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The Isle of Man *Aequipecten opercularis* fishery stock assessment 2018

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1.1 The 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 2017 fishing season these included:

- Two temporary closed areas where fishing for scallops was prohibited (Figure 1).
- 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 (maximum of 3360 kg for trawl and 10500 kg for dredge)
- Minimum landing size (55 mm)
- Limited TAC (992 t)

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

Of the 46 vessels licenced to fish for queen scallops during the 2017/18 fishing season 42 prosecuted the fishery (35 trawl vessels and 7 dredge vessels) landing approximately 979 tonnes. The trawl fishery opened on 3rd July 2017 and closed on 22nd September 2017 whilst the dredge fishery opened on 2nd October 2017 and closed on 27th October 2017.

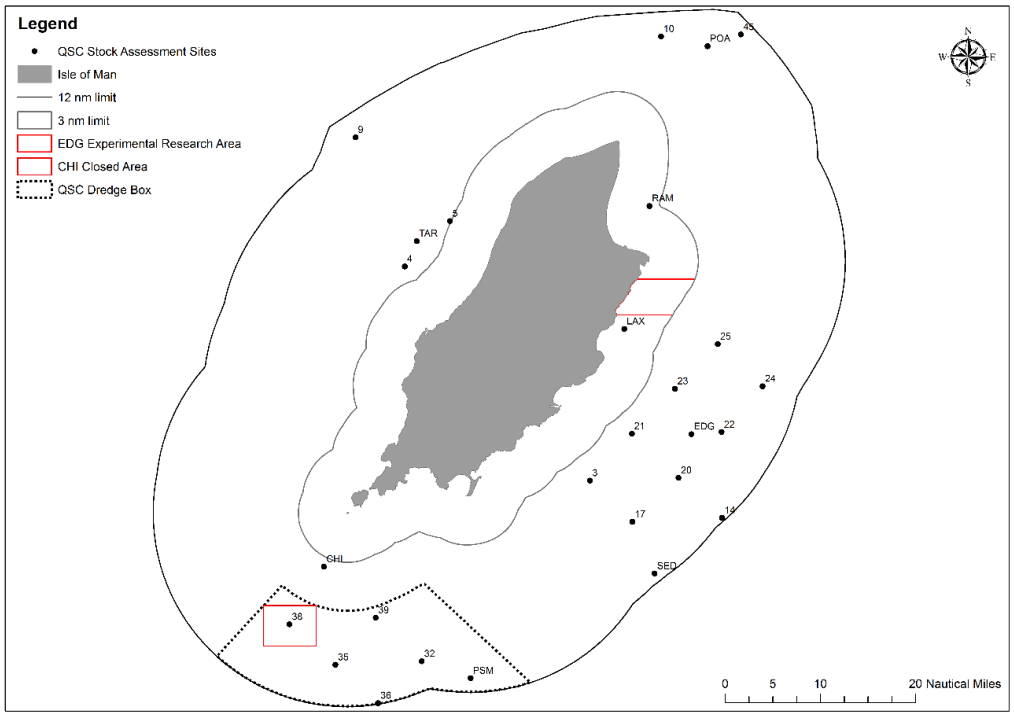

Figure 1: Two temporary queen scallop closed areas were put in place for the 2017/2018 fishing season, East Douglas Experimental Research Area (EDG) which remains closed and Chickens Closed Area (CHI) which was opened ahead of the 2017/2018 king scallop fishing season (both areas shown in red). The location of the QSC dredge box off the south coast is also shown (dotted lines) along with the point locations of survey sites used within the queen scallop stock assessment.

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) is now statutory for ICES areas VIa and VIIa.

1.2 Scallop surveys and abundance index

Spring surveys of the Isle of Man's scallop populations have been undertaken annually since 1992 (Beukers-Stewart *et al*., 2003). The 2018 stock assessment survey was undertaken using the RV Prince Madog from 4th – 17th April. Stations that have been sampled over at least two years (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 1). 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. All stations were surveyed using the protocol described by Hinz *et al*. (2009) and Murray *et al*. (2009).

The geometric mean of queen scallop density was calculated across survey stations and was used to derive the abundance indices. This method was 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 abundance index shows a declining trend in the mean abundance of recruits (scallops < 55 mm) from 2009 to 2017 with slight increases observed in 2012, 2014 and 2018 (Figure 2). 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 3).

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 2). However, some positive signs of recruitment were observed at several sites during the 2018 survey (Figure 2 and Figure 4), specifically on the north east coast, which, if managed correctly, may increase the post-recruit abundance at these sites over the next couple of years.

Figure 2: 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 3: 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.

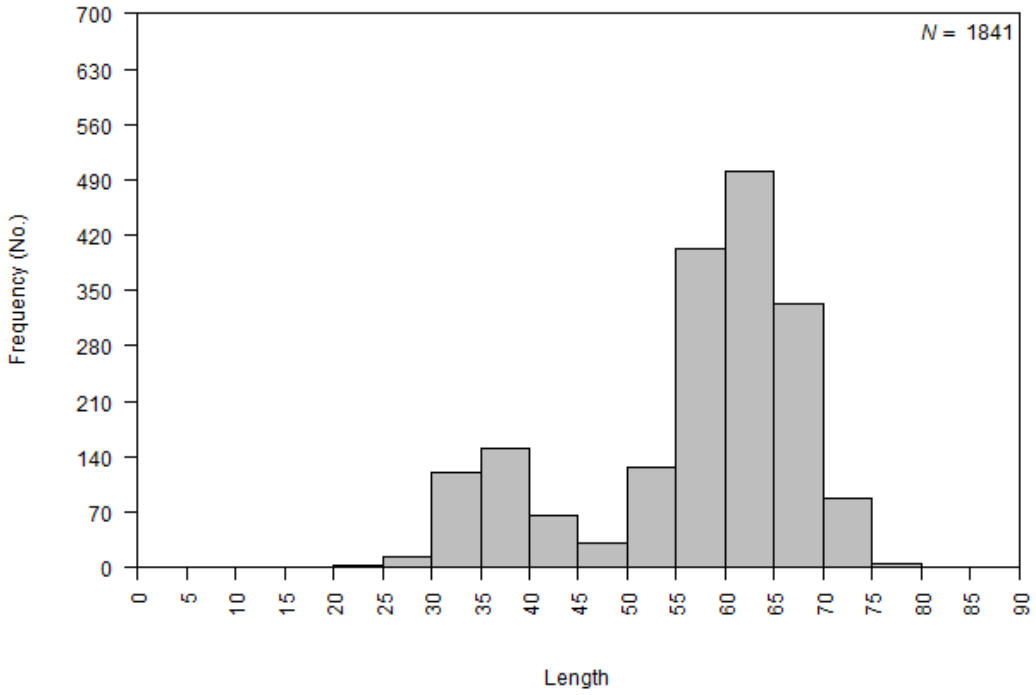

Figure 4: Length Frequency Histogram of queen scallops surveyed during the 2018 spring scallop survey. Combined data from stations used in the stock assessment and obtained from queen scallop dredges only.

1.3 Landings and fishing effort

Landings from FAO Fishing Area 27 VIIa which covers the Irish Sea, have sharply declined since 2015 (Figure 5 and Figure 6). Figure 5, which shows landings with and without the months of April, May and June, shows that the decrease in landings pattern from 27 VIIa (landings are displayed from outside the TS only as there were no TACs in place outside the TS) is not just an artefact of the voluntary closures that were put in place by industry as the landings show the same pattern with and without data from closed months included. In addition, landings displayed by month (Figure 6) indicate that this reduction has occurred across the year with large reductions in all months compared to 2012 and 2013 when the fishery was at its peak and there were minimal restrictions on landings (landings are displayed from inside and outside the TS).

