Assessment of Queen Scallop stock status for the Isle of Man territorial sea 2019/2020

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Preface:

Queen Scallops within the Isle of Man's territorial sea support the second most valuable commercial fishery in the region. The stocks are internationally exploited primarily by Manx and UK vessels using otter trawls with a small number of vessels continuing to use towed dredges. These fisheries are not governed by EU quotas but are subject to national TACs and the stocks have been routinely monitored and formally assessed since 2013.

This report describes the assessment of the status of the queen scallop stock within the Isle of Man's territorial sea in 2019 by Bangor University and is intended to provide guidance to the fishing industry and the Isle of Man Government.

1. Fishery:

A fishery for queen scallops, *Aequipecten opercularis*, has been prosecuted in and around the Isle of Man's territorial sea since the 1950s. Inside the territorial sea Manx vessels now fish exclusively for queen scallops (QSC) with otter trawls, while UK vessels continue to use both otter trawls and toothless dredges. The fishery within the territorial sea is regulated by several management measures. For the 2018 fishing season these included:

- Two closed areas where fishing for king and queen scallops was prohibited (Figure 4).
- Queenie conservation zones where dredging for queen scallops was prohibited.
- Spawning protection closure (1st April to 31st May)
- Voluntary Irish Sea closure (1st April to 30th June)
- Weekend ban
- Daily curfew (06:00 – 18:00)
- Weekly catch limits for trawl fishery (maximum of 2695 kg)
- Individual quotas for dredge fishery (16166 kg per vessel)
- Minimum landing size (55 mm)
- Limited TAC of 794 t (split: 697 t trawl fishery and 97 t dredge fishery)

These management measures were covered by the Fisheries Act 2012 and through restrictive licencing conditions.

The 2018 Isle of Man queen scallop fishery had a total allowable catch (TAC) of 794 t which represented a 20 % reduction in the quota following a decline in the 2018 survey abundance index. The TAC was fished by two separate metiers: Trawl fishery (41 eligible vessels) and dredge fishery (6 eligible vessels).

The trawl fishery had a sub TAC of 697 t and opened on 2nd July 2018 and closed on 15th October 2018. For the trawl fishery a weekly catch limit of 2695 kg was implemented. An allocation of 25 t was ring fenced for the Ramsey Bay permit only fishery. Total reported landings for the trawl fishery during the 2018 fishing season were ~ 659.39 t with 30 unique vessels reporting landings.

Average weekly landings per unit effort, standardised to kg per hour fished per fathom of net, is displayed for each of the main fishing grounds in Figure 1. The fishery on the west coast in IS9 occurred within a small ground at the very western edge of the 12 nm limit. Average weekly LPUE varied between 3.1 and 46.8 kg per fished hour per net fathom in the open fished areas and averaged 50.0 kg per fished hour per net fathom in the Ramsey Bay permit only fishery. LPUE decreased across the season at all main fishing grounds except for IS10: Ramsey Bay (which was a 1 week limited access fishery) and Chickens where LPUE was similar at the start and end of the season (33.9 kg Week 28 and 35.8 kg Week 42).

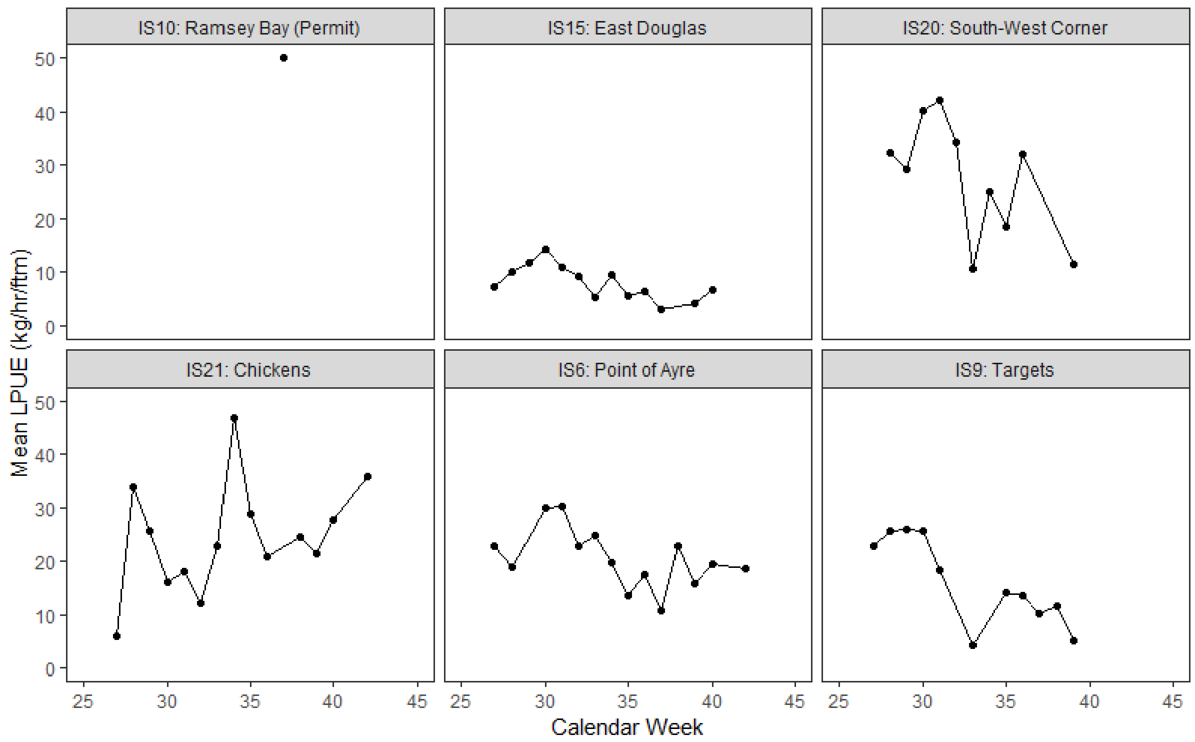

Figure 1: Landings per unit effort (kg per hour fished per net fathom) for the 2018 Isle of Man queen scallop trawl fishery displayed as an average for each week by Main Fished Ground. Data source: DEFA Daily Catch Return Forms.

For the 2018 queen scallop trawl fishery there was a relatively even spatial split of landings between the four main fishing grounds (IS9: Targets; IS6: Point of Ayre; IS21: Chickens; IS15: East of Douglas; Figure 2). In previous years landings have been predominately from a single ground (i.e. IS15 East Douglas in 2017 and IS9: Targets in 2016 and 2015).

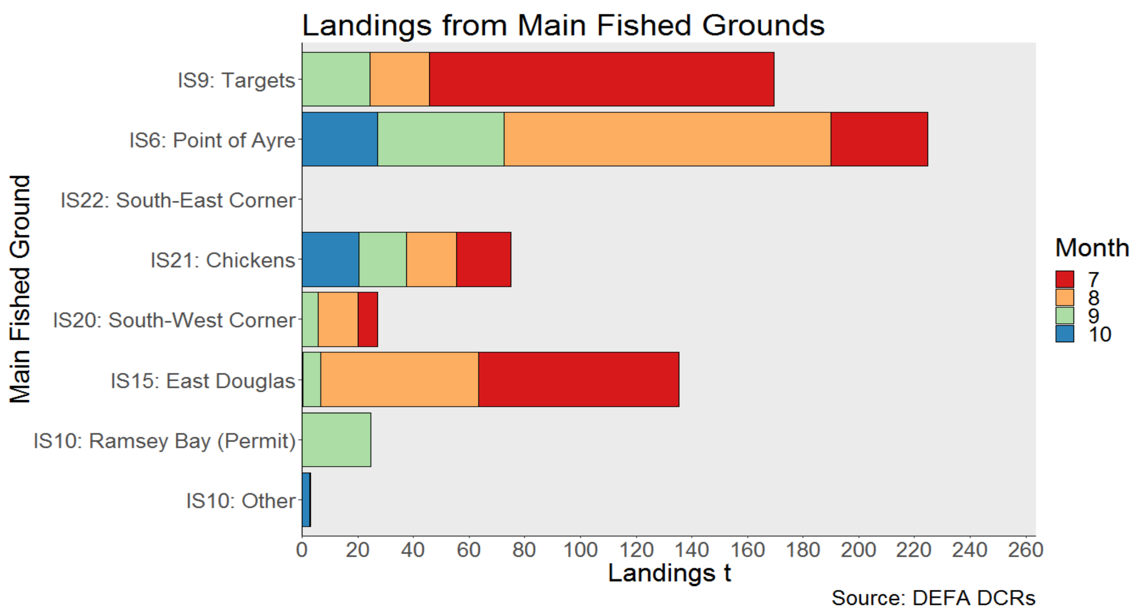

Figure 2: Spatial distribution of queen scallop trawl landings from the Isle of Man's territorial sea (2018). Data source: DEFA Daily Catch Return Forms.

