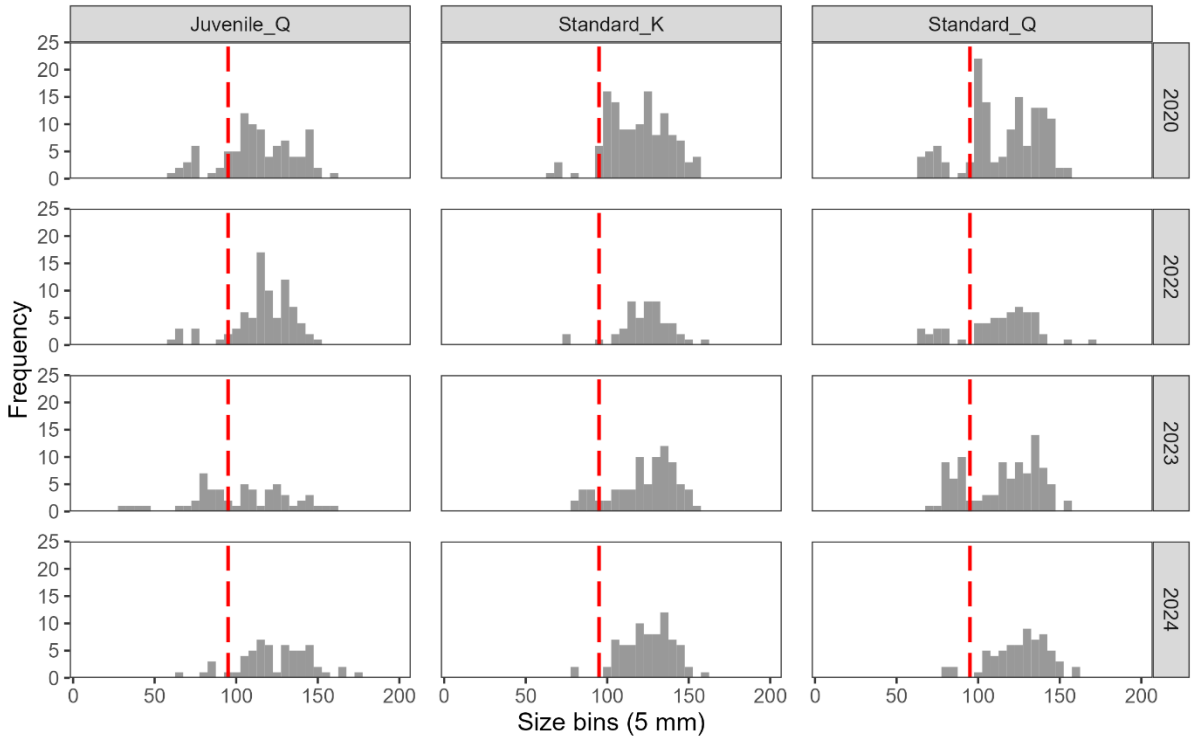

Figure 33: Size frequency of absolute counts of king scallops at Point of Ayre displayed by survey year and survey dredge type (red dotted line indicates the estimated recruit cut-off of 95 mm). Targeted survey cells excluded. The absolute count is calculated by using a scalar (i.e. the ratio of total observed to subsampled counts) to scale the size frequency distributions.

4.3.4 Fishing Grounds (0- 3 nm)

4.3.4.1 East Coast

Spatial plots of the survey data from the four most recent survey years (2021 – 2024) are presented for ECO for both recruits (under 95 mm) in Figure 34 and post-recruits (over 95 mm) in Figure 35. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 recruits (bottom right; Figure 34) densities were lower than in previous years and mainly located in northern areas of the fishing ground (up to 0.75 scallops per 100m^2) Densities of post-recruits at ECO in 2024 were at the higher end for this ground (up to 3.0 scallops per 100m^2) but again were restricted to the northern part of the fishing ground (bottom right; Figure 35).

The data from ECO, which has no comparative survey data from 2019, indicates that for post-recruits (over 95 mm) the survey index declined (from 1.52 in 2023 to 0.45 in 2024; Table 7). For recruits (under 95 mm) the survey index also declined (from 0.38 in 2023 to 0.12 in 2024; Table 7) (*N.B. Survey effort was lower for this ground in 2022*).

The size frequency histogram for ECO in 2024 (Figure 36) also indicated that limited recruitment was detected in the survey.

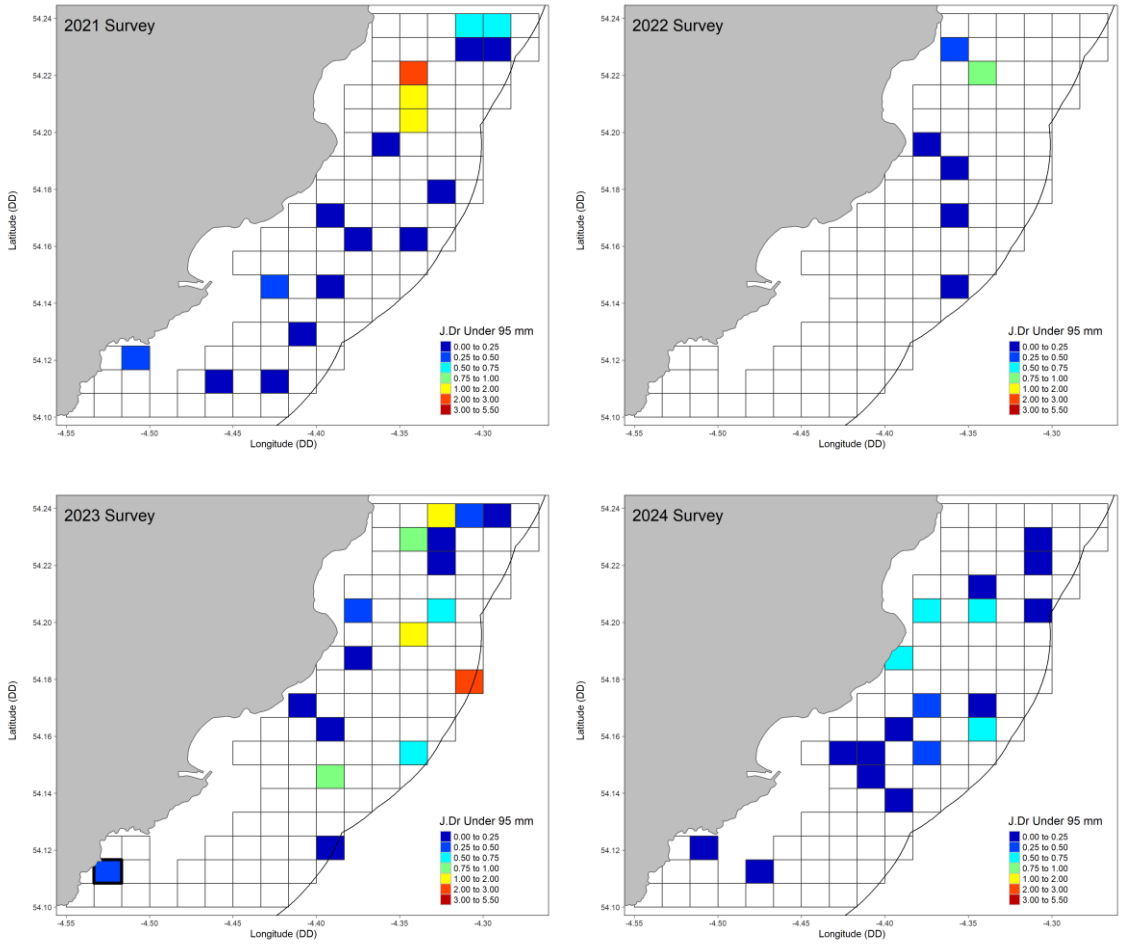

Figure 34: Map illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2021, 2022, 2023 and 2024 at East Coast 0 – 3 nm (East coast).

