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Isle of Man king scallop (*Pecten maximus*) stock advice:

A data-limited approach for setting a total allowable catch for the 2017/2018 fishing season and progress towards a quantitative stock assessment for the 2018/2019 fishing season

Preliminary Report

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Executive Summary

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

Stock advice (2017/2018)

Applying the precautionary, ICES data limited Category 3 stock approach it is advised that catch in 2017/2018 from within the territorial sea should be no more than 2563 t (precautionary buffer applied due to past historical considerations).

Stock development over time

The length based abundance index for recruits (< 105 mm) declined in 2016 and decreased significantly in 2017. A similar decrease was evident for post-recruits (> 105 mm) in 2017 (Figure I). The commercial catch continued to increase in 2016 (Figure I). There was a decrease in the overall abundance index (all size scallops) in 2017 which is also observed in the estimates of biomass from both length based (Figure I) and age based stock assessments (see Section 3 Main Report).

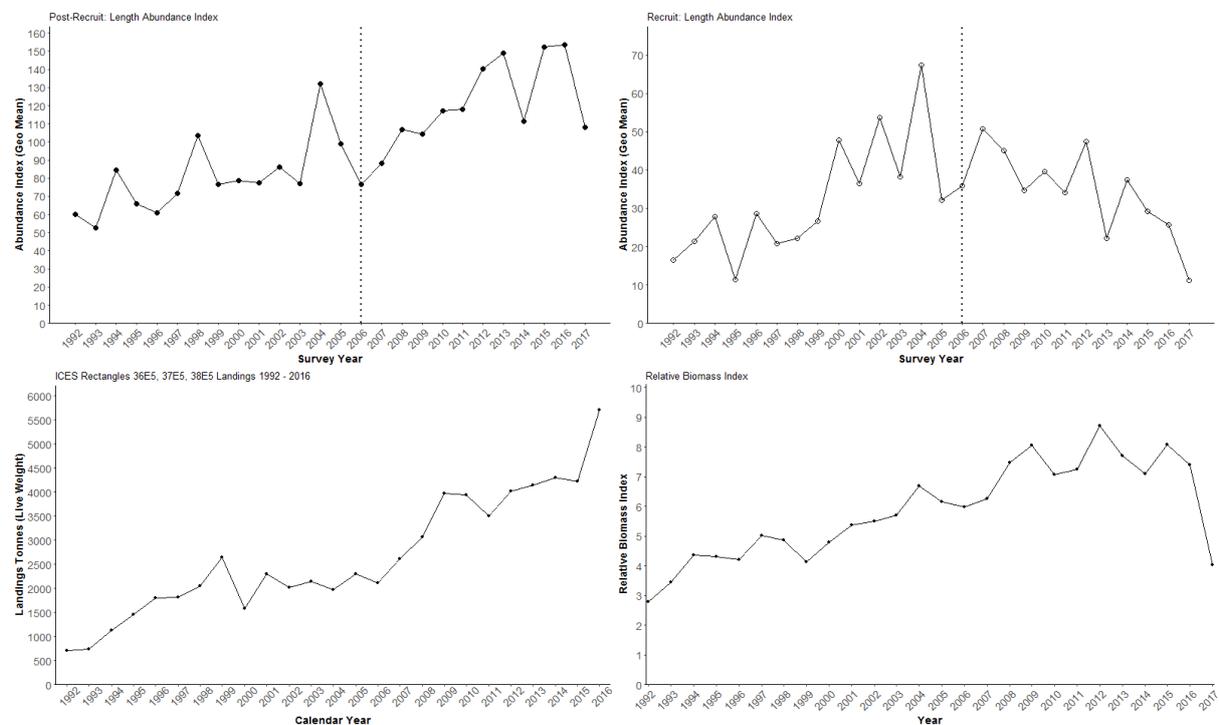


Figure I: King scallops in ICES Rectangles 36E5, 37E5 and 38E5. Upper left, Post-Recruit abundance index from survey; Upper right, Recruit abundance index from survey; Lower left, landings from ICES Rectangles 36E5, 37E5 and 38E5 by calendar year; Lower right, Relative biomass index calculated using CSA v 4.3.

Catch options

The ICES framework for category 3 stocks was applied (ICES, 2012). The spring scallop dredge survey abundance index was used as an index of stock development. The advice is based on a comparison of the latest index value (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 14% 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 not applied. The stock status relative to candidate reference points

is unknown, since there is also evidence of recruitment impairment and high fishing mortality (F), the precautionary buffer (a 20% reduction in catch to safeguard against significant biomass declines) was applied.

Table I: King scallops in the Isle of Man's territorial sea. The basis for catch options. Index A is the average of the last two year's survey abundance indices (2016 – 2017); Index B is the average of the three preceding year's survey abundance indices (2011 – 2015); 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 reference 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 (2016 - 2017)	149.29	149.29
Index B (2011 - 2015)	172.81	172.81
Index Ratio (A/B)	0.86	0.86
Uncertainty cap	NA	NA
Averaged catch for 2012 – 2017 seasons*	3708	3708
Discard rate	-	-
Precautionary buffer	NA	0.8
Catch advice for 2017/2018**	3203	2563

* The average catch (estimated for TS) has been averaged for the last 5 seasons and used as a proxy for the 'Advised catch for 2016/2017 season within the TAC calculation process

** For Scenario I: advice for 2016/2017 x Index Ratio

** For Scenario II: (advice for 2016/2017 x Index Ratio) x Precautionary Buffer

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 – 2017. A formal stock assessment is under development (Section 3 Main Report) at which point a biomass index will be used for the calculation of the index ratio change in future king scallop fishing seasons.

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.

Issues relevant for the advice

The recruit index (scallops under 105 mm) shows a change in the long term trend since 2006 from increasing (1994 – 2004) to decreasing (2007- 2017; Figure 1). The absence of strong recruitment raises concerns about the future productivity of the stock.

Reference points

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

Conclusions

- It is recommended that a TAC for the 2017/2018 Isle of Man's king scallop fishery is defined on the basis of ICES protocol for Category 3 stocks (Method 3.2).
- For the 2017/2018 king scallop fishing season the TAC calculation is based on the abundance index pending the peer review of the quantitative stock assessment methods. Once the stock assessment methods have been externally reviewed and validated then the relative biomass index will be used for the calculation of the TAC percentage change in future king scallop fishing seasons (i.e. 2018/2019 onwards).
- Method 3.2 outlined by ICES compares the values from the two most recent years of the abundance index with the values from the three preceding years. The TAC is then adjusted by the percentage difference of these two values taking into account the 20% uncertainty cap. As there is evidence of recruitment impairment and high fishing mortality (F) the 20% precautionary buffer was applied.
- Previously no TAC has been set for the Isle of Man's king scallop fishery within the territorial sea. As a result, the SMB recommended that a proxy for the previous seasons catch advice was calculated from the average landings from the previous 5 fishing seasons (3708 t), with a proportion of landings from ICES Rectangles 36E5, 37E5 and 38E5 attributed to the territorial sea using VMS and landings data.
- The provisional catch advice for 2017/2018 king scallop fishery within the territorial sea is 2563 t (precautionary buffer applied).
- Should the TAC be adopted without the application of the precautionary buffer (3203 t) it is recommended that a review of the fishery is undertaken following the first month of the season with the option to revisit the application of the Precautionary Buffer or the proxy for the previous seasons catch advice (i.e. this could be taken as a longer term average of landings e.g. 1992 – 2016).
- 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. Isle of Man king scallop stock advice

1.1 Background

Bangor University was requested to provide scientific advice for the Isle of Man's king scallop stocks. This report represents the advice provided by Bangor University for this stock. The first section of this report provides a background to the king scallop fishery within the Irish Sea (particularly within the Isle of Man's territorial sea). The second section 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 an index-adjusted total allowable catch (TAC) harvest control rule was used to determine a TAC for the Isle of Man's king scallop fishery for the 2017/2018 fishing season. The final section of this report summarises additional work that has been undertaken on producing a quantitative stock assessment for king scallops in ICES Rectangles 36E5, 37E5 and 38E5. A summary of the results of these stock assessment approaches, using both length (catch-survey analysis) and age (statistical catch at age) based methods, are provided. The full results of these stock assessments will be provided in a separate report which will be available from Bangor University's Fisheries and Conservation Science Group website (<http://fisheries-conservation.bangor.ac.uk>) following completion of a full external review.

1.2 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. A total of 94 vessels from the Isle of Man, Wales, Scotland, England and Northern Ireland have licences to fish for king scallops in the Isle of Man's territorial sea 3- 12 nm limit and of those 42 vessels also have permits to fish for king scallops within the 0- 3 nm limit. For the 2016/2017 fishing season the management measures that governed the fishery included:

- 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]
- 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 covered by the Fisheries Act 2012 and through restrictive licencing conditions.

Of the 94 vessels licenced to fish for king scallops during the 2016/17 fishing season 93 vessels reported landings of king scallops from within 36E5, 37E5 or 38E5.

1.3 Landings

The annual landings of king scallops from the Irish Sea (Area VIIa) over the period 1950 – 2015 are shown in Figure 1 (ICES 2017a, b). Since 2006 landings have increased rapidly peaking in 2009 and 2012 at ~ 9500 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 2015 the average annual Manx share has declined to around 18%, with landings from United Kingdom vessels (Scotland, England, Wales and Northern Ireland) landing around 66% (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 current quantity of landings from the Irish Sea (VIIa) are unprecedented and of concern, given the general lack of knowledge and management of the stock at these high fishing levels (Duncan et al., 2016).