The median LPUE (kg per hour fished per net fathom) from the 2018 fishery was lower than for the 2017 fishery (Figure 3).

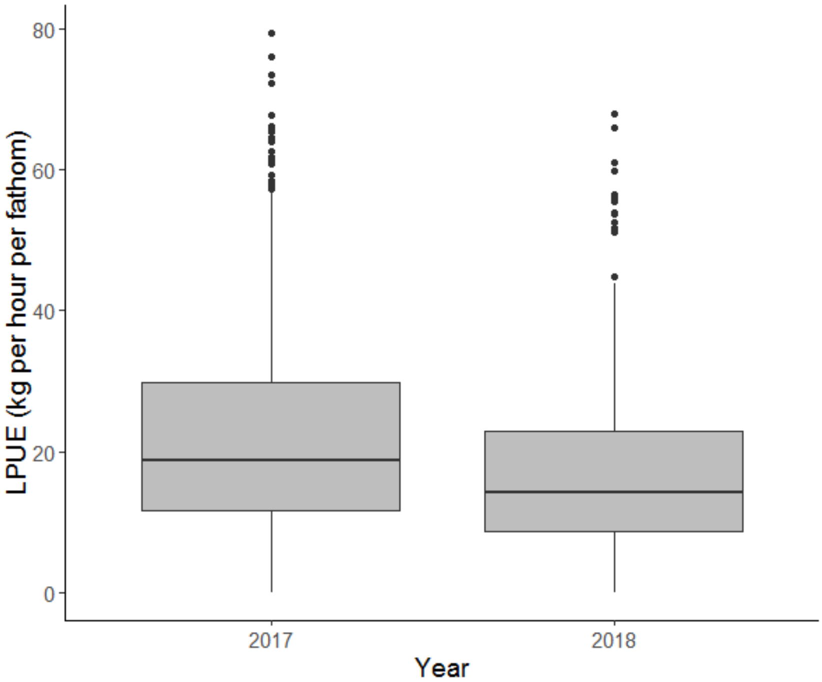

Figure 3: Boxplot of LPUE (kg per hour fished per net fathom) for 2017 and 2018 queen scallop trawl fishery. Data source: DEFA Daily Catch Return Forms.

The dredge fishery had a sub TAC of 97 t and opened on 1st October 2018 and remained open until 31st March 2019. For the dredge fishery each eligible vessel was allocated an individual quota of 16166 kg which could be fished as and when suited by the vessel (before 31st March 2019). Total reported landings for the dredge fishery during the 2018/2019 season were ~ 62.6 t with 4 unique vessels reporting landings.

Outside of the territorial sea although a minimum landing size of 40 mm is enforced, the fishery is subject to very few additional management measures. Industry have however implemented voluntary closures in 2016 (May) and 2017 (April, May & June) in ICES areas VIa and VIIa during one of the spawning periods. For 2018, the 3 month closure (April, May and June) became statutory for ICES areas VIa and VIIa.

2. Survey:

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 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 4). 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).

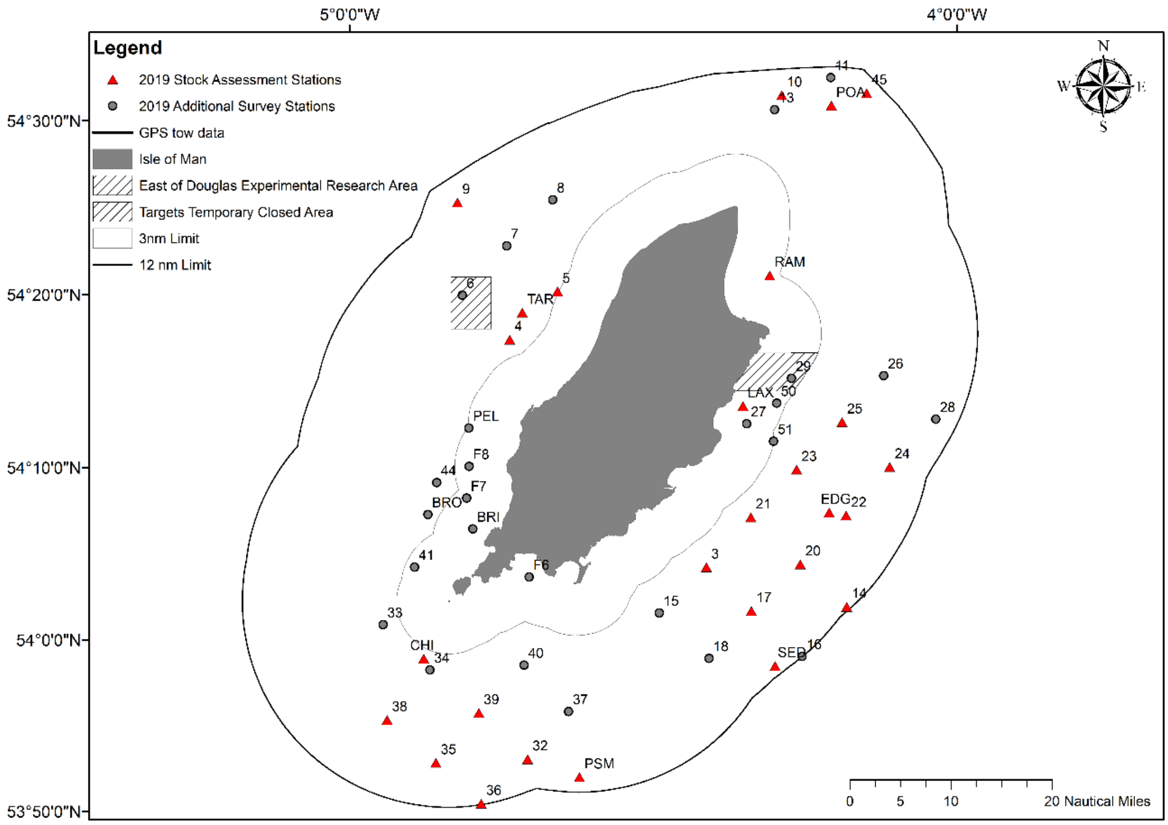

Figure 4: A map showing the location of all 2019 survey stations (red = Stations used in stock assessment; grey = Additional survey stations). Also marked on the map are two temporary closed areas which were in place for the 2018/2019 fishing season, East Douglas Experimental Research Area (EDG ERA) and Targets queen scallop Closed Area (TAR CA) both of which remain closed (both areas shown in hatched black).

2.2 Size Frequency

A frequency-density plot of queen scallop size data is presented in Figure 5 from samples measured at all stock assessment stations (queen scallop dredge data only). Two main cohorts can be seen in the size data 15 – 40 mm (Cohort 1) and 45 – 90 mm (Cohort 2). Cohort 1 indicates pre-recruits that will be recruiting into next year's fishery whilst Cohort 2 represents recruits, queen scallops that are already at minimum landings size (MLS) or that will grow into the fishery during the current fishing season.