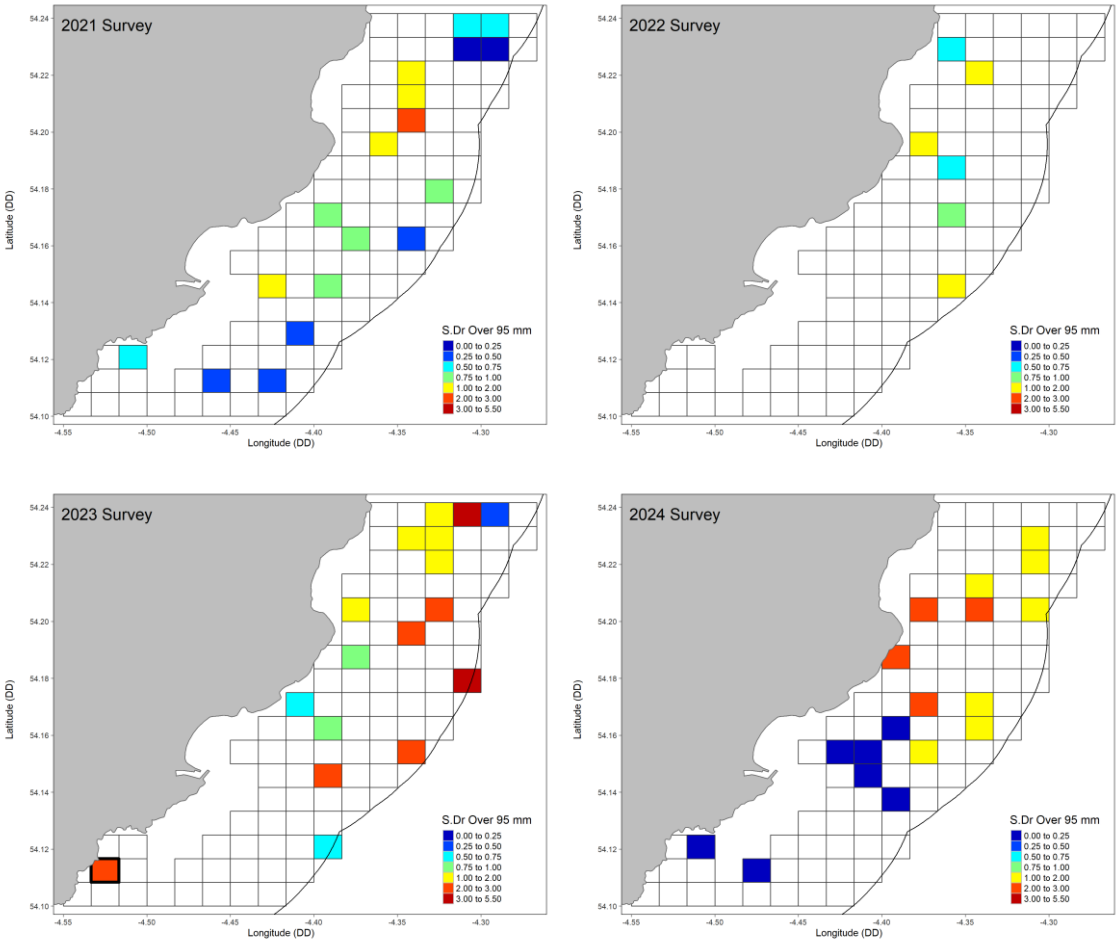

Figure 35: Map illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2021, 2022, 2023 and 2024 at East Coast 0 – 3 nm (East coast).

Table 7: Survey index (geometric mean) of king scallops per 100 m² for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for East Coast 0 – 3 nm; note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's).

Year	< 95 mm	≥ 95 mm
2019		
2020	0.15	0.55
2021	0.24	0.61
2022	0.22	1.12
2023	0.38	1.52
2024	0.12	0.45

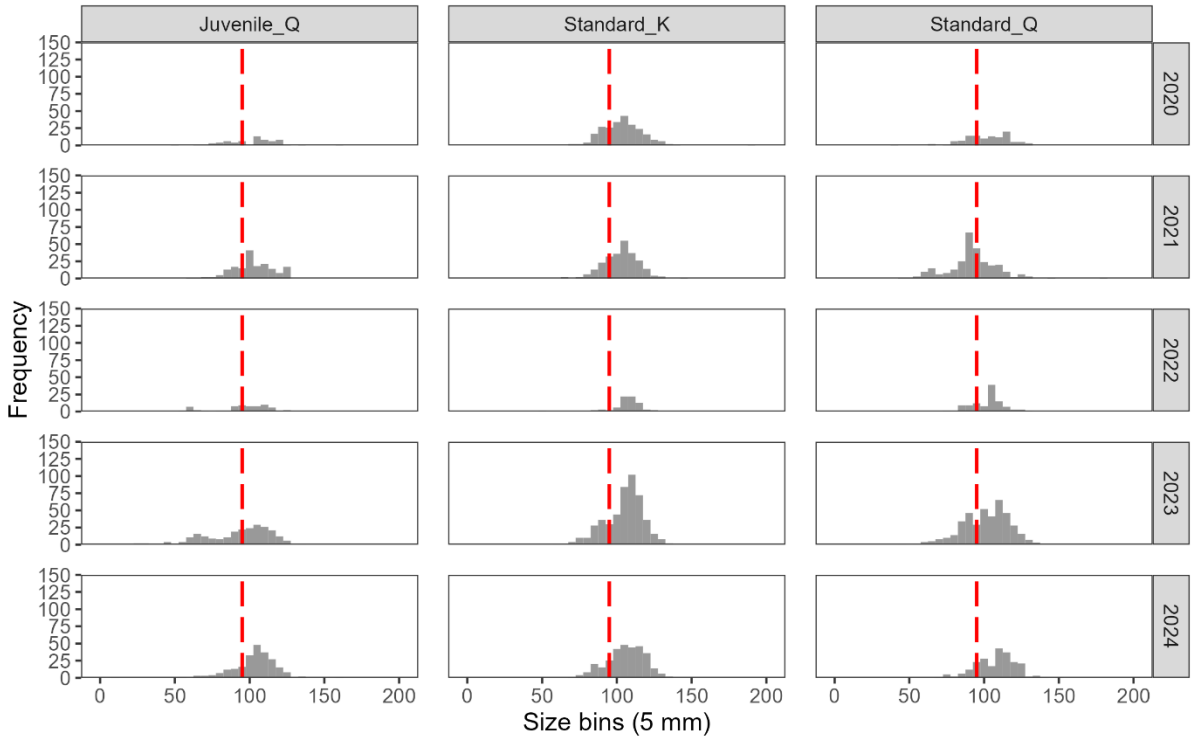

Figure 36: Size frequency of absolute counts of king scallops by dredge type for East Coast 0 – 3 nm. The red dashed line indicates the estimated recruit cut-off of 95 mm.

4.3.4.2 Bradda (inshore and offshore)

Spatial plots of the survey data from the four most recent survey years (2021 – 2024) are presented for BRA for both recruits (under 95 mm) in Figure 38 and post-recruits (over 95 mm) in Figure 39. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 at BRA recruit densities (bottom right; Figure 38) were higher than in previous years and mainly located in the previous season's closed area or to the south of the fishing ground (up to 10.5 scallops per 100m^2) Densities of post-recruits at BRA in 2024 were also at the higher end for this ground (up to 8.5 scallops per 100m^2) the previous season's closed area or to the south of the fishing ground (bottom right; Figure 39).

The data from BRA, which has no comparative survey data from 2019, indicates that for post-recruits (over 95 mm) the survey index was the highest recorded in the five-year time series in 2024 at 1.43 (Table 8). For recruits (under 95 mm) after year on year declines since the start of the survey period the survey index was also the highest recorded in the five-year time series in 2024 at 0.47 (Table 8).

The size frequency histogram for BRA in 2024 (Figure 36) also indicated good recruitment in the 40-60 mm (pre-recruit; Figure 37) and 70-95 mm (recruit) ranges such that with good management these scallops should recruit well in within the next 1-3 years.

