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Isle of Man King Scallop (*Pecten maximus*) Stock Advice for 2019/2020 Season

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Executive Summary

King scallops (*Pecten maximus*) in ICES Rectangles 36E5, 37E5 and 38E5 (Isle of Man territorial sea)

Stock advice (2019/2020)

A TAC of 2049 t for the 2019/2020 Isle of Man king scallop fishery was calculated based on the ICES protocol for Category 3 approach using Method 3.2 (Table I: Scenario 1- a 20 % reduction of the 2018/2019 TAC ≈2049t). Total landings from 2018/2019 were however ~28% lower than the original TAC (i.e. 1883 t landed from 2562 t TAC), leading to Scenario 2 (Table 1: Scenario 2- a 20 % reduction of actual landings from the 2018/2019 season ≈ 1446t). It is recommended that in setting a TAC for the forthcoming season there is a discussion of the merits of Scenario 1 versus Scenario 2. This discussion should recognise that Scenario 1 will set a TAC which is higher than total landings from the previous season.

Stock development over time

The length based abundance indices for recruits (< 95 mm) (Figure 1: Top left) and post-recruits (>95 mm) (Figure 1: Top right) from the April survey are presented below. Both indices have shown recent decreasing trends although there is a slight increase in the recruit index in 2019 compared to 2018. The commercial catch (ICES Rectangles 36E5, 37E5 and 38E5) has decreased since 2017 alongside the introduction of a TAC within the Isle of Man's territorial sea (Figure I; Bottom left). There was a slight increase in the overall abundance index (all size scallops) in 2019 (Figure I; Bottom right).

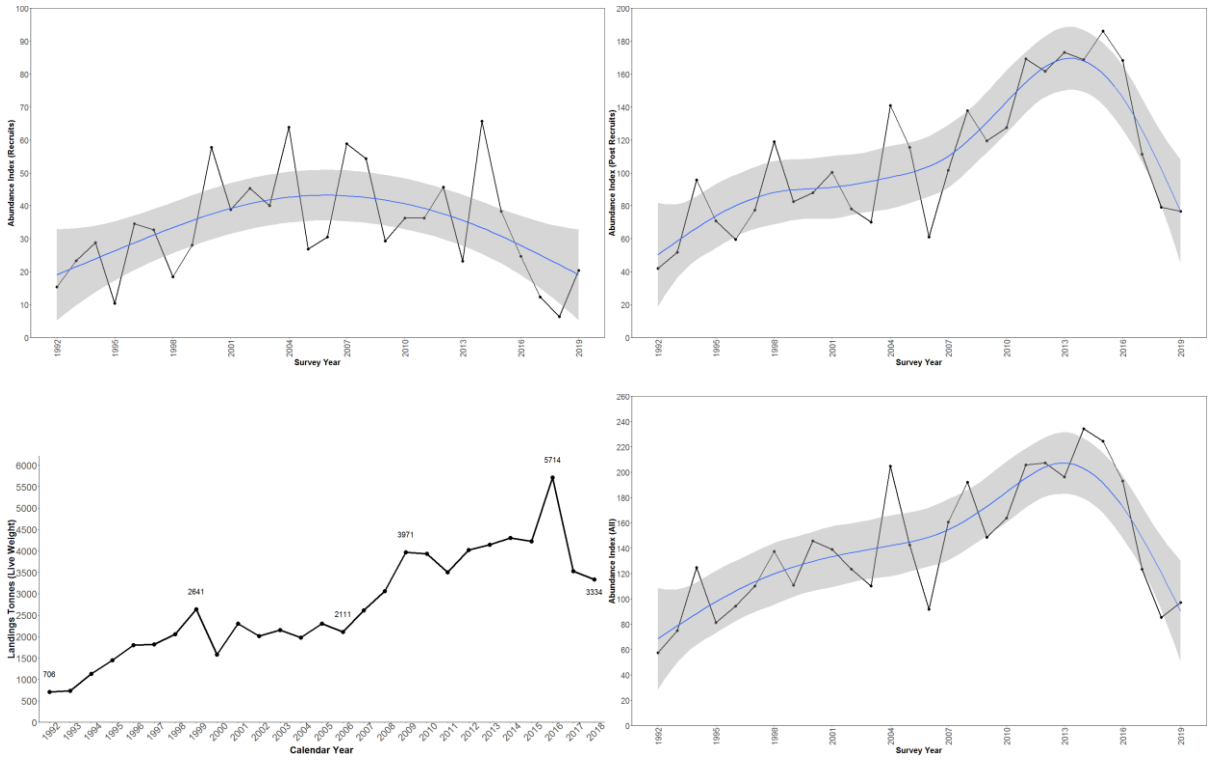

*Figure I: King scallops in ICES Rectangles 36E5, **37E5 and 38E5. Upper left,** Recruit **length** abundance index from **April** survey; Upper right, **Post-**Recruit **length** abundance index from **April** survey; Lower left, landings from ICES Rectangles 36E5, 37E5 and 38E5 by calendar year; Lower right, **length abundance index from April survey for all scallops combined.***

Catch options

The ICES framework for category 3 stocks was applied (ICES, 2012). The spring scallop dredge survey abundance index (calculated using king scallop data from queen scallop dredges only) was used as an index of stock development. The advice is based on a comparison of the latest two index values (index A) with the three preceding index values (index B), multiplied by a proxy for recent advised catch. The abundance index is estimated to have decreased by 49% and thus the uncertainty cap (a +/- 20% cap on inter annual changes to account for the level of uncertainty contained in a survey index) was applied. Total landings from 2018/2019 were however ~28% lower than the original TAC (i.e. 1883 t landed from 2562 t TAC), leading to presentation of Scenario 2 (a 20 % reduction of actual landings from the 2018/2019 season ≈ 1446t).

Table I: Calculations and catch advice for the Isle of Man king scallop fishery using the ICES methodology outlined for a Category 3 stock (Method 3.2). Index A is the average of the last two year's survey abundance indices (2018 – 2019); Index B is the average of the three preceding year's survey abundance indices (2015 – 2017); Index Ratio is a ratio of Index A divided by Index B. Survey indices can contain a level of noise within the data, as such a +/- 20% cap (Uncertainty Cap) on inter annual changes to the TAC from the Index Ratio is advised (ICES, 2012). These methods are designed to be precautionary and so where there is uncertainty due to a deficiency of information (i.e. stock status relative to references points or exploitation is unknown) a 'Precautionary Buffer' of a 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).

	I	**II**
Index A (2018 - 2019)	91	91
Index B (2015 – 2017)	180	180
Index Ratio (A/B)	0.49	0.49
Uncertainty cap	0.80	0.80
TAC from 2018/2019 season	2562	1833
Discard rate	-	-
Precautionary buffer	NA	NA
Catch advice for 2019/2020**	2049	1466

*** For Scenario II: only 72% of the TAC for 2018/2019 was achieved. Therefore Scenario II: (actual landings for 2018/2019 x Uncertainty Cap)*

Basis of the advice

Table II: King scallops in ICES Rectangles 36E5, 37E5 and 38E5. The basis of advice.

Advice basis	Precautionary approach
Management plan	There is no management plan for the stock

Quality of the assessment

The advice is currently based on abundance index estimates from a dredge survey, available for 1992 – 2019. A preliminary quantitative stock assessment is under development. Once the stock assessment methods are finalised and peer-reviewed the calculation of the index ratio change for future king scallop fishing seasons will be based solely on the stock assessment biomass index. An additional fine-scale industry survey was also undertaken for the first time this year and the results are being incorporated into stock advice.

The stock structure of king scallops within the Irish Sea (Area VIIa) has not been formally delimited. The current dredge survey covers only part of the potential distribution of this stock (Isle of Man's

territorial sea/ 36E5, 37E5 and 38E5) and not the whole of Area VIIa. An extension to the survey and assessment will be required to assess this stock at its full biological extent.

Reference points

No reference points (e.g. F_{msy}, B_{pa} etc.) are defined for this stock.

Conclusions

2019/2020 Management Recommendations:

- A TAC of 2049 t for the 2019/2020 Isle of Man king scallop fishery was calculated based on the ICES protocol for Category 3 approach using Method 3.2 (Scenario 1- a 20 % reduction of the 2018/2019 TAC ≈2049t). Total landings from 2018/2019 were however ~28% lower than the original TAC (i.e. 1883 t landed from 2562 t TAC), leading to Scenario 2 (a 20 % reduction of actual landings from the 2018/2019 season ≈ 1446t). It is recommended that in setting a TAC for the forthcoming season there is a discussion of the merits of Scenario 1 versus Scenario 2. This discussion should recognise that Scenario 1 will set a TAC which is higher than total landings from the previous season.
- Protection of areas surveyed in the April and June survey that recorded large proportions of pre-recruit (i.e. less than 95 or 100 mm respectively) should be considered ahead of the fishing season in order to protect stock for future years.
- A review of the fishery to be undertaken by the SMB following the first month of the season to review the fishery dependent data collected (i.e. LPUE, Spatial distribution of landings, proportion of vessels meeting daily quota etc.).

Additional Recommendations:

- The fine-scale industry survey undertaken in June helps both corroborate the April survey data and provide additional useful information and should be continued on an annual basis.
- Spatial management and assessment of king scallops should be developed and considered for future years. As part of this, a literature review and meta-analysis will be undertaken to review spatial management examples from both scallop fisheries and other sessile aggregating species to look at potential options, data analysis and management methods for spatial management in the 2020 fishery based on all available data. This will include ascertaining options for managing high densities of either juvenile (“protected areas”) or adults (“Fishery Hotspot areas”). This review will be produced by Bangor University staff by January 2020.
- The Irish Sea king scallop fishery should be managed at the appropriate spatial scale. Unpublished genetic and oceanographic research indicates that the northern Irish Sea may be the most appropriate management unit for the fishery surrounding the Isle of Man. It is therefore vital that work continues towards achieving a collaborative management approach for king scallop stocks within the different regions of the Irish Sea.

Sources and references

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

1. Background

Bangor University was requested to provide scientific advice for the Isle of Man's king scallop stocks. This report represents the advice provided for this stock for the 2019/2020 fishing season. The first part of the report provides a background to the king scallop fishery within the Irish Sea and the scallop surveys undertaken within it (particularly within the Isle of Man's territorial sea). The second part of the report outlines the International Council for Exploration of the Seas (ICES) methods to assess data limited (Category 3) stocks for which a biomass index is not available. Using this method a survey index-adjusted total allowable catch (TAC) harvest control rule has been used by the Scallop Management Board (SMB) to determine a TAC for the Isle of Man's king scallop fishery since 2017/2018 fishing season.

2. The Fishery

A fishery for king scallops, *Pecten maximus*, has been prosecuted in and around the Isle of Man's territorial sea since 1937 and developed rapidly in the 1960s as more and larger boats joined the fishery (Duncan et al., 2016). The Isle of Man's king scallop fishery is prosecuted from 1st November to 31st May by vessels using toothed, Newhaven, dredges. Management of the fishery differs between an inner 0 to 3 nautical mile zone, and an outer 3 to 12 nautical mile zone, with more stringent regulations in the inner zone. For the 2018/2019 season a total of 86 vessels from the Isle of Man, Wales, Scotland, England and Northern Ireland had active licences to fish for king scallops in the Isle of Man's territorial sea 3- 12 nm limit and of those 40 vessels also have permits to fish for king scallops within the 0- 3 nm limit. For the 2018/2019 fishing season the management measures that governed the fishery included:

- TAC of 2562 tonnes
- A daily catch limit of 700 kg
- Daily curfew (18:00 – 06:00) [0 – 12 nm zone]
- Closed season: 01/06 to 31/10 [0 – 12 nm zone]
- ≤ 15.24 m vessel registered length [0 – 3 nm]
- Under 221 kw [0 -12 nm; excluding Grandfather rights vessels]
- Closed areas
- VMS required [0 – 12 nm zone] for all vessels irrespective of size
- Minimum landing size (110 mm)
- Maximum of 9 teeth per dredge
- Minimum tooth spacing of 75 mm [0 – 12 nm zone]
- Aggregate dredge width of 762 cm [0 – 3 nm zone]
- Aggregate dredge width of 1067 cm [3 – 12 nm zone]
- Maximum tow bar diameter of 185 mm [0 – 12 nm]
- Minimum belly ring diameter of 75 mm & Minimum dredge net mesh of 100 mm

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

Of the 86 vessels licenced to fish for king scallops during the 2018/19 fishing season 74 vessels reported landings of king scallops from within the Isle of Man's territorial sea. The TAC for 2018/2019 was 2562 t of which only 1833.24 t was landed (~ 72 %).

3. Annual Landings and Fishing Effort

3.1 Irish Sea

Annual landings of king scallops from the Irish Sea (Area VIIa) over the period 1950 – 2017 are shown in *Figure 1* (ICES 2019a,b). Since 2006, landings have increased rapidly peaking in 2016 at > 11000 t. In the early part of the Irish Sea fishery (1950 – 1975), boats from the Isle of Man took the majority of the catch (80%), but between 2006 and 2017 the average annual Manx share has declined to around 20%, with landings from United Kingdom vessels (Scotland, England, Wales and Northern Ireland) landing around 64% (the remainder was taken by vessels from Belgium and the Republic of Ireland). Whilst there are some management measures in place 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), the recent (2008 – 2017) quantity of landings from the Irish Sea (VIIa) are unprecedented (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).

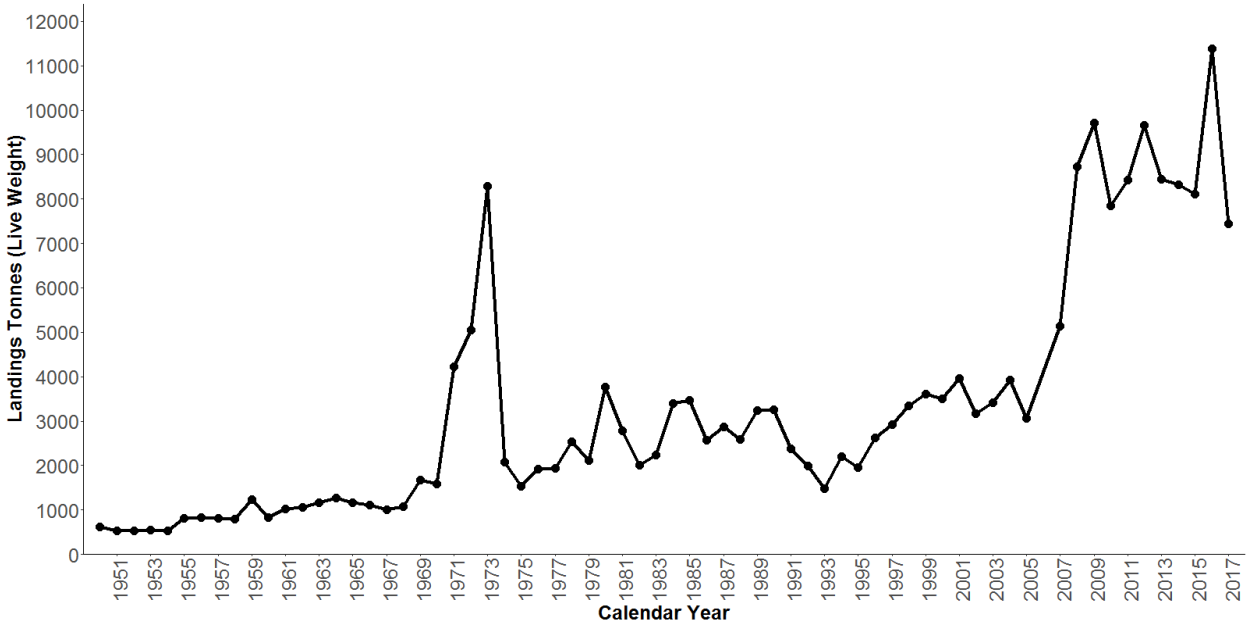

Figure 1: Annual King Scallop landings (t) from ICES Area VIIa for 1950 to 2017 using scallop landings from species Great Atlantic Scallop (SCE) and Scallop Nei (ICES 2019a; ICES 2019b).

3.2 ICES Rectangles 36E5, 37E5 and 38E5

The annual landings of king scallops from the ICES Rectangles 36E5, 37E5 and 38E5, which cover the main extent of the Isle of Man's territorial sea, show a similar pattern of landings to those from the wider Irish Sea (Area VIIa) over the period 1992 – 2016 (Figure 2). Landings increased rapidly from 2006 to 2009 almost doubling during that period from 2111t to 3971t. Annual landings continued to increase since 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 and 2018 following the introduction of TACs within the Isle of Man's territorial sea; however landings continue to exceed pre-2006 values.