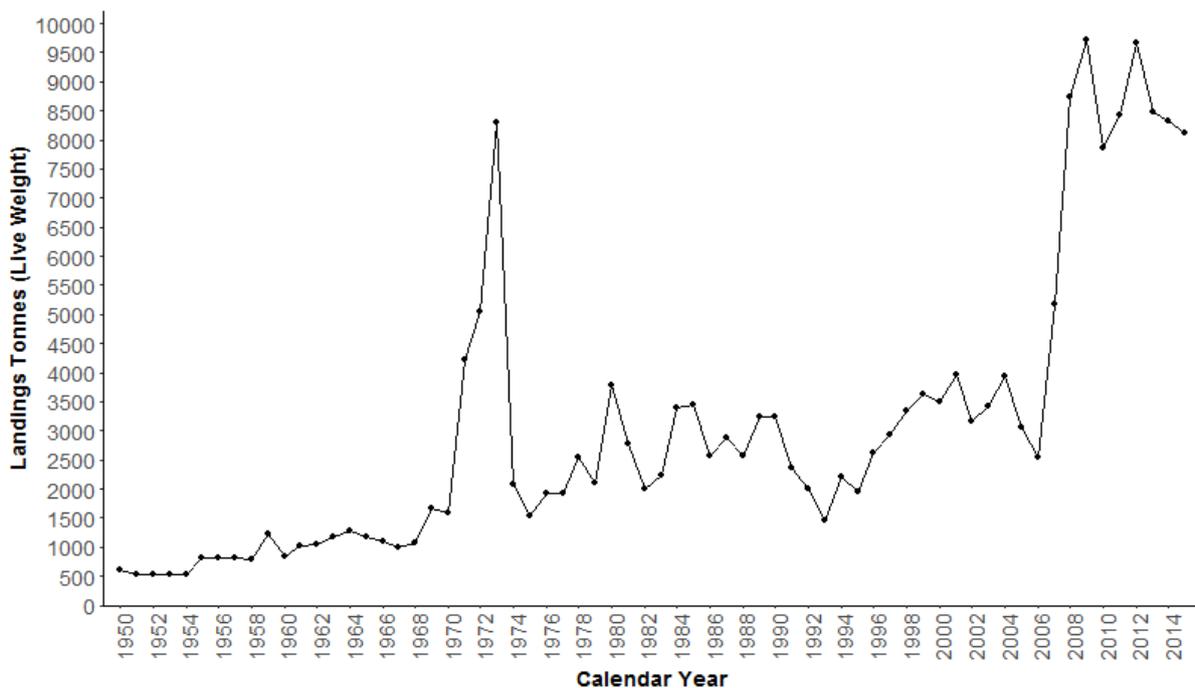


Figure 1: Annual King Scallop landings (t) from ICES Area VIIa for 1950 to 2015 using scallop landings from species Great Atlantic Scallop and Scallop Nei (ICES 2017a; ICES 2017b).

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 very 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 have continued to increase since 2009 with an annual average of 4020t from 2010 – 2015 and a peak in 2016 of 5714t.

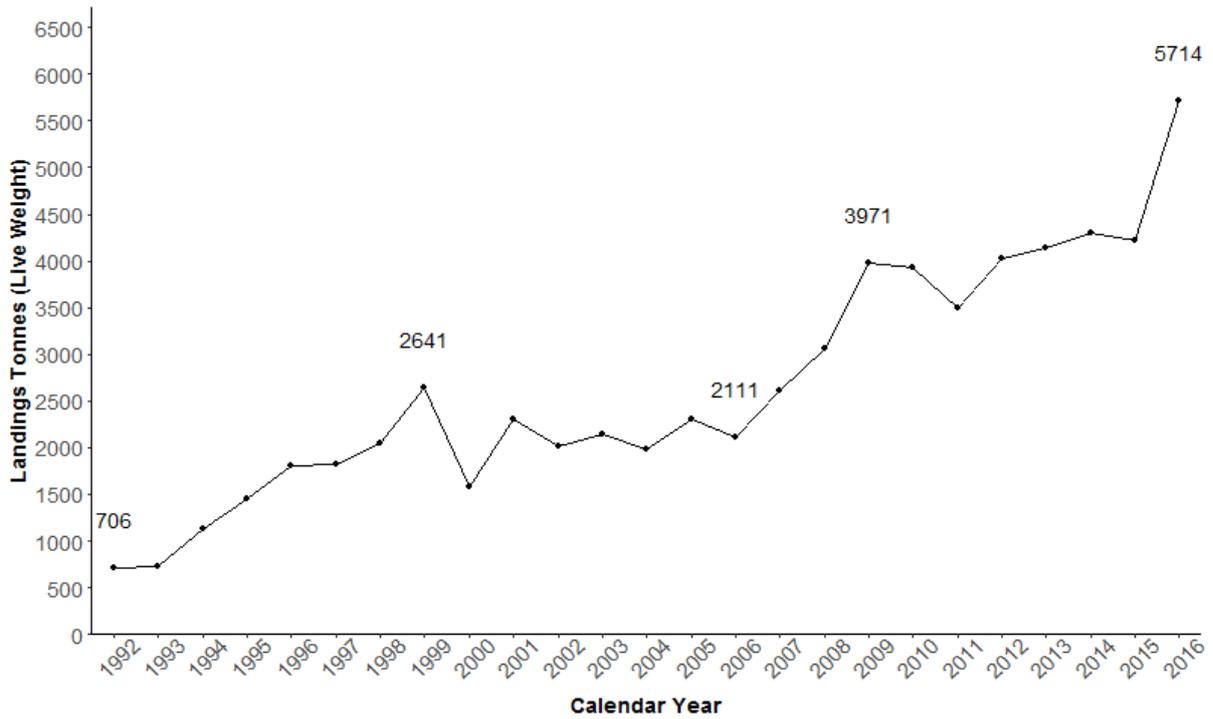


Figure 2: Annual King Scallop landings (t) from ICES Rectangles 36E5, 37E5 and 38E5 (Source: Logbook data DEFA, Marine Scotland, MMO). For information the landings (t) values from key years are annotated on the graph.

Seasonal landings of king scallops (1st November Yearⁿ – 31st May Yearⁿ⁺¹) from ICES statistical rectangles 36E5, 37E5 and 38E5 have been relatively stable over the last six seasons (average 3961 t), although the last season (2016/2017) saw an increase to 4861 t (Figure 3). In addition to the increase in overall landings the temporal pattern of landings within the season differed from other seasons with a large spike in landings (> 2000t) during the first month of the 2016/2017 fishery while previous fishing seasons were more stable at ~1000t or less (Figure 4).

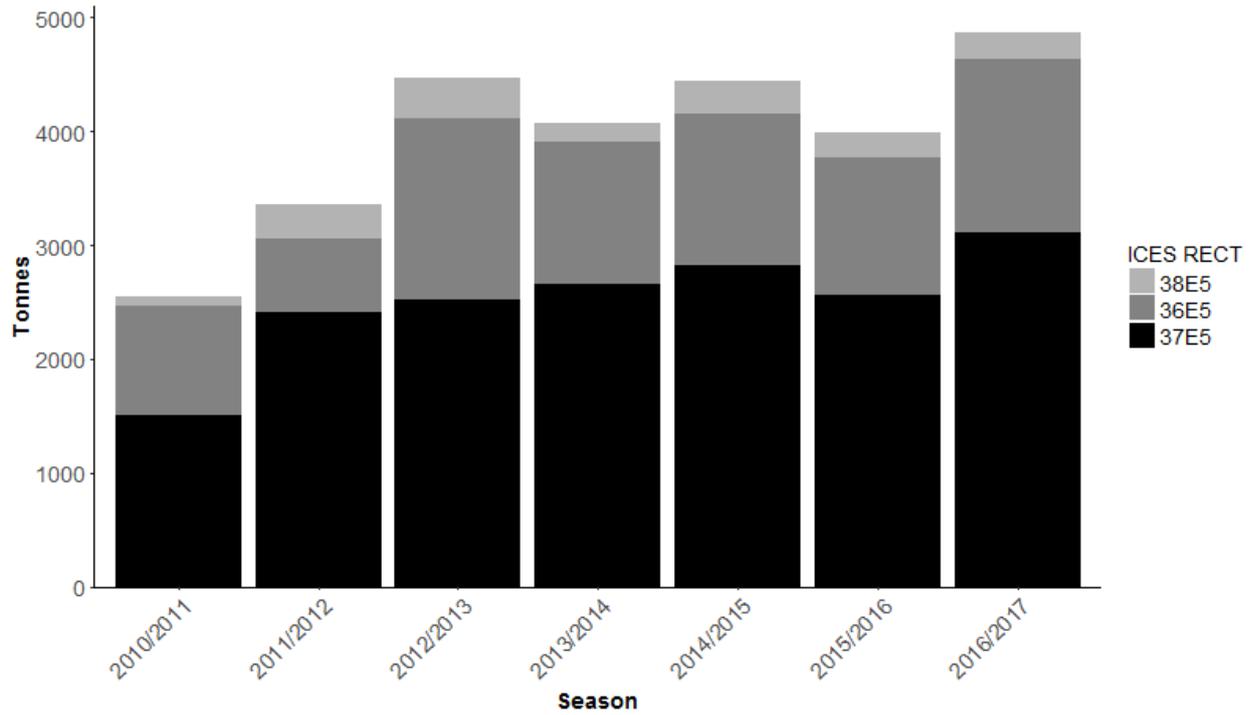


Figure 3: Seasonal landings (t) of king scallops from ICES Rectangles 36E5, 37E5 and 38E5. Data source: EU Logbooks downloaded through IFISH2. *NB. This data includes all vessels fishing for king scallops (except vessels from Ireland for which we do not receive EU logbook data) and not only those vessels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