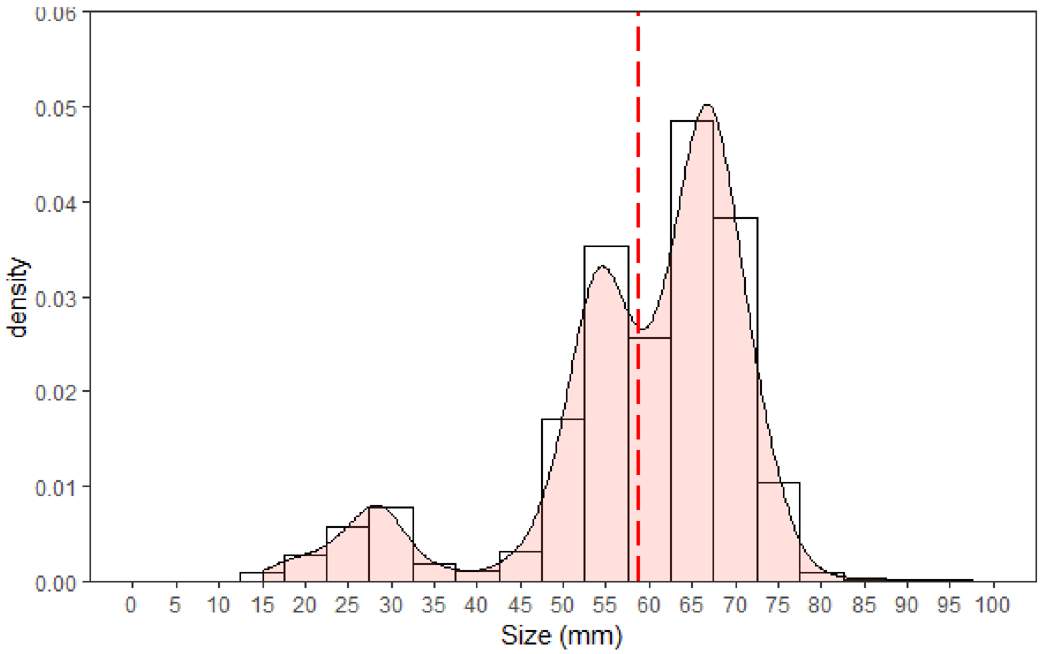

Figure 5: Queen Scallop Size frequency-density plot. Red line indicates mean size of sample. Data from stock assessment sites and queen scallop dredges only.

When comparing the percentage size ranges (over or under MLS) of sampled queen scallops from the 2019 survey to the 2018 survey it is apparent the proportion of the stock that is under MLS has increased slightly since 2018 (Figure 6).

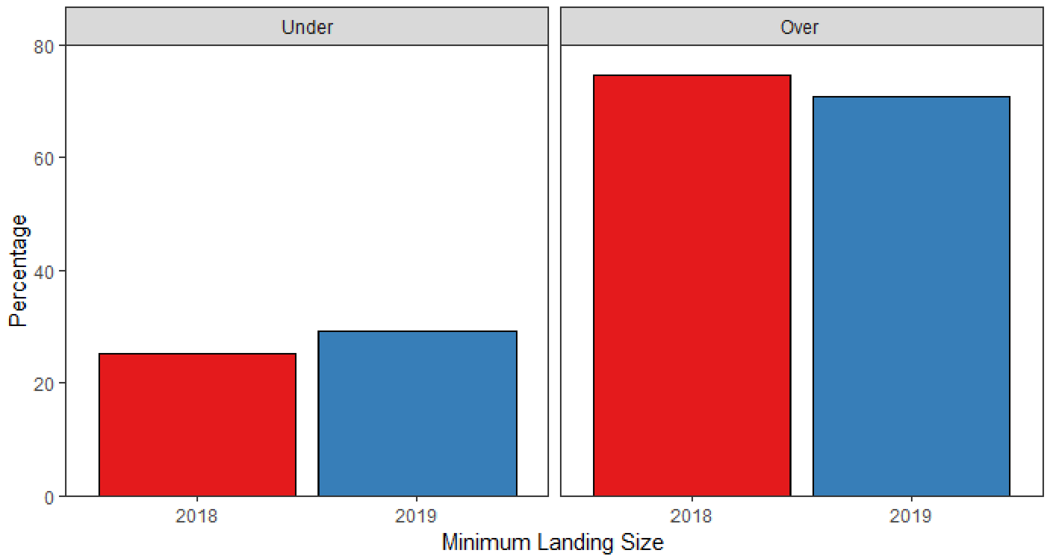

Figure 6: under and over MLS for 2018 and 2019 queen scallops. Data from stock assessment stations and queen scallop dredges only.

When the size data are split into main fished grounds (i.e. individual stations grouped into fishing grounds), it is clear that the majority of pre-recruits identified in the survey were found at the Chickens fishing ground (Figure 7). 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 did not show strong recruitment signals among the other main queen scallop fishing grounds.

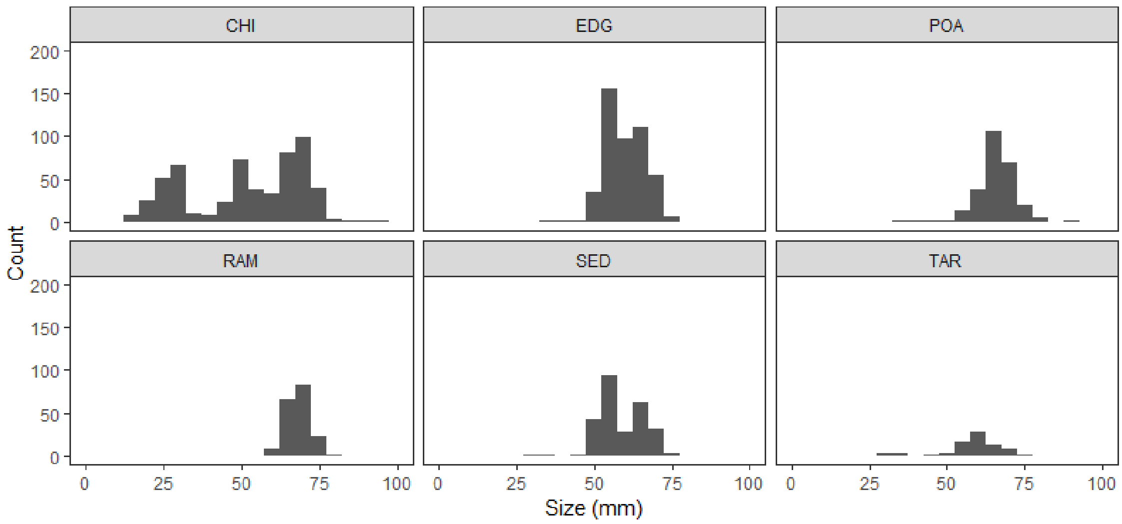

Figure 7: Size frequency (count) of queen scallops from 2019 survey grouped by fished ground. Data from stock assessment stations and queen scallop dredges only. CHI: Chickens, EDG: East of Douglas, POA: Point of Ayre, RAM: Ramsey Bay, SED: South East of Douglas and TAR: Targets.

2.3 Density Estimates

The mean density (scallops per 100 m^2) of queen scallops from queen scallop dredges for all stations surveyed is displayed in Figure 8. The four highest density sites are Station 13, POA, Station 11, all of which are to the North of the island at the Point of Ayre ground, and RAM (Ramsey Bay; North-East). These stations all show densities above 15 scallops per 100 m^2.