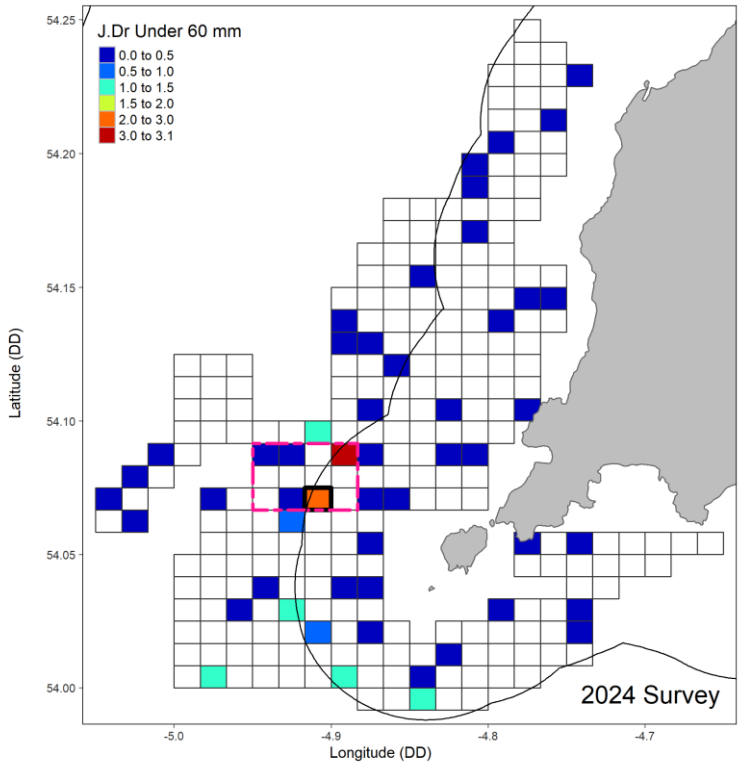

Figure 37: Map illustrating the survey densities (scallops per 100 m2) for king scallops under 60 mm from juvenile queen and standard queen scallop dredges for 2024 at Bradda (inshore and offshore) (South-west coast).

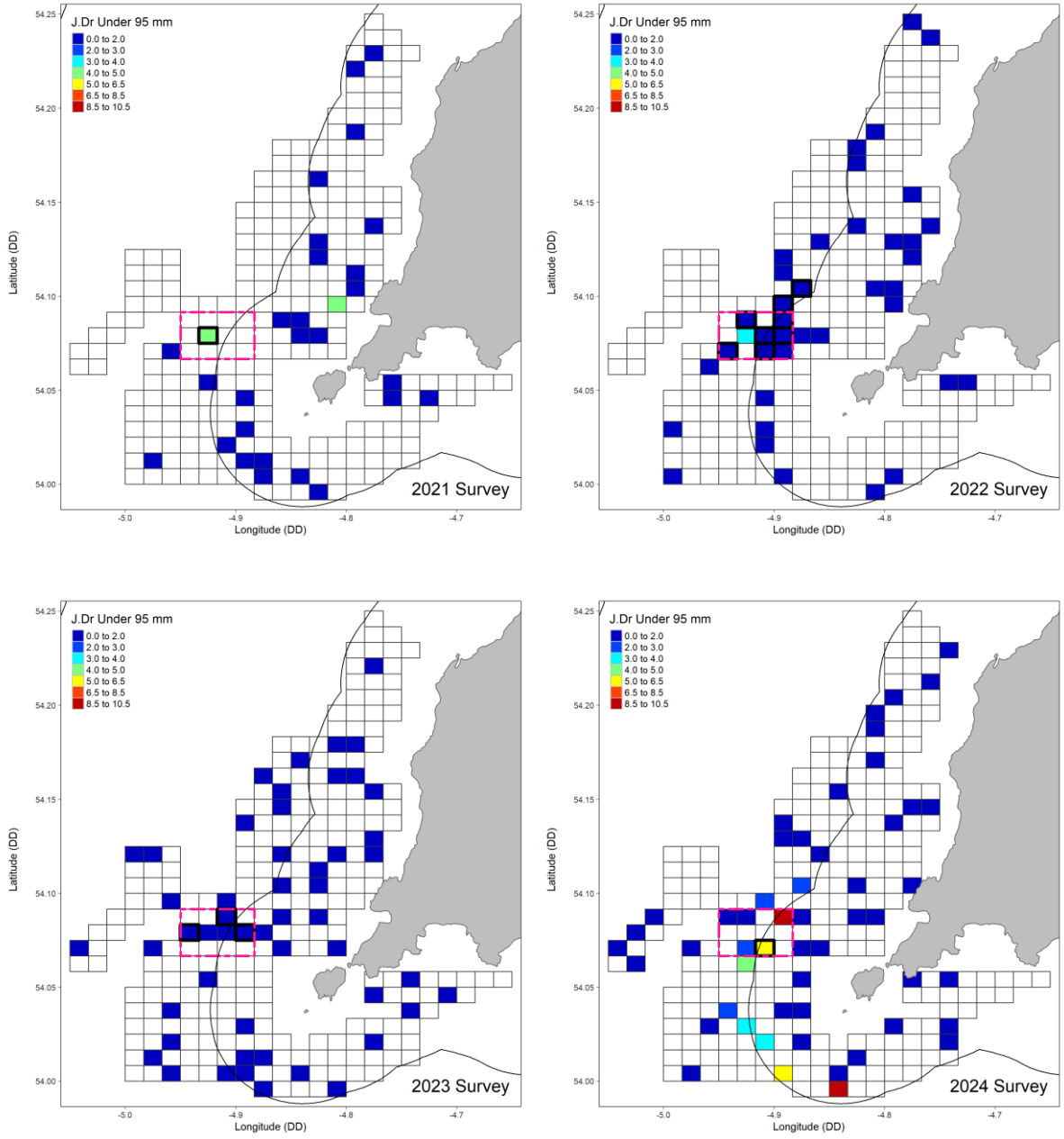

Figure 38: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2021, 2022, 2023 and 2024 at Bradda (inshore and offshore) (South-west coast).