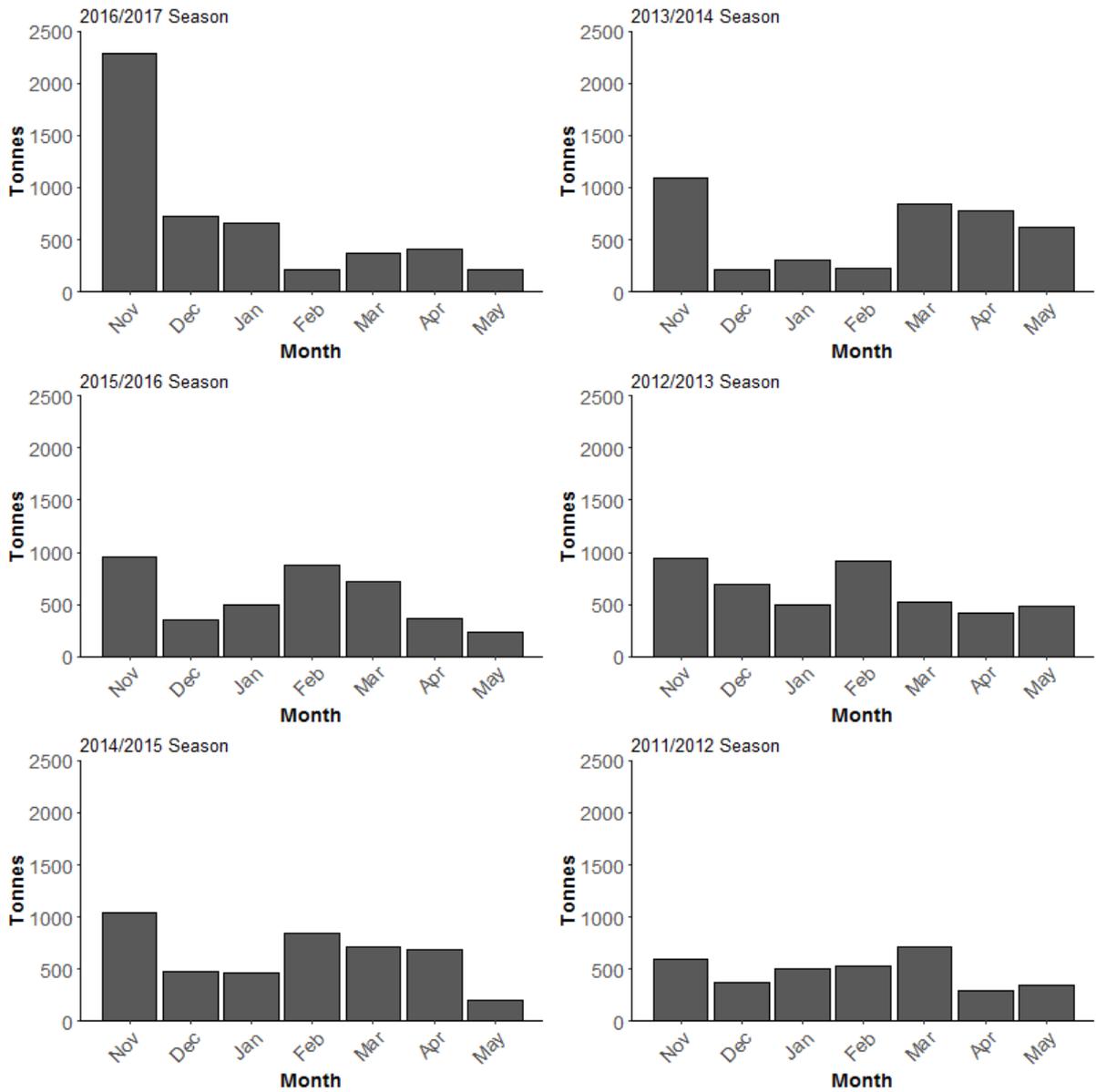


Figure 4: Landings of king scallops from 36E5, 37E5 and 38E5. Data are presented for each fishing season (1st Nov Yearⁿ to 31st May Yearⁿ⁺¹). Data source: EU Logbooks downloaded through IFISH2. *NB. This data includes all vessels fishing for king scallops (except vessels from Ireland for which we do 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.*

2. TAC Calculation for 2017/2018 SCE fishing season

2.1 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 analytical 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 was 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. Survey indices can contain a level of noise within the data, as such a +/- 20% cap on inter annual changes in the TAC is advised (ICES, 2012). The 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) 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). When a biomass index becomes available this should be used in preference to an abundance index.

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 survey's noise with the uncertainty cap (+/- 20 %)
3. Apply the precautionary buffer to the catch advice

2.2 Survey abundance index

Spring surveys of the Isle of Man's scallop populations have been undertaken annually since 1992. The 2017 scallop survey was undertaken using the RV Prince Madog from 28th March – 10th April. Although the extent and number of survey stations has been increased since 2013 (recently introduced stations are represented by either just a number e.g. 46 or a number prefixed with an F e.g. F12; Figure 5 & Figure 6) only the standard eleven historical queen scallop survey stations (BRI, BRO, CHI, EDG, LAX, PEL, POA, PSM, RAM, SED and TAR), were included in the current survey abundance index assessment as these reflect the extent of the main, persistent king scallop beds within the Isle of Man's territorial sea. All stations were surveyed using the protocol described by Murray *et al.* (2009).

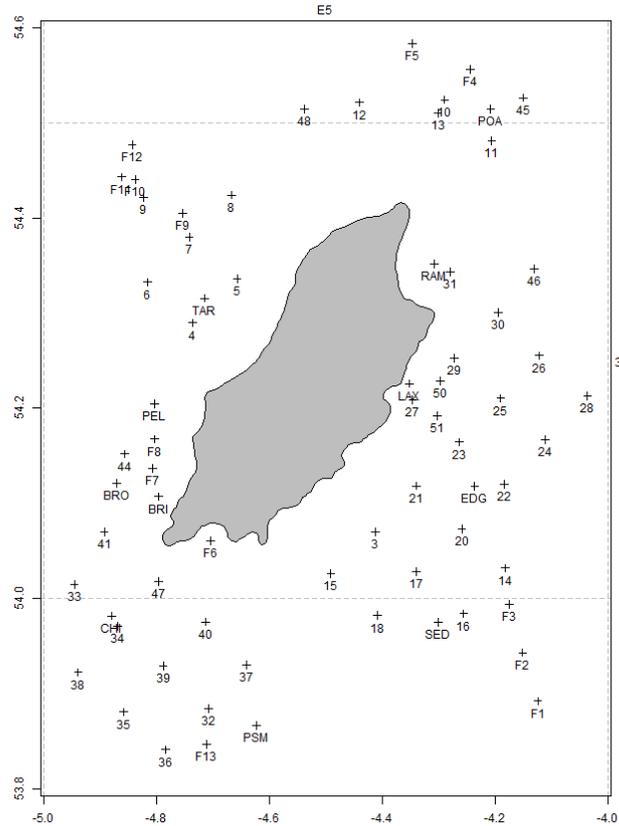


Figure 5: All survey stations sampled onboard the R.V. Prince Madog as part of the scallop stock assessment survey. The stations labelled with 3 letter codes (e.g. CHI) are the 11 historical stations that have been surveyed since 1992. The stations labelled with numbers (e.g. 12) are the newer stations 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.

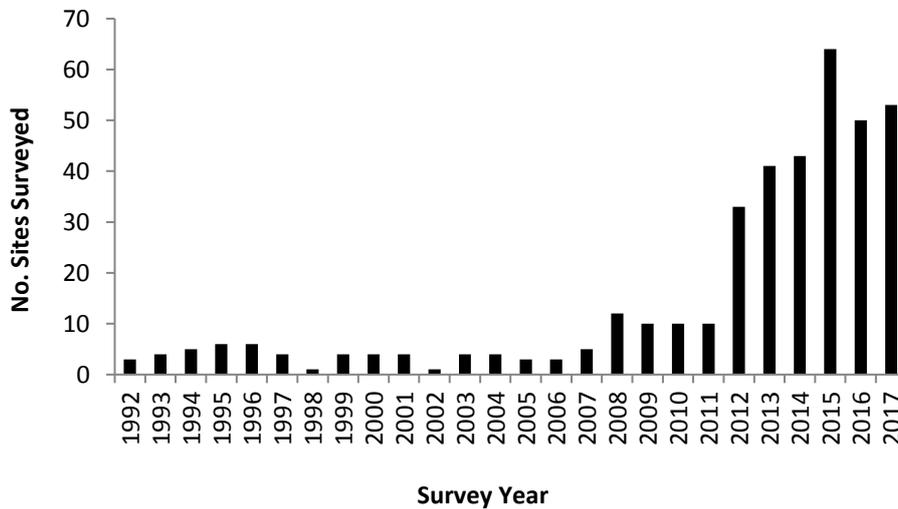


Figure 6: Sampling frequency for survey stations within the annual spring scallop stock abundance surveys indicating the substantial increase in survey sampling effort from 2012 onwards.