Within the Irish Sea, landings from the territorial sea have been managed by quota since 2014 and have remained relatively stable (range: 992 – 1240 t). Landings from outside the territorial sea, which have a lower MLS (40 mm) and little additional management, except for a voluntary industry closure of 1 month (May) in 2016 and 3 months (April, May & June) in 2017, have been more variable since 2014 (range: 3299 – 9342 t), declining sharply in the last three years (2015 to 2017) (Table 3).

In 2017 (Jan to Dec) queen scallop landings from 36E5 and 37E5 were 2106t (Figure 7) with an additional 982t from 38E5 (total of 3087t for all three ICES Rectangles). Figure 7 shows that landings from these three ICES Rectangles have continued to fall below the long-term average. Of the total taken across these three ICES Rectangles 2056t (67%) was caught by dredgers and 1030t (33%) by otter trawlers. Landings of queen scallops from within the territorial sea were approximately 979t in 2017; this represents 32% of total landings from 36E5, 37E5 and 38E5 (Jan to Dec).

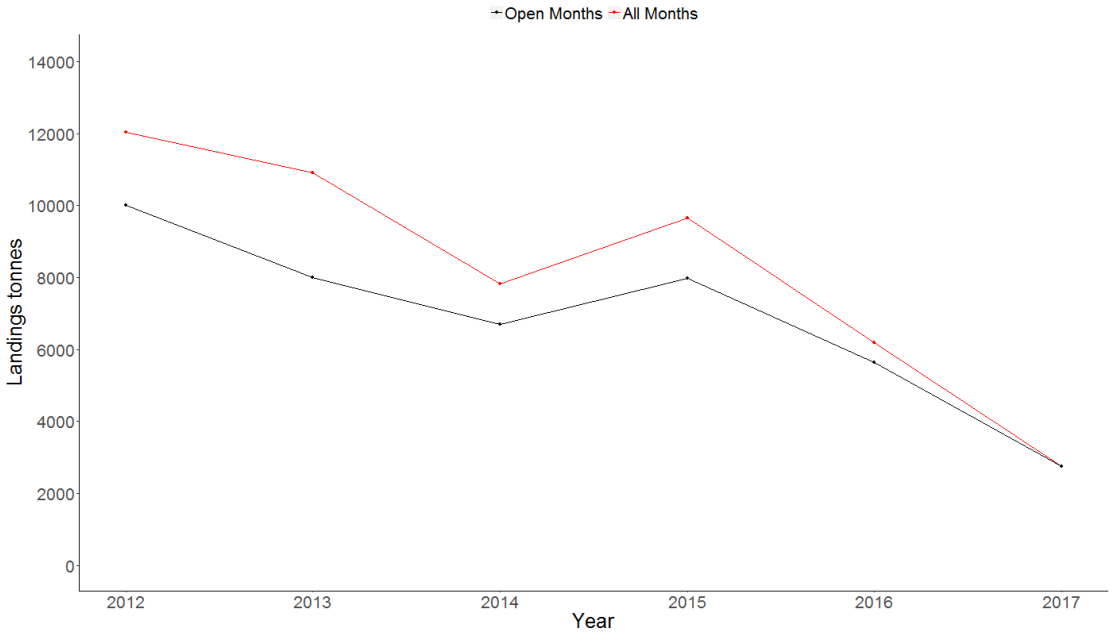

Figure 5: Landings (live weight) of queen scallops from FAO Fishing Area 27 VIIa from 2012 to 2017 (landings are from outside the TS only as the TS had different TACs in different years whilst total landings from outside the TS were unrestricted). Data are for calendar years (i.e. from Jan to Dec). The red line shows landings from the whole calendar year whilst the black line shows landings with April, May and June (which was a voluntary closure period in 2017) removed to make the data comparable among years. Data source: DEFA and IFISH. A voluntary industry led closure was in place for May 2016 and April, May and June 2017. The data for 2017 is the same value as no landings were made during the closure.

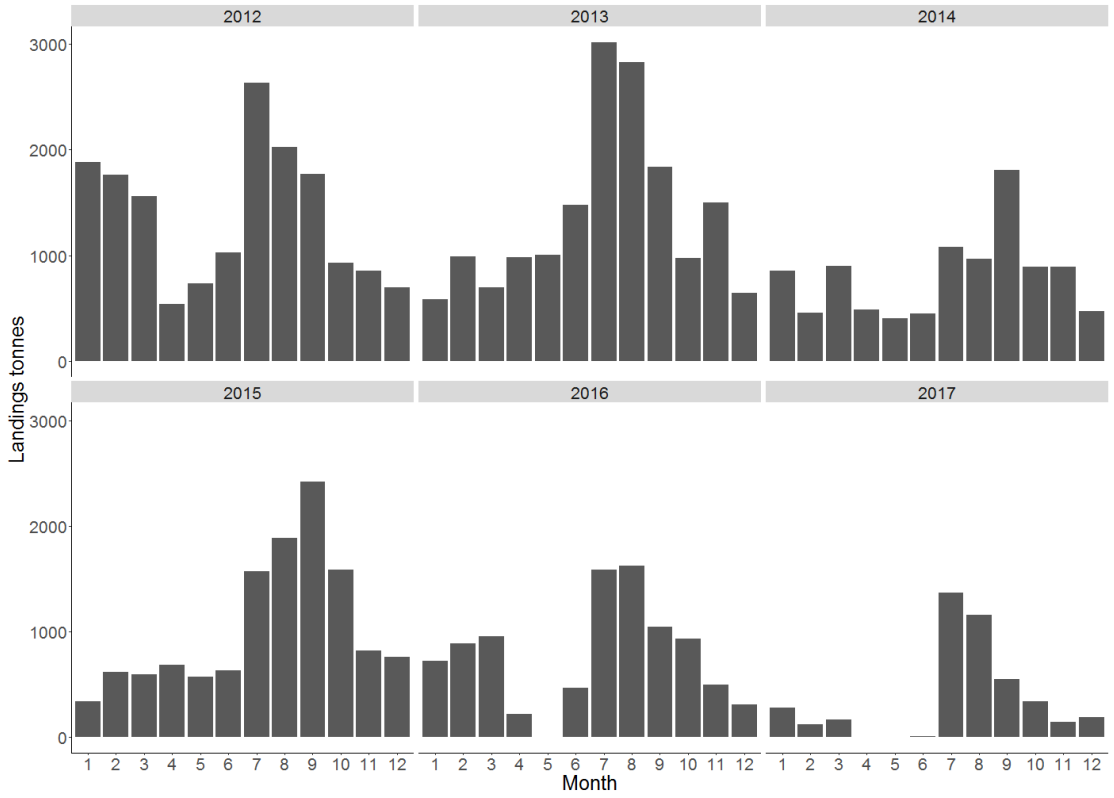

Figure 6: Landings (live weight) of queen scallops from FAO Fishing Area 27 VIIa from 2012 to 2017 (landings are from inside and outside the TS). Data are for calendar years (i.e. from Jan to Dec). Data source: DEFA and IFISH. *N.B.* A voluntary industry led closure was in place for May 2016 and April, May and June 2017.