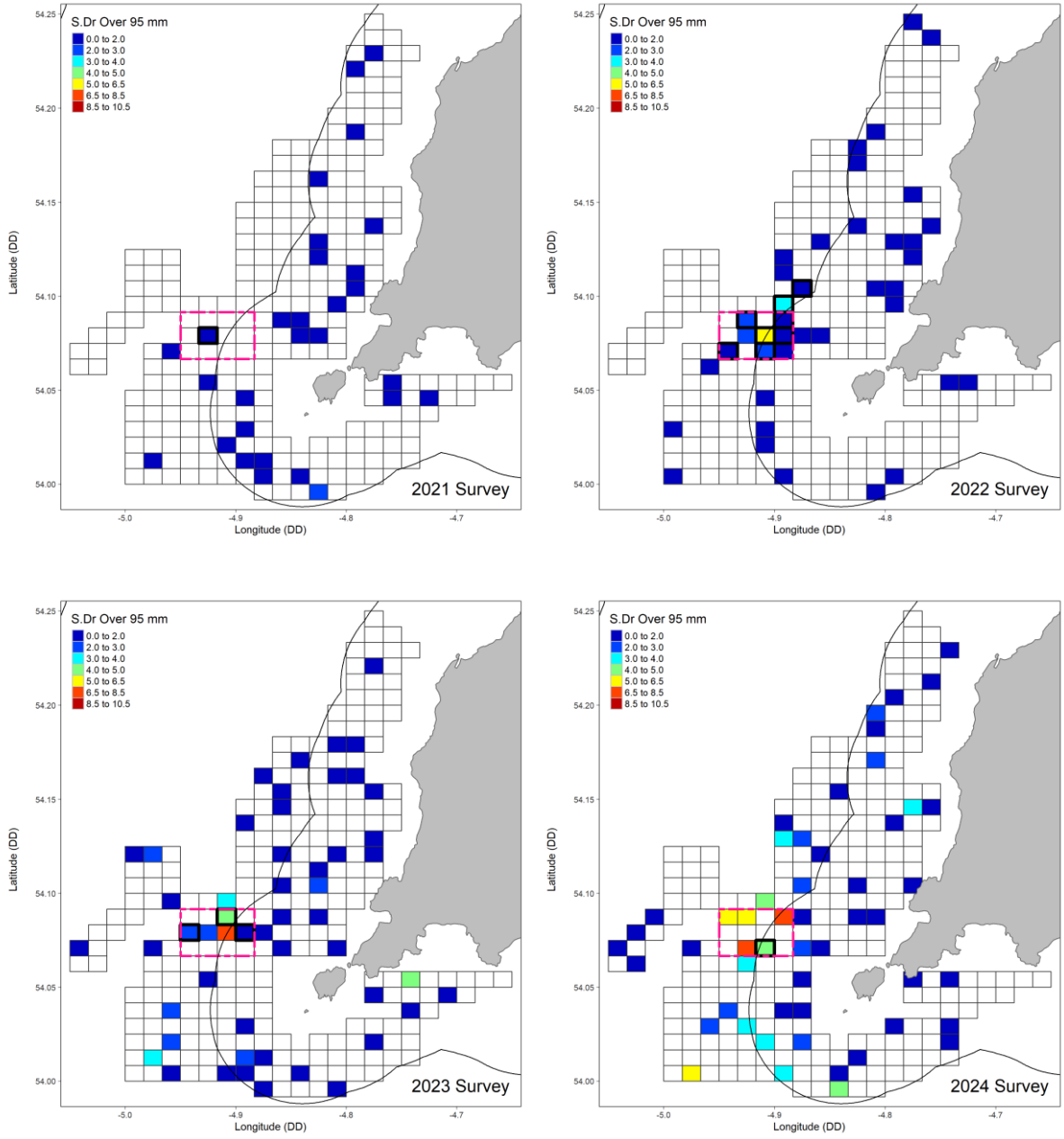

Figure 39: Map illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2021, 2022, 2023 and 2024 at Bradda (inshore and offshore) (South-west coast).

Table 8: Survey index (geometric mean) of king scallops per 100 m² for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for Bradda (0 – 3 nm and offshore); note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's).

Year	< 95 mm	≥ 95 mm
2019		
2020	0.26	1.01
2021	0.20	0.62
2022	0.18	0.94
2023	0.16	1.07
2024	0.47	1.43

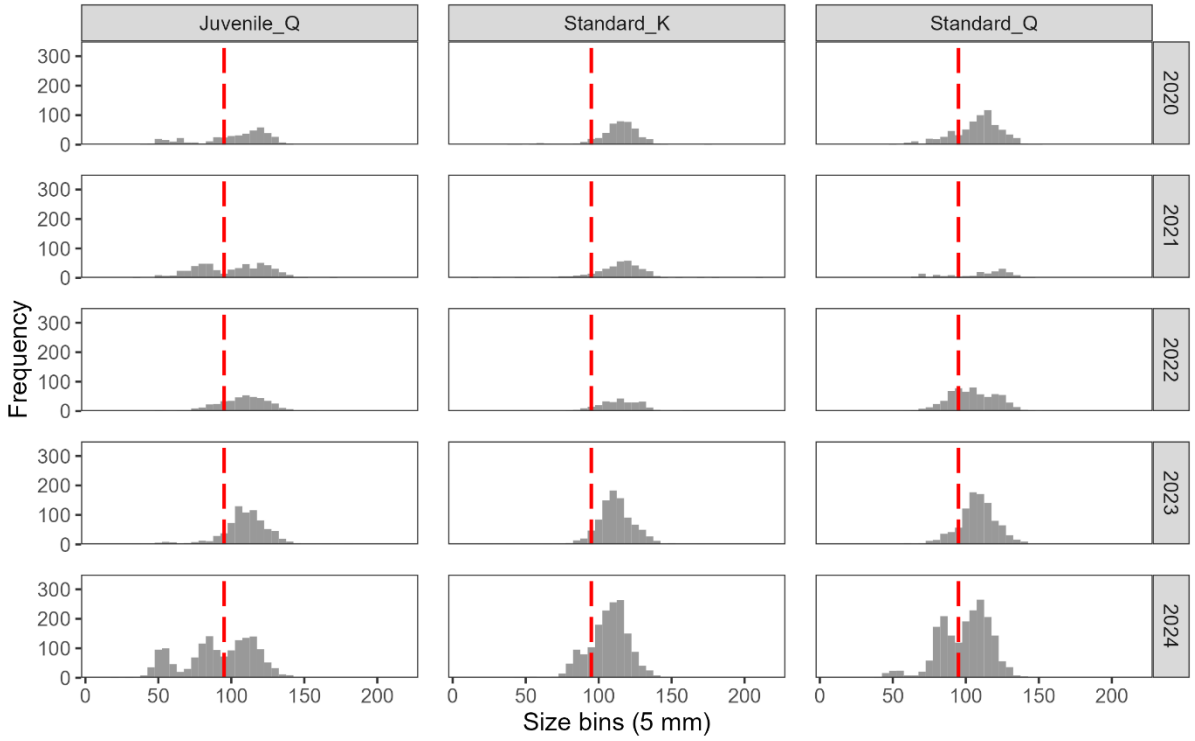

Figure 40: Size frequency of absolute counts of king scallops by dredge type for Bradda (inshore and offshore). The red dashed line indicates the estimated recruit cut-off of 95 mm.

4.3.4.3 Maughold 0-3nm

Spatial plots of the survey data from the four most recent survey years (2020, 2022 – 2024) are presented for MGH for both recruits (under 95 mm) in Figure 41 and post-recruits (over 95 mm) in Figure 42. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 at MGH recruit densities (bottom right; Figure 41) were lower than in the year prior (up to 0.5 scallops per 100m^2). Densities of post-recruits at MGH in 2024 were at the higher end with densities ranging from 0.5 – 2.0 scallops per 100m^2 for this fishing ground (bottom right; Figure 42).

The data from MGH, which has no comparative survey data for 2019 or 2021, indicates that for post-recruits (over 95 mm) the survey index in 2024 was the highest in the four-year time series. For recruits (under 95 mm) the survey index has declined from 0.31 in 2023 to 0.25 in 2024 (Table 9).

The size frequency histogram for MGH in 2024 (Figure 43) indicates some recruitment in the 70-95 mm (recruit) range.