The geometric mean of king scallop density was calculated across survey stations using data from both king and queen scallop dredges to derive the abundance indices. Data from both dredge types was used as the number of king scallops of Ages 1- 4 was generally higher in the queen scallop dredges and the numbers of king scallops of Ages 5 + was relatively consistent in both dredge types (Figure 7).

The use of the geometric mean 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 length based abundance index presented within this section shows a declining trend in the mean abundance of recruits (scallops < 105 mm) from 2007 to 2017 with slight increases observed in 2010, 2012 and 2014 (Figure 8). From 2006 to 2016 the abundance index shows an increasing trend in the mean abundance of post-recruits (scallops ≥ 105 mm), with a decrease in 2014, reaching the highest levels on record in 2016. However, the mean abundance of post-recruits has shown a decrease again in 2017 (Figure 9).

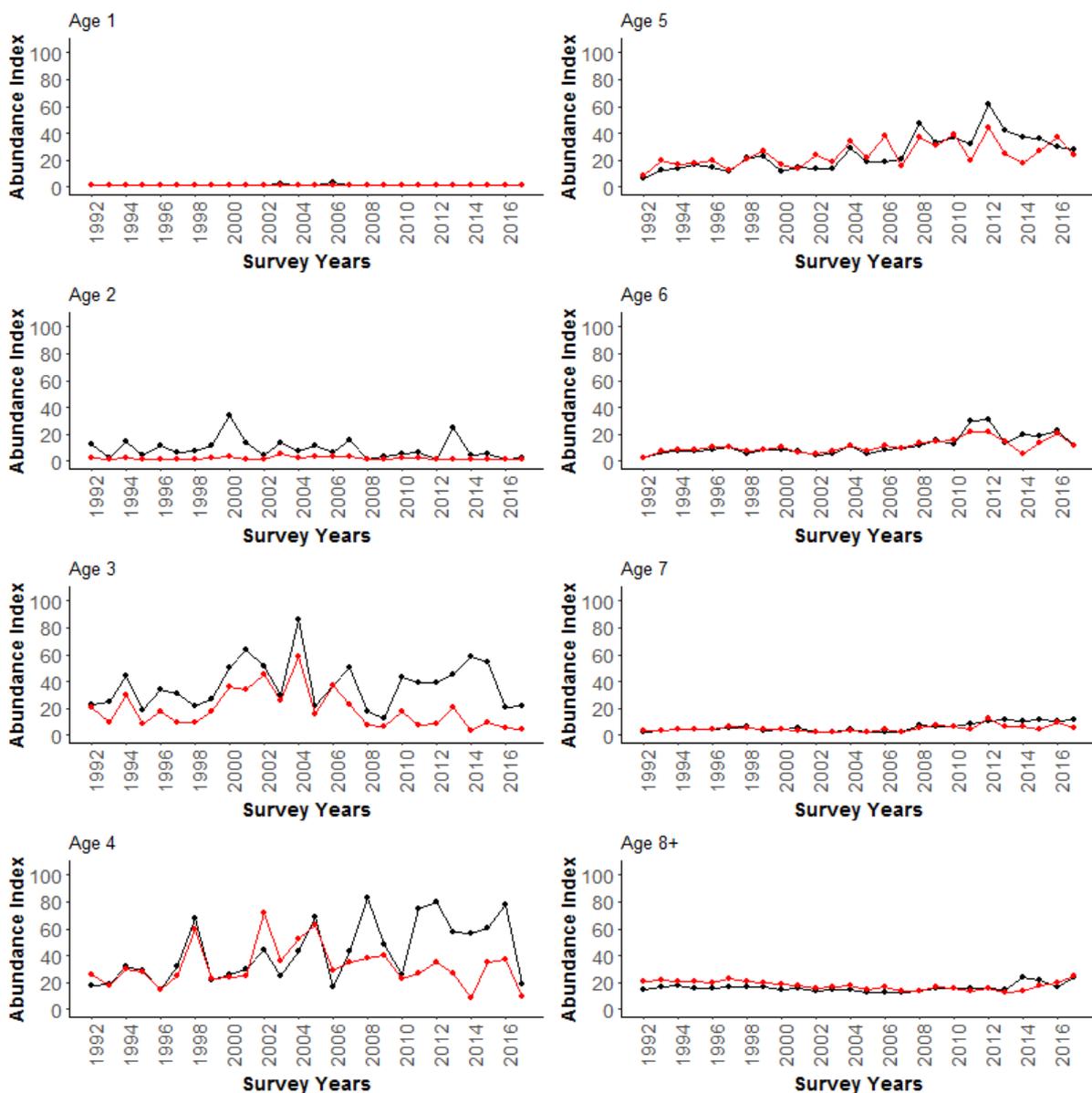


Figure 7: Abundance indices (based on geometric mean) for each Age class displayed separately for king scallop dredges (red lines) and queen scallop dredges (green lines). This is calculated using data from only the stations used in the 2017 stock assessment model. Zero data values have been treated as 0.01 in order to calculate the geometric mean.

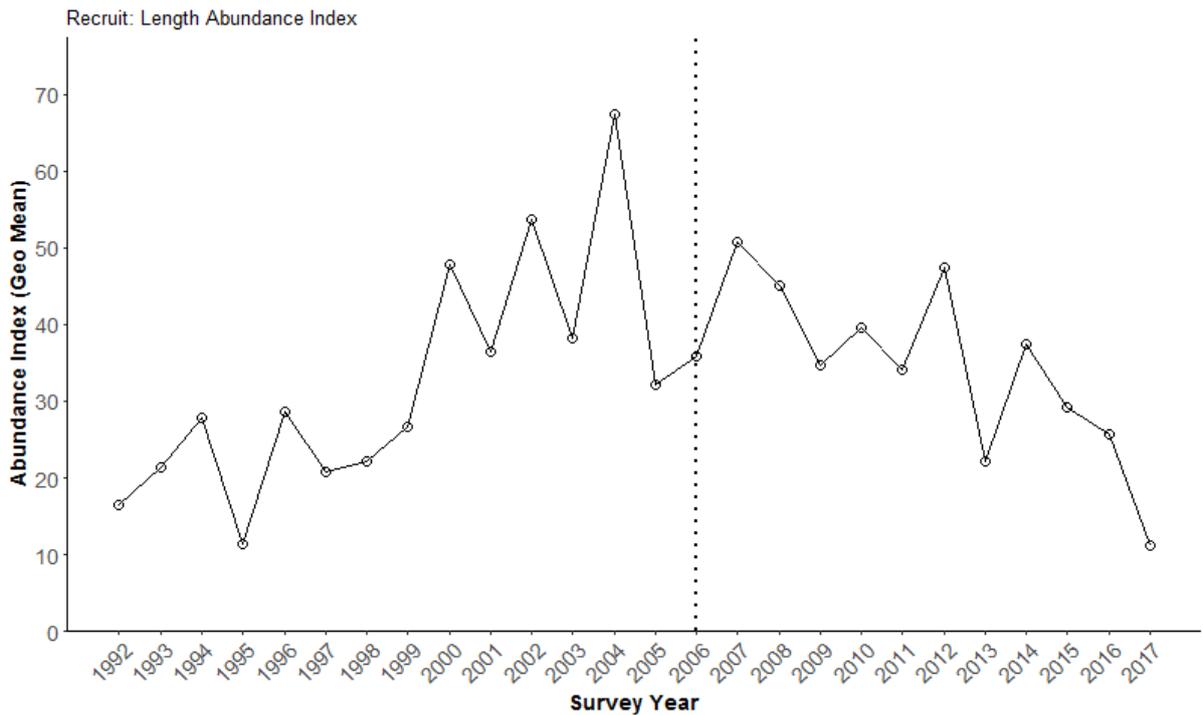


Figure 8: Length based abundance index (based on geometric mean) for recruits (scallops under 105 mm). This is calculated using data from only the 11 historical survey stations. Zero data values have been treated as 0.01 in order to calculate the geometric mean. The dashed black line indicates a change in trend from the earlier period (1992- 2006) to the later period 2007 – 2017).