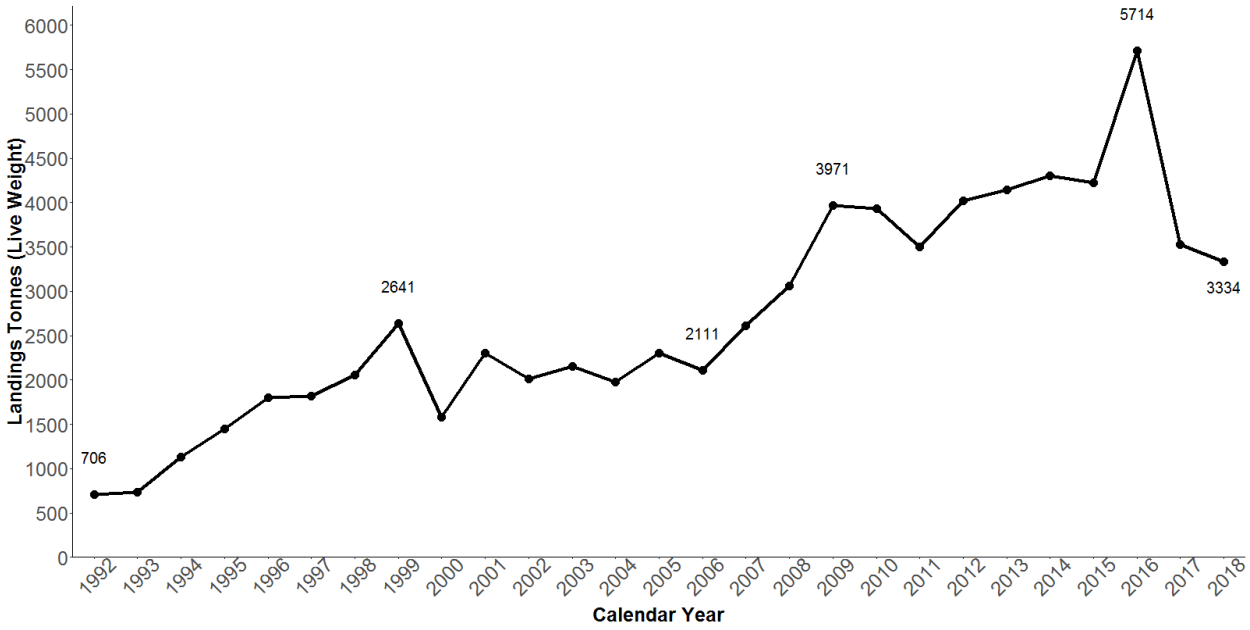

Figure 2: Annual King Scallop landings (t) from ICES Rectangles 36E5, 37E5 and 38E5 (Source: Logbook data DEFA, Marine Scotland, MMO). For information the landings (t) values from key years are annotated on the graph.

4. Seasonal Landings and Fishing Effort

4.1 ICES Rectangles 36E5, 37E5 and 38E5

Seasonal landings of king scallops (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 5134 t followed by decline to a low of 2163 t in the 2018/2019 season (Figure 3).

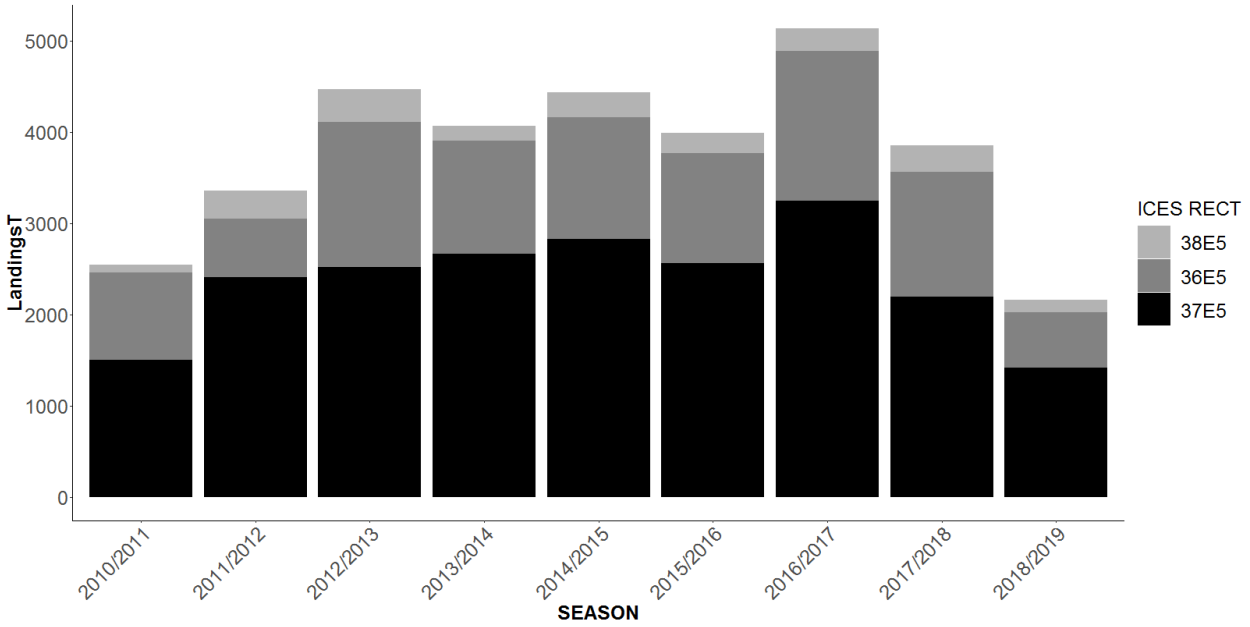

Figure 3: Seasonal landings (t) of king scallops from ICES Rectangles 36E5, 37E5 and 38E5. Data source: EU Logbooks downloaded through IFISH2. *NB. This data includes **ALL** vessels fishing for king scallops (except vessels from Ireland for which we do not receive EU logbook data) and not only those vessels that are currently licenced to fish for king scallops within the Isle of Man's territorial sea.*

The temporal pattern of landings varied among seasons. In the 2016/2017 season, when landings reached their peak, there was a large spike in landings (> 2000t) during the first month of the fishery while previous fishing seasons were more stable at ~1000t or less (Figure 4). In contrast landings were uniformly low across all months in the 2018/2019 season compared to other seasons (Figure 4).

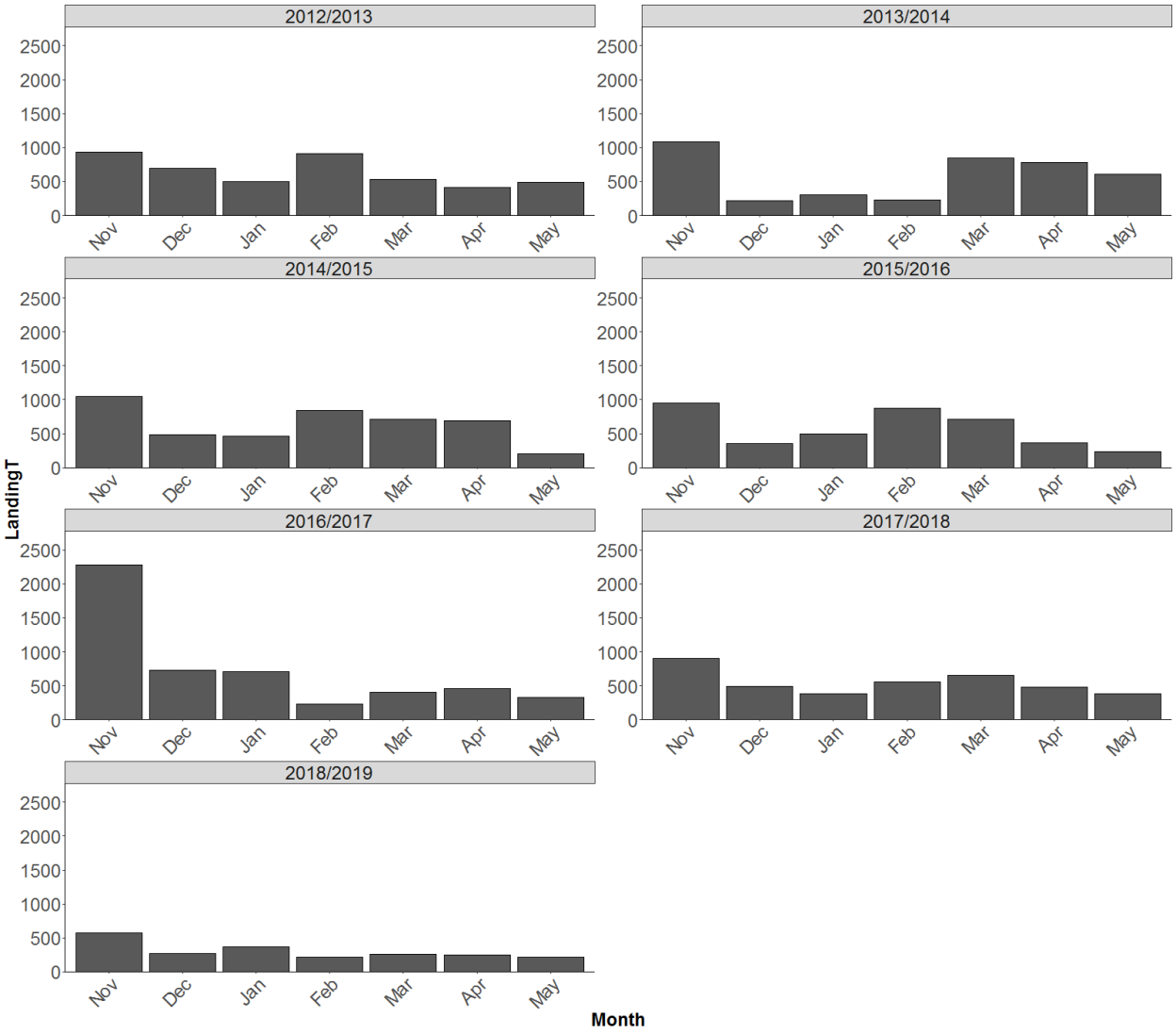

Figure 4: Landings of king scallops from 36E5, 37E5 and 38E5. Data are presented for each fishing season from 2012/2013 to 2018/2019 (1st Nov Year^{n} to 31st May Year^{n+1}). Data source: *EU Logbooks downloaded through IFISH2. NB. This data includes **ALL** vessels fishing for king scallops (except 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 the Isle of Man's territorial sea.*

4.2 Isle of Man Territorial Sea

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 provides almost real-time fisheries dependent data for the fishery for monitoring TACs and catch rates etc. The spatial location of landings varies annually and often reflects densities. The data from the 2018/2019 fishing season are displayed in Figure 5. Landings in the 2018/2019 fishing season were fairly equally distributed among the four main fishing grounds (IS9: Targets; IS21: Chickens; IS15 East Douglas and IS14: Bradda/Port St Mary).

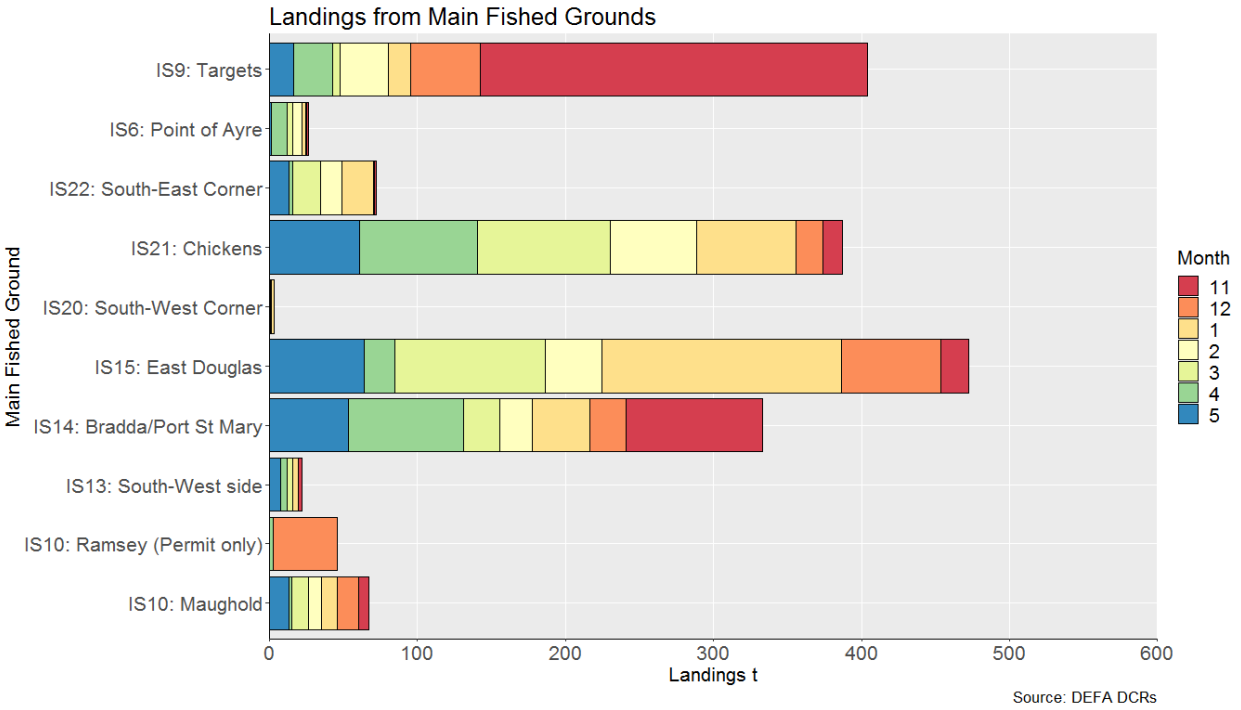

Figure 5: Landings (t) reported by main fished ground (IS Box) and separated by colour for each month to show the spatial and temporal pattern of landings for the 2018/2019 king scallop fishing season.

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 and 2018/19 seasons by fished week. LPUE for the 2018/2019 fishing season was lower at almost every ground compared to the 2017/2018 fishing season.

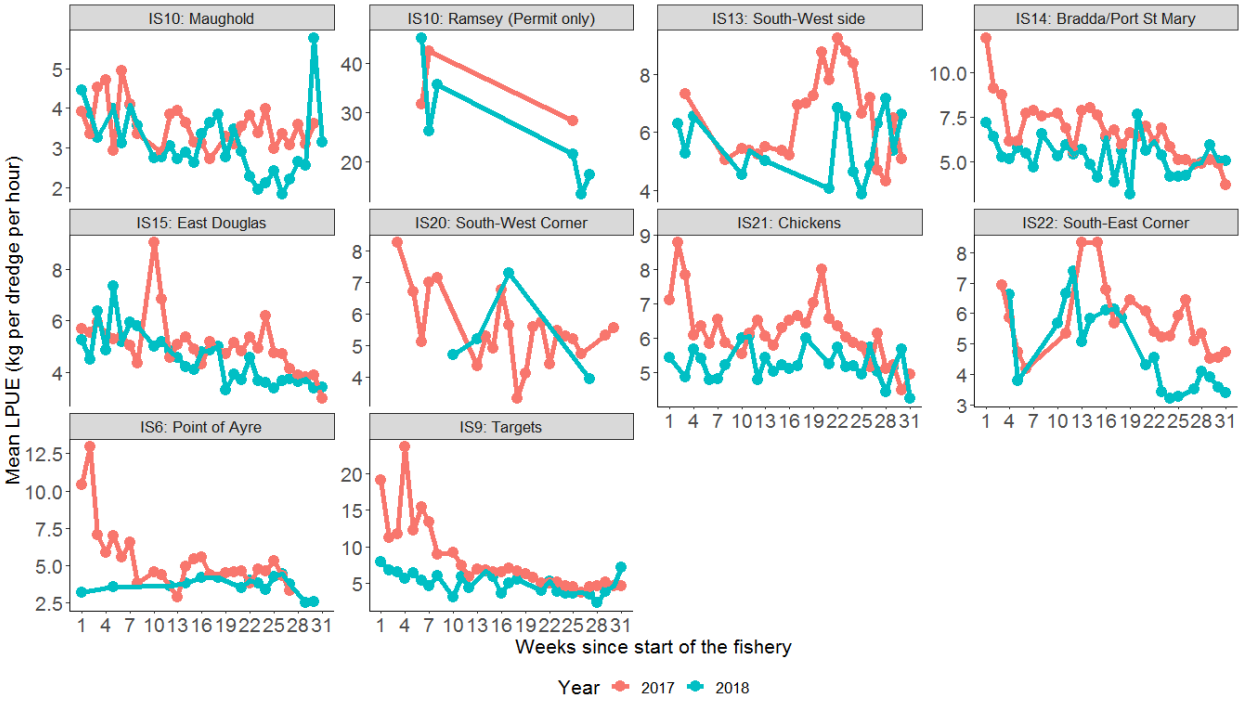

Figure 6: LPUE (kg per hour fished per dredge) displayed by main fished ground for each week of the 2017/2018 (red) and 2018/2019 (green) seasons. Note the different scales on the Y-axis, in addition the fishery closed for Christmas during Week 9 in both seasons

5. Scallop surveys

5.1 April Survey

5.1.1 Survey Methods

Spring surveys of the Isle of Man's scallop populations have been undertaken annually since 1992 (Beukers-Stewart *et al.*, 2003). The 2019 spring scallop survey was undertaken by the R.V. Prince Madog over 10 days from 4th – 13th April 2019. A total of 52 survey stations were sampled (Figure 7). 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 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).