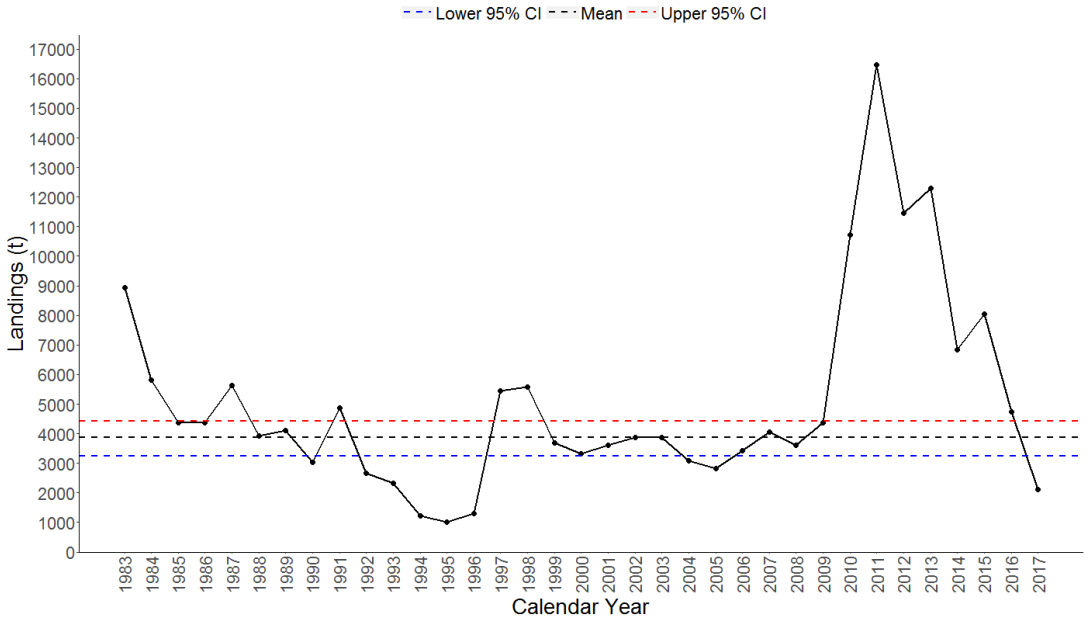

Figure 7: Landings (live weight) of queen scallops from ICES Statistical Rectangles 36E5 and 37E5 to the UK and Isle of Man. *NB.* Isle of Man landings before 1994 are total landings to the Isle of Man, which are likely to be predominantly from these two statistical rectangles. Data are for calendar 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.

For 2017, queen scallop fishing effort (days spent fishing; dredge and trawl) within the three ICES rectangles 36E5, 37E5 and 38E5, indicates that days at sea decreased annually from 2015 for UK vessels (979, 881 and 694 days in 2015, 2016 and 2017 respectively) and was accompanied by a corresponding decrease in landings (6595, 4001 and 2340t in 2015, 2016 and 2017 respectively). For IOM vessels, days at sea increased slightly from 2015 (623, 647 and 663 days in 2015, 2016 and 2017 respectively) whilst the corresponding landings decreased (1496, 959 and 663t in 2015, 2016 and 2017 respectively). For Manx vessels, landings were exclusively trawl caught and originated from within the Isle of Man's territorial sea (where both total and weekly catch limits were in place). For UK vessels, most landings are dredge caught and originate from outside the territorial sea (where neither total nor weekly catch limits were in place).

Landings per unit effort (LPUE) was standardised to kg per hour at sea per Vessel Capacity Units (VCU), 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 8 shows the LPUE for each of the four main metiers that operate within ICES Rectangles 36E5, 37E5 and 38E5 and target queen scallops. The graph shows that the trawl and dredge fisheries inside the territorial sea are more productive than the equivalent fisheries that operate outside the territorial sea limit. However, all four metiers 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.

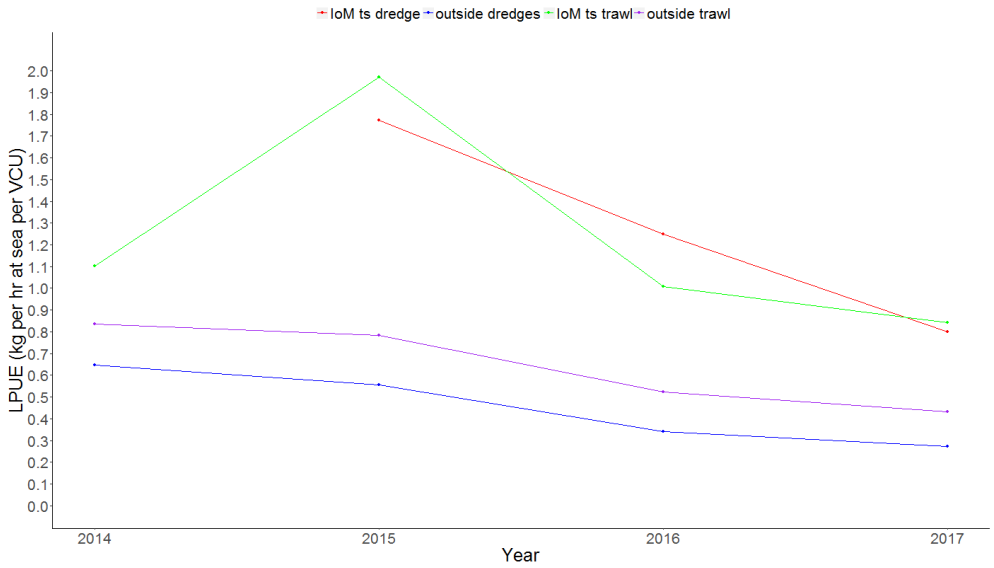

Figure 8: LPUE (kg per hour at sea per VCU) of queen scallops from FAO Fishing Area 27 VIIa from 2014 to 2017. Data are for calendar years (i.e. from Jan to Dec). The lines each indicate a different metier. There was no dredge fishery within the IoM TS during the 2014 fishing season. The data has been standardised by VCUs. Data source: EU Logbooks (IFISH2).

1.4 Stock assessment

An annual stock 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). 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 SCA 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 v3.1.1 (NOAA, 2008) [further details on CSA v4.3 (NOAA, 2014) and a comparison of outputs between the two CSA versions can be found in the Appendices]. Data from the spring surveys was used since this is when temperature is lower and dredges are a more effective means of sampling queen scallops (Jenkins *et al*., 2003), and before the main queen scallop fishing season.

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 eight years (2011–2018) (Figure 9).