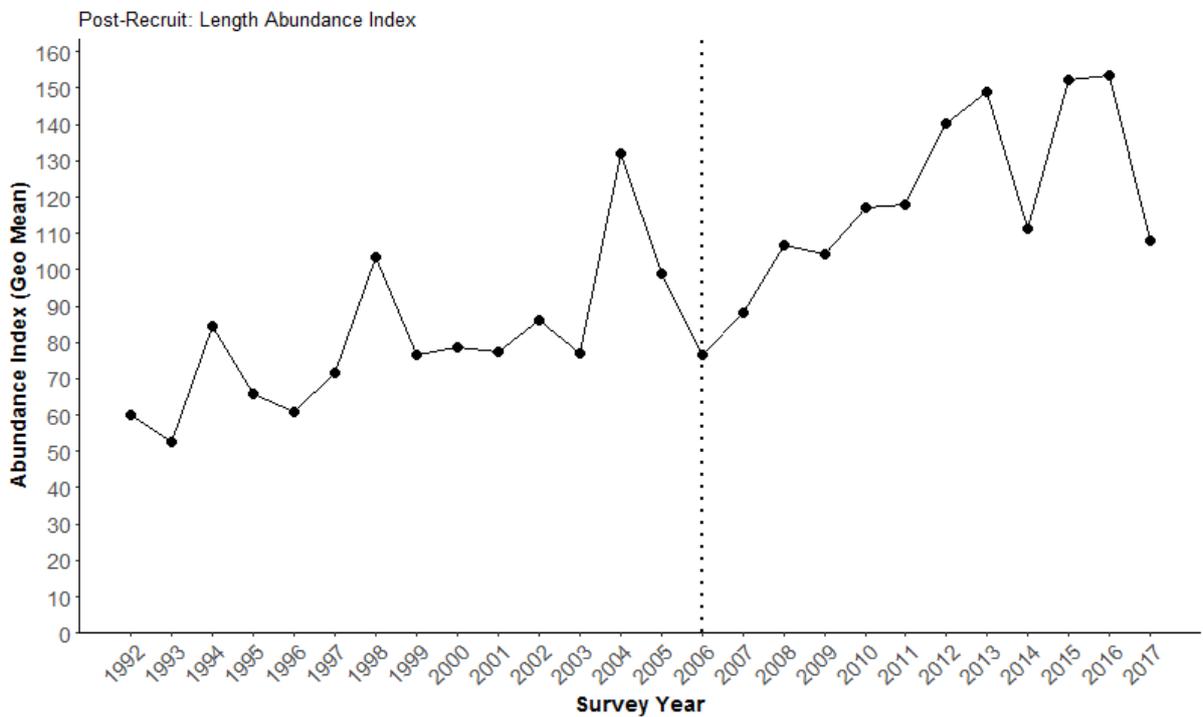


Figure 9: Length based abundance index (based on geometric mean) for post-recruits (scallops over 105 mm). This is calculated using data from only the 11 historical survey stations. Zero data values have been treated as 0.01 in order to calculate the geometric mean. The dashed black line indicates a change in trend from 2006 to 2017.

The recruit index (scallops under 105 mm) shows a change in the long term trend since 2006 from increasing (1994 to 2004) to decreasing (2007 to date) coinciding with a significant increase in landings

(2006 onwards) both within the wider Irish Sea (VIIa; Figure 1) and within the more localised territorial sea fishing area (36E5, 37E5 and 38E5; Figure 3 & Figure 10). Whilst the Post-recruit index (scallop over 105 mm) indicates a general increasing trend over the same time period as recruits grew into the stock. However, the continued decline 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 removals of adult king scallops from the stock, as a result of high fishing effort, exceeds stock replacement by recruits. Given the current knowledge of spat distribution and settlement which indicates a strong link between the Irish Sea king scallop stocks the significant increase in fishing effort not just within the locality of 36E5, 37E5 and 38E5 but also the wider Irish Sea (Area VIIa) could additionally be impacting recruitment within the Isle of Man’s territorial sea.

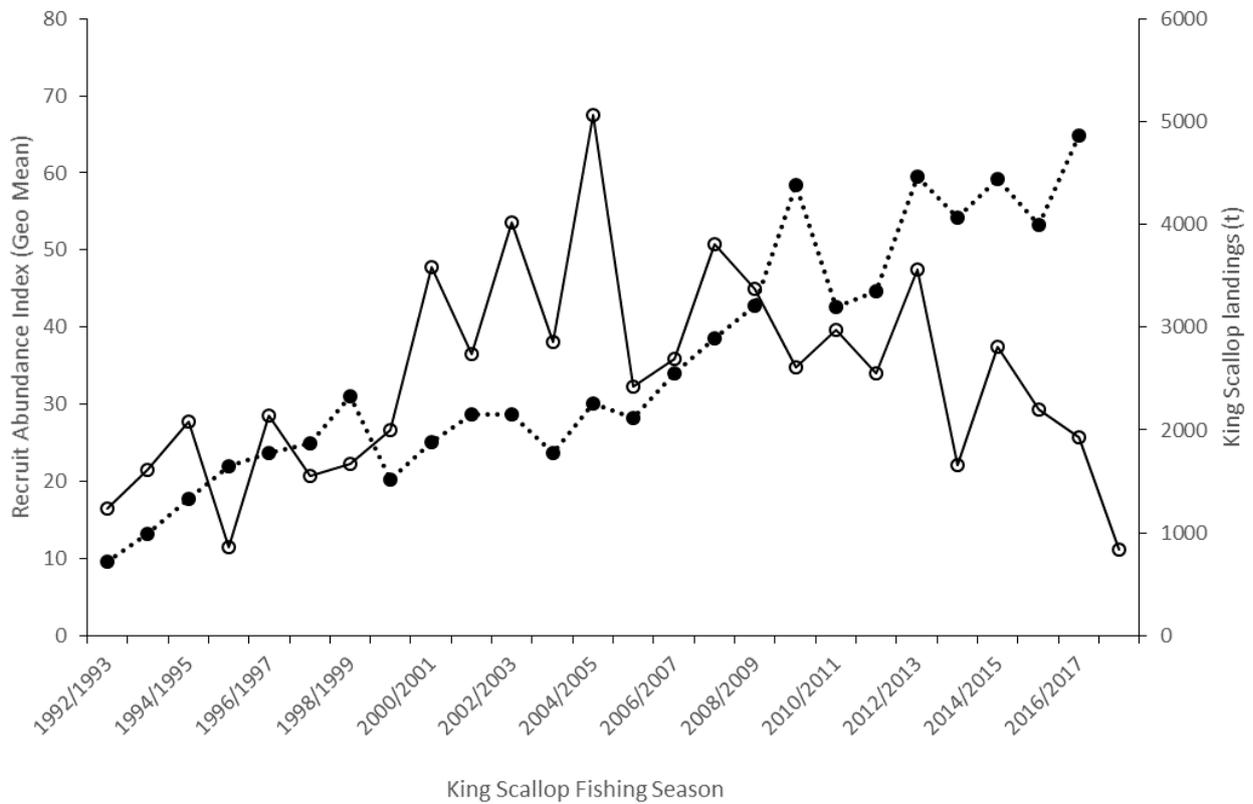


Figure 10: Recruit (scallops under 105 mm) abundance index (geometric mean) plotted against seasonal king scallop landings (t) from ICES Rectangles 36E5, 37E5 and 38E5. The graph indicates a potential tipping point in landings at around 3000 t when the recruit abundance index changed from an upward trend to a downward trend.

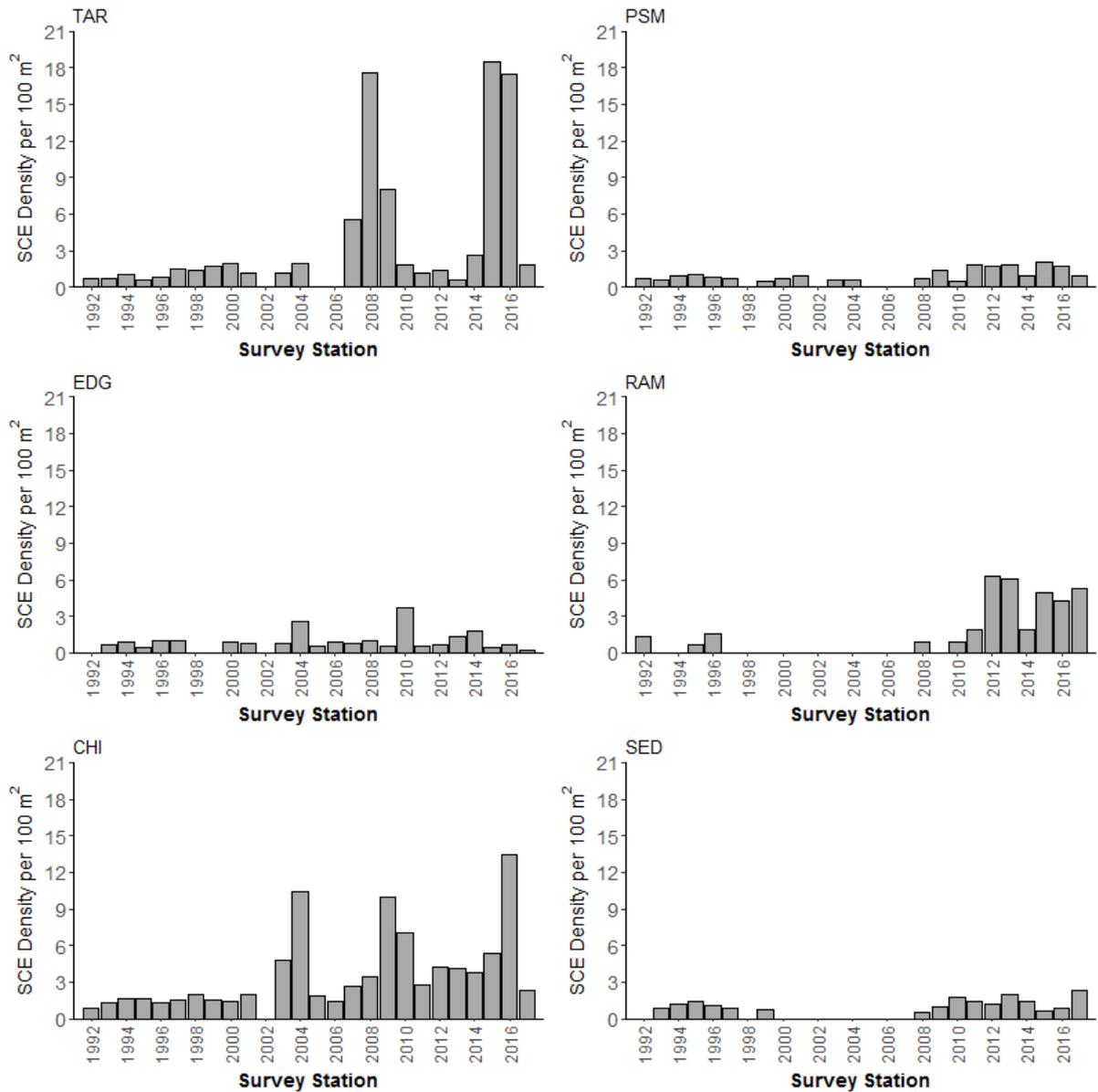


Figure 11: Survey densities (king scallops per 100 m²) displayed by survey station for six historical stations for surveys from 1992 to 2017: TAR – Targets, EDG – East Douglas, CHI – Chickens, PSM – Port St Mary, RAM – Ramsey and SED – South East Douglas. *Please note: all missing bars reflect years in which the site was not surveyed rather than 0 survey densities.*