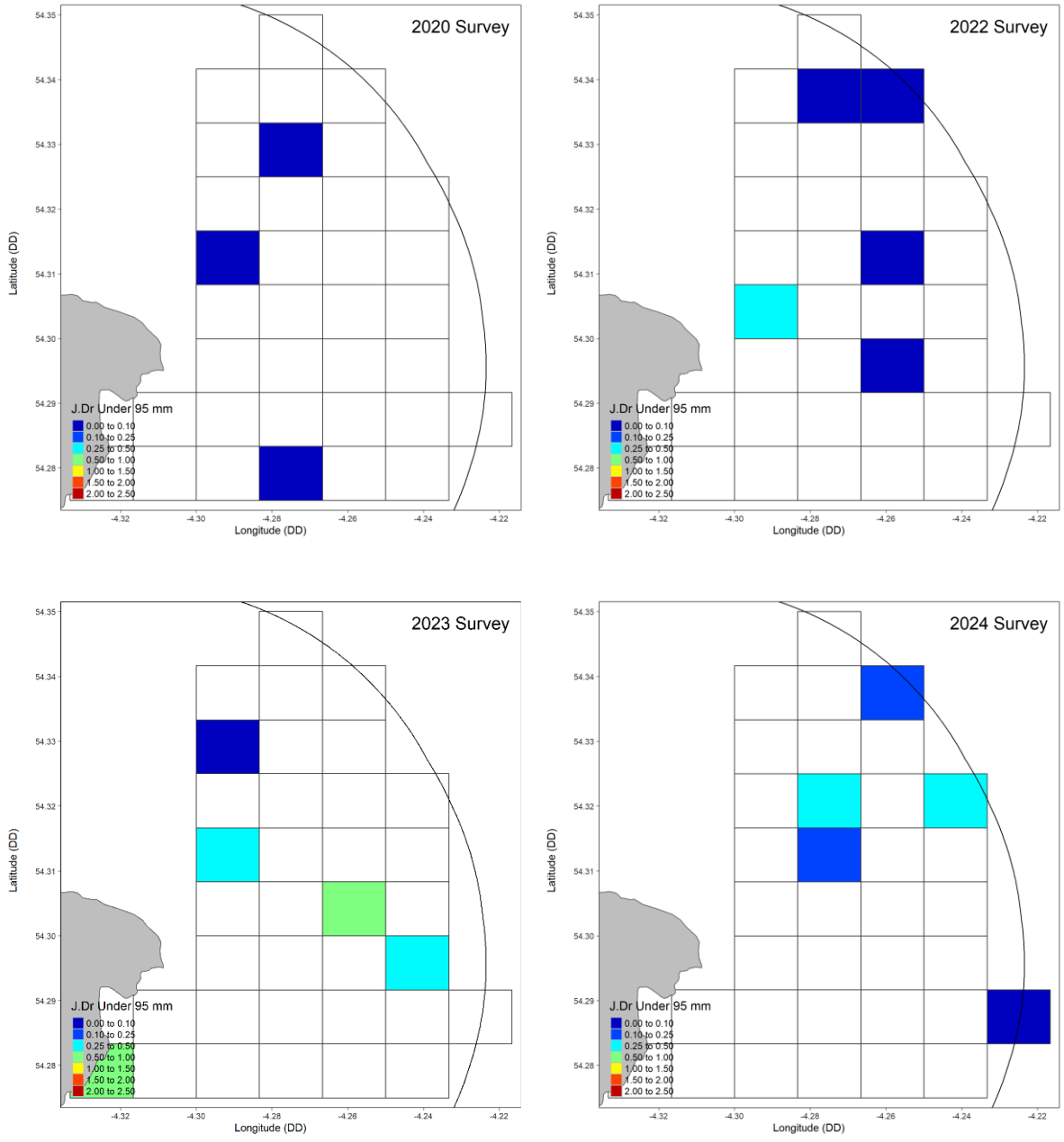

Figure 41: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2020, 2022, 2023 and 2024 (no data for 2021) at Maughold (0 – 3 nm; north-east coast).

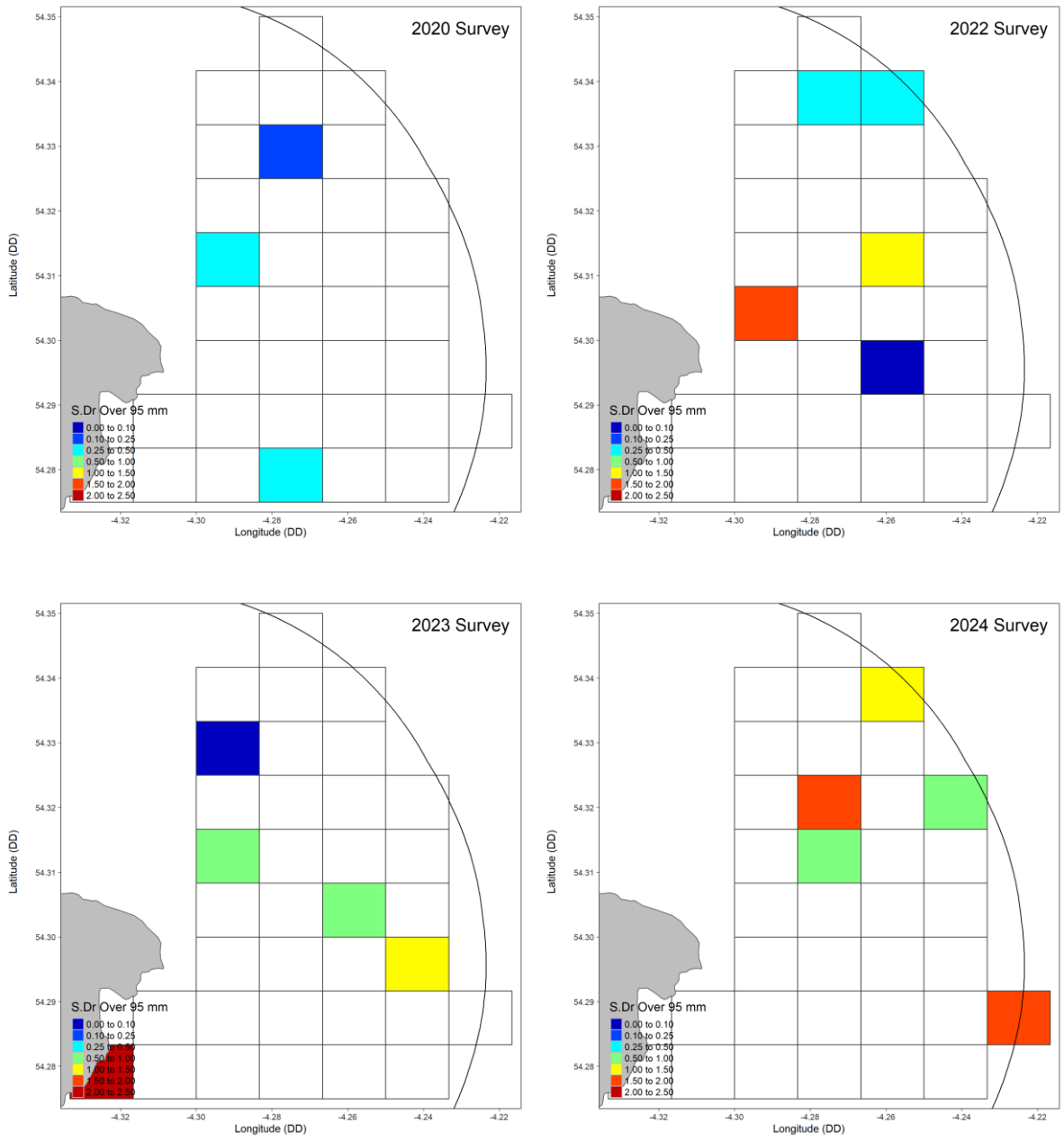

Figure 42: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm from standard queen and standard king scallop dredges for 2020, 2022, 2023 and 2024 (no data for 2021) at Maughold (0 – 3 nm; north-east coast).

Table 9: Survey index (geometric mean) of king scallops per 100 m^2 for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for Maughold (0 – 3 nm); note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's).

Year	< 95 mm	≥ 95 mm
2019		
2020	0.08	0.34
2021		
2022	0.13	0.45
2023	0.31	0.76
2024	0.25	1.28