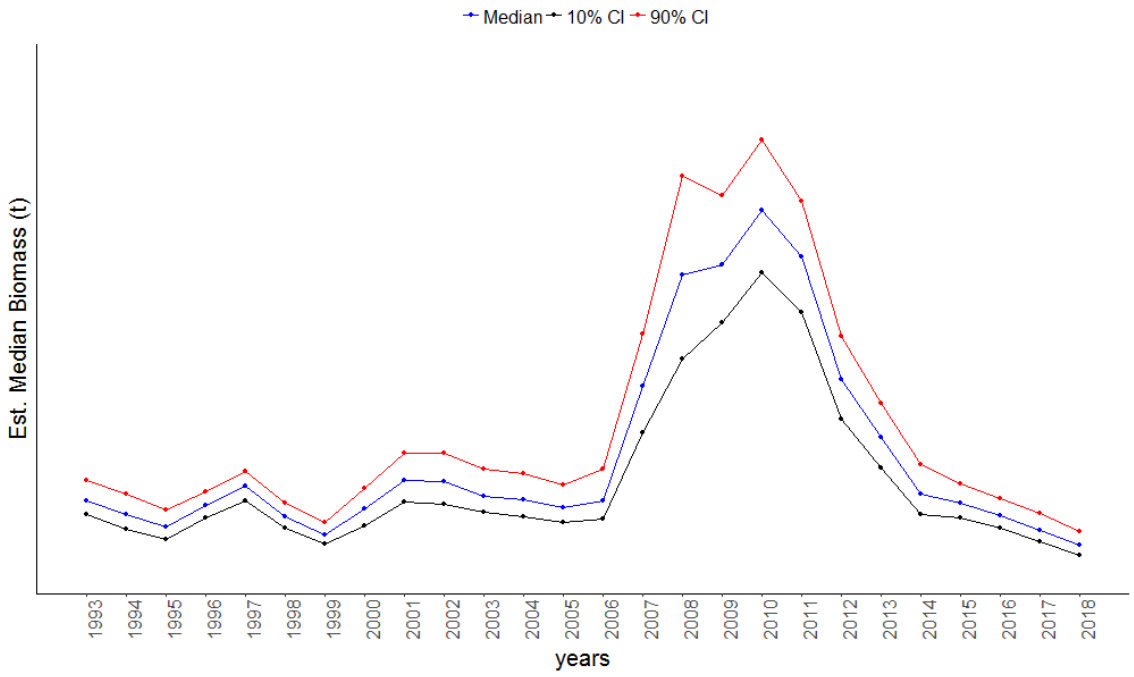

Figure 9: Trend in total estimated biomass for the stock assessment unit (Isle of Man territorial sea) bootstrap results.

Whilst the trend in biomass of the whole stock has declined annually since 2011, densities vary significantly among the five main fishing grounds: East Douglas (EDG), Chickens (CHI), Targets (TAR), Ramsey (RAM) and Point of Ayre (POA) (e.g. Figure 10 and Figure 11). In addition, due to the aggregating nature of queen scallops some areas of relatively high densities are still evident within each of these fishing grounds.

The 2018 survey indicates that Point of Ayre on the north coast, Station 32 on the south coast and Ramsey Bay on the north-east coast are the highest density fishing grounds (Figure 10). The survey results also indicate that there have been reductions in density at a large number of survey sites compared to 2017 (Figure 10 and Figure 11).

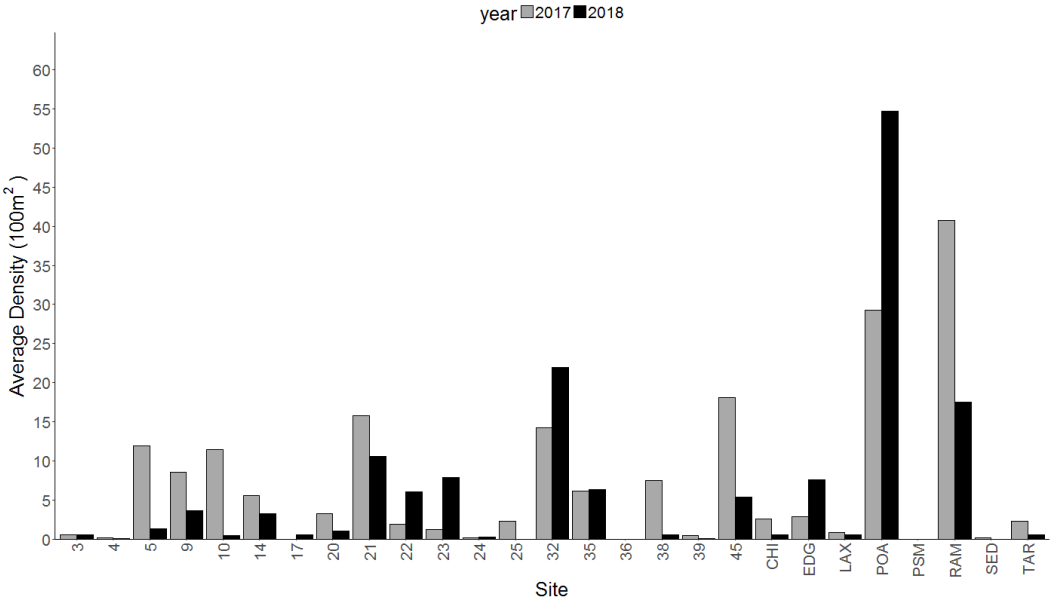

Figure 10: The average density of queen scallops from queen scallop dredges for each of the listed survey stations. Grey bars show the data from 2017 and black bars show the data from 2018.

Changes in the spatial and temporal distribution of queen scallop densities can be seen in Figure 11. In addition, maps of the spatial and temporal distribution of queen scallop trawl fishing intensity (hours fished) and king scallop dredge fishing intensity (Fished Hrs calculated from VMS points at fishing speed) can be seen in Figure 12 and Figure 13. The 2014 survey data indicates a spread of densities around all main fishing grounds within the territorial sea (Figure 11). This is reflected in the fishing effort which was also spread across all grounds (Figure 12 and Table 2). During the 2014 season a closure was in place in the north end of the west coast fishing ground off Targets which allowed the density within this area to be protected. In the 2015 fishing season the previously closed area at the northern part of Targets was opened and the southern end was closed. A large proportion of the fishing effort was subsequently focused in the opened area with a total of 748 tonnes and 1288 fished hours (Figure 12 and Table 2). In the 2016 fishing season the northern area was closed and the southern area reopened at Targets. Fishing effort was again focused in the opened area with a total of 594 tonnes and 2466 fished hours (Figure 12 and Table 2). The 2017 survey showed greatly reduced densities on both the northern and southern fishing grounds off the west coast at Targets following two years of intense queen scallop fishing. During the 2017 fishing season the whole ground at Targets was opened but due to the low densities present it attracted relatively little fishing effort with 94 tonnes and 465 fished hours. A higher density area on the south east coast was instead the focal point of the fishery (Figure 12) with 478 tonnes and 2334 fished hours.

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 (Figure 13) 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.