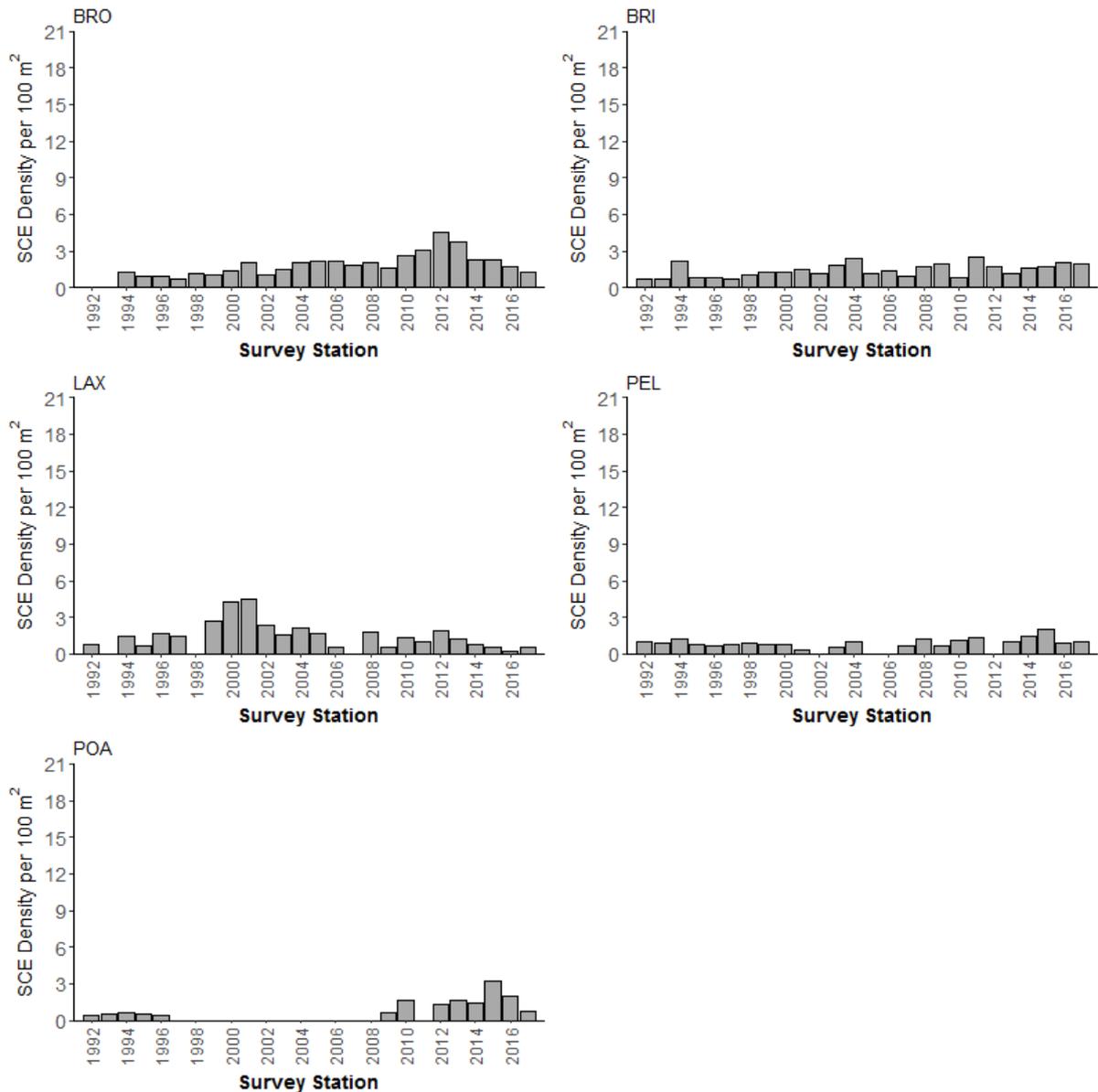


Figure 12: Survey densities (king scallops per 100 m²) displayed by survey station for six historical stations for surveys from 1992 to 2017: BRO – Bradda Offshore, LAX – Laxey, POA – Point of Ayre, BRI – Bradda Inshore, PEL – Peel. **Please note: all missing bars reflect years in which the site was not surveyed rather than 0 survey densities.**

The average density of king scallops (of all sizes caught) per 100 m² among fishing grounds around the Isle of Man for 2016 and 2017 surveys are displayed in Figure 13 for all survey stations. In 2016 the fishing grounds to the west and south of the Island (TAR and CHI) had the highest densities of king scallops per 100 m² (18 and 13 king scallops per 100 m² respectively). Fishing grounds to the east of the Island (EDG, SED, LAX) had the lowest density (< 1 king scallop per 100 m²) (Figure 13). For 2017 there was a large decrease in scallop density on the west and south coasts of the Island (reduced from 18 to 2 king scallops per 100 m² at TAR and from 13 to 2 queen scallops per 100 m² at CHI) following a relatively large proportion of the total fishing activity (and landings) from the king scallop fishery originating from these grounds during the 2016 fishery (Figure 13). On the east coast of the Island densities remained at < 1 king scallop per 100 m² at EDG and LAX and had increased to 2 king scallops per 100 m² at SED, following a relatively small proportion of total king scallop fishing activity originating from these grounds during the 2016 fishery (Figure 13). In addition, densities continue to increase within the closed area on the north-east coast (RAM) following the continued limited annual December fishery in 2016 (increase from 4 to 5 king scallops per 100 m²) (Figure 13).

For 2017 the highest densities are at Station 5 (West coast) and Ramsey (North-East coast) with densities of ~ 6.5 and 5.5 scallops per 100 m² respectively. However, these densities are significantly lower than the highest densities recorded in 2016 at Chickens and Targets (13 and 18 scallops per 100 m² respectively).

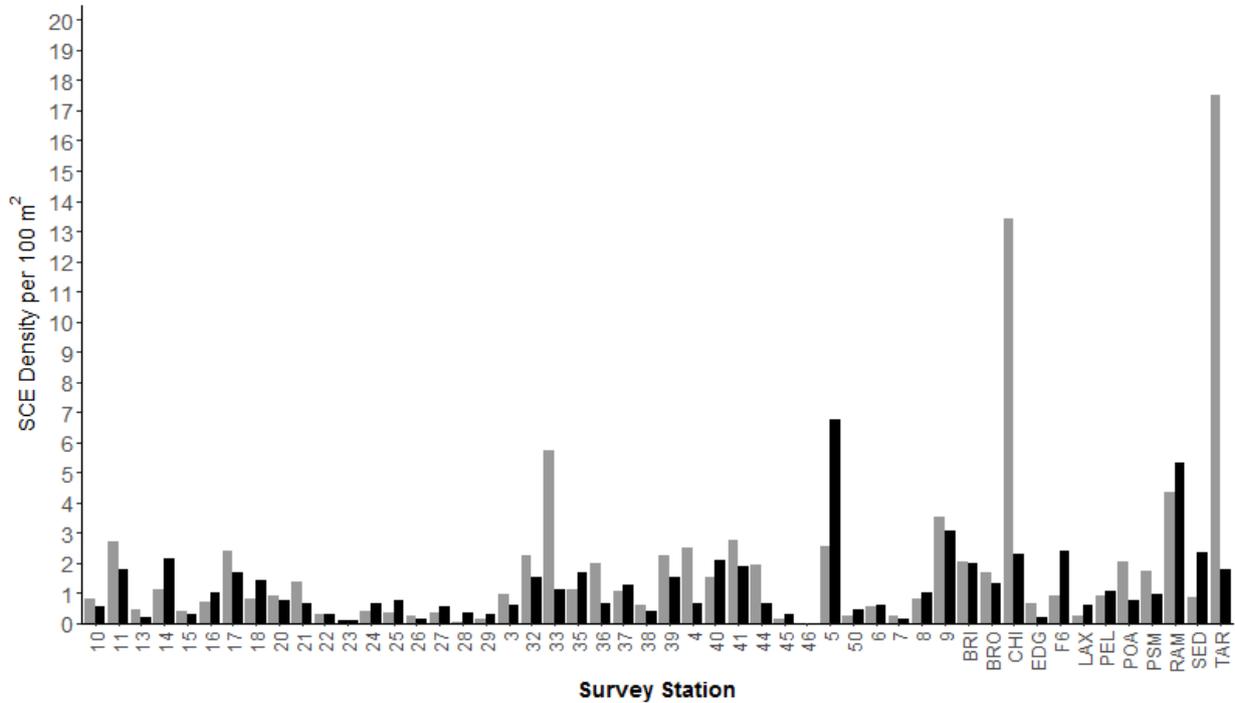


Figure 13: Survey densities (king scallops per 100 m²) displayed by survey station for spring 2016 & 2017 surveys. 2016 = Grey bars and 2017 = black bars.