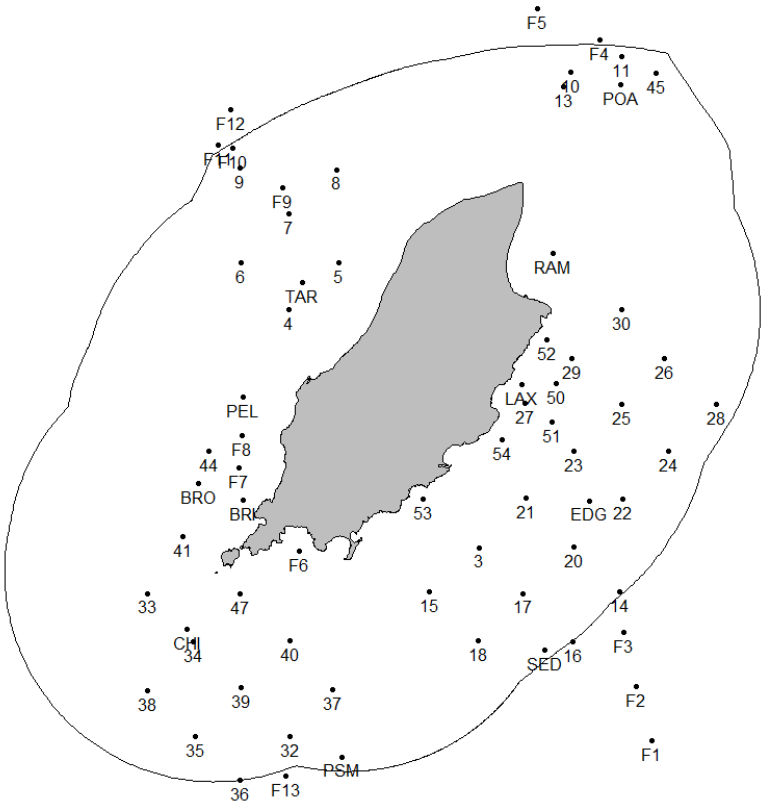

Figure 7: All survey stations sampled onboard the R.V. Prince Madog as part of the scallop stock assessment survey. The stations labelled with 3 letter codes (e.g. CHI) are the 11 historical stations that have been surveyed since 1992. The stations labelled with numbers (e.g. 11) are the newer stations added since Bangor University took over the survey in 2013 and the stations prefixed with F (e.g. F1) are stations suggested by industry in 2015.

5.1.2 Size Frequency

A frequency-density plot of king scallop size data is presented 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). Two main cohorts can be seen in the size data: Cohort 1 with a peak at 50-55 mm and Cohort 2 with a peak of 120 mm. Cohort 1 indicates pre-recruits that will be recruiting into the fishery in one or two years, whilst Cohort 2 represents recruits, king scallops that are typically

already at minimum landings size (MLS) or that will grow into the fishery during the following fishing season (for king scallops this is estimated that on average scallops of 95 mm or above at the time of the survey in April year^{0} will typically have reached 110 mm by 31st May Year^{+1} i.e. the end of the following fishing season).

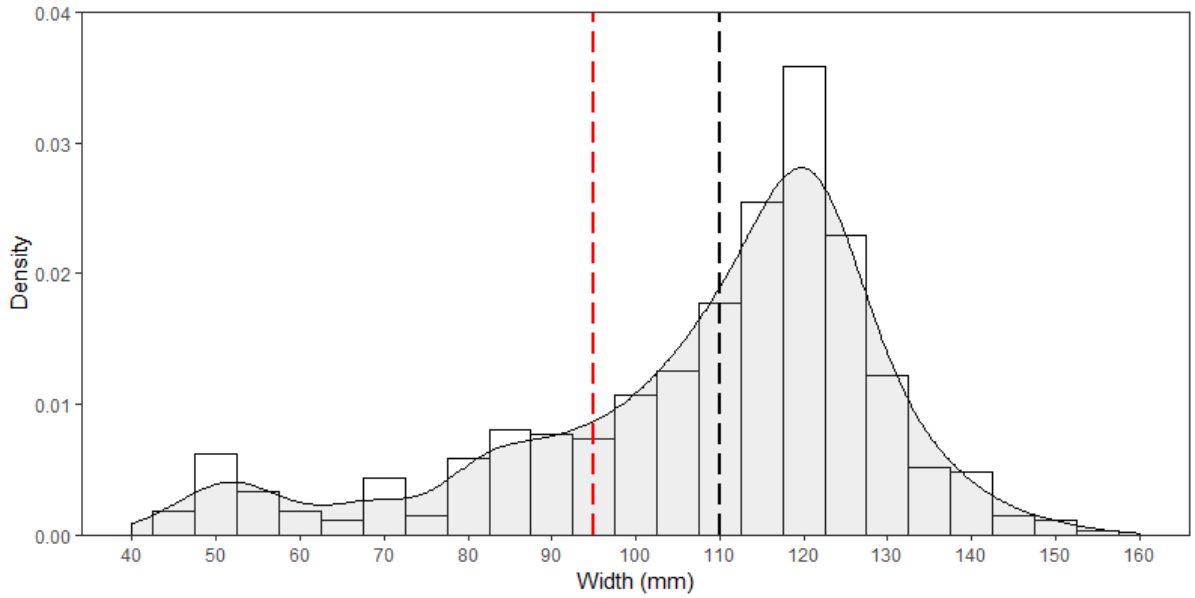

Figure 8: King scallop size frequency-density plot. Black dashed line indicates MLS (110 mm) and the red dashed line indicates the estimated MLS cut-off width (95 mm) for the territorial sea (i.e. the size at which scallops sampled in April Year^{0} will typically have reached MLS by 31st May Year^{+1}).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

When the size data are split into individual historical stations it is clear that the majority of pre-recruits (i.e. Cohort 1) identified in the survey were found at the Chickens fishing ground (Figure 9). If managed correctly these pre-recruits could represent an important post-recruit abundance for the fishery at this site over the next couple of years. Size frequency data also showed recruitment signals of slightly larger size class (70 – 100 mm) at some of the historical stations in particularly at BRI and POA.

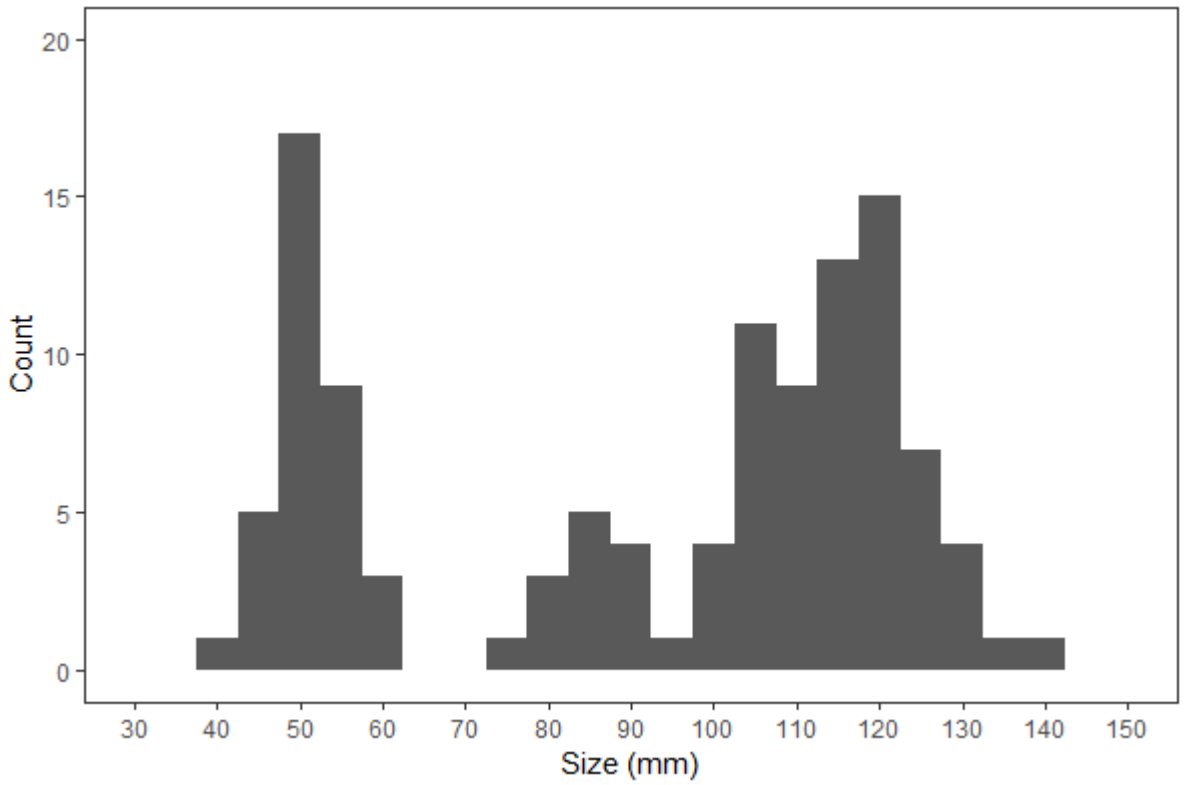

Figure 9: Size frequency (count) of king scallops from 2019 at CHI historical station (including both king and queen scallop dredge data).

5.1.3 Density Estimates

The average survey density of king scallops (of all sizes caught) per 100 m^2 around the Isle of Man for the 2019 survey are displayed in Figure 10 for all survey stations. In 2019 the fishing grounds to the north-east and south of the Island (RAM and ST36) had the highest densities of king scallops per 100 m^2 (~4.6 and 4.1 king scallops per 100 m2 respectively) (Figure 10).

The difference in mean survey density (scallops per 100 m^2) of king scallops from queen scallop dredges between 2018 and 2019 is displayed for the ten historical stations used in the stock assessment advice (Figure 11). This indicates positive increases between 2018 and 2019 in total scallop density at six of the ten historical stations.

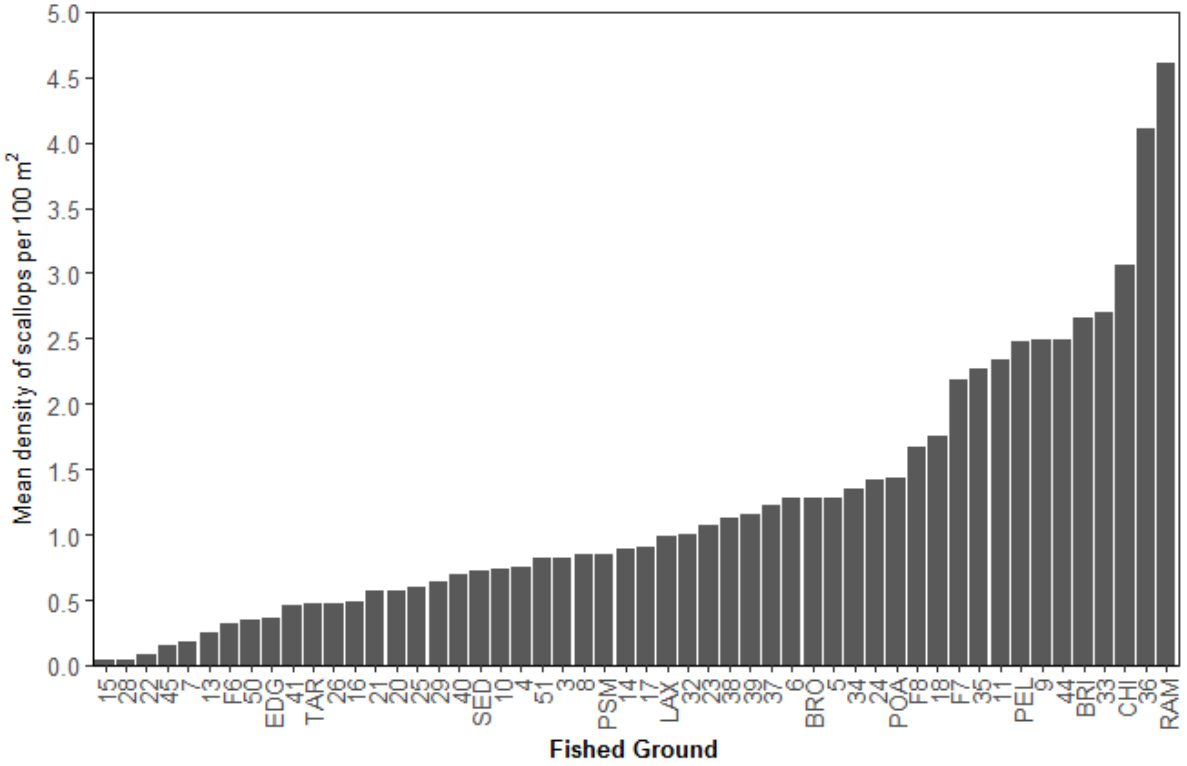

Figure 10: Survey densities (king scallops per 100 m^2) displayed by survey station for spring 2019 survey (average of queen scallop dredge data).

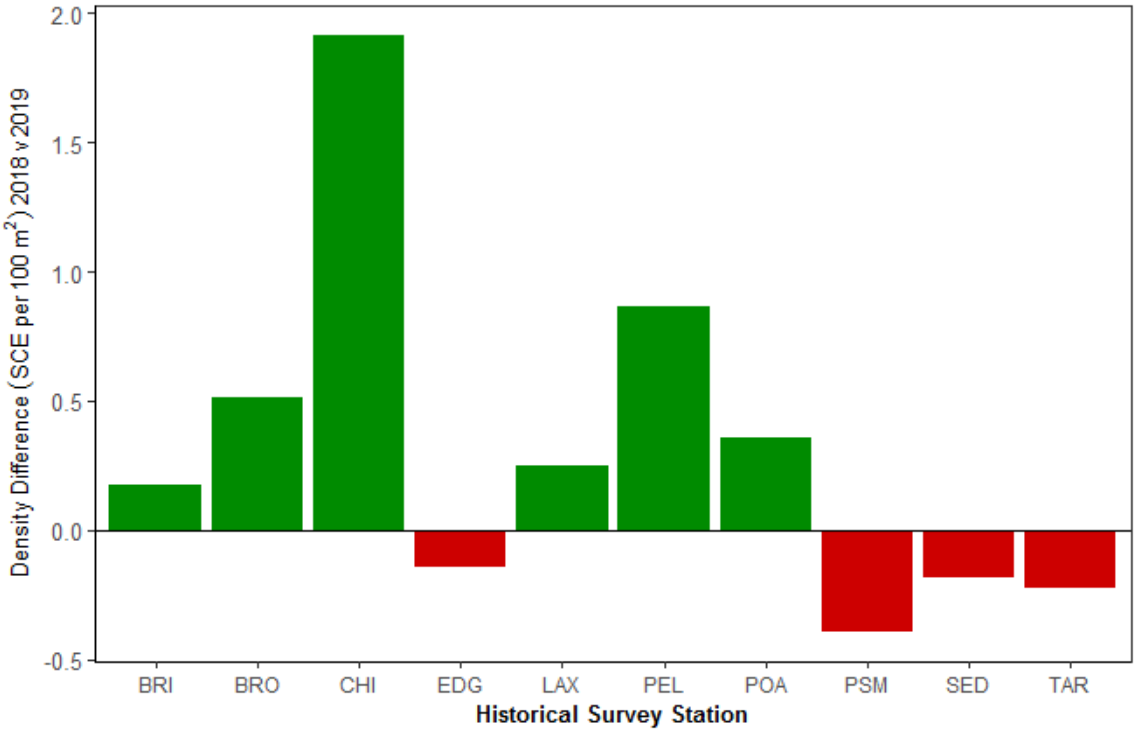

Figure 11: Difference in average survey density (scallops per 100 m^2) of king scallops between 2018 and 2019 from queen scallop dredges for the ten historical stations used in the stock advice (red bars indicate a reduction in scallop densities and green bars indicate an increase in scallop density from 2018 to 2019).

Despite positive increases in six out of ten of the historical stations between 2018 and 2019 the data need to be considered in the wider context of the time series. Figure 12 and Figure 13 indicate the density of king scallops per 100 m^2 for each of the eleven historical stations from 1992 to 2019. The longer term data shows that for 2019 the densities are typically at the lower end of the range of values for these stations (Figure 12 and Figure 13).