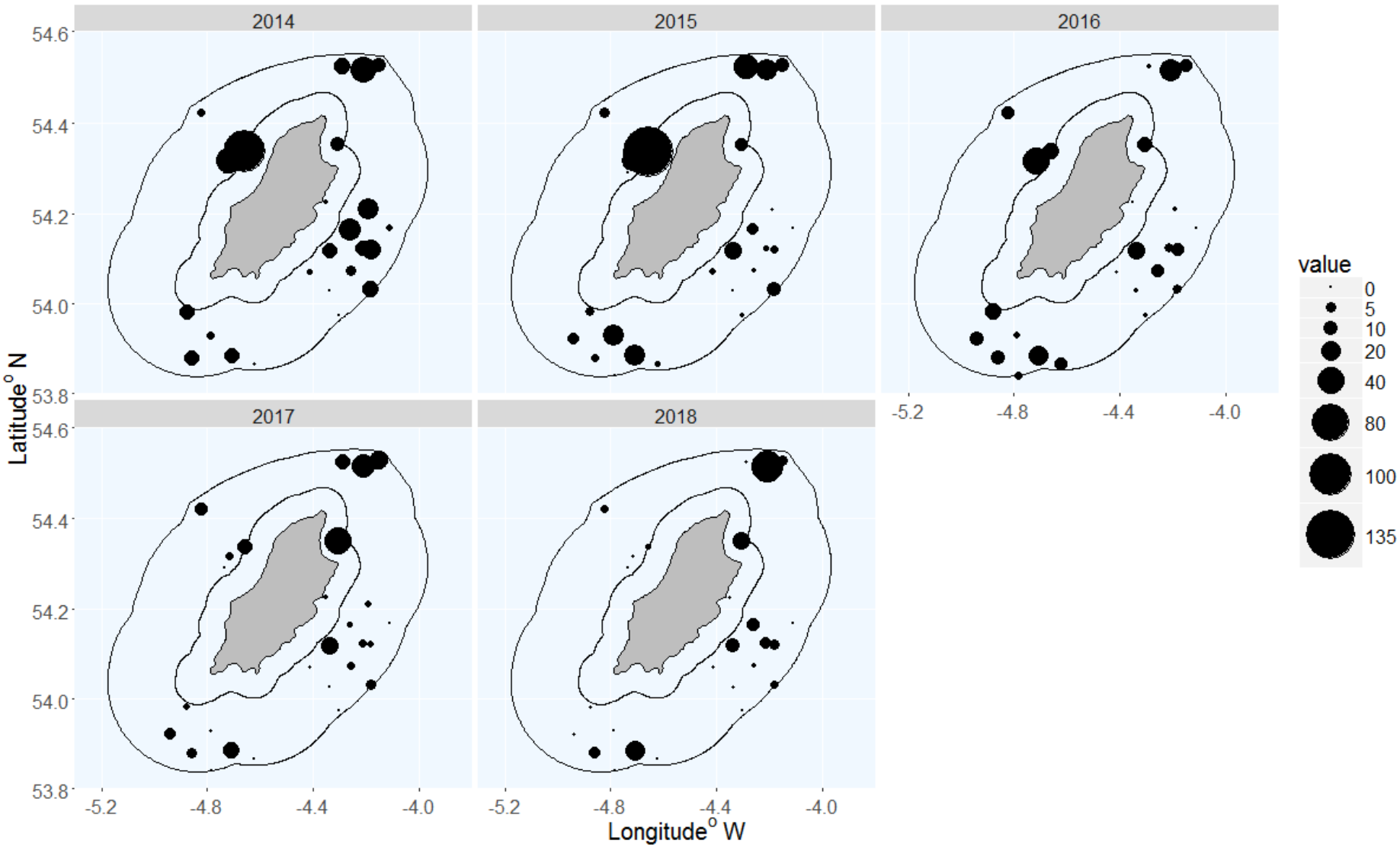

Figure 11: Map showing Survey Density (queen scallops per 100 m^2) by year for stations used in the stock assessment analysis.

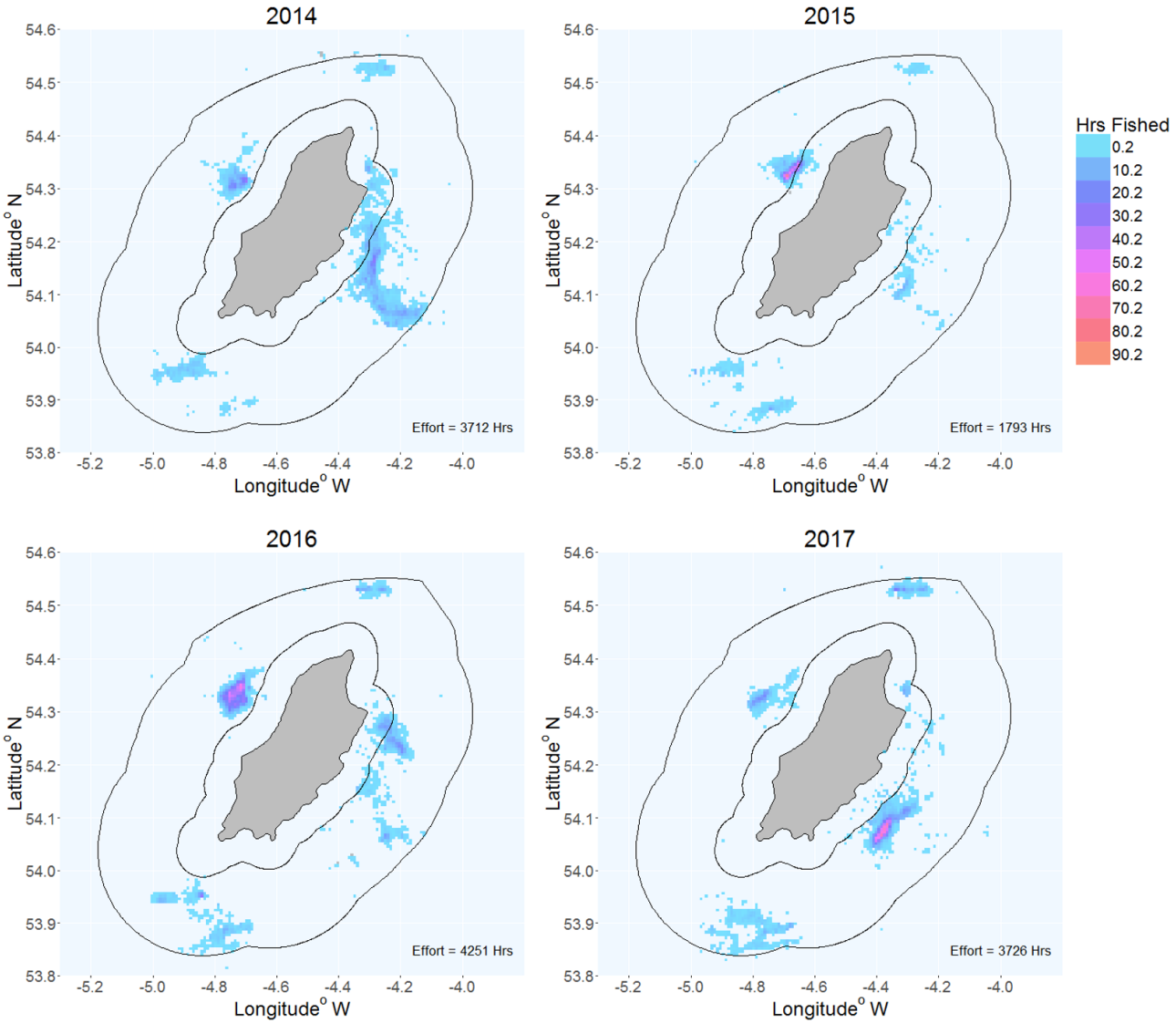

Figure 12: Map showing Fishing Effort (fished hours) for QSC trawl boats, based on start and end coordinates of tows across a raster of 1 km^2 by 1 km^2 cell size. Total effort in hours from Daily Catch Return Forms are displayed in the bottom right corner (this does not include dredge activity and some trawl points were removed due to incorrect spatial positioning i.e. on land).