The advice for the 2017/2018 king scallop fishing season is based on a length based abundance index (Table 1) which is calculated from annual survey data. This is a temporary measure while a formal quantitative Stock Assessment is developed for king scallops and a full external peer reviewed biomass index becomes available.

Table 1: Abundance Index values for 2013 to 2017 from the annual spring scallop survey.

Survey Year	Abundance Index Value
2013	187.96
2014	148.72
2015	181.75
2016	179.32
2017	119.26

- Index A (2016 – 2017) = 149.29; Index B (2013 – 2015) = 172.81; Index Ratio = 0.86

2.3 Previous catch advice

The 2017/2018 king scallop fishing season will be the first year in which a TAC has been set. In order to provide an adjusted TAC for 2017/2018 then a starting value will be taken as the average catch over the last 5 fishing seasons (Table 2).

Landings data are only available by ICES Rectangle. The three ICES rectangles that cover the majority of the Isle of Man's territorial sea are 36 E5, 37 E5 & 38 E5. However, whilst the majority of 37 E5 falls within the territorial sea, a large proportion of 36 E5 and 38 E5 fall outside the territorial sea. Of particular importance is 36 E5 for which a proportion is situated in Welsh king scallop fishing grounds.

In order to adjust the total landings from 36 E5, 37E5 and 38E5 to an approximation of landings from within the territorial sea the following procedure was undertaken:

EU Logbook data was downloaded for all three ICES Rectangles for the period 1st November 2012 to 31st May 2017 to cover the five relevant fishing seasons and filtered for each season to the following dates:

- 2012/2013: 1st November 2012 to 31st May 2013
- 2013/2014: 1st November 2013 to 31st May 2014
- 2014/2015: 1st November 2014 to 31st May 2015
- 2015/2016: 1st November 2015 to 31st May 2016
- 2016/2017: 1st November 2016 to 31st May 2017

For each season the data was then further filtered to include only those vessels with a relevant Isle of Man king scallop licence for that season. This removed landings from any unlicensed fishing vessels which by definition would not be landing king scallops from within the territorial sea. This left landings from licenced vessels that would be able to fish inside or outside of the territorial sea. In order to try and apportion the remaining landings to inside or outside the territorial sea the VMS for 2016/2017 fishing season was filtered to licenced vessels and to a fishing speed of 1 – 4 knots. The proportion of points inside and outside the territorial sea for each rectangle were then calculated and the landings for these rectangles adjusted accordingly.

Whilst VMS data is accessible for the whole of 37 E5 we only have access to part of the VMS data for 36 E5 and 38 E5. This means that licenced vessels may have been fishing in Welsh or Scottish waters but that the VMS data would not be available to allow the landings to be adjusted. This is particularly pertinent for UK vessels (Welsh, Scottish, Northern Irish and English) that may regularly fish in the Isle of Man's and Scottish and Welsh waters. As this proportion of the landings cannot be estimated using VMS then a precautionary approach has been taken where a further 10% reduction in landings from 36E5 and a further 2% reduction in landings from 38E5 have been assumed to account for the unknown proportion of landings by licenced vessels in Welsh or Scottish waters.

The proxy for the previous catch advice (2016/2017) is 3708 t (Table 2).

Table 2: Seasonal king scallop landings (t) for 36, 37 and 38E5. Total landings are all landings from these three ICES Rectangles, Adjusted TS Landings are those landings from vessels licenced to fish for king scallops within the Isle of Man that are estimated to have originated from within the territorial sea.

Fishing Season	Total Landings	Adjusted TS Landings
2012/2013	4469.2	3715.1
2013/2014	4070.3	3487.9
2014/2015	4435.8	3784.4
2015/2016	3990.1	3409.1
2016/2017	4861.2	4143.5
Average	4365.3	3708.0

2.4 TAC calculation and catch advice

Using the data and methods outlined in the previous sections, the provisional catch advice for 2017/2018 was calculated with (2563 t) and without (3203 t) the precautionary buffer applied (Table 3). Given the recruit index shows a declining trend (recruitment impaired; Figure 8) and the continued increase in fishing mortality (high F; Figure 1) combined with a decrease in the post-recruit index (Figure 9) the advice would be to use the catch advice with the precautionary buffer. It is worth noting that this level of catch is similar to the period of the fishery when recruitment was on an increasing trajectory (Figure 10) and may be indicative of a level of fishing that maintains the population in a more healthy and stable state.

Table 3: 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 (2016 – 2017); Index B is the average of the three preceding year's survey abundance indices (2011 – 2015); 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 reference 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 (2016 - 2017)	149.29	149.29
Index B (2011 - 2015)	172.81	172.81
Index Ratio (A/B)	0.86	0.86
Uncertainty cap	NA	NA
Averaged catch for 2012 – 2017 seasons*	3708	3708
Discard rate	-	-
Precautionary buffer	NA	0.8
Catch advice for 2017/2018**	3203	2563

* The average catch (estimated for TS) has been averaged for the last 5 seasons and used as a proxy for the 'Advised catch for 2016/2017 season within the TAC calculation process

** For Scenario I: advice for 2016/2017 x Index Ratio; For Scenario II: (advice for 2016/2017 x Index Ratio) x Precautionary Buffer

3. Stock Assessment

Two alternative approaches to estimating stock status for king scallops in ICES Rectangles 36E5, 37E5 and 38E5 were investigated. The first was a length based approach known as catch-survey analysis (CSA) that has previously been used for the Isle of Man's queen scallop stocks. The second was a statistical catch at age based approach based on the stock assessment software a4a that has been developed as part of the FLP project (<http://flr-project.org>) and was undertaken in collaboration with the developers at the Joint Research Centre for the European Commission based in Ispra, Italy in September 2017.

3.1 Stock assessment (length based analysis)

A preliminary length based stock assessment has been implemented using CSA v4.3 (NOAA, 2014). Data from the spring surveys was used from both king and queen dredges combined. Please note growth between April (survey month) and November (first month of the fishing season) has not been accounted for within this preliminary length based model. Whilst the additional growth and weight during these 6 months would lead to a slight increase in the values of the relative biomass index, the trends would remain constant.

Within the stock assessment unit (36E5, 37E5 and 38E5), the model output indicates that following a general trend of increasing biomass (1992 – 2012), relative biomass has shown a decreasing trend over recent years (2013–2017) with a large decrease in the most recent year (2017) (Figure 14). Despite the recent decreasing trend at the stock level it is acknowledged that king scallop densities can still vary significantly among the main fishing grounds: East Douglas (EDG), South East Douglas (SED), Chickens (CHI), Targets (TAR), Bradda (BRO/BRI), Ramsey (RAM) and Point of Ayre (POA) (Figure 11 & Figure 12). In addition, due to the aggregating nature of scallops some localised areas of very high densities are observed within these fishing grounds (e.g. TAR 2016; Figure 11 & Figure 13).

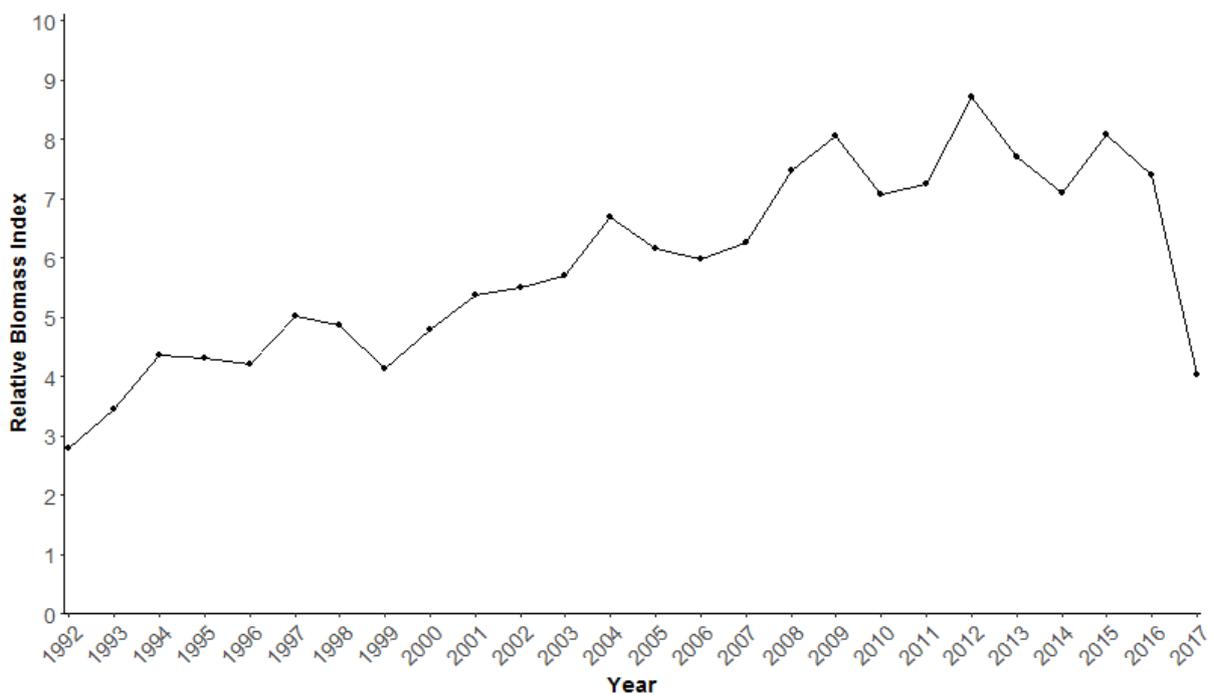


Figure 14: Relative biomass index for king scallops from the stock assessment unit (36E5, 37E5 and 38E5) bootstrap results.