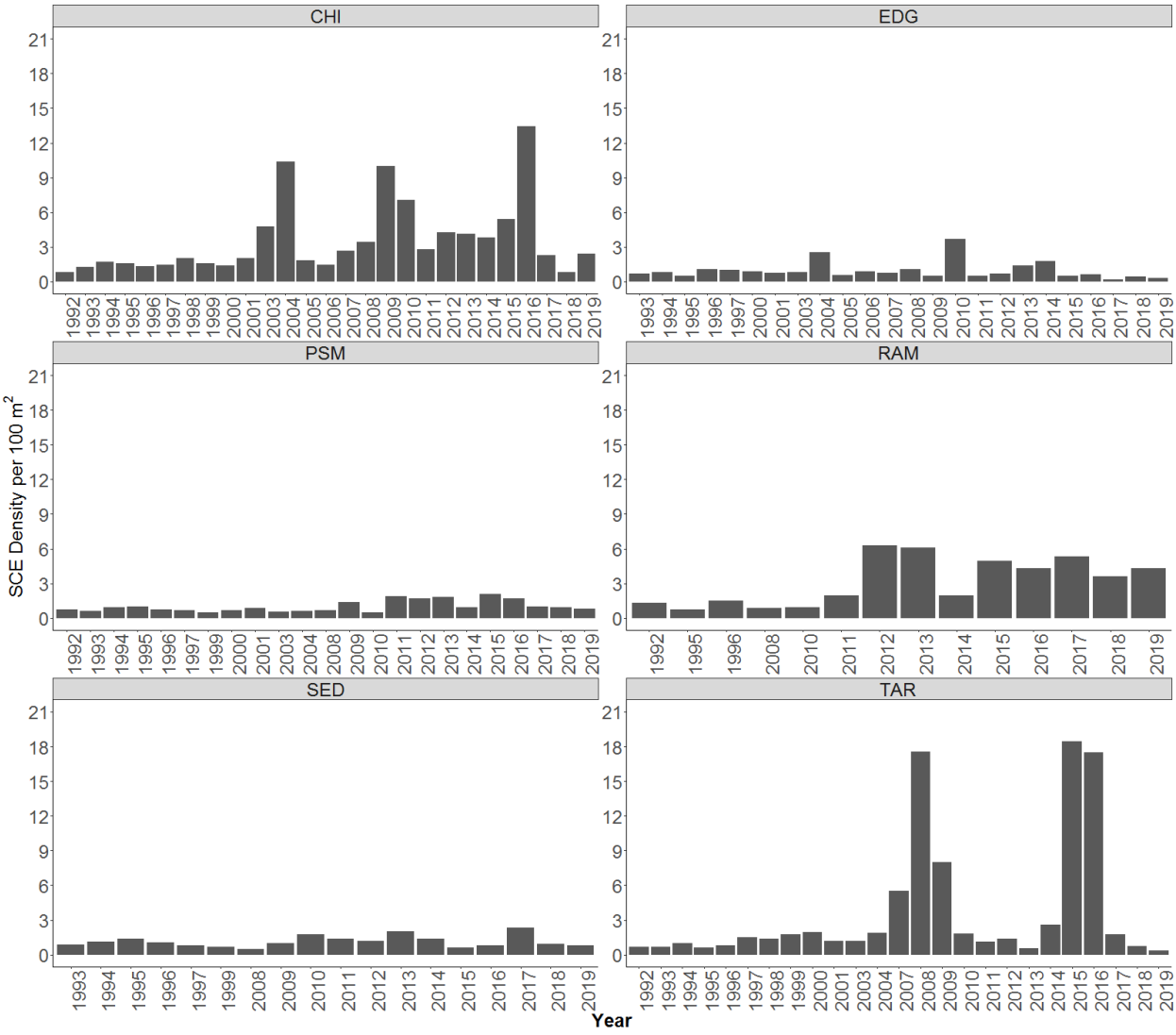

Figure 12: Survey densities (king scallops per 100 m2) displayed by survey station for six historical stations for surveys from 1992 to 2018: TAR – Targets, EDG – East Douglas, CHI – Chickens, PSM – Port St Mary, RAM – Ramsey and SED – South East Douglas. Data are from queen scallop dredges only. ***Please note: x axes only displays years when the stations were surveyed***.

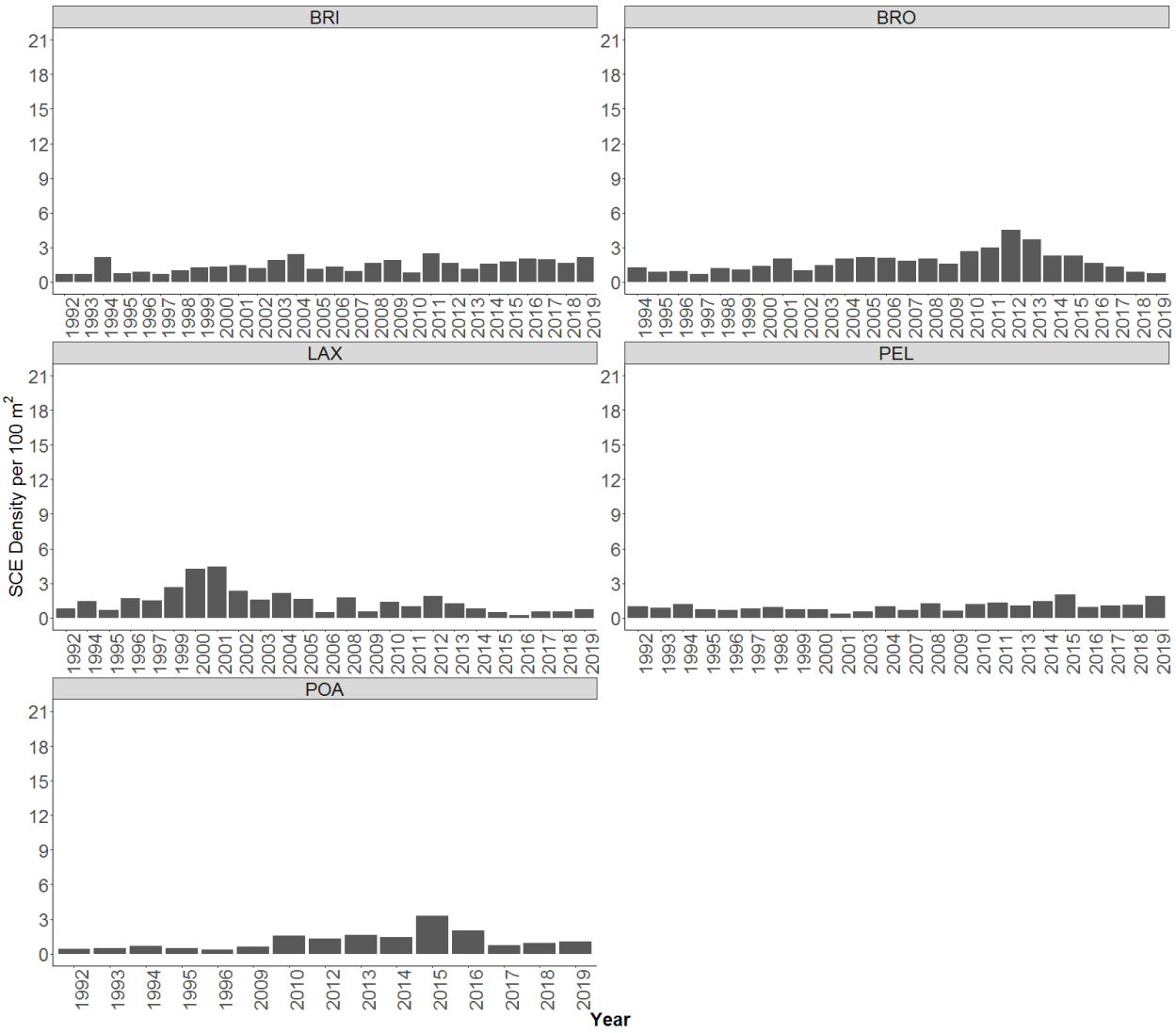

Figure 13: Survey densities (king scallops per 100 m^2) displayed by survey station for six historical stations for surveys from 1992 to 2018: BRO – Bradda Offshore, LAX – Laxey, POA – Point of Ayre, BRI – Bradda Inshore, PEL – Peel. Data are from queen scallop dredges only. ***Please note: x axes only displays years when the stations were surveyed.***

5.2 June Survey

5.2.1 Survey Methods

A juvenile scallop survey was undertaken onboard two industry vessels (F.V. Benolas and F.V. Sarah Lena) from 19th – 27th June 2019. The survey was undertaken at three of the main queen scallop fishing grounds (these areas are also fished for king scallops: Targets – 3 vessel days; Chickens – 3 vessel days and Douglas – 6 vessel days).

At each fishing ground the outer survey extent was delineated using vessel monitoring system data (VMS) at fishing speed for the queen scallop fishing season, amalgamated from 2007 – 2018. These survey areas were then split into a fixed grid with a resolution of 1 min (longitude) x 0.5 min (latitude). Survey cells were sampled randomly within each sub-area 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' of the same design but using Queen dredges with 17 teeth

with a mesh (60 mm) attached internally that when stretched into a fixed position resulted in a maximum mesh size of 38 mm. The catch from each dredge was counted and a subsample of up to ~ 50 kings and 50 queens were measured.

In addition to the random Survey Cells described above, additional cells (5 sites at CHI [Survey Cells: 5057, 5058, 5129, 5130 and 5203] and 1 site at TAR [Survey Cell: 2067) were surveyed in those areas targeted for juvenile closed area placement. These were excluded from the main analysis below because these areas were chosen specifically because they were known high density areas of queen scallops (i.e. they were not a random selection of the identified fishing ground) but are presented in maps.

5.2.2 Size Frequency

In the following analysis we have made a distinction between king scallops under and over 100 mm size. Scallops over 100mm in size are expected to reach the MLS of 110mm by the end of the coming fishing season (i.e. on average scallops of 100 mm shell width or above in June Year^{0} will typically have reached 110 mm by 31st May Year^{+1}).

The size distribution of individuals from juvenile dredges shows two cohorts (one under and one over the 100mm cut-off point) at all three grounds. The cohort of scallops under 100mm at Chickens peaks at a smaller size than at the other two grounds as also observed in the April survey. In the standard dredges Douglas was the only site with any significant cohort observed under the 100mm cut-off point (Figure 14)

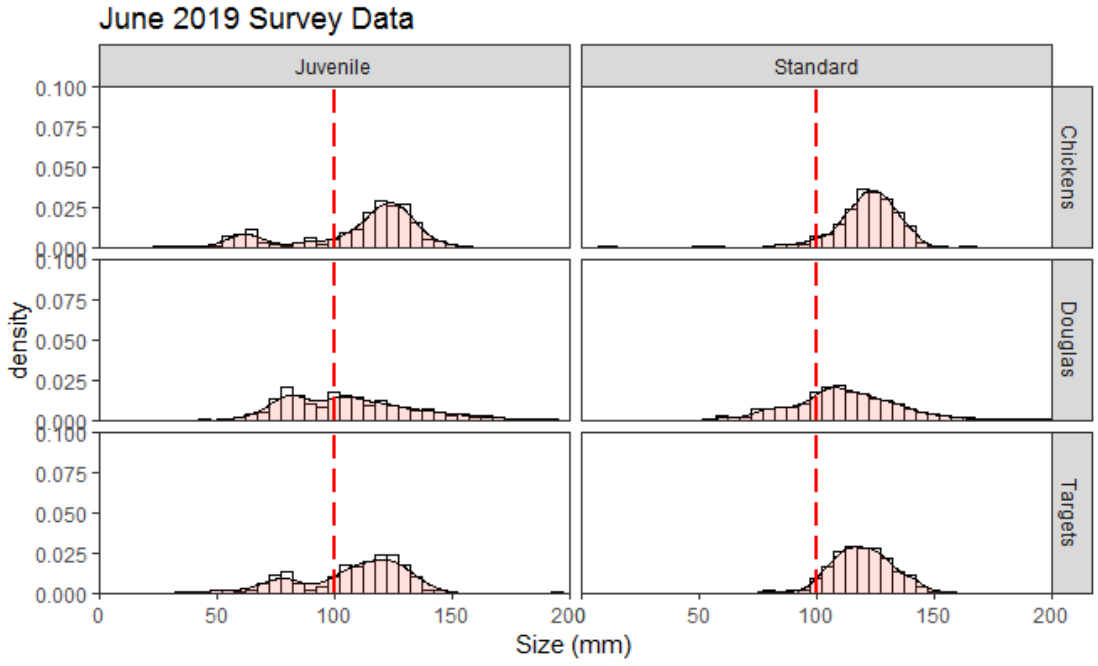

Figure 14: Density plots of size ranges of king scallops sampled during the survey and displayed by Main Fished Ground. The red dotted line indicates the estimated cut-off point of 100 mm for scallops expected to reach MLS of 110 mm by the end of the fishing season (31st May).

Estimated mean densities varied among the three grounds. Average density of king scallops under the MLS cut-off point was highest at Douglas in both dredge types. The average density of king scallops

over the MLS cut-off point was also highest for Douglas in the standard dredges and for Chickens in the juvenile dredges (Figure 15 and Figure 16).

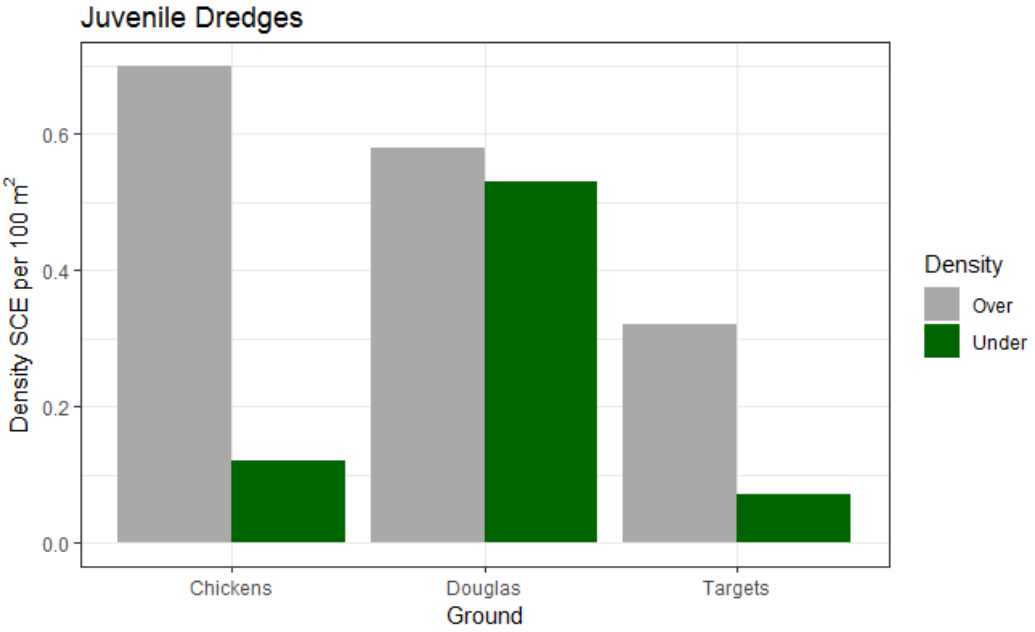

Figure 15: Density of king scallops from queen scallop dredges (standard dredges with 10 teeth and experimental dredges with 17 teeth) split into over and under the estimated cut-off point of 100 mm for scallops expected to reach MLS of 110 mm by the end of the fishing season (31st May) and displayed by Main Fished Ground (Queen Scallop Dredges Only)

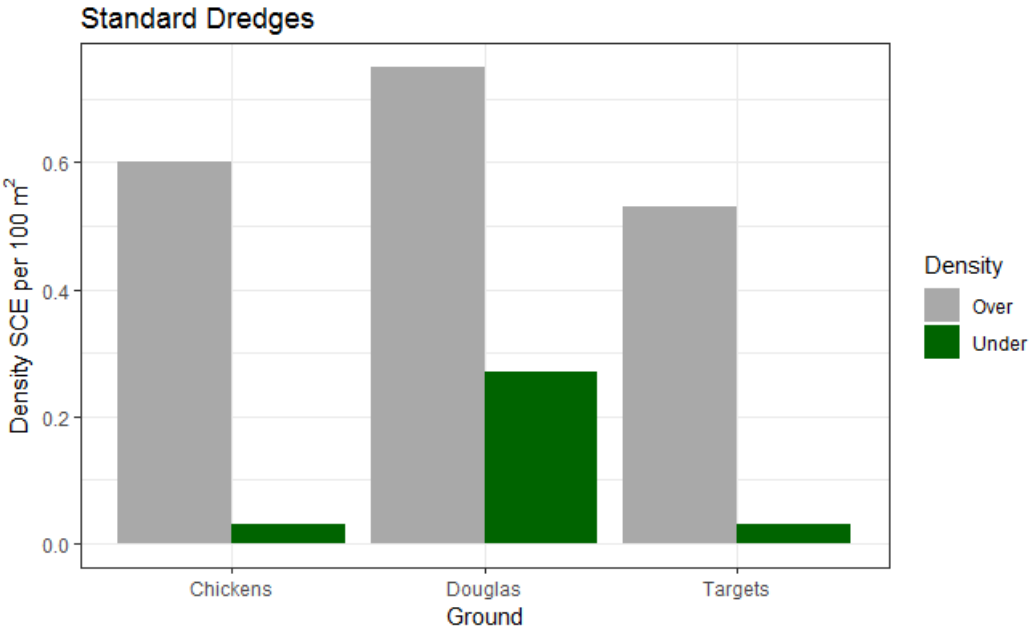

Figure 16: Density of king scallops from king scallop dredges (all standard king scallop dredges) split into over and under the estimated cut-off point of 100 mm for scallops expected to reach MLS of 110 mm by the end of the fishing season (31st May) and displayed by Main Fished Ground (King Scallop Dredges Only)

5.2.3 Density Estimates

The overall densities of king scallops (of all sizes) are displayed below for each of the three main fished grounds surveyed (Targets, Chickens and Douglas) by dredge type (i.e. SQD = standard king scallop dredges and JQD = queen scallop dredges [standard and juvenile]) (Figures 11 – 16).