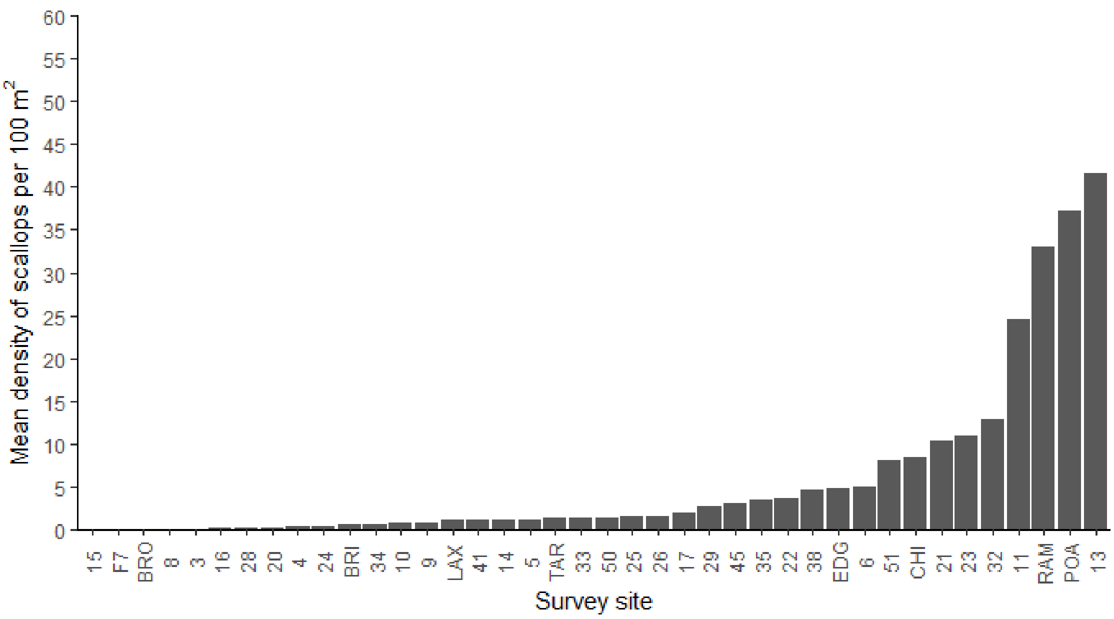

Figure 8: Average survey density (scallops per 100m^2) of queen Scallops from queen scallop dredges. Sites without queen scallops present were removed for plotting purposes.

Stations that have been sampled over at least two years and at which queen scallops are present (3, 4, 5, 9, 10, 14, 17, 20, 21, 22, 23, 24, 25, 32, 35, 36, 38, 39 and 45), in addition to the standard historical queen scallop survey stations (CHI, EDG, LAX, POA, PSM, RAM, SED and TAR), were included in the current stock assessment (Figure 4). Since 2016 the model has been run at a smaller spatial scale using landings and survey data exclusive to the Isle of Man territorial sea.

The difference in mean survey density (scallops per 100 m^2) of queen scallops from queen scallop dredges between 2018 and 2019 is displayed for all stations used in the stock assessment in Figure 9.

Figure 9: Difference in average survey density (scallops per 100m^2) of queen scallops from queen scallop dredges between 2018 and 2019 (red bars indicate a reduction in scallop density and turquoise bars indicate an increase in scallop density from 2018 to 2019).

The abundance index (derived from the survey data using the geometric mean of queen scallop densities) shows a declining trend in the mean abundance of recruits (scallops < 55 mm) from 2009 to 2019 with slight increases observed in 2012, 2014 and 2018 (Figure 10). From 2006 to 2010 there were annual increases in the mean abundance of post-recruits (scallops ≥ 55 mm), reaching the highest levels on record in 2010. However, the mean abundance of post-recruits has shown a declining trend since 2010, returning to a level similar to that recorded prior to 2007 (Figure 11).

One of the major issues for this fishery remains the continued lack of significant recruitment events within the territorial sea, as evident from the low values observed in the abundance index for recruits (Figure 10). However, some positive signs of recruitment were observed at fishing grounds during the 2019 survey (Figure 5, Figure 6 and Figure 7), specifically on the south coast, which, if managed correctly, may increase the post-recruit abundance at this ground over the next couple of years.

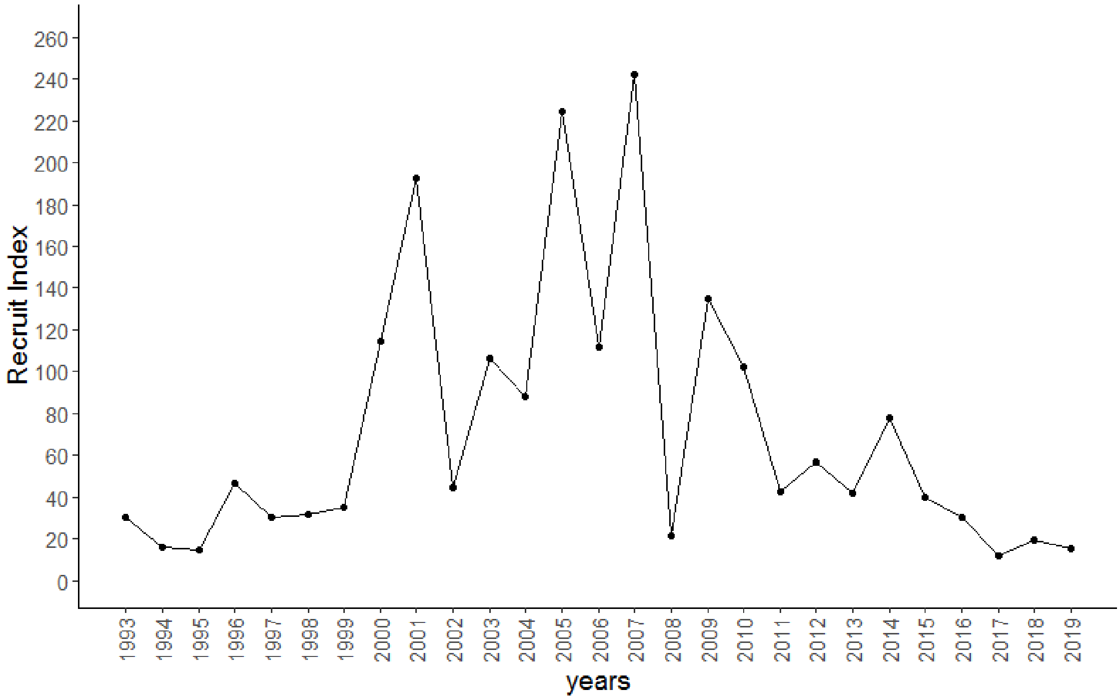

Figure 10: Abundance indices (based on geometric mean) for recruits (under 55 mm) used in the catch survey analysis model. This is calculated using data from only the stations used in the stock assessment model. Zero data values have been treated as 0.01 in order to calculate the geometric mean.

Figure 11: Abundance indices (based on geometric mean) for post-recruits (over 55 mm) used in the catch survey analysis model. This is calculated using data from only the stations used in the stock assessment model. Zero data values have been treated as 0.01 in order to calculate the geometric mean.

3. Landings and fishing effort:

Official EU logbook landings of queen scallops are referenced to ICES statistical rectangles only. Landings from ICES Statistical Rectangles 36E5 and 37E5 are used as the nearest approximation to landings from the Isle of Man's territorial sea. It is important to note however that 36E5 extends south to near Anglesey and that total landings from these two rectangles may therefore be substantially higher that from the territorial sea alone. A small amount of additional landings from the territorial sea may also come from 38E5 which overlays a section of the northern end of the territorial sea.

In 2018 (Jan to Dec) queen scallop landings from 36E5 and 37E5 were 1478t (Figure 12) with an additional 388t from 38E5 (total of 1866t for all three ICES Rectangles). Figure 12 shows that combined landings from ICES Rectangles 36E5 and 37E5 have continued to fall below the long-term average. Figure 13 shows that landings from ICES Rectangles 36E5, 37E5 and 38E5 have also followed a downward trend since 2011. In 2018, of the total taken across these three ICES Rectangles 1106t (59%) was caught by dredgers and 760t (41%) by otter trawlers. Landings of queen scallops from within the territorial sea were approximately 794t in 2018; this represents 43% of total landings from 36E5, 37E5 and 38E5 (Jan to Dec).