3.2 Stock assessment (Statistical Catch at Age)

Assessment for All (a4a) is an innovative data-limited approach to stock assessment developed by the Joint Research Centre for the European Commission (Jardim et al., 2017). The a4a initiative is based on a risk type analysis that explicitly accounts for major sources of uncertainty and uses a statistical catch at age assessment model implemented in R (R Core Team, 2016) and FLR.

The *a4a* stock assessment model requires setting up three submodels for the fishing mortality (the *fmodel*), the index catchability (the *qmodel*, one for each index) and recruitment (the *rmodel*). For the *fmodel*, age and year were considered to interact and were thus modelled using a tensor product of cubic splines with the 'te' method while the *qmodel* incorporated a smoother on age only. The degrees of freedom on the smoothers and tensor splines was adjusted for the number ages and years of data within the survey and catch.

For this assessment the survey data was split into two separate indices (Index 1: king scallops from queen scallop dredges; Index 2: king scallops from king scallop dredges). Index 1 was used to create an age based survey abundance index and Index 2 (adjusted for the growth period between the survey and the fishery and filtered to scallops above 110 mm) was used to assign the commercial landings to age categories. Preliminary results from the a4a assessment model showed a good fit to the data through all the model diagnostics and residuals, which allow the fit quality and assumptions of the model to be inspected. Standardised log-residuals were checked for biased results or large variances. The standardisation should produce residuals with variance 1, which means that most residual values should be between -2 and 2, which they were for this model, indicating that there were no deviances from the log normal assumption (Jardim et al., 2017). In addition information on the number of parameters, observations, generalised cross-validation (GCV) score and Akaike information criterion (AIC) and Bayesian information criterion (BIC) were quantified (Table 4).

Table 4: Model diagnostics used to assess the fit of the model

	Model values
No. Parameters	107
No. Observations	350
GCV	3.51
AIC	757
BIC	1169

The model estimates of stock abundance and fishing mortality are shown in Figure 15 and indicate a decline in Spawning Stock Biomass (SSB; Age 2+) for king scallops within the stock assessment unit since 2013, following a period of increasing SSB between 1992 and 2013. SSB is taken as the fully mature biomass (Age 2+) that is available at the time of spawning. In this instance SSB is calculated at the end of the season after all fishing activity has occurred. For the purpose of modelling each calendar year is taken to run from 1st November yearⁿ to 31st October yearⁿ⁺¹. This means that SSB is taken at the point of 1st August which is after all fishing mortality (F) for that fishing season, which runs from 1st November Yearⁿ to 31st May Yearⁿ⁺¹, has occurred. The number of recruits (Age 2) has also shown a large decrease since 2014.

A forecast can be run on the current data to estimate the SSB for the following year (2017 season e.g. SSB as of 1st August 2018) using the proposed TAC of 3203 t under a range of recruitment scenarios

(e.g. high recruitment, long term average recruitment). Under both these recruitment scenarios the forecast produces a severe reduction in SSB from ~6500 t to ~ 4000 t as the high F combined with the low recruitment levels from the year prior (2016 season) which indicates that a TAC of 3203 t for the 2017/2018 fishing season is too high to produce a sustainable harvest level. This could lead to a negative impact on SSB and future catches from this stock in the short term until recruitment levels improve.

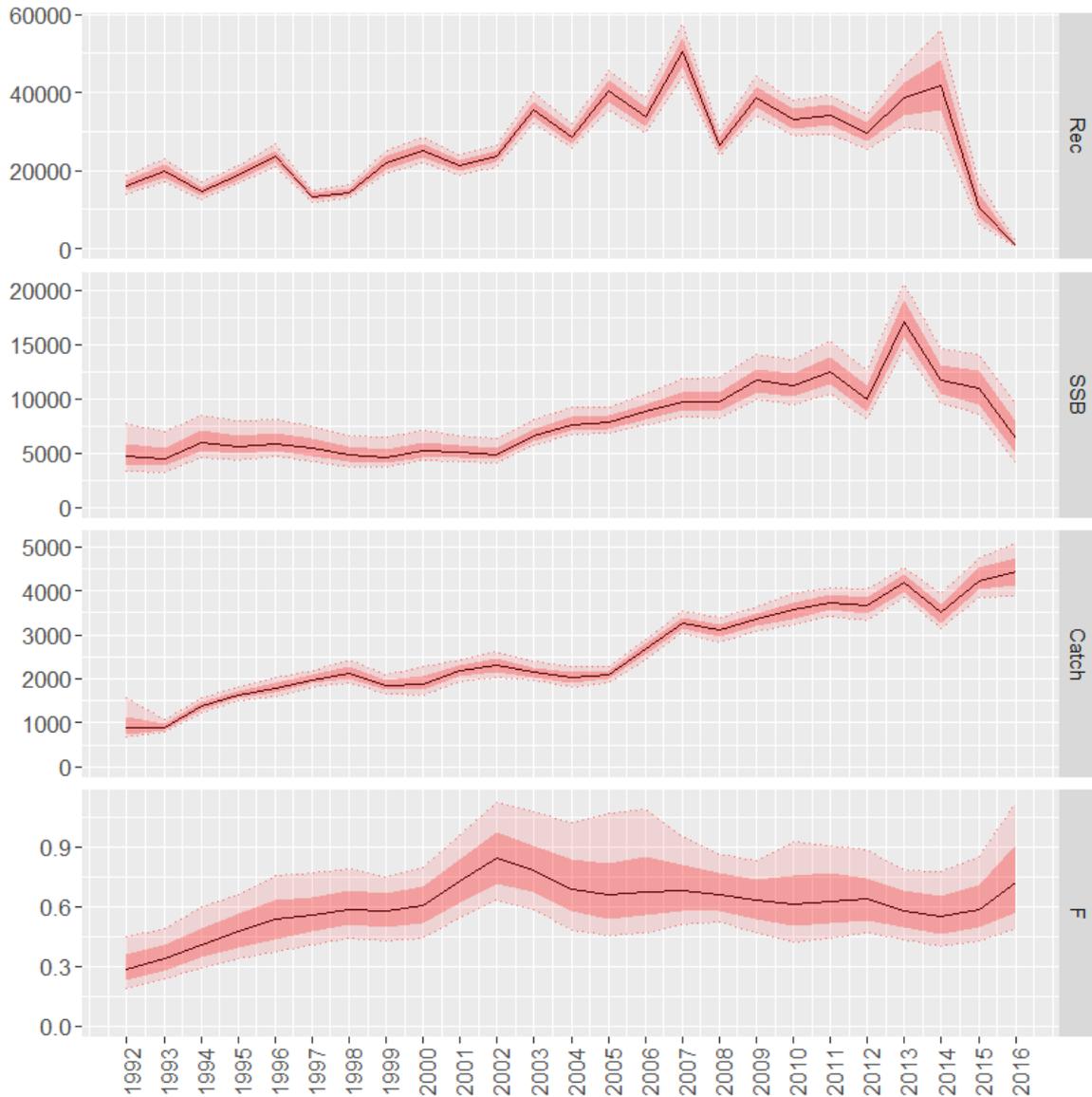


Figure 15: Stock summary for king scallops in ICES Rectangles 36E5, 37E5 and 38E5. Recruits (Rec) (individuals) taken here as Age 2 scallops, SSB (Spawning Stock Biomass) (t), Catch (t) and harvest (F). The black lines indicate the mean value and the red shaded areas indicate confidence intervals produced from 500 model simulations.

4. Further developmental work

- September 2017: Compile and analyse landings per unit effort (LPUE) data for the Isle of Man king scallop fleet from 1992 – 2017.
- October 9th – 12th 2017: Presentation and review of Isle of Man Stock Assessment at the ICES working group scallop stock assessment.
- December 2017: External Peer Review of Isle of Man Stock Assessment.

5. Conclusions

- It is recommended that a TAC for the 2017/2018 Isle of Man's king scallop fishery is defined on the basis of ICES protocol for Category 3 stocks (Method 3.2).
- For the 2017/2018 king scallop fishing season the TAC calculation is based on the abundance index pending the peer review of the quantitative stock assessment methods. Once the stock assessment methods have been externally reviewed and validated then the relative biomass index will be used for the calculation of the TAC percentage change in future king scallop fishing seasons (i.e. 2018/2019 onwards).
- Method 3.2 outlined by ICES compares the values from the two most recent years of the abundance index with the values from the three preceding years. The TAC is then adjusted by the percentage difference of these two values taking into account the 20% uncertainty cap. As there is evidence of recruitment impairment and high fishing mortality (F) the 20% precautionary buffer was applied.
- Previously no TAC has been set for the Isle of Man's king scallop fishery within the territorial sea. As a result, the SMB recommended that a proxy for the previous seasons catch advice was calculated from the average landings from the previous 5 fishing seasons (3708 t), with a proportion of landings from ICES Rectangles 36E5, 37E5 and 38E5 attributed to the territorial sea using VMS and landings data.
- The provisional catch advice for 2017/2018 king scallop fishery within the territorial sea is 2563 t (precautionary buffer applied).
- Should the TAC be adopted without the application of the precautionary buffer (3203 t) it is recommended that a review of the fishery is undertaken following the first month of the season with the option to revisit the application of the Precautionary Buffer or the proxy for the previous seasons catch advice (i.e. this could be taken as a longer term average of landings e.g. 1992 – 2016).
- 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.

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