Targets: The highest density of king scallops from standard dredges was recorded within the current closed area (2018/2019) within this fishing ground. The highest density from juvenile dredges was recorded in survey cell 2147.

Chickens: The highest density of king scallops from juvenile and standard dredges was recorded at an area along the 3 nm line that was identified in the April survey and the extent was further delineated as part of the survey work undertaken in June (targeted sampling of juveniles).

Douglas: The highest density of king scallops from both the juvenile and standard dredges was recorded at adjacent survey cells in the middle of the fishing ground (3997 and 3924 respectively). A 'hotspot' area of densities ~ 3-4 scallops per 100 m^2 in the juvenile dredges was also identified. It should be noted that the highest density area identified in the June 2019 survey is located in an area that was closed as part of the overall queen scallop management plan both in 2014/2015 and 2015/2016 queen scallop fishing seasons and remained closed during the king scallop fishing seasons in those years as well. The current size and age range of samples of these king scallops was around 70 mm from the juvenile dredges and ~3-4 years old from photos taken by fishermen during the fishery in this area). King scallops settling as spat in the summer of 2016, 2015 and 2014 would be 3, 4 or 5 years old respectively in the summer of 2019. However, it is unlikely these smaller scallops (mean size 70 mm) will grow into the fishery in the current year and so protection of these areas should be considered.

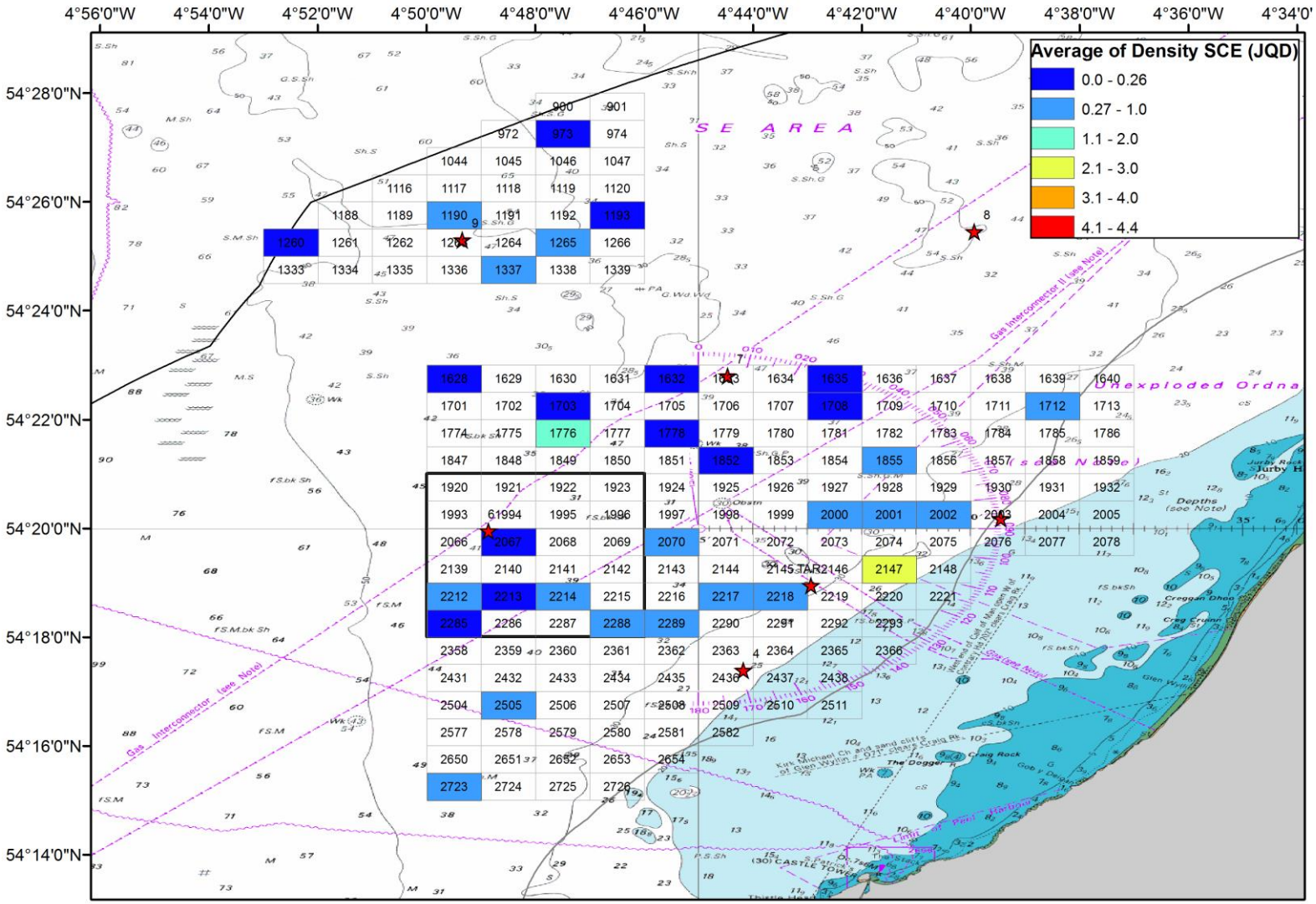

Figure 17: June survey results from Targets displaying density of king scallops (all sizes) from juvenile (10 and 17 teeth) queen scallop dredges. The black box indicates the current closed area (closed for 2017/2018 and 2018/2019 king and queen scallop fishing seasons). Red stars indicate April survey stations.

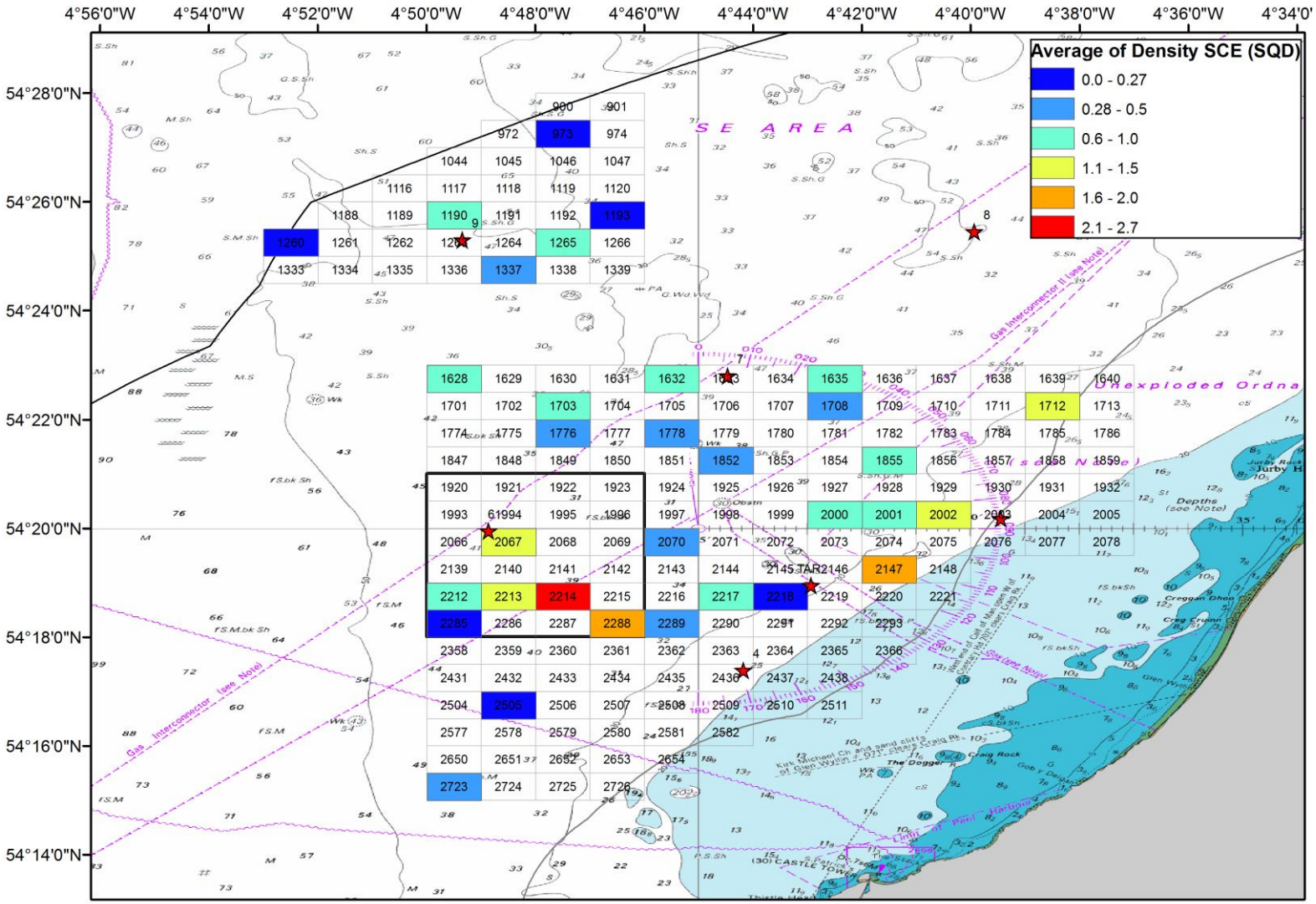

Figure 18: June survey results from Targets displaying density of king scallops (all sizes) from standard king scallop dredges. The black box indicates the current closed area (closed for 2017/2018 and 2018/2019 king and queen scallop fishing seasons). Red stars indicate April survey stations.

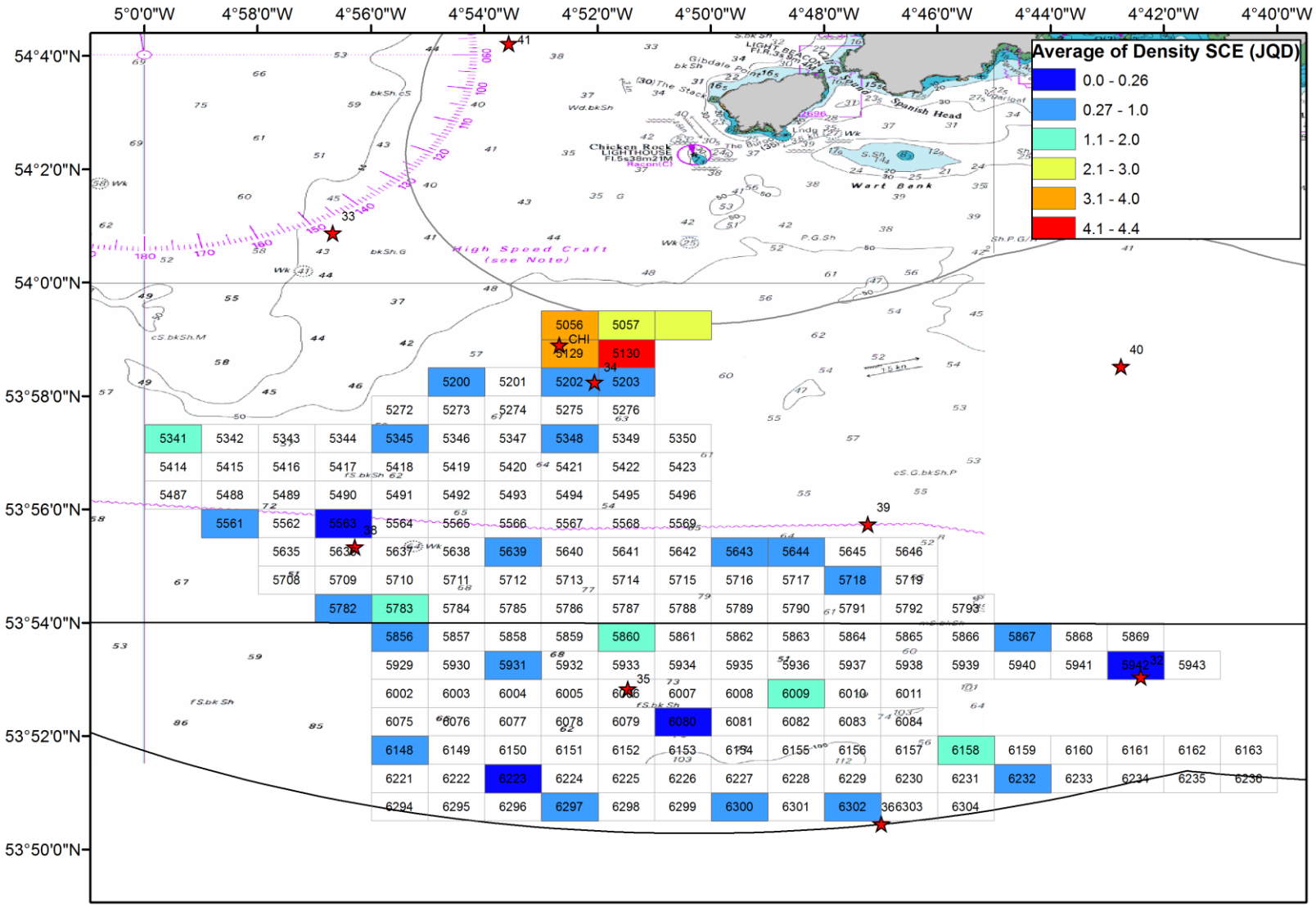

Figure 19: June survey results from Chickens displaying density of king scallops (all sizes) from juvenile (10 and 17 teeth) queen scallop dredges. Red stars indicate April survey stations.

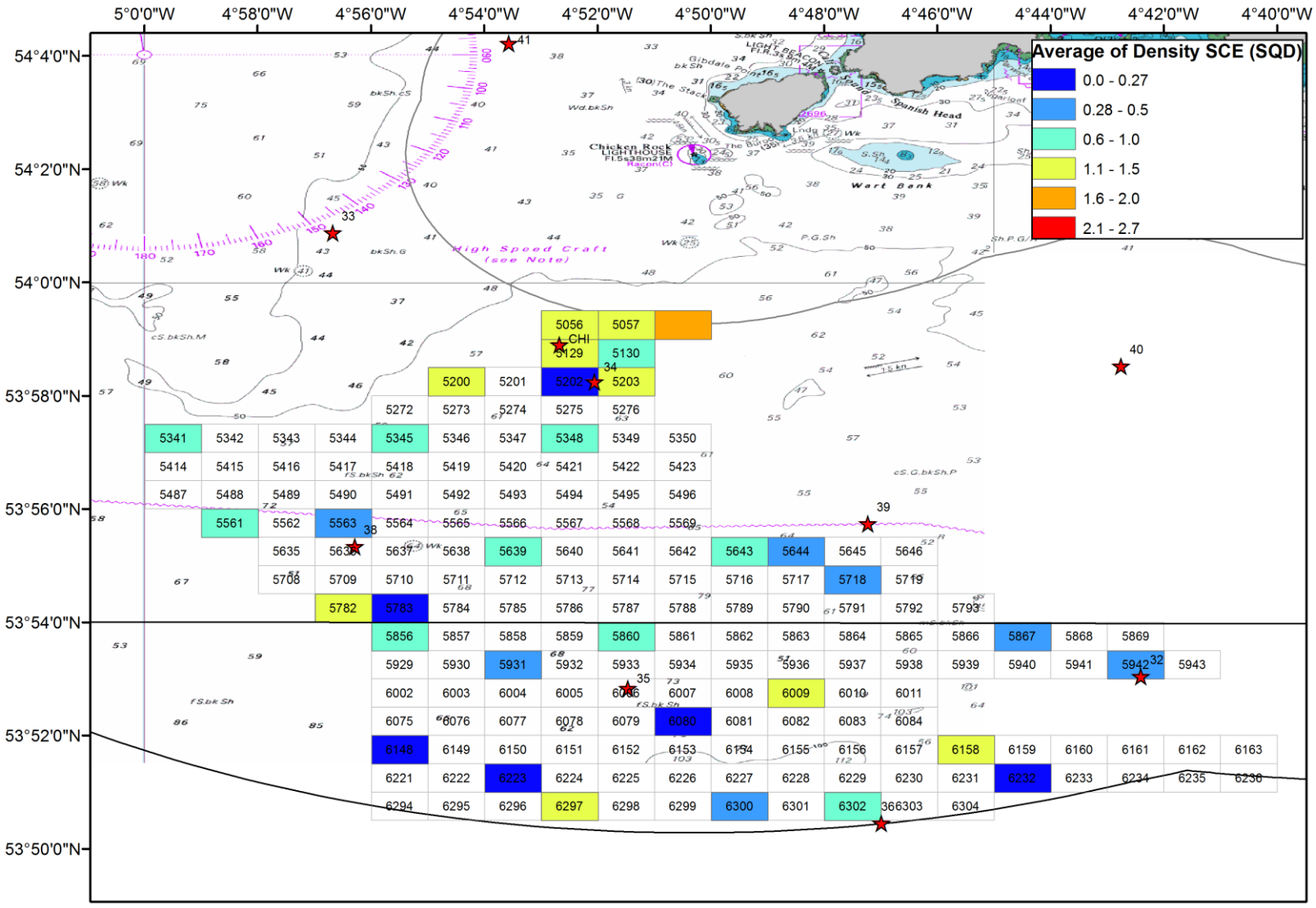

Figure 20: June survey results from Chickens displaying density of king scallops (all sizes) from standard king scallop dredges. Red stars indicate April survey stations.