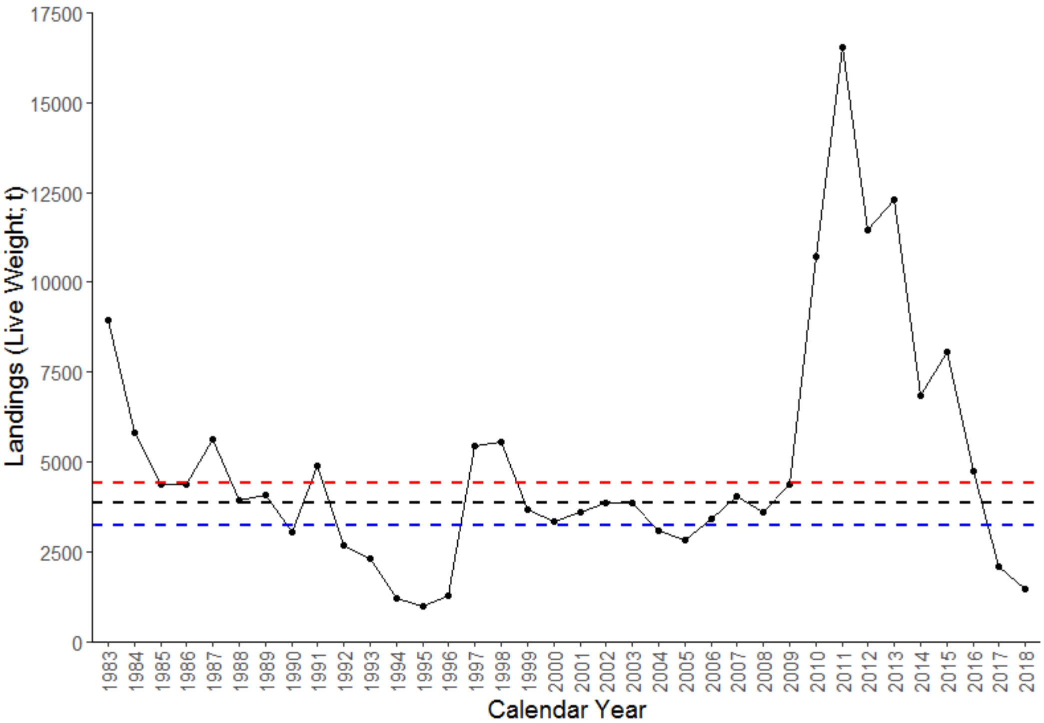

Figure 12: Landings (live weight) of queen scallops from ICES Statistical Rectangles 36E5 and 37E5 to the UK and Isle of Man. NB. Isle of Man landings before 1994 are total landings to the Isle of Man, which are likely to be predominantly from these two statistical rectangles. Data are for calendar years (i.e. from Jan to Dec). The long-term historic mean landings (1983 – 2009; before the peak) of 3865 t is displayed on the graph by a black dotted line and the upper and lower bounds of the 95% confidence interval for this value are displayed with blue and red dotted lines respectively. Data source: DEFA and IFISH.

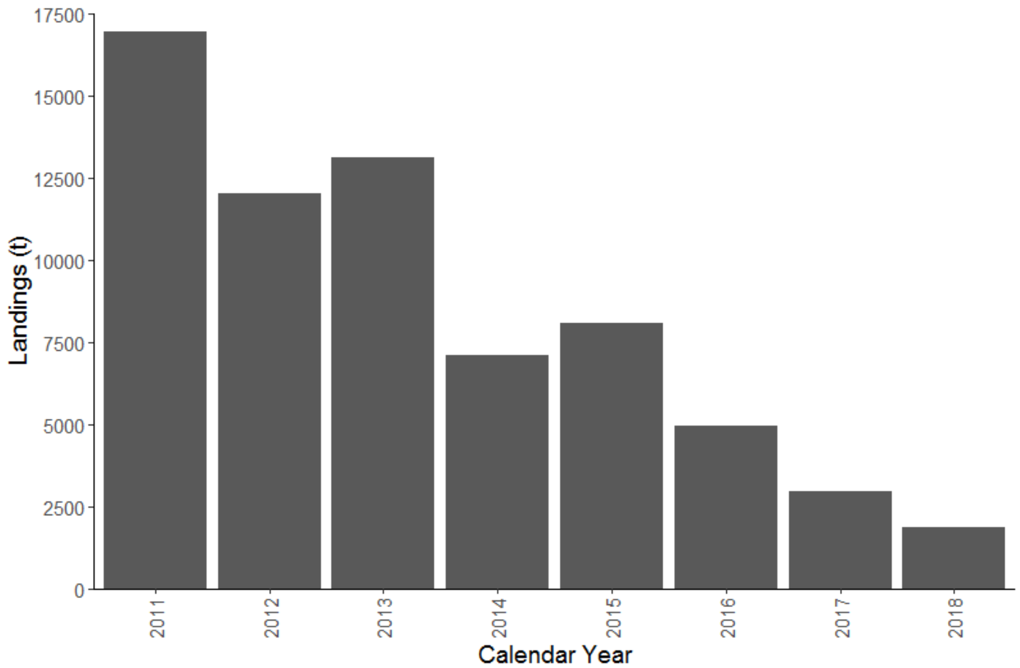

Figure 13: Landings (live weight) of queen scallops from ICES Statistical Rectangles 36E5, 37E5 and 38E5 from 2011 – 2018 (Calendar Year: 1st January – 31st December). Data source: IFISH

Landings per unit effort (LPUE) was standardised to kg per hour at sea per Vessel Capacity Units (VCUs), with VCUs used as a proxy to account for the differences between vessels, where VCU = vessel length x breadth +(0.45 x engine power) (Pascoe et al., 2003). Figure 14 shows the LPUE for each of the two main metiers that operate within ICES Rectangles 36E5, 37E5 and 38E5 and target queen scallops. The graph shows that both trawl and dredge fisheries have seen a continued decrease in LPUE since 2015, which in addition to the data from the survey and landings from these area, indicates a continued decline in stock status.

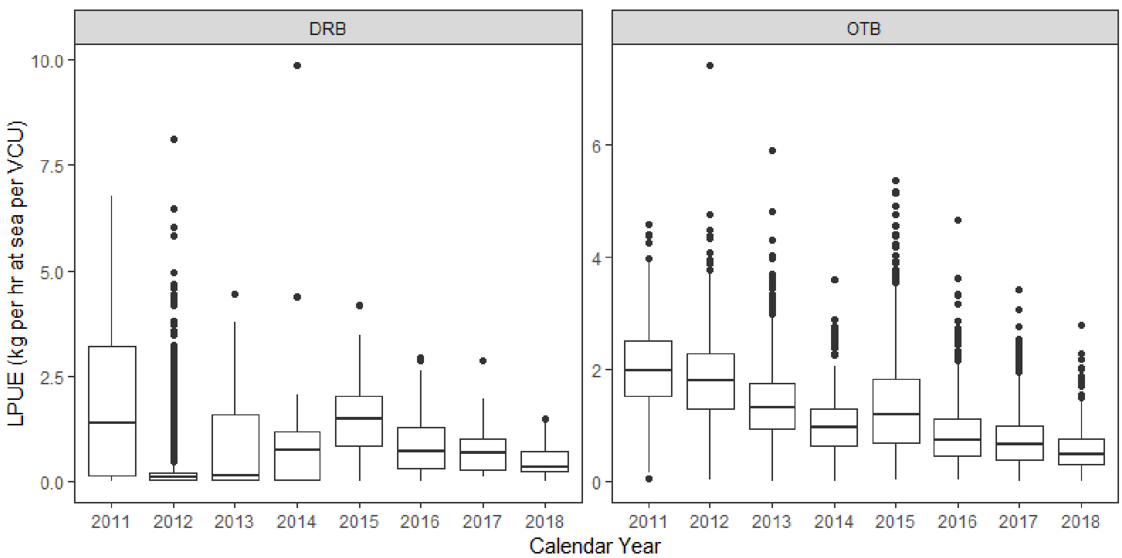

Figure 14: Boxplot of LPUE (kg per hour at sea per VCU) of queen scallops from ICES Rectangles 36E5, 37E5 and 38E5 from 2011 to 2018 by gear type (DRB = Dredge and OTB = Otter Trawl). Data are for calendar years (i.e. from Jan to Dec). The data has been standardised by VCUs. Data source: EU Logbooks (IFISH2).