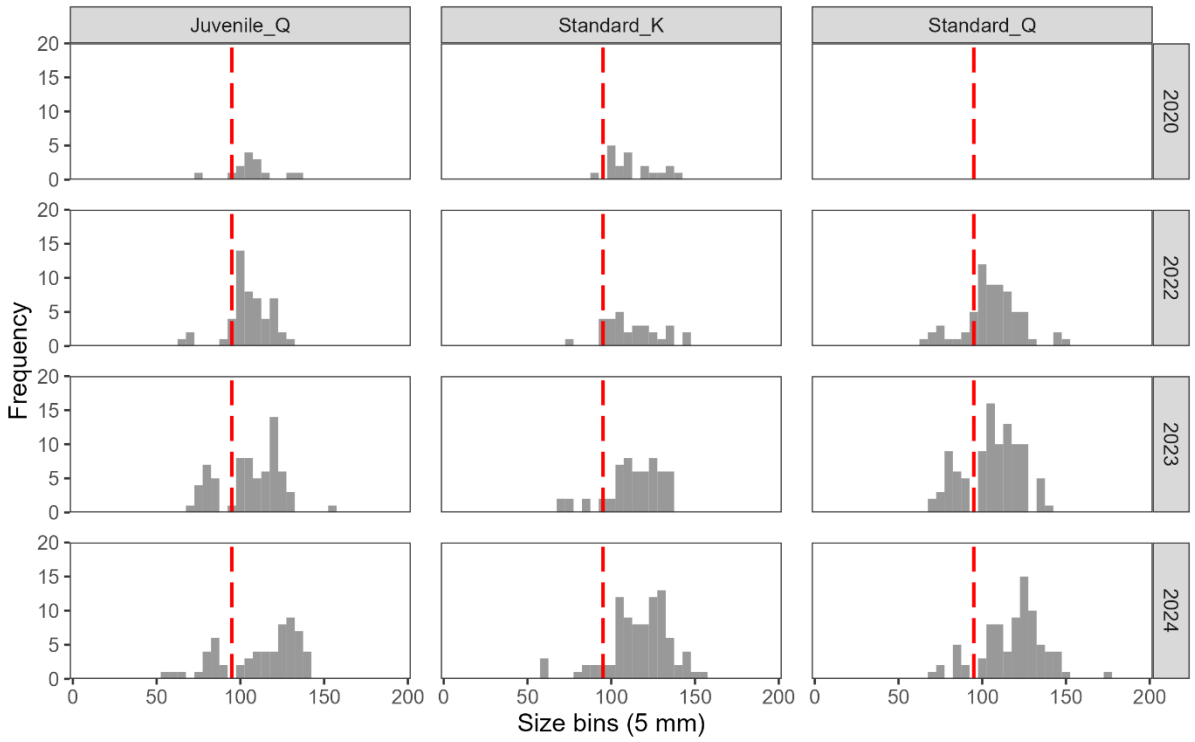

Figure 43: Size frequency of absolute counts of king scallops by dredge type for Maughold (0 – 3 nm). The red dashed line indicates the estimated recruit cut-off of 95 mm.

4.3.4.4 East of Douglas Experimental Research Area 0-3nm

Spatial plots of the survey data from the three most recent survey years (2022 – 2024) are presented for EDGERA for both recruits (under 95 mm) in Figure 44 and post-recruits (over 95 mm) in Figure 45. This enables recent spatial and temporal patterns in density to be visualised for this ground. For 2024 at EDGERA recruit densities (bottom left; Figure 44) were lower than in previous years (≤ 0.5 scallops per 100m^2). Densities of post-recruits at EDGERA in 2024 were at the higher end with densities up to 7.5 scallops per 100m^2 recorded for this fishing ground (bottom left; Figure 45).

The data from EDGERA, which has no comparative survey data for 2019 to 2021, indicates that for post-recruits (over 95 mm) the survey index in 2024 (1.21) was the highest in the three-year time series. However, for recruits the survey index for 2024 (0.09) was the lowest in the three-year time series (Table 10).

The size frequency histogram for EDGERA in 2024 (Figure 43) indicated limited recruitment.

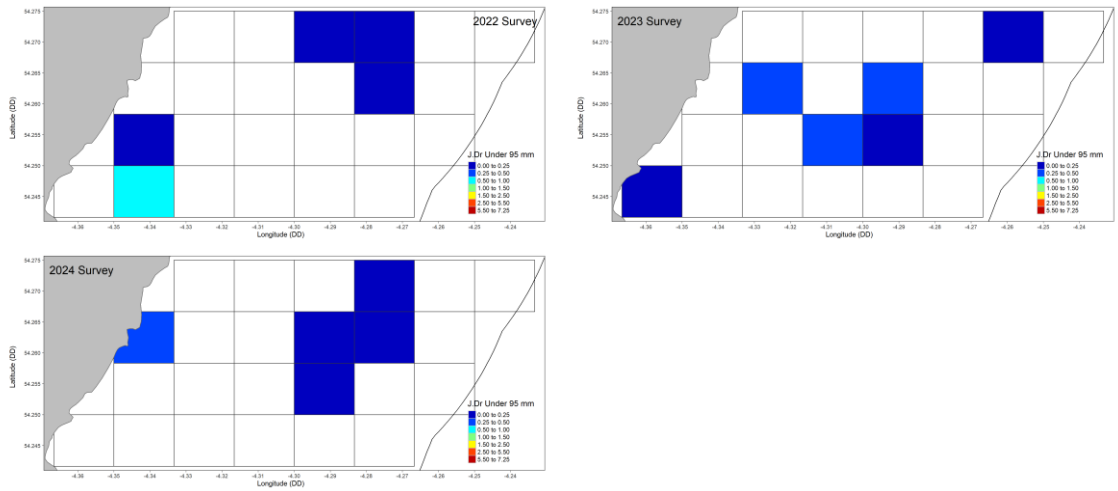

Figure 44: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops under 95 mm from juvenile queen and standard queen scallop dredges for 2022 (top left), 2023 (top right) and 2024 (bottom left) in East of Douglas Experimental Research area (EDGERA) (0 – 3 nm and north-east coast).

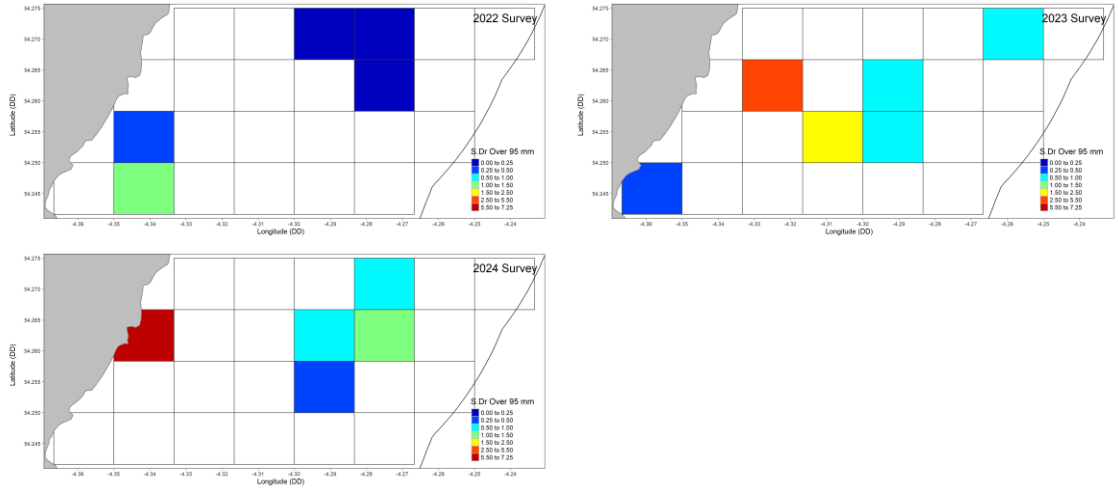

Figure 45: Maps illustrating the survey densities (scallops per 100 m^2) for king scallops over 95 mm (bottom row) from standard queen and standard king scallop dredges for 2022 (top left), 2023 (top right) and 2024 (bottom left) in East of Douglas Experimental Research area (EDGERA) (0 – 3 nm and north-east coast).

Table 10: Survey index (geometric mean) of king scallops per 100 m^2 for all scallops and also split by over (from standard king and standard queen scallop dredges) and under (from juvenile queen and standard queen scallop dredges) 95 mm for East of Douglas Experimental Research Area (0 – 3 nm); note that a constant of 0.05 was added prior to calculation of the geometric mean (to eliminate 0's).