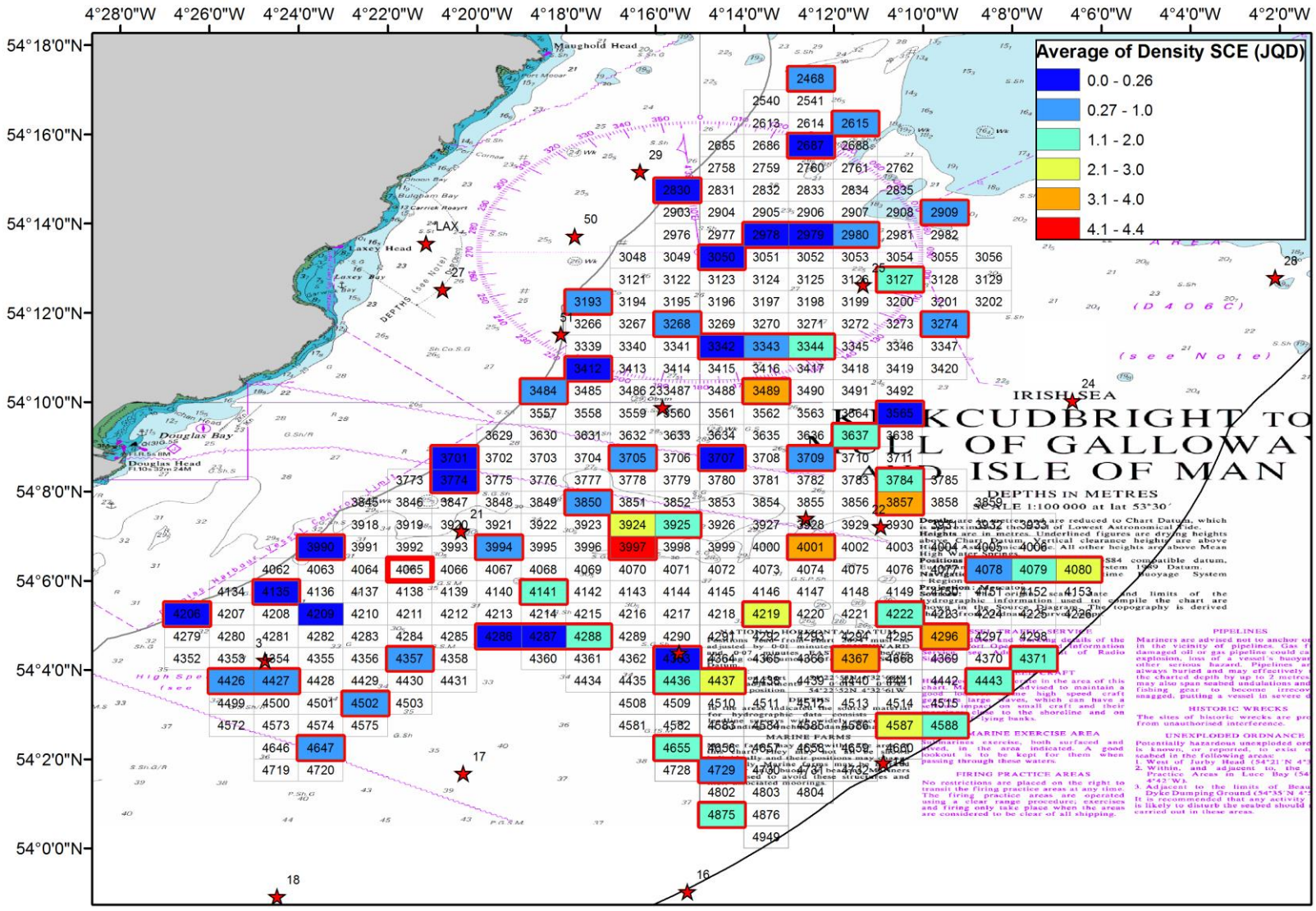

Figure 21: June survey results from Douglas displaying density of king scallops (all sizes) from juvenile (10 and 17 teeth) queen scallop dredges. Red stars indicate April survey stations.

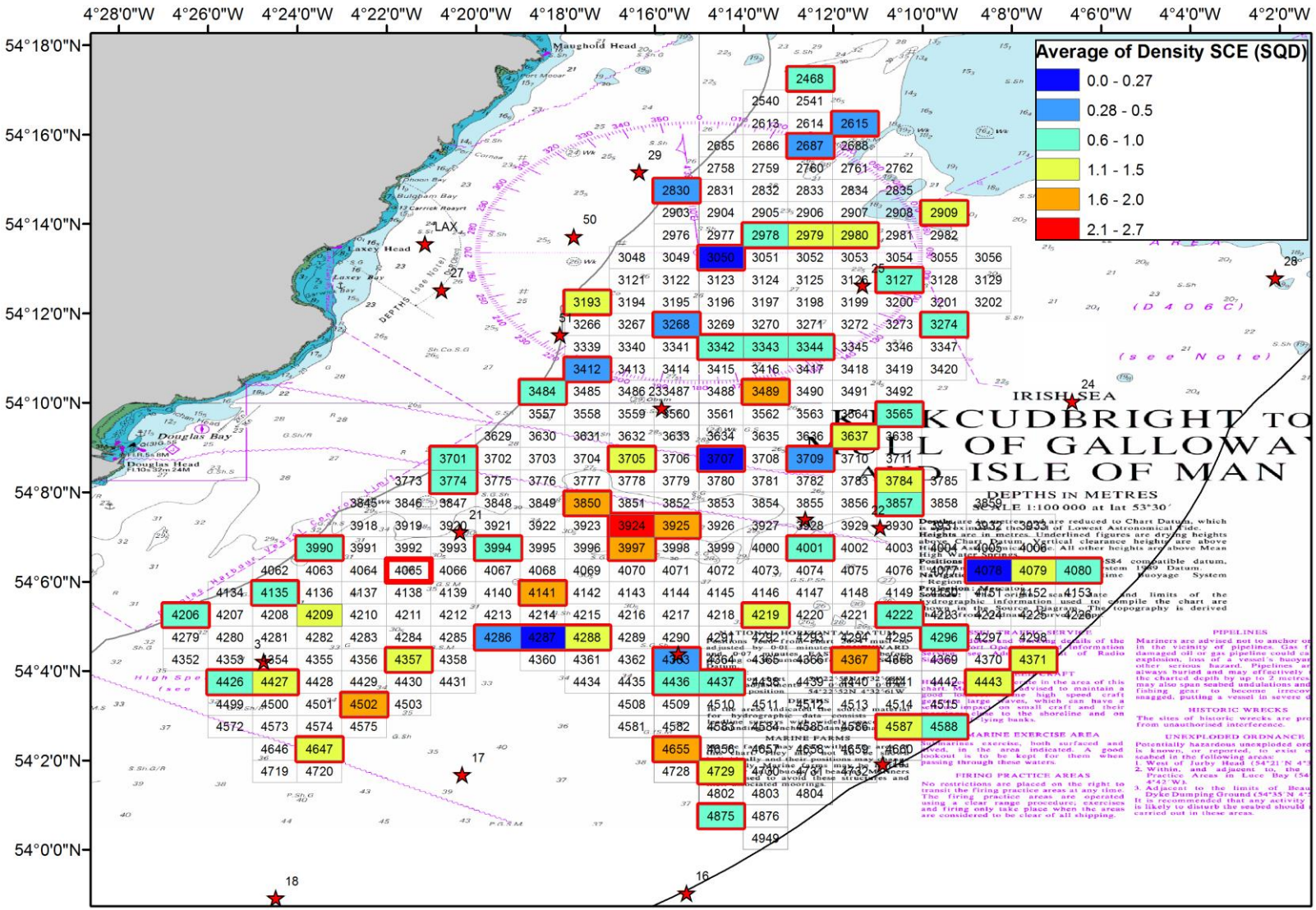

Figure 22: June survey results from Douglas displaying density of king scallops (all sizes) from standard king scallop dredges. Red stars indicate April survey station

5.2.4 Anecdotal evidence from fishermen

During the 2019 queen scallop trawl fishery there were numerous reports from fishermen of juvenile king scallops (65 – 90 mm) being caught in notable numbers in the otter trawl nets (i.e. Figure 23; Pers Comms. MFPO 2019). This corresponds to the locations in the industry survey off East of Douglas that identified large proportions of pre-recruits.

Figure 23: Small king scallops caught in queen scallop otter trawl fishery of the east coast of the Isle of Man in July by F.V. Frey.

6. TAC Calculation for 2019/2020 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 the ICES it is considered a category 3 stock (i.e. a stock for which survey-based assessments indicate trends (ICES 2012)).

The proposal that a king scallop TAC would be based on the precautionary approach outlined by ICES for Category 3 (Data-limited) stocks has been accepted by the SMB. 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.

6.2 Survey abundance index

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), 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.

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 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.

6.3 Recruits

Overall stock trends can be observed using the recruit abundance index calculated using the geometric mean (solid line; Figure 24; Figure 25) 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 2019. The recruit index (geometric mean) peaked in 2014 with subsequent year on year reductions until 2018. However, the most recent year (2019) shows a small increase in the abundance of recruits for the first time since 2014 (solid line; Figure 24; Figure 25).

Cyclical spatially specific recruitment events can be observed using the recruit abundance index calculated using the arithmetic mean (dashed line; Figure 24) 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).

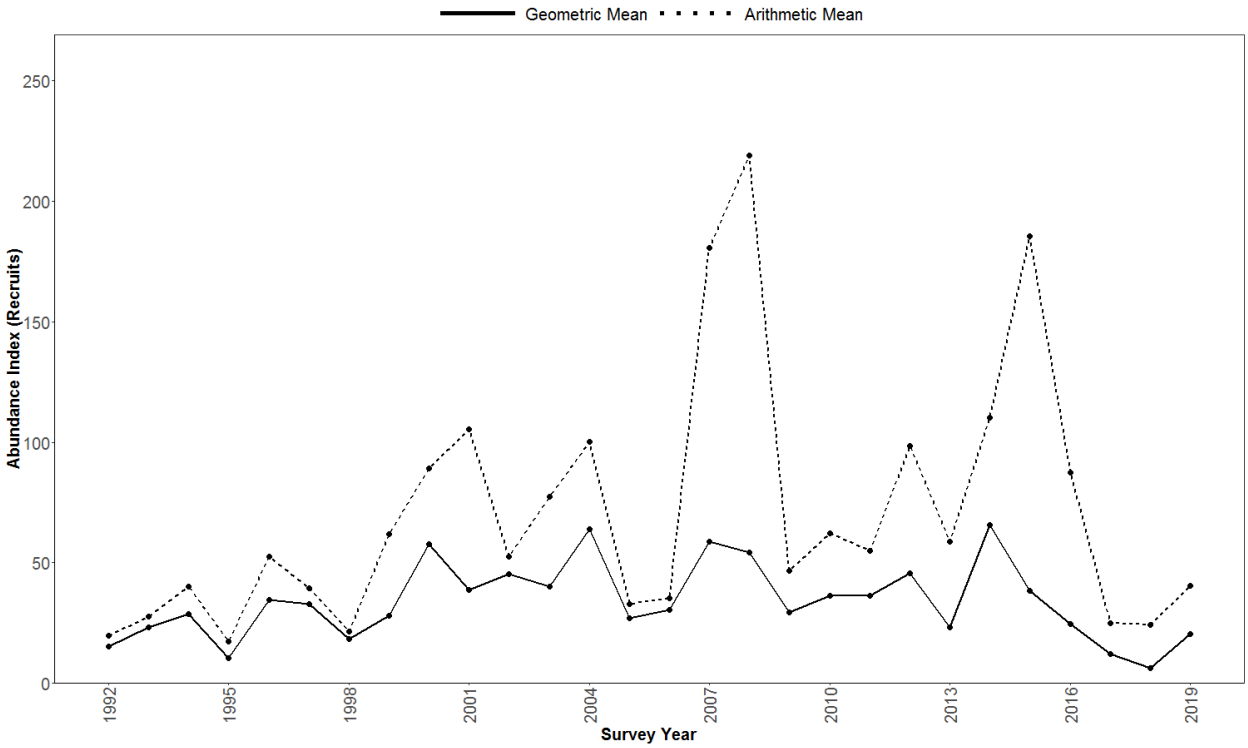

Figure 24: Recruit abundance index (scallops < 95 mm). Calculated based on length-based data where recruits were categorised as scallops under 95 mm at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. final day of 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.

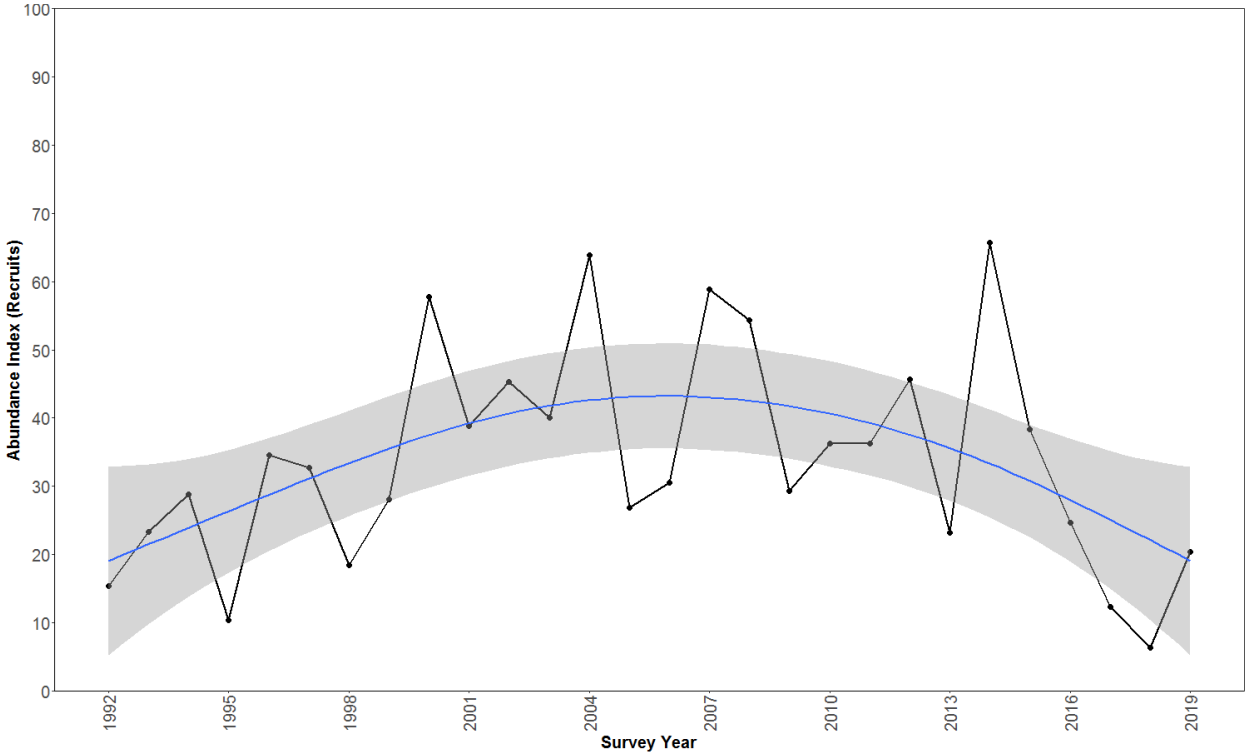

Figure 25: Recruit abundance index (scallops < 95 mm). Calculated based on length-based data where recruits were categorised as scallops under 95 mm at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. final day of the following season). The index is displayed here using calculation of the Geometric mean (solid line) for general stock trends only. A geometric smooth (methods = "loess") with confidence bands (0.95) is also displayed to indicate the general trends of the index. The data is sourced from the April scallop survey using data from queen scallop dredges only.