The data show that landings from 36E5, 37E5 and 38E5 have decreased by ≈ 89 % from 2011 (16,957 t) to 2018 (1,866 t) and trawl catch rates (kg per hour at sea per VCU) have also decreased from an average of 1.97 kg/hr/VCU (2011) to 0.56 kg/hr/VCU (2018) in parallel. Despite these observed declines in stock productivity, commercial viability in these fisheries has been supported by increased product value of scallops (£ kg^{-1}) (e.g. Figure 15) and low fuel costs (£ l^{-1}). These favourable economic conditions sustain profitability even in low-density queen scallop beds potentially resulting in an increased environmental impact on the seabed, both in terms of the extent and the intensity of fishing, as more effort is required to maintain catch levels. An important point to note is that should the price of queen scallops drop during the 2019/2020 fishing season then commercial viability will be at risk, particularly if fuel prices become more volatile within the fishing season.

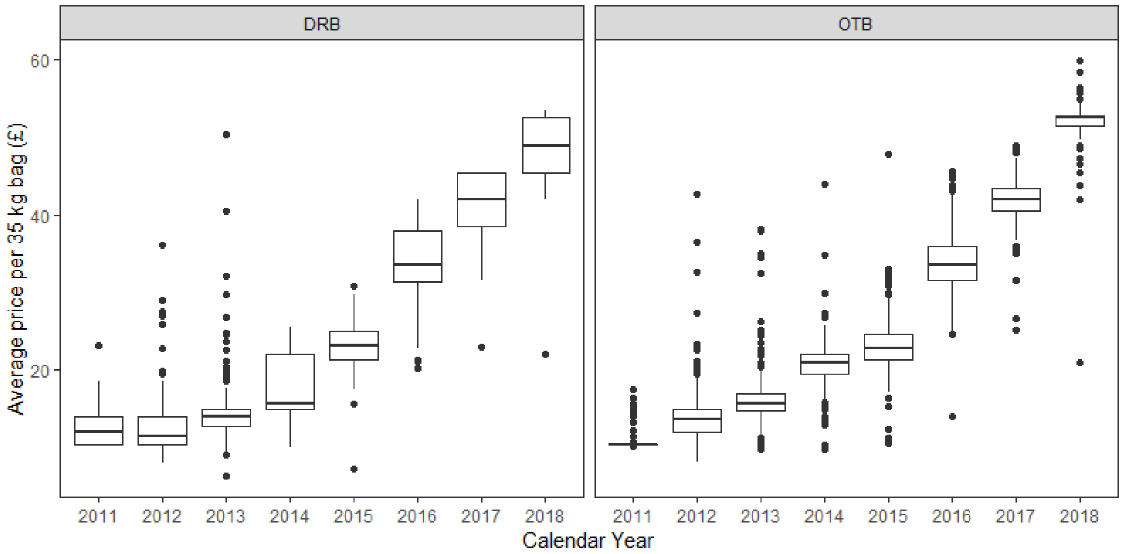

Figure 15: Boxplot showing price per 35 kg bag of queen scallops. Data displayed by gear type (DRB = Dredge and OTB = Otter Trawl). Data source: EU Logbooks (IFISH2) for ICES Statistical Rectangles 36E5, 37E5 and 38E5.

4. Stock Assessment:

An annual assessment of the Isle of Man queen scallop stock has been undertaken using the Catch-Survey Analysis (CSA) method, first developed by Collie and Sissenwine (1983), since 2012. Further information on this method and the results from previous stock assessment are presented by Murray and Kaiser (2012a, 2012b), Murray (2013) and Bloor et al., (2014, 2015, 2016, 2017 and 2018). CSA has been advocated as a valuable method to support management advice where age data is not available (Mesnil, 2003). The CSA method estimates stock size using abundance indices and is generally well-suited to the data available for the Isle of Man's queen scallop fishery. Absolute estimates of stock size and fishing mortality derived from CSA are sensitive to input parameters, although trends over time are more robust to changes in these input parameters (Mesnil, 2003). The stock assessment was implemented using CSA v4.3 (NOAA, 2014). The timing of the survey in spring allows data collection before the main queen scallop fishing season and at a time of year when seawater temperatures mean dredges are a more effective means of sampling queen scallops (Jenkins *et al*., 2003).

Within the stock assessment unit (Isle of Man's territorial sea), the trend from the model output indicates that following five years of increasing biomass (2006-2010), total biomass has decreased during each of the subsequent nine years (2011–2019) and is now estimated to be at the lowest levels since data collection began in 1993 (2019: 1208 t) (Figure 16).

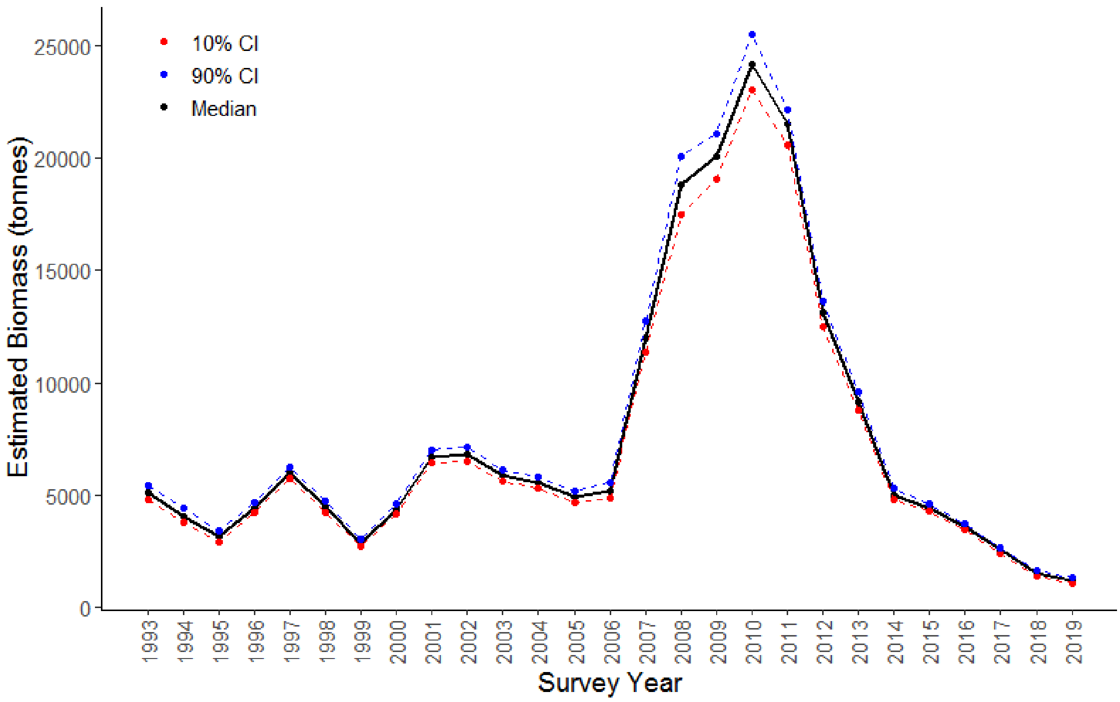

Figure 16: Estimated biomass for the stock assessment unit (Isle of Man territorial sea) MCMC results from CSA Version 4.3.