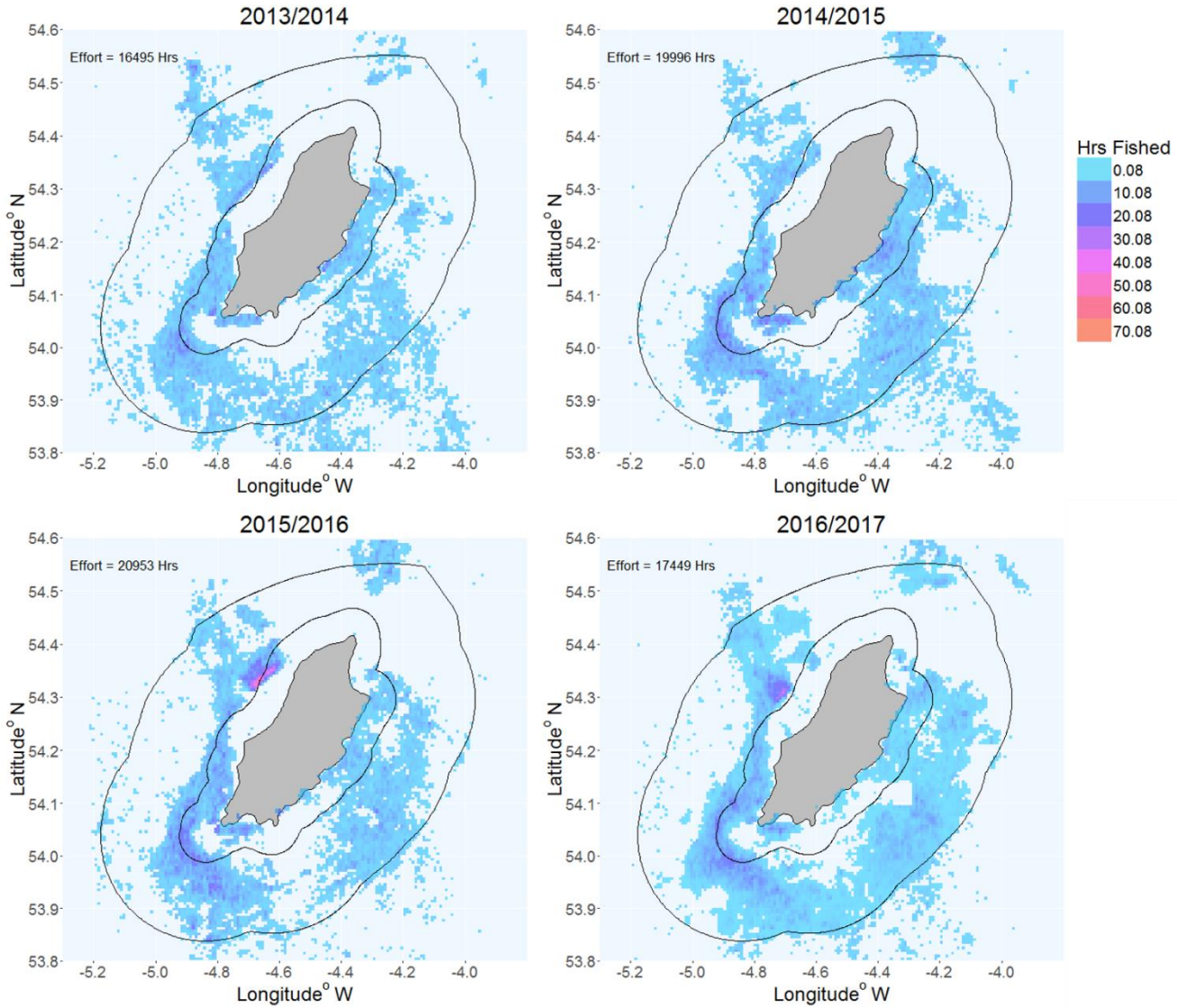

Figure 13: Map showing Fishing Effort (Hrs Fished) for SCE licenced vessels from VMS points at fishing speed (2.0 to 2.6 knots) during the king scallop (Jan, Feb, March, April, May, Nov, Dec) by season [1st Nov Year – 31st May Year+1] across a raster of 1 km^2 by 1 km^2 cell size. Note: VMS polling changed from 2 hrs to 15 mins on 1st November 2016.

The average density of queen scallops (of all sizes caught) per 100 m^2 among fishing grounds around the Isle of Man can be seen in Table 1 for the 2014 to 2018 surveys. These are the average densities of queen scallops from queen scallop dredges for survey sites within each of the main fishing areas.

- EDG saw a sharp decline from a high of 13.5 QSC per 100m^2 in 2014 following a period of high fishing activity (1025 hrs 2014 fishery) to a low of 1.5 QSC per 100m^2 in 2017. There has been an increase in 2018 to 4.5 QSC per 100m^2 following a period of light fishing activity (70 hrs 2017 fishery).

- SED maintained a relatively stable density from 2014 to 2017 (range 4.2 to 5.4 QSC per 100m^2) which has declined in 2018 following a period of intense fishing effort during the 2017 fishery (2334 hrs 2017 fishery) (Figure 12 and Table 2).

- CHI also maintained a relatively stable density from 2014 to 2016 (range 8.2 to 9.9 QSC per 100m^2) but has also seen a decline in the last two survey years averaging a density of around 4.3 QSC per 100m^2. It is important to remember that the dredge fishery also occurred at Chickens during the 2015, 2016 and 2017 fishing seasons (data shown in brackets in Table 1 and Table 2).

- TAR has seen the largest decline in survey densities across this period with densities of 34 – 44 QSC per 100m^2 in 2014 and 2015 dropping to as low as 1.4 QSC per 100m^2 in 2018 following several years of intense fishing for both queen and king scallops within this area and a move away from using closed areas. TAR has seen the greatest quantity of landings removed during the 4 year period with approximately 1600 tonnes of queen scallop landings reported with an accompanying ~ 5000 fished hours.

- POA which typically sees the least effort is the ground that has best maintained relatively high densities (range 12.3 – 22.1 QSC per 100m^2). The data on survey densities over this five year period indicates that with moderate fishing effort densities of queen scallops can be maintained.

LPUE data from the queen scallop trawl fleet also show similar decreases at TAR and CHI and a similar maintenance of levels at POA (Figure 14).

Table 1: A Comparison of the average survey densities (QSC per 100 m^2) per fishing ground for 2015 to 2017 to show increases and decreases across fishing grounds (larger areas rather than individual sites). Total landings for the period are also displayed from each fishing ground (trawl only). The data from the QSC dredge fishery at CHI is reported in brackets next to the trawl data (not in brackets). Average Survey Density (Avg. Surv. Den) is reported in queen scallops per 100 m^2. Data from Ramsey Bay is not reported as there is only one survey site and a limited managed fishery that did not operate in all the years reported below. NB. Temporary closures were in place in some areas of the territorial sea during these years. Only stations included in the stock assessment model have been included. EDG [EDG, LAX, ST22, ST23, ST24 & ST25]; SED [SED, ST3, ST14, ST17, ST20 & ST21]; CHI [CHI, PSM, ST32, ST35, ST36, ST38 & ST39]; TAR [TAR, ST4, ST5 & ST9] and POA [POA, ST10 & ST45].

GRN.	Land 2014/17	Hrs Fish 2014/17	Avg. Surv. Den 2014	Avg. Surv. Den 2015	Avg. Surv. Den 2016	Avg. Surv. Den 2017	Avg. Surv. Den 2018
EDG	253	2060	13.5	2.5	2.9	1.5	4.5
SED	808	4182	5.4	5.3	5.4	4.2	2.7
CHI	592 (559)	1545 (652)	8.2	9.2	9.9	4.4	4.2
TAR	1621	4936	34.0	44.1	15.4	5.9	1.4
POA	227	627	20.7	22.1	17.6	19.6	20.2

Table 2: Landings and hours fished by fishing ground and season (2014 to 2017). Data source: Daily Catch Returns. The data from the QSC dredge fishery at CHI is reported in brackets next to the trawl data (not in brackets).