Year	< 95 mm	≥ 95 mm
2019		
2020		
2021		
2022	0.10	0.15
2023	0.23	0.93
2024	0.09	1.21

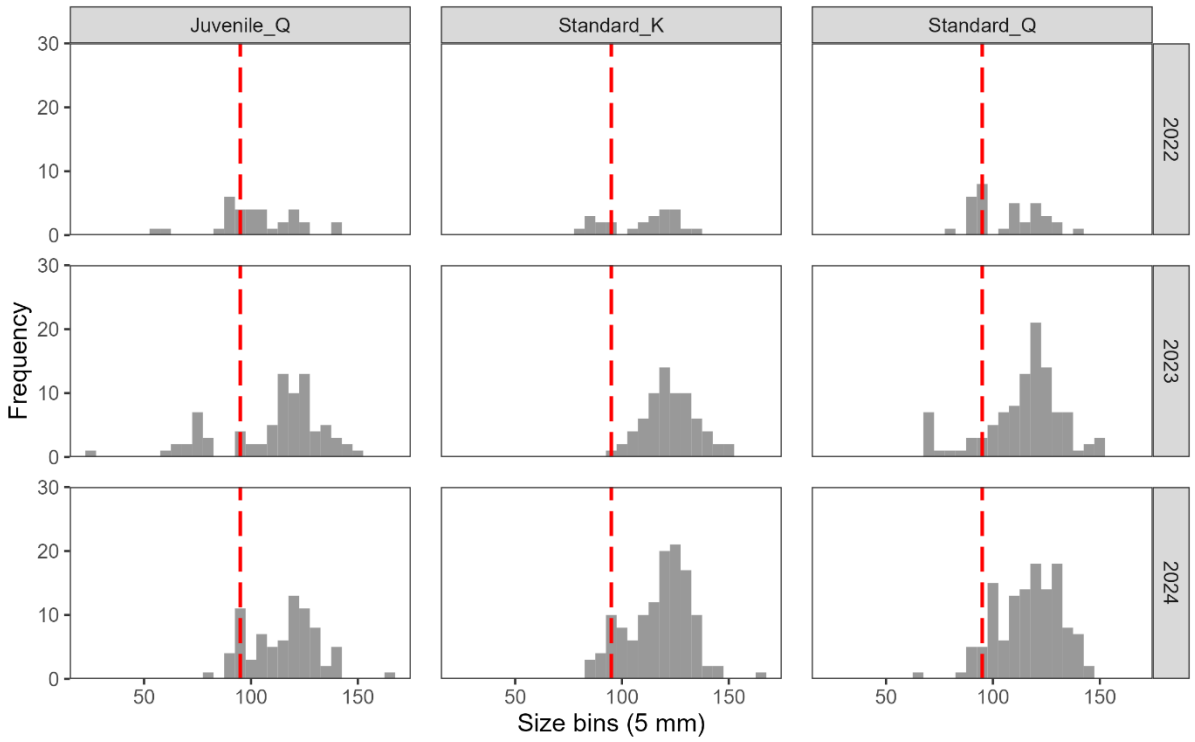

Figure 46: Size frequency of absolute counts of king scallops by dredge type for EDGERA (0 – 3 nm). The red dashed line indicates the estimated recruit cut-off of 95 mm.

5. Overall Spatial and Temporal Comparisons

Within the territorial sea (0 - 12 nm) there has been an overall increase in the survey abundance index of all scallop sizes from 2023 to 2024 for both the Prince Madog (Figure 13 & Figure 14) and industry survey (Figure 17). When split into post-recruit and recruit abundance the Prince Madog survey showed increases in both indices in 2024 relative to 2023. In addition, both indices were the highest in the current time series (33 year time series).

High densities identified in the surveys were not confined to a small subset of grounds, but occurred across a range of fishing grounds, which varied depending on the survey. The industry survey recorded highest densities (8.2 – 15.5 scallops per 100 m^2) at eleven survey cells within BRA, CHI and TAR. The Prince Madog survey recorded highest densities (5.3 - 10.1 scallops per 100 m^2) at four survey stations within ECO, TAR, CHI and EDG.

Within the 0-3 nm limit the industry survey showed decreases in the recruit abundance index at ECO, MGH and EDGERA, whilst for BRA the recruit abundance index was the highest in the time series for that ground. The industry survey also showed decreases in the post-recruit abundance index at ECO, whilst BRA, MGH and EDGERA all showed increases (all three had the highest value in the time series for that ground). In the Prince Madog survey, which has fewer sites located within the 0-3 nm limit, recruit abundance was high (> 1 king scallop per 100 m^2) at one site within the ECO ground (LAX) whilst post-recruit abundance was high (2.1 – 2.3 king scallops per 100 m^2) within the BRA (BRI & ST41) and ECO (LAX) grounds.

Within the 3-12 nm limit the industry survey has shown increases in the recruit and post-recruit abundance index at the majority of grounds (EDG, CHI and TAR; with most values for these grounds

the highest in the time series for the ground). There was however a decrease in both the post-recruit and recruit indices at POA. In the Prince Madog survey, the recruit abundance index was high (> 1 king scallop per 100 m^2) at TAR (TAR), CHI (ST39), BRA (BRO & ST44) and EDG (ST17 & ST26). The Prince Madog survey also recorded a high post-recruit abundance index (> 3 king scallop per 100 m^2) at TAR (TAR), CHI (ST39) and EDG (ST17, ST21 and ST51).

In summary, in both surveys, densities of both king scallop post-recruits and recruits are indicating positive improvements spread around the main fishing grounds which is positive for the current and future fishery seasons as long as the current stock and fishery impacts continue to be well managed. In addition, LPUE remained high across all of the main scallop fishing grounds at the end of the 2023/2024 fishing season.

6. TAC Calculation for 2024/2025 SCE fishing season (Abundance Index)

6.1 ICES data-limited approach for Category 3 stocks

The king scallop stock within the Isle of Man's territorial sea is currently categorised as data-limited as there is no full peer-reviewed quantitative stock assessment in place. Within the framework outlined by ICES it is considered a category 3 stock (i.e. a stock for which survey-based assessments indicate trends (ICES 2012)). The SMB proposed that the king scallop TAC should be based on the precautionary approach outlined by ICES for Category 3 (Data-limited) stocks. For category 3 stocks, without a quantitative assessment, an abundance index from research surveys, can be used as an indicator of stock size to estimate the level of TAC advised for the following year.

The annual advice is based on a two-over-three rule with a comparison of the average of the last two year's survey indices relative to the average of the three preceding years producing a % increase or decrease in TAC. Survey indices can contain a level of noise within the data and as such a +/- 20% uncertainty cap on inter annual changes in the TAC is advised (ICES, 2012). As such, if the ratio change is + 5% then the TAC is increased by 5% whilst if the ratio change is -10% then the TAC is decreased by 10%. However if the ratio change is ≥20% (+/-) then the uncertainty cap is applied and any inter annual increase or decrease of the TAC is capped at 20%. These methods are designed to be precautionary and where there is uncertainty due to a deficiency of information (i.e. stock status relative to reference points or exploitation is unknown) an additional 'Precautionary Buffer', which equates to a further 20% reduction in catch, is advised, unless expert knowledge or evidence indicates that the stock is not reproductively impaired or that stock size is increasing (ICES, 2012).

As per the Survey Based Methods (Category 3) Decision Tree, Method 3.2 will be used. The protocol for this method is (ICES, 2012):

1. Use the survey trend to adjust the catch
2. Limit the influence of the survey's noise with the uncertainty cap (+/- 20 %)
3. If recommended, apply an additional 20% precautionary buffer to the catch advice

When a biomass index becomes available this should be used in preference to an abundance index.