6.4 Post-Recruits

Overall stock trends for post recruits can be observed using the abundance index calculated using the geometric mean (solid line Figure 26 and Figure 27) which shows a general increasing trend in the mean abundance of post recruits (scallops ≥ 95 mm) from 1992 to 2015 and a general decreasing trend from 2015 to 2019. The mean abundance of post-recruits (scallops ≥ 95 mm) reached the highest levels on record in 2015, decreasing annually every year since (solid line Figure 26 and Figure 27).

The recent low levels observed in the recruitment index together with increasing fishing pressure on post-recruits is likely to explain, at least in part, the recent decline in the post-recruit index, as the rate of removal of adult king scallops from the stock, as a result of high fishing effort, exceeds stock replacement by recruits. The current knowledge of spat distribution and settlement indicates a strong link between the Irish Sea king scallop stocks and those in the Isle of Man's territorial sea. Thus the significant increase in fishing effort across the wider Irish Sea (Area VIIa) and not just within the locality of 36E5, 37E5 and 38E5 could be impacting recruitment within the Isle of Man's territorial sea.

Cyclical spatially specific recruitment events can be observed using the recruit abundance index calculated using the arithmetic mean (dashed line Figure 26) 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 2009 and 2016 which tally with large recruitment events observed in the recruit index the year prior (Figure 24 and Figure 26) at both Chickens (south coast) and Targets (west coast).

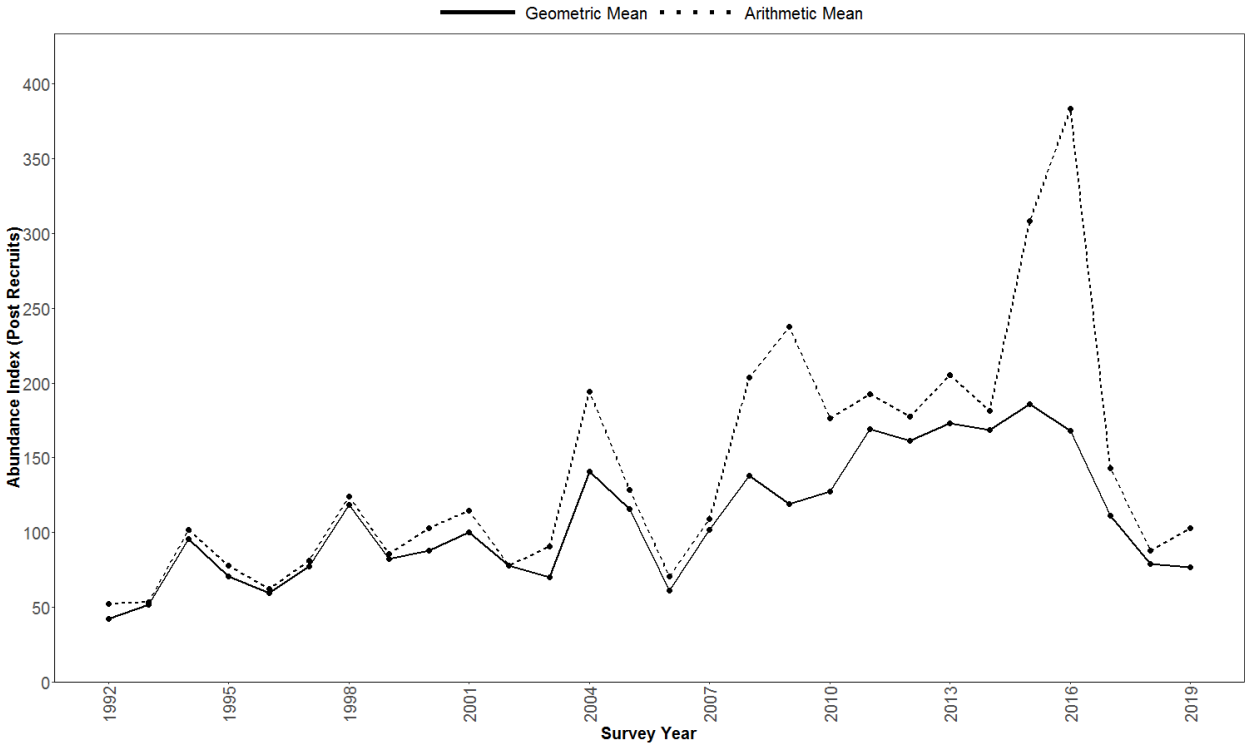

Figure 26: Post recruit abundance index (scallops ≥ 95 mm). Calculated based on length-based data where post recruits were categorised as scallops 95 mm or above at the time of the spring survey (generally April) which would typically be considered too small to grow into the fishery by 31st May (i.e. 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.

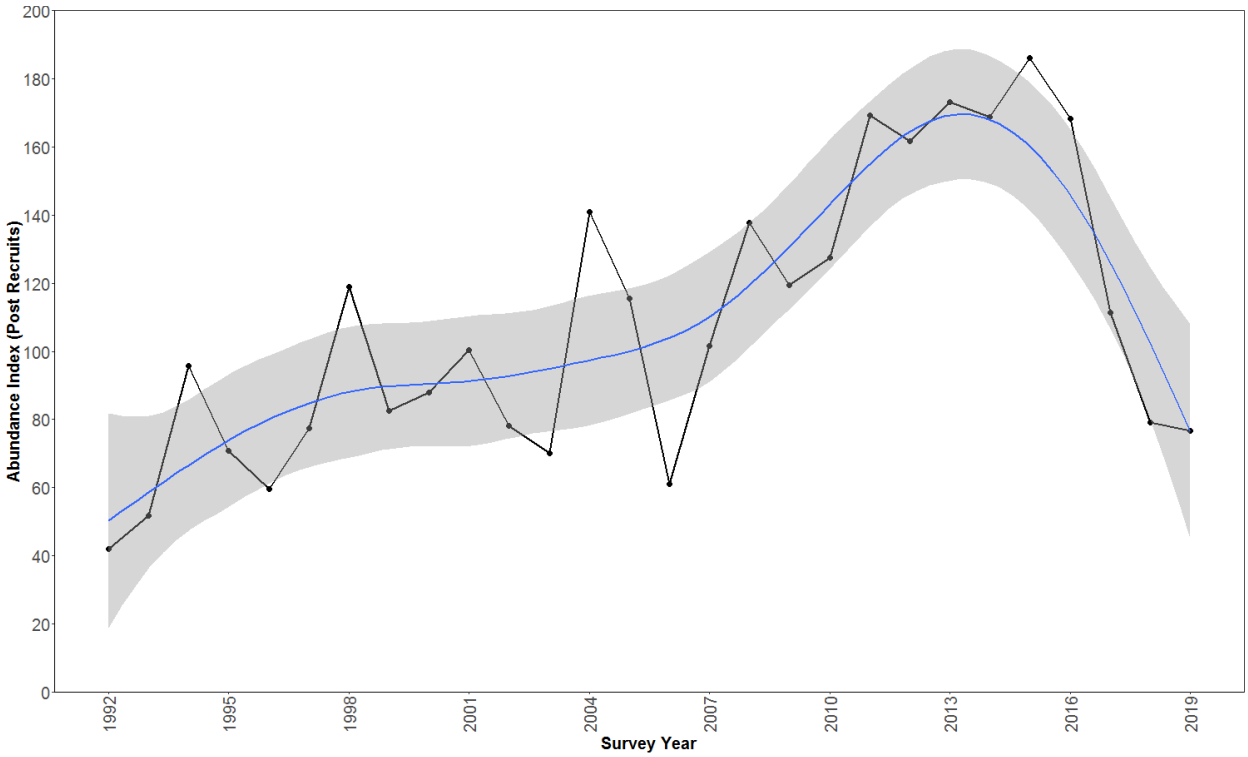

Figure 27: Post recruit abundance index (scallops ≥ 95 mm). Calculated based on length-based data where post recruits were categorised as scallops 95 mm or above at the time of the spring survey (generally April) which would typically be considered of size to grow into the fishery by 31st May (i.e. final day of the current season). The index is displayed here using calculation of the Geometric mean (solid line) for general stock trends only. A geometric smooth (methods = "loess") with confidence bands (0.95) is also displayed to indicate the general trends of the index. The data is sourced from the April scallop survey using data from queen scallop dredges only.

6.5 All

Overall stock trends for all scallops (regardless of size) can be observed using an abundance index calculated using the geometric mean (solid line Figure 28 and Figure 29) which shows a general increasing trend in the mean total abundance of scallops from 1992 to 2014 and a general decreasing trend from 2014 to 2019. The mean abundance of all scallops (geometric mean) peaked in 2015 with subsequent year on year reductions until 2018. However, the most recent year (2019) shows a small increase in the total abundance of scallops for the first time since 2015 (solid line Figure 28and Figure 29).

The total abundance index calculated using the arithmetic mean (dashed line Figure 28) shows peaks in 2008 and 2015/2016 which tally with large recruitment events and high density fisheries at Targets (west coast).

It is important to note the positive aspect of the current increase in the total abundance index for 2019. However, it is equally important to emphasise that in order to maintain and build upon these increases in abundance it is important to continue to use the precautionary approach and in addition to ensure areas of pre-recruits are adequately protected for harvesting in the fishery in future years.

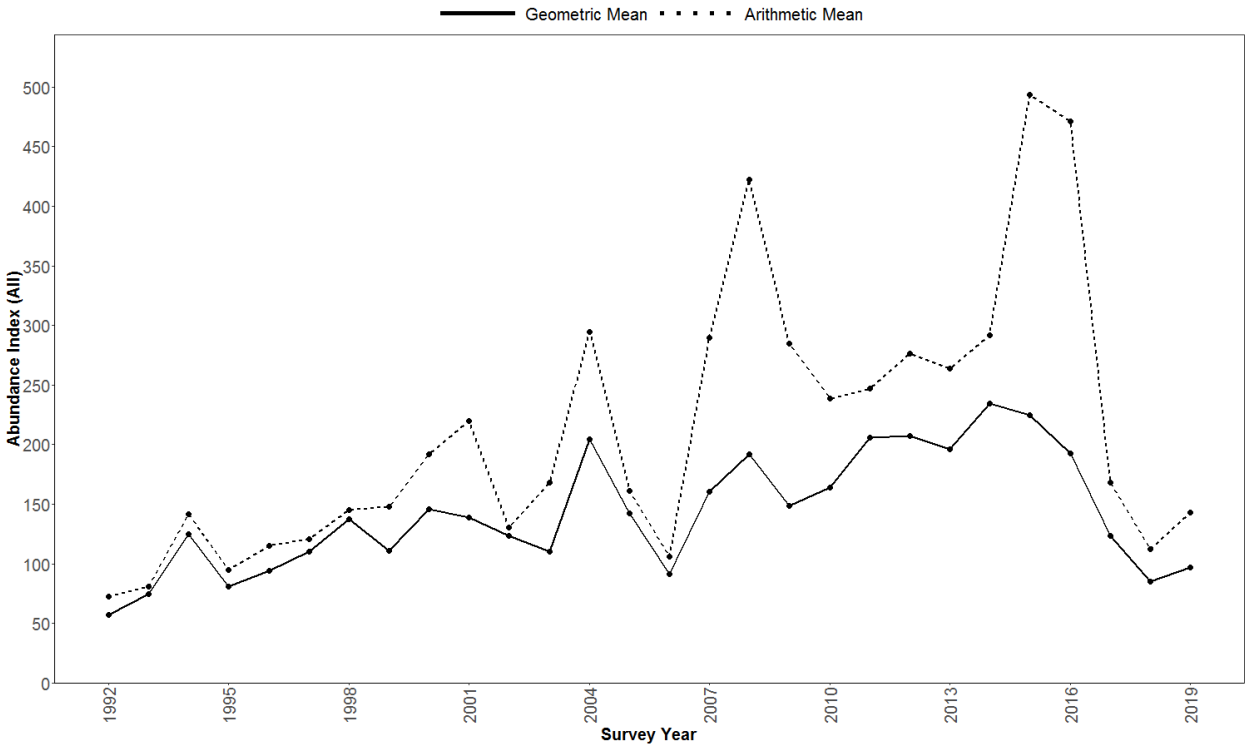

Figure 28: Total scallops abundance index. Calculated based on length-based data including scallops of all sizes in a single index. These scallops may or may not grow into the fishery by 31st May (i.e. final day of the current season). The index is displayed using calculation of both the Geometric mean (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.

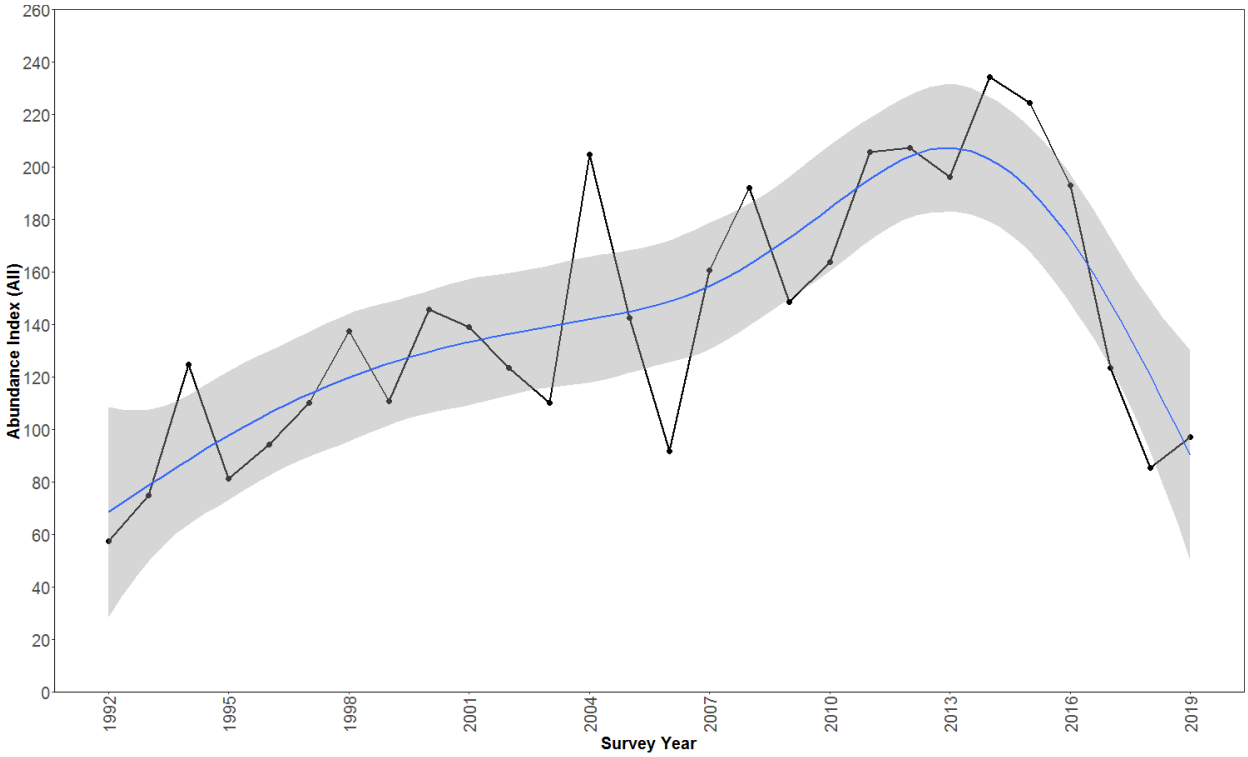

Figure 29: Total scallops abundance index. Calculated based on length-based data including scallops of all sizes in a single index. These scallops may or may not grow into the fishery by 31st May (i.e. final day of the current season). The index is displayed here using calculation of the Geometric mean (solid line) for general stock trends only. A geometric smooth (methods = "loess") with confidence bands (0.95) is also displayed to indicate the general trends of the index. The data is sourced from the April scallop survey using data from queen scallop dredges only.

The boxplot below indicates the average density from the historical sites surveyed in each year of the survey (Figure 30). The average values for the territorial sea remain fairly constant at around 1 -2 scallops per 100 m^2. However, in years where isolated high-density patches of recruitment occur, anomalies are indicated as black points (Figure 30). Typically anomalies over 10 scallops per 100 m^2 only occur at CHI (south coast) or TAR (west coast). In these years densities in these areas are very high and as such may need to be managed differently from the rest of the fishery.