GRN.	Land 2014	Hrs Fish 2014	Land 2015	Hrs Fish 2015	Land 2016	Hrs Fish 2016	Land 2017	Hrs Fish 2017
EDG	127	1025	2	51	117	913	7	70
SED	282	1471	25	173	23	202	478	2334
CHI	124 (0)	351 (0)	146 (208)	231 (197)	173 (217)	489 (268)	119 (134)	474 (187)
TAR	185	717	748	1288	594	2466	94	465
POA	59	107	17	51	54	161	97	308

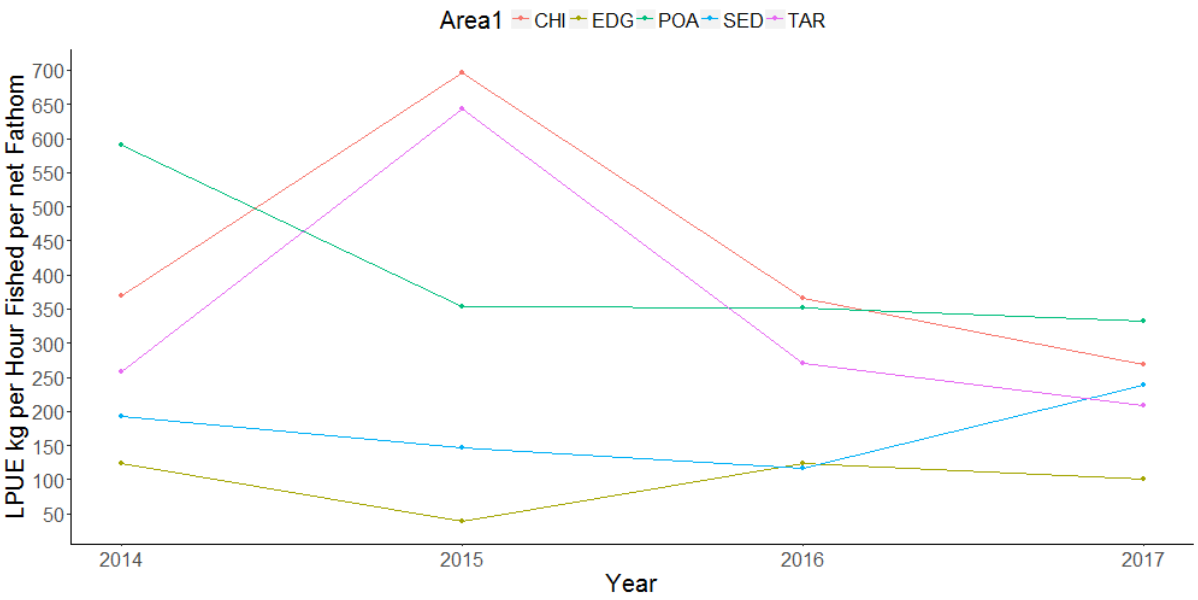

Figure 14: LPUE (kg per hour fished per net fathom) from 2014 to 2018 (trawl data only). Source Daily Catch Returns.

For the area of the territorial sea the median biomass for 2018 is lower than for 2017 (Table 3) and is estimated as 1701t (with a 10% and 90% confidence interval range of 1033t to 2677t, respectively). At these low biomass levels the fishery is likely to be heavily dependent on annual recruitment success to allow biomass levels to increase.

For scallops a direct relationship has yet to be found between spawning stock biomass and recruitment for scallops so it is likely that biomass levels do not act in isolation to determine stock levels but rather that it is one of multiple factors that have threshold limits that affect stock biomass 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 3).

1.5 TAC Calculation for 2018 queen scallop fishing season

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 biomass estimate from this assessment. Biomass and Fishing mortality reference points are however difficult to estimate for scallop populations which have no known stock recruitment relationship, are relatively sedentary and which can aggregate into localised high density areas. 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.

Recent data from the fishery indicates that with estimated biomass removals of ~20 % and over, biomass declined in each subsequent year, with insufficient recruitment to replace the losses from natural and fishing mortality combined. As such, while recruitment levels remain low, a precautionary approach should be adopted with biomass removals from fishing mortality limited to less than 20% until biomass depletion has stabilised or 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 indicated in Table 3, 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 3: A comparison of scientific advice and actual TAC/landings (2013-2018). Landings here are represented annually (1st January to 31st December); BM = biomass. 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 in 27 VIIa and VIa. *N.B.* Retrospective changes to the median biomass estimates for preceding years occur as new data years are incorporated in the model, within the ranges of the estimated 10% and 90% Confidence Intervals, changes highlighted in grey text.

	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	9406t	2500t	1881t	5000t	53%	8138t
2014	5346t	0t	1069t	1000t	19%	6107t
2015	4700t	0t	940t	1240t	26%	6866t
2016	3788t	0t	758t	1240t	33%	3723t
2017	2759t	0t	552t	992t	36%	2095t
2018	1701t	0 - 340 t	340t	TBC	TBC	TBC

1.6 Spatial management and closed areas

Scallops are broadcast spawners and as such successful reproduction is likely to be higher when adults are present at higher densities with fertilisation success 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.

2. Conclusions

- The estimated median biomass for 2018 (1701t) is lower than 2017 (approx 38% decrease).
- 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 2017 is advised for the 2018 fishing season, for example, limiting biomass removal within the territorial sea to less than 20% of the estimated median biomass (e.g. < 340t) could assist with trying to stabilise biomass declines and/or promote an increase in biomass.
- 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 (an industry survey is recommended at Targets to trial methods of localised absolute biomass estimates).
- 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.
- Since 2014, landings within the territorial sea have remained low as a result of restrictive management measures (992 - 1240t). 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 2095 t) a downward trend that remains the same even when voluntary 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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Appendix 1: Data Input for CSA Versions 3.1.1 and 4.3

Table 4: Data for inputting into CSA version 3.1.1 and 3.4 for the 2018 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	0.0334	0.0104	0.0104	0.0334	NA	NA	NA	NA	NA	NA	0.2	0.35	0.3333	0.1	0.1	19.1135	72.056

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). Within the appendices of this report the outputs of the two model versions are detailed (Appendix, 2). 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.

Appendix 2: Data outputs for CSA version 3.1.1

Table 5: Summary of results from CSA model (Version 3.1.1) with median estimates (M=0.2; s = 0.35 and percentile range = 10% - 50% -90%) from 2018 stock assessment model for territorial sea area

Year	10 % CI biomass (t)	Total median biomass (t)	90 % CI biomass (t)
1993	3891.2	4901.3	6365.3
1994	2885.8	3869.4	5343.8
1995	2141.7	3037.6	4259.5
1996	3629.8	4538.4	5509.5
1997	4892.9	5908	6999.2
1998	2921.3	3720.2	4721.2
1999	1838.9	2441.8	3342.7
2000	3123.4	4298.5	5732.3
2001	4772	6343.5	8223.4
2002	4590.5	6245.1	8268.5
2003	4080.4	5199.5	7096.4
2004	3754.4	4929	6812.6
2005	3299.9	4411.3	6013.6
2006	3550.7	4911	7114.1
2007	9708	13017.4	16747.6
2008	14942.4	20975.1	27992.1
2009	17570.9	21703.3	26624
2010	21095.8	25531	30555.8
2011	18272.1	22268.7	26224.2
2012	10695.4	13530	16580.8
2013	7228	9406.3	11792.9
2014	3872.4	5345.9	7415.7
2015	3651.7	4699.8	6091.2
2016	2952.3	3787.7	5055
2017	1970.9	2759.1	3971.9
2018	1032.9	1701.5	2677.4