*Table 11: Abundance Index values for 2019 to 2023 from the annual spring scallop survey. The survey abundance index is based on the 10 historical stations (BRI, BRO, CHI, EDG, LAX, PEL, POA, PSM. SED and TAR). **Estimated value for 2020 (mean of 2021 and 2019).*

Survey Year	Abundance Index All	Abundance Index Post-Recruit	Abundance Index Recruits

2019	97	77	20
2020	147**	NA	NA
2021	196	168	28
2022	202	143	60
2023	220	170	50
2024	297	206	91

6.1.1 Previous catch advice

The TAC for 2023/2024 was 2179 t of which 1960 t was landed (~ 90 %)

6.1.2 TAC calculation and catch advice

*Table 12: King scallops in Isle of Man territorial waters, TAC calculation for the 2024/2025 fishery based on ICES Category 3 stock approach (total abundance index i.e. scallops of all sizes).*An average of 2021 and 2019 were used as a proxy for 2020 survey abundance index figure (no data due to Covid).*

	TAC Calculation
Index A (2024 & 2023)	258.5
Index B (2022-2020; no data for 2020)*	181.7
Index ratio (A/B)	1.42
Uncertainty cap	Applied| 0.8
Landings from 2023/2024 season	1960 tonnes
Precautionary buffer	Not applied| NA
Catch advice for 2024/2025	2352 tonnes
% advice change relative to prior season	+ 20 %

In considering the output of the ICES Category 3 approach, which would give a recommended TAC of 2352 t (equating to an uplift of 20% on 2023/2024 landings), the following points should be noted:

- In the case of the Isle of Man king scallop fishery the original TAC, which is then adjusted each season, was not biomass linked.
- The ICES protocol uses actual landings (as above) rather than proposed TAC as the metric for adjustment for setting the next seasons TAC.
- There was no Prince Madog survey undertaken in 2020 due to covid restrictions but the industry survey in 2020 showed an increase and so the average of 2019 and 2021 data has been used in the calculation.

7. Recommendations:

A TAC of 2352t for the 2024/2025 fishing season has been calculated in the main report using the ICES Category 3 data limited approach (based on the abundance index for all sizes of scallops).

It is recommended that the management approach for 2024/2025 king scallop fishery continues to be precautionary and that it should incorporate all of the following three elements:

- **In-season reviews:** Monthly reviews of the fishery by the SMB or a subgroup for the entire TS fishery should be scheduled as standard.
- **Spatial monitoring and management:** Spatial monitoring for each individual ground should be undertaken as part of the in-season review to allow flexible spatial management (i.e. individual grounds to be opened or closed) based on the real-time data collected by the

fishery. High-density areas within a ground may require additional fine scale 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 2024/2025 king scallop fishery based on the survey data analysis produced here therefore include:

- A precautionary management approach should be considered in line with the long-term management plan for this fishery and to promote continued stock improvements.
- An initial starting TAC based on a 20% increase of actual landings (TAC = 2352 t) is advised. This approach (i.e. basing uplift relative to actual landings rather than to previous TAC) is in line with ICES recommendations. However, it should be noted that under achievement of the TAC in recent seasons (2020, 2021, 2022, 2023 and 2024) may be a consequence, not simply of stock status, but also of various management measures, including the use of a DCL to ensure the TAC lasts throughout the season, and various logistical issues as a result of BREXIT and Coronavirus. For these reasons in-season review of TAC, taking into account multiple relevant factors, is recommended.
- 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.
- Consideration of restricted access and additional management measures within the high-density fishing areas at Chickens, Targets and East of Douglas.
- Consideration of temporary closed areas implemented to protect any high densities of recruits identified in the survey. For 2024, survey cells within BRA and CHI had the highest densities of recruits in the industry surveys and hence closures in these areas should be considered.
- Monitoring of 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. Metrics illustrating the relationship between different levels of LPUE and fishing intensity with consideration of possible impacts on the stock are under development and will continue to be examined in order to develop future threshold values for use in management.
- Monthly reviews of the TAC and fishery with consideration of LPUE and fishing intensity within each fishing ground should include combined fishing intensity of king and queen scallop activity (see consideration of this point below).

Long-term fisheries management plan:

A long-term management plan (LTMP) for the king scallop fishery has been developed and agreed with collaborative input from industry, and will be essential for ongoing monitoring, management and recovery of this stock. The LTMP includes a set of aims and goals for the fishery and ongoing and future work relevant to this plan includes:

Relative benthic status and fishing intensity:

Bottom-trawling, using gears such as benthic otter trawls, beam trawls and scallop dredges, is thought to be one of the greatest causes of disturbance and damage to marine benthic communities. As well

as having direct effects on target species through a reduction in abundances, trawling has wider impacts on the environment. Scallops typically form aggregations and so fishing activity is often focused within spatially discrete areas with high scallop density. A quantification of the impact of fishing activity in benthic habitats is therefore an important metric for monitoring the fishery to ensure sustainability of scallop recruitment as well as the overall condition of the habitats and benthic communities. Fishing intensity is defined as the fishing effort per unit area per unit time. Consideration needs to be given to the potential for cumulative impacts of queen scallop trawling and queen and king scallop dredging within each fishing ground which may have disproportionally damaging effects compared to one or the other in isolation. So as to provide a metric that is usable in real time through the season, fishing intensity data could be incorporated from both the king and queen scallop seasons.

Relative Benthic Status (RBS) is a metric that should also be further developed and assessed for monitoring scallop fisheries. The status of trawled habitats and hence their RBS value depends on impact rate (depletion per trawl), recovery rate and exposure to trawling. This enables a quantitative estimate of status relative to an unimpacted baseline and could provide a useful monitoring metric for scallop fisheries. Using pre-defined management criteria to assess each habitat type within the territorial waters or within a fishing ground would indicate areas at risk from higher fishing intensities and whether levels of fishing intensity would have a negative impact on habitat status. A Benthic Impacts Tool (BIT) has been developed by researchers at Bangor University (Evans et al., 2020) that enables RBS to be assessed.

Recruitment:

The high-resolution industry survey has allowed greater insight into the patterns of recruitment across the three major fishing grounds of the territorial sea. The differences in general oceanography and frontal systems across the territorial sea might lead to long-term recruitment patterns varying considerably among individual fishing grounds. At present we only have a short time series of data for the main king scallop fishing grounds within the 3-12 nm. As the time series continues to extend, the survey data will provide a better insight into what is average, good and poor in terms of recruitment densities for individual grounds. Historical analysis of the scientific survey data would, for example, indicate that larger recruitment events typically occur at CHI and TAR compared to EDG or POA. A longer-term data set will therefore provide more information on what is normal in terms of recruitment at the fishing ground level. This in turn will assist with a longer-term management approach and forecasting when to expect above average fisheries within each ground.

Irish Sea Management:

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

8. References:

Anderson SC, Ward EJ, English PA, Barnett LAK, Thorson JT (2024). "sdmTMB: an R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields." *bioRxiv*, 2022.03.24.485545. doi:10.1101/2022.03.24.485545.

Beukers-Stewart, B.D., Mosley, M.W.J. and Brand, A.R. (2003). Population dynamics and predictions in the Isle of Man fishery for the great scallop, *Pecten maximus* (L.). ICES Journal of Marine Science, 60:223-241.

Bloor, I.S.M., Emmerson, J., and Kaiser, M.J. (2017). The Isle of Man *Aequipecten opercularis* fishery stock assessment 2017. Fisheries and Conservation Report No. IOM 72. Pp 9

Duncan, P.F., Brand, A.R., Strand, Ø and Foucher, E (2016). The European Scallop Fisheries for Pecten maximus, *Aequipecten opercularis, Chlamys islandica* and *Mimachlamys varia*. In Scallops: Biology, Ecology, Aquaculture, and Fisheries. Developments in Aquaculture and Fisheries Science 3rd Edition, Volume 40, Edited by Shumway, S.E. and Parsons, G.J.

Evans, L.E., Shepperson, J and Hiddink, J.G. (2020). EMFF Benthic Impacts Decision Support Tool. User Manual V.4.0. Accessed on 30/08/2024 via https://data.jncc.gov.uk/data/101bb59f-55ce-4195-9710-6ff9abe4c8dd/EMFF-BenthicImpactsTool-UserManual-V4.0.pdf

Hutchings, J.A. (1996). Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. Canadian Journal of Fisheries and Aquatic Sciences, 53, 943-962

ICES (2012). ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM 68/ 42pp.

ICES (2023a). Official Nominal Catches 2006 – 2021. Accessed on 22/08/2023 via https://www.ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx

ICES (2023b). Historical Nominal Catches 1950 – 2010. (Accessed on 06/09/2022) via https://www.ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx

IFISH2 (2024). EU Logbook Data. (Accessed on 22/08/2024)

Long-Term Fisheries Management Plan King Scallops via https://www.gov.im/media/1376550/ltmp-10-260522.pdf (Assessed on 30/08/2023)