These recruitment patterns can be looked at in more detail if the data is split spatially into individual grounds. Figure 31 shows the higher levels of recruitment that are observed in some years at Chickens (South) (i.e. 2004, 2009 and 2016 abundance index all over 500) and Targets (West) (i.e. 2008 and 2015/2016 abundance index all ~ 2000). Peaks in abundance are also observed at the other main fishing grounds but in these cases the abundance index always remains below 400 (Figure 31).

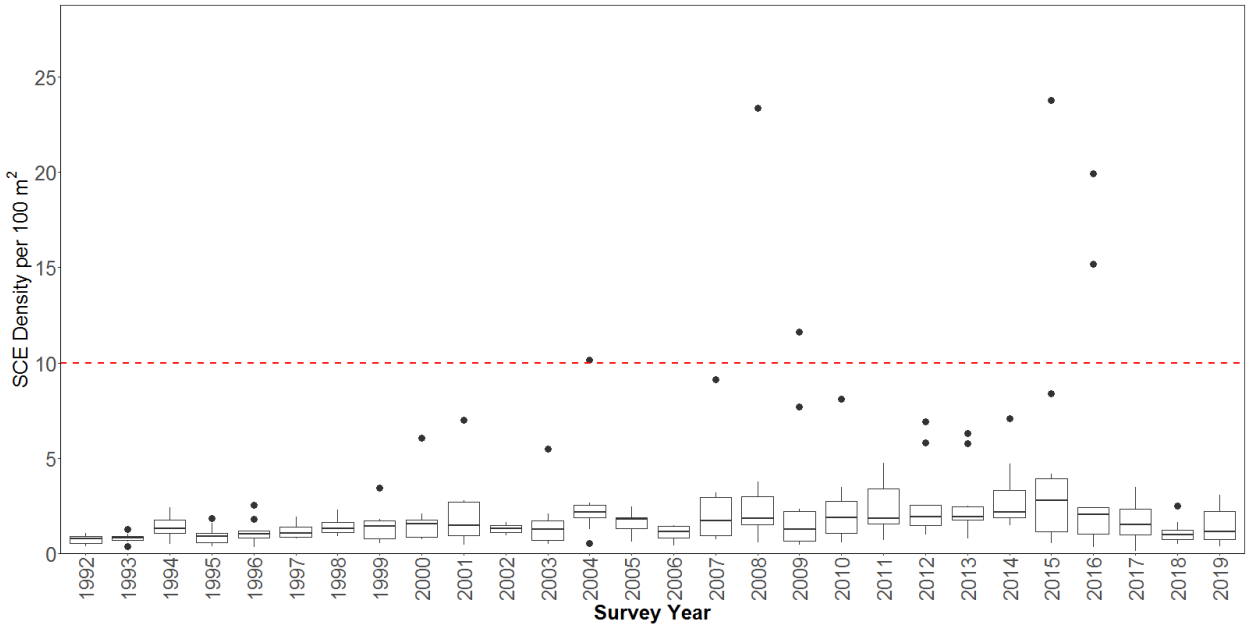

Figure 30: Boxplot of total scallop density per 100 m^2 (includes all scallops regardless of size) for each of the ten historical stations that were surveyed within a year. Outliers over 10 (which appear as black points above the red dashed line) are exceptional years of recruitment/post-recruits to Chickens or Targets for which management may need to be considered separately to the rest of the stock.

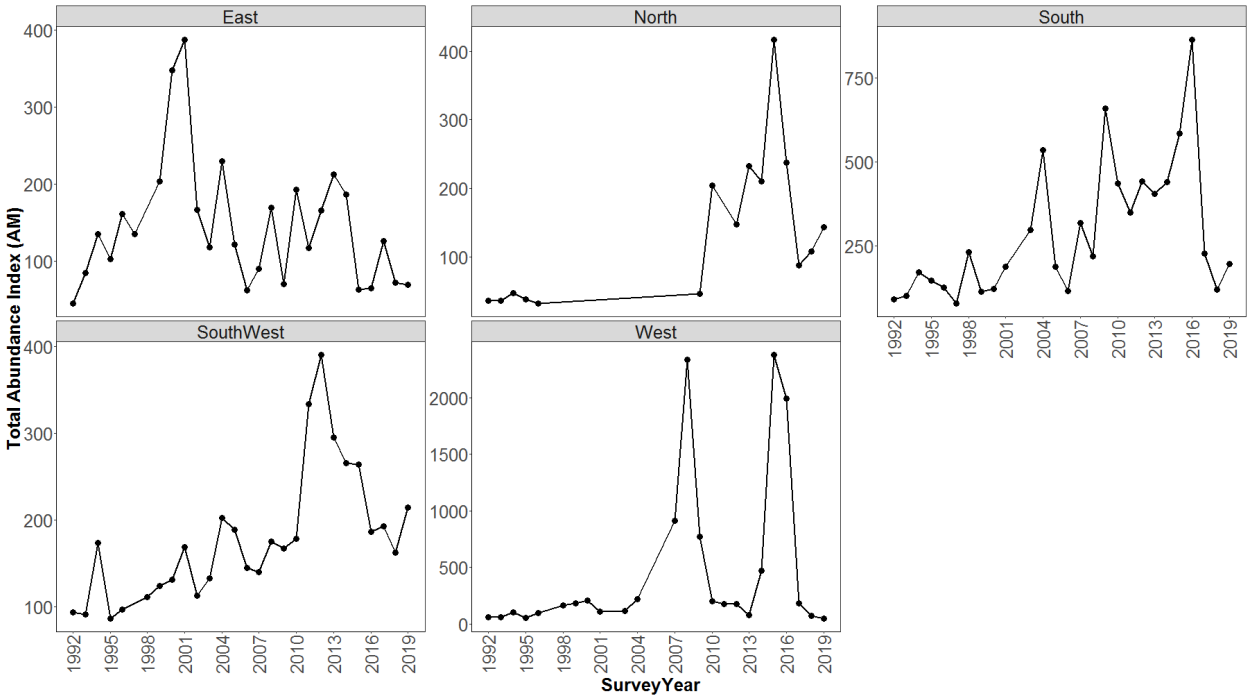

Figure 31: Total scallops abundance index for ten historical stations displayed separately by main fished ground. Calculated based on length-based data including scallops of all sizes in a single index. These scallops may or may not grow into the fishery by 31st May (i.e. final day of the current season). The index is displayed here using calculation of the Arithmetic mean for visually assessing spatially specific cyclical recruitment events. The data is sourced from the April scallop survey using data from queen scallop dredges only. East = SED, EDG and LAX; North = POA; South = CHI and PSM; SouthWest = PEL, BRI and BRO and West = TAR. *Please note: The y-axis scales differ for South and West, in addition TAR (North) was not sampled between 1997 and 2009 inclusive.*

6.6 TAC Calculation

Table 1: Abundance Index values for 2014 to 2018 from the annual spring scallop survey.

Survey Year	Abundance Index Value
2015	224
2016	193
2017	124
2018	85
2019	97

- Index A (average 2018 – 2019) = 91; Index B (average 2015 – 2017) = 180; Index Ratio = -49 %
- Due to the ratio change of – 49% being greater than 20% then the uncertainty cap is applied and thus the inter annual change in TAC is capped at reduction of 20%.

6.6.1 Previous catch advice

The TAC for 2018/2019 was 2562 t of which only 1833.24 t was landed (~ 72 %).

6.6.2 TAC calculation and catch advice

Two scenarios are presented for consideration:

Scenario 1: Using the data and methods outlined in the previous sections, the provisional catch advice for 2019/2020 is calculated as 2049 t based on a 20% reduction in the previous year's TAC (Scenario I; Table 2).

Scenario 2: Given that only 72% of the 2018/2019 TAC was achieved, the TAC calculated in Scenario I is **still above the total landings from last season** of 1833.24 t. If, instead of basing the proposed TAC on a reduction of last season's TAC, it is based on a reduction of 20% of actual landings, then a TAC of 1466 t is reached (Scenario II; Table 2). An additional precautionary buffer has not been applied for the TAC calculations for 2019/2020 as the recruitment index has increased from the year prior.

For the 2019/2020 season a total of 83 vessels from the Isle of Man, Wales, Scotland, England and Northern Ireland have active licences to fish for king scallops in the Isle of Man's territorial sea 3- 12 nm limit and of those 38 vessels also have permits to fish for king scallops within the 0- 3 nm limit.

Table 2: Calculations and catch advice for the Isle of Man king scallop fishery using the ICES methodology outlined for a Category 3 stock (Method 3.2). Index A is the average of the last two year's survey abundance indices (2018 – 2019); Index B is the average of the three preceding year's survey abundance indices (2015 – 2017); Index Ratio is a ratio of Index A divided by Index B. Survey indices can contain a level of noise within the data, as such a +/- 20% cap (Uncertainty Cap) on inter annual changes to the TAC from the Index Ratio is advised (ICES, 2012). These methods are designed to be precautionary and so where there is uncertainty due to a deficiency of information (i.e. stock status relative to references points or exploitation is unknown) a 'Precautionary Buffer' of a 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).

	I	**II**
Index A (2018 - 2019)	91	91
Index B (2015 – 2017)	180	180
Index Ratio (A/B)	0.49	0.49
Uncertainty cap	0.80	0.80
TAC from 2018/2019 season	2562	1833
Discard rate	-	-
Precautionary buffer	NA	NA
Catch advice for 2019/2020**	2049	1466

*** For Scenario II: only 72% of the TAC for 2018/2019 was achieved. Therefore Scenario II: (actual landings for 2018/2019 x Uncertainty Cap)*

7. Spatial Management and Stock Advice/Assessment

With increased data collection and improved knowledge of the fine-scale spatial variability around the territorial sea in growth rates (as a result of different frontal systems), recruitment variability, isolated small-scale hotspots and fishing intensity the need to assess and manage the Isle of Man king scallop fishery at a finer spatial scale is becoming increasingly apparent.

By combining knowledge of spatial variation in growth rates, recruitment variability and fishing effort, a number of discrete fishing grounds can be identified. These include four offshore (3 – 12 nm) fishing grounds: POA (1), EDG (3), CHI (4) and TAR (6) and four inshore (0 – 3 nm) fishing grounds: RAM (2), BRA (5), CHI inshore (4) and EDG inshore (3) (Figure 32).

A transfer to such a spatial assessment and management process would require current data collection, management and enforcement requirements to be reviewed.

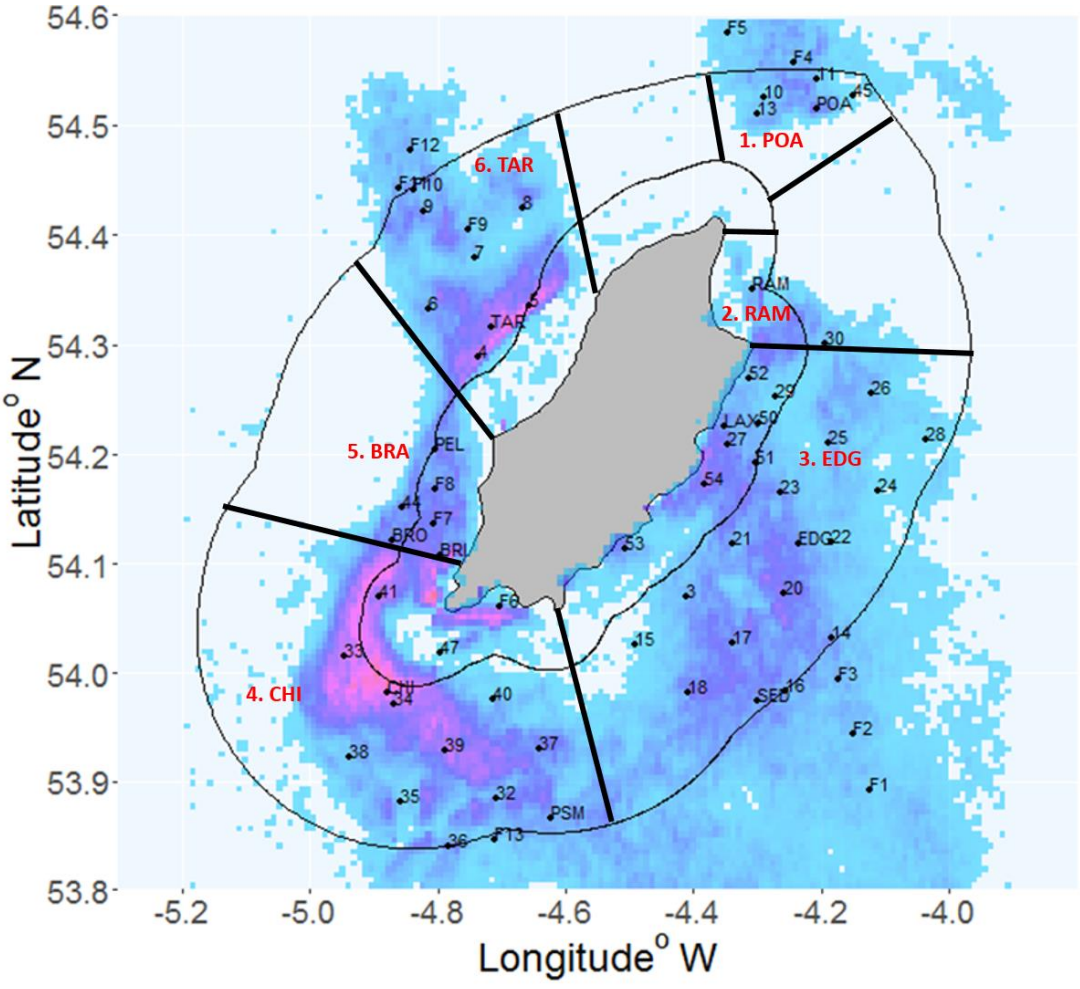

Figure 32: An example of how the main fished grounds might be split for future management and assessment purposes of king scallops in the Isle of Man territorial sea. The black lines demarcate the 6 main grounds identified which are labelled and numbered in red. The underlying heat map indicates estimated fishing time from VMS points from 2010 to 2019 at fishing speed (2.5 – 3.5 knots) for vessel trips with associated landings of king scallops during the king scallop fishing season (i.e. 1st Nov – 31st May). Lighter blue colours indicate low fishing time and darker pink areas indicate higher fishing time.

8. Recommendations

8.1 Territorial Sea Management

- A TAC of 2049 t for the 2019/2020 Isle of Man king scallop fishery was calculated based on the ICES protocol for Category 3 approach using Method 3.2 (Scenario 1- a 20 % reduction of the 2018/2019 TAC ≈2049t). Total landings from 2018/2019 were however ~28% lower than the original TAC (i.e. 1883 t landed from 2562 t TAC), leading to Scenario 2 (a 20 % reduction of actual landings from the 2018/2019 season ≈ 1446t). It is recommended that in setting a TAC for the forthcoming season there is a discussion of the merits of Scenario 1 versus Scenario 2. This discussion should recognise that Scenario 1 will set a TAC which is higher than total landings from the previous season.
    - Protection of areas surveyed in the April and June survey that recorded large proportions of pre-recruit (i.e. less than 95 or 100 mm respectively) should be considered ahead of the fishing season in order to protect stock for future years.
    - A review of the fishery to be undertaken by the SMB following the first month of the season to review the fishery dependent data collected (i.e. LPUE, Spatial distribution of landings, proportion of vessels meeting daily quota etc.).

8.2 Industry Surveys

- The fine-scale industry survey undertaken in June helps both corroborate the April survey data and provide additional useful information and should be continued on an annual basis.
- A robust funding source and process should be put into place to ensure that fine-scale industry scallop surveys are able to be undertaken each year.
- Prior to the 2020 survey, knowledge from the survey skippers should be used to remove unsuitable habitats etc. from within the current survey extent. The fourth main fished ground at Point of Ayre should also be included in any future surveys (Ramsey is surveyed independently by the MFPO). Survey methods and analysis will also be reviewed for optimisation going forward.
- In addition to the core survey area within each of the main fishing grounds a proportion of additional survey time should be allocated to each ground to a) allow refinement of the extent of hotspots of adults and juveniles which is useful in the context of spatial management goals (see Section 8.3); b) explore additional survey cells in traditionally unfished areas.

8.3 Spatial Management and Assessment

- Spatial management and assessment of king scallops should be developed and considered for future years. As part of this, a literature review and meta-analysis will be undertaken to review spatial management examples from both scallop fisheries and other sessile aggregating species to look at potential options, data analysis and management methods for spatial management in the 2020 fishery based on all available data. This will include ascertaining options for managing high densities of either juvenile (“protected areas”) or adults (“Fishery Hotspot areas”). This review will be produced by Bangor University staff by January 2020.

8.4 Irish Sea Management

- The Irish Sea king scallop fishery should be managed at the appropriate spatial scale. Unpublished genetic and oceanographic research indicates that the northern Irish Sea may be the most appropriate management unit for the fishery surrounding the Isle of Man. It is therefore vital that work continues towards achieving a collaborative management approach for king scallop stocks within the different regions of the Irish Sea.

9. References

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