5. Recommendations:

A quantitative stock assessment is available for the queen scallop fishery within the Isle of Man's territorial sea. It is therefore possible to calculate a biomass linked TAC for the fishery using the relative biomass estimates from this assessment.

Estimated biomass for 2019 is down from 2018 and is now at the lowest level (1208t) since data collection began in 1993 (Figure 16). As such, there is no scientific evidence that the stock could support the 2018 TAC (e.g. 794t). Furthermore, although the Scallop Management Board agreed in 2017 to the use of the ICES Category 3 data limited approach for calculating TACs, a 20% reduction of the current TAC using this method still equates to a removal of ~53% of estimated stock biomass.

Since 2013 queen scallop stocks have been exploited beyond the recommended independent scientific advice and biomass has declined. In order to promote stock recovery it is recommended that no fishing occurs within the stock assessment unit. Should fishing occur for socio-economic reasons, data from previous Isle of Man queen scallop fishing seasons indicate that in years when 20 % or more of the stock biomass was removed through fishing mortality, stock biomass declined in each subsequent year. This is likely a result of annual recruitment being insufficient to sustainably replace the losses from natural and fishing mortality combined. As such, while recruitment levels remain low, a precautionary socio-economic approach should be adopted with biomass removals from fishing mortality limited to less than 20% until biomass depletion has stabilised or substantial biomass increases are achieved. Not only does intense fishing effort remove greater quantities of biomass but there are additional negative impacts from these types of towed bottom gears that can also increase in line with fishing activity. ***As such, a TAC of 0 – 242t is recommended for the 2019 queen scallop fishing season*.**

As indicated in Table 1, in each year that the stock assessment has been undertaken for the queen scallop fishery, the TAC for the territorial sea has not been set in line with scientific recommendations and there has continued to be a downward trend in estimated biomass, landings and LPUE.

*Table 1: Estimated median biomass (BM) for the Isle of Man's territorial sea from 2019 using CSA **version 4.3** and scientific advice and actual TAC/landings (2013-2019). Landings here are represented annually (1st January to 31st December). NB. It should be noted that a 1 month voluntary closure (May) was in place in 2016 and a 3 month voluntary closure (April, May & June) in 2017 and a 3 month statutory closure in 2018 (April, May & June) for 27 VIIa and VIa.*

	Territorial Sea					36E5, 37E5 & 38E5
Year	Median Estimated BM	Scientifically Advised TAC	20 % of Est. Biomass	Actual TAC	Estimated BM Removed (%)	Additional annual landings
2013	9162t	2500t	1832t	5000t	55%	8138t
2014	5009t	0t	1001t	1000t	20%	6107t
2015	4447t	0t	889t	1240t	28%	6866t
2016	3594t	0t	719t	1240t	35%	3723t
2017	2570t	0t	514t	992t	39%	2095t
2018	1530t	0 – 20%	306t	794t	52%	1072t
2019	1208t	0 – 20%	242t	476t	39%	TBC

6. Discussion points:

6.1: Cumulative gear impacts:

An important point to note is that the queen scallop fishery (trawl and dredge) does not operate in isolation or on exclusive fishing grounds. Thus, whilst the queen scallop fishery only operates from July to October the same areas are fished by king scallop dredgers in the winter months (November to May) and effort is often focused in the same areas which means that these fishing grounds are subjected to dredge and trawl activity almost year round and importantly during what is thought to be the main queen scallop spawning season in the autumn.

6.2: Stock-recruit relationship:

For scallops a direct relationship has yet to be found between spawning stock biomass and recruitment for scallops. Hence it is likely that biomass levels do not act in isolation to determine recruitment but rather that it is one of multiple factors that have threshold limits including:

- Spatial variation in local densities of spawning individuals (e.g. Allee effect) which impact spawning success
- The physical impact of fishing on the benthic habitats utilised by scallop larvae during settlement
- The impact of fishing outside the territorial sea which may impact larval supply into the territorial sea and
- The impact of ambient environmental factors (e.g. water temperature and chlorophyll levels)

These factors may interact to determine the success of annual recruitment to the stock. Identifying a single reference point that incorporates the correct combination of these factors will be difficult and may take many years. Therefore, the combination of low total biomass and the removal of a high proportion of biomass must continue to be interpreted as a high risk strategy for the fishery and one that will sustain only low annual landings (Table 1).

6.3: Closed Areas:

Scallops are broadcast spawners and as such successful reproduction is likely to be higher when adults are present at higher densities. Fertilisation success will be limited if local densities drop below some threshold level as a result of Allee effects. Spatial management (e.g. closed areas) may therefore be particularly important as a mechanism by which to maintain sufficient densities, in at least some areas, to ensure successful fertilization, recruitment and long-term viability.

In addition, closed areas could also provide effective control of fishing effort in habitats that are easily damaged by fishing activity and that may be important for spat settlement and recruitment. Suitable areas should be identified which either contain a large proportion of pre-recruits or recruits to be protected as 'on-growing' areas, areas with high densities of post-recruits to protect spawning potential or areas that may be suitable for habitat recovery to try and promote the development of structures suitable for spat settlement.

6.4: Biological Reference Points

Current research is focused on setting biological reference points for scallops that allow for the spatial distribution of productivity and fishing effort (e.g. Smith et al., 2016) and these methods should be investigated in more detail in relation to the Isle of Man queen scallop stock.

7. Conclusions:

- The estimated median biomass for 2019 (1208t) is lower than 2018 (1530t) equating to ~ 21% decrease [CSA version 4.3].
- Each year the fishery has taken more than the scientific advice and biomass has declined. In order to promote the earliest return of the stock to above the minimum biomass limit it is again recommended that no fishing occurs within the stock assessment unit.
- Should fishing occur for socio-economic purposes a more precautionary approach to previous years is advised for the 2019 fishing season. Biomass removal within the territorial sea should be limited to less than 20% of the estimated median biomass (e.g. < 242t). This precautionary approach aims to stabilise biomass declines and/or promote an increase in biomass.
- Biomass depletion has rendered the fishery heavily dependent on annual recruitment. Management promoting successful spawning and recruitment using closed areas is essential.
- An annual beam trawl survey (which better targets recruits) is recommended to be undertaken across the territorial sea led by Industry in order to better identify and manage abundances of recruits that were identified during the survey at several stations.
- Spatial management of the fishery is advised to reduce the risk of high density areas being depleted by more than 20% of the commercially exploitable biomass (additional surveys would be required to attain localised absolute biomass estimates).
- Since 2014, landings within the territorial sea have remained low as a result of restrictive management measures (794 - 1240t). Within the same period, landings in the remainder of 36, 37 & 38E5, which covers the wider area of the biological stock and which is not subject to restricted management measures, continue to experience significant reductions (range 6866 to 1072 t); a downward trend that remains the same even when seasonal closures are accounted for.
- The Irish Sea queen scallop fishery should be managed as a single biological stock with advice provided based on data collected across the Irish Sea. It is vital that work continues towards achieving a collaborative management approach for queen scallop stocks within the Irish Sea.