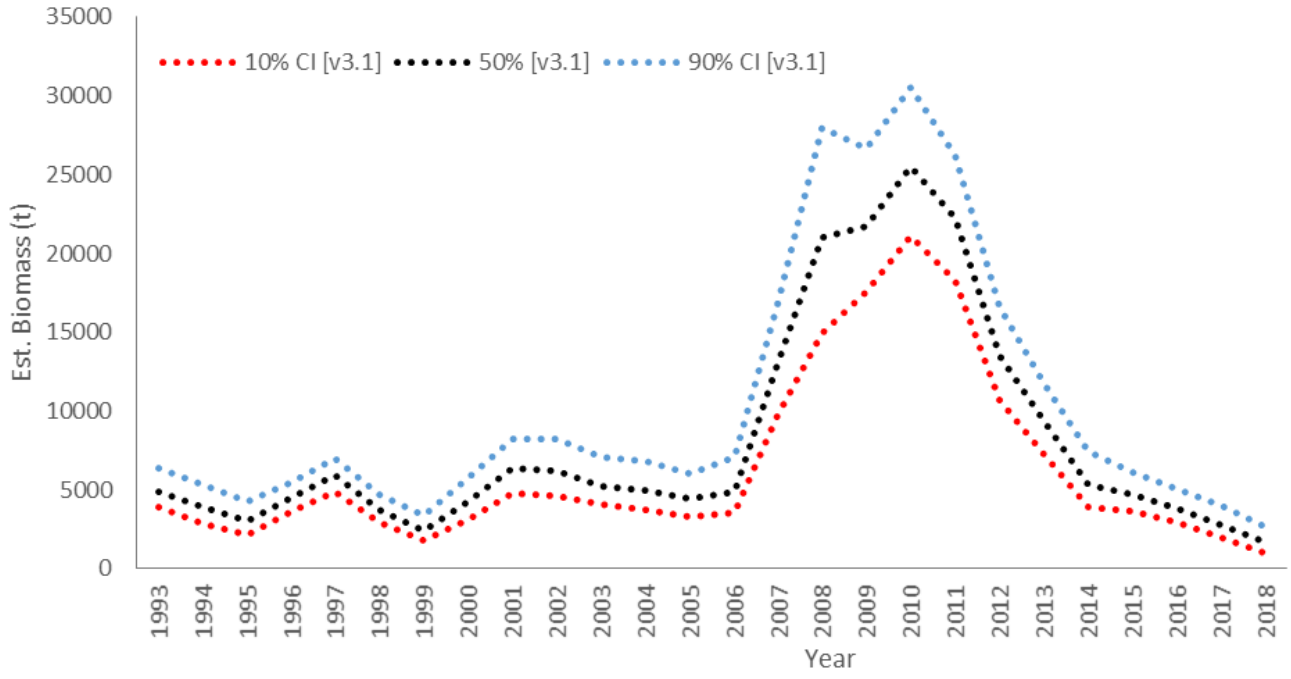

Figure 15: Estimated biomass for the Isle of Man territorial sea, bootstrap results. From 2018 stock assessment model (CSA V3.1.1)

Appendix 2: Data outputs for CSA version 4.3

Table 6: 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 2018 stock assessment model for territorial sea area

Year	10 % CI biomass (t)	Total median biomass (t)	90 % CI biomass (t)
1993	4742.5	5012.3	5328.6
1994	3785.9	4028.5	4312.7
1995	2968.3	3173.2	3402.7
1996	4342.9	4550.7	4762.2
1997	5909.4	6139.1	6424.2
1998	4405.2	4604.8	4845.2
1999	2792.5	2944.5	3129.2
2000	4225.3	4440.6	4643.5
2001	6552.2	6846.5	7202.4
2002	6670.4	7024.6	7401.4
2003	5767.5	6094.8	6438.1
2004	5419.1	5727.4	6120.2
2005	4803.9	5136.9	5496
2006	5034.2	5458.5	5889.8
2007	11402.6	12248.5	13102.7
2008	17527.6	18884.4	20343.7
2009	19567.5	20568.8	21556.9
2010	23750.9	24841.6	26087
2011	20982.2	21762.1	22606.9
2012	12809.7	13339.9	13882.4
2013	8958.9	9334.4	9819.9
2014	4935.2	5185.6	5518.7
2015	4362.3	4563.3	4785
2016	3519.5	3688.4	3920.5
2017	2518.4	2678.6	2897.6
2018	1447.2	1586.8	1766.9

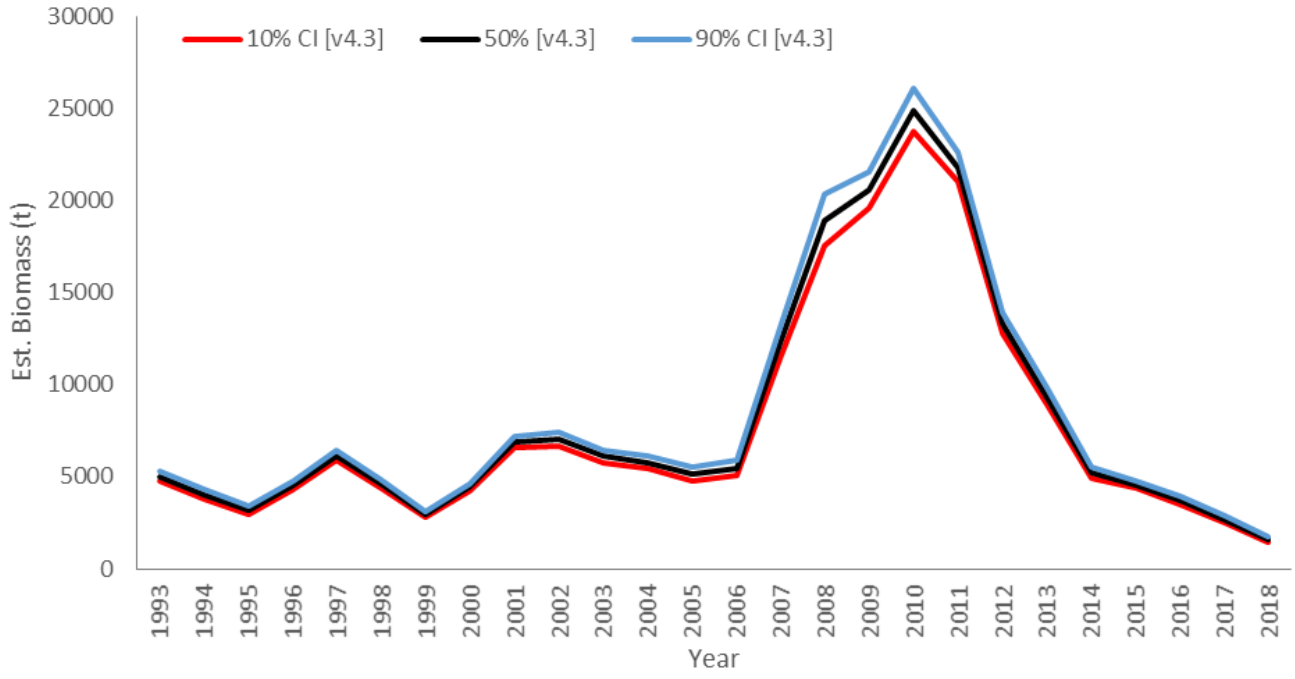

Figure 16: Estimated biomass for the Isle of Man territorial sea, bootstrap results. From 2018 stock assessment model (CSA V3.1.1)