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9. Appendix:

9.1 Data inputs for CSA Version 4.3:

Table 2: Data for inputting into CEA Version 3.4 for the 2019 Isle of Man queen scallop stock assessment

years	month	WT.Land	WT.Disc	WT.Rec	WT.PRec	CT.Seas	CT.Source	CT.NoLand	CT.NoDisc	CT.LandDivTh	CT.DiscDivTh	NatMort	RecSel	tos	RecCV	PoRecCV	AI.Recs	AI.PoRec
1993	6	0.0391	0.0187	0.0187	0.0391	1488	5	38056.2660	1902.8133	38.0563	1.9028	0.2	0.35	0.5	0.1	0.1	30.1343	347.0402
1994	6	0.0436	0.0183	0.0183	0.0436	886	5	20321.1009	1016.0550	20.3211	1.0161	0.2	0.35	0.5	0.1	0.1	15.8658	174.5157
1995	6	0.0434	0.0171	0.0171	0.0434	1029	5	23709.6774	1185.4839	23.7097	1.1855	0.2	0.35	0.5	0.1	0.1	15.0205	127.149
1996	6	0.0391	0.0172	0.0172	0.0391	1888	5	48286.4450	2414.3223	48.2864	2.4143	0.2	0.35	0.5	0.1	0.1	46.9139	77.4644
1997	6	0.0402	0.0182	0.0182	0.0402	3344	5	83184.0796	4159.2040	83.1841	4.1592	0.2	0.35	0.5	0.1	0.1	30.137	337.8036
1998	6	0.0506	0.0147	0.0147	0.0506	3129	5	61837.9447	3091.8972	61.8379	3.0919	0.2	0.35	0.5	0.1	0.1	31.4622	355.656
1999	6	0.0416	0.0144	0.0144	0.0416	2157	5	51850.9615	2592.5481	51.8510	2.5925	0.2	0.35	0.5	0.1	0.1	35.294	33.812
2000	6	0.0352	0.0171	0.0171	0.0352	2109	4	59914.7727	2995.7386	59.9148	2.9957	0.2	0.35	0.5	0.1	0.1	114.277	250.3251
2001	6	0.0375	0.0183	0.0183	0.0375	2171	4	57893.3333	2894.6667	57.8933	2.8947	0.2	0.35	0.5	0.1	0.1	192.7073	293.7747
2002	6	0.0396	0.0135	0.0135	0.0396	2249	4	56792.9293	2839.6465	56.7929	2.8396	0.2	0.35	0.5	0.1	0.1	44.4438	269.4851
2003	6	0.0399	0.0175	0.0175	0.0399	1530	4	38345.8647	1917.2932	38.3459	1.9173	0.2	0.35	0.5	0.1	0.1	106.7079	411.6928
2004	6	0.0401	0.0141	0.0141	0.0401	1985	4	49501.2469	2475.0623	49.5012	2.4751	0.2	0.35	0.5	0.1	0.1	87.8303	507.5868
2005	6	0.0364	0.017	0.017	0.0364	1897	4	52115.3846	2605.7692	52.1154	2.6058	0.2	0.35	0.5	0.1	0.1	224.3407	108.3704
2006	6	0.0353	0.0181	0.0181	0.0353	1423	4	40311.6147	2015.5807	40.3116	2.0156	0.2	0.35	0.5	0.1	0.1	111.7935	69.6202
2007	6	0.0395	0.0161	0.0161	0.0395	1982	3	50177.2152	2508.8608	50.1772	2.5089	0.2	0.35	0.5	0.1	0.1	242.488	157.6294
2008	6	0.0436	0.0141	0.0141	0.0436	2223	3	50986.2385	2549.3119	50.9862	2.5493	0.2	0.35	0.5	0.1	0.1	21.6189	581.4203
2009	6	0.0385	0.0186	0.0186	0.0385	3169	3	82311.6883	4115.5844	82.3117	4.1156	0.2	0.35	0.5	0.1	0.1	135.1149	1282.488
2010	6	0.0401	0.0136	0.0136	0.0401	5985	3	149251.8703	7462.5935	149.2519	7.4626	0.2	0.35	0.5	0.1	0.1	102.6364	1642.3506
2011	6	0.0424	0.016	0.016	0.0424	8015	3	189033.0189	9451.6509	189.0330	9.4517	0.2	0.35	0.5	0.1	0.1	42.4943	877.5682
2012	5	0.0427	0.0151	0.0151	0.0427	4520	2	105854.8009	5292.7400	105.8548	5.2927	0.2	0.35	0.4167	0.1	0.1	56.9496	1228.427
2013	2	0.0427	0.0145	0.0145	0.0427	5000	2	117096.0187	5854.8009	117.0960	5.8548	0.2	0.35	0.1667	0.1	0.1	41.5851	716.3315
2014	4	0.0421	0.0157	0.0157	0.0421	1000	1	23752.9691	1187.6485	23.7530	1.1876	0.2	0.35	0.3333	0.1	0.1	77.5957	329.293
2015	4	0.0332	0.0164	0.0164	0.0332	1240	1	37349.3976	1867.4699	37.3494	1.8675	0.2	0.35	0.3333	0.1	0.1	39.5598	215.1596
2016	4	0.0335	0.0155	0.0155	0.0335	1240	1	37014.9254	1850.7463	37.0149	1.8507	0.2	0.35	0.3333	0.1	0.1	30.4479	320.2973
2017	4	0.0358	0.0139	0.0139	0.0358	992	1	27709.4972	1385.4749	27.7095	1.3855	0.2	0.35	0.3333	0.1	0.1	11.9196	192.2132
2018	4	0.0337	0.0099	0.0099	0.0337	794	1	23560.8309	1178.0415	23.5608	1.1780	0.2	0.35	0.3333	0.1	0.1	19.1135	72.056
2019	4	0.0372	0.0133	0.0133	0.0372	NA	NA	NA	NA	NA	NA	0.2	0.35	0.3333	0.1	0.1	15.1194	65.1499

9.2 Data outputs for CSA Version 4.3:

Table 3: Summary of results from CSA model (Version 4.3) with median estimates (M=0.2; s = 0.35 and percentile range = 10% - 50% -90%) from 2019 stock assessment model for territorial sea area

Year	10 % CI biomass (t)	Total median biomass (t)	90 % CI biomass (t)
1993	4780.7	5111	5451.9
1994	3783.5	4071.6	4407.9
1995	2923.2	3152.7	3443.3
1996	4249.3	4458.6	4671.5
1997	5764.7	6024.8	6271.6
1998	4233.5	4470.8	4714.4
1999	2718.1	2864.7	3041.3
2000	4181.2	4371.5	4588.2
2001	6430.8	6729.1	7008.1
2002	6489.6	6814.2	7129.5
2003	5630.8	5895.9	6127.8
2004	5282.1	5543.3	5802.4
2005	4681.8	4945.9	5210.8
2006	4849	5195.8	5553.8
2007	11361.9	12000.9	12761.1
2008	17494.4	18835.1	20074
2009	19086.5	20053.7	21078.1
2010	23064.2	24167.2	25494.8
2011	20566.4	21517.4	22127.4
2012	12525.6	13138.4	13639.8
2013	8752.2	9162.3	9633.2
2014	4788.3	5008.6	5296.8
2015	4284.9	4446.8	4600.1
2016	3457.7	3593.9	3724.2
2017	2435.2	2569.9	2683.3
2018	1422.4	1530.4	1628.2
2019	1106.6	1207.9	1332

To date all stock assessments have been undertaken using CSA version 3.1.1. (NOAA, 2008). However, as of 2014 an updated version of the stock assessment software, CSA version 4.3 (NOAA, 2014), became available. The main differences in these two package versions are that the new model uses maximum likelihood rather than weighted sums of squares to estimate parameters and also uses Baranov's catch equation exclusively to simulate the population (NOAA, 2008). In addition, users can now supply the model with multiple surveys and survey types and specify the time of year that each survey occurred (NOAA, 2008). The outputs of the two model versions have been detailed in the Appendices of previous reports (Bloor et al., 2018). A comparison of these outputs reveals that whilst the new model (version 4.3) consistently estimates biomass at a slightly lower value than the old model (version 3.1.1.), these values remain within the 10% and 90% confidence interval predictions for the old model and more importantly the trends in biomass remain constant between the two models. For 2019 only the outputs from the most recent CSA version 4.3 are reported.