The Isle of Man *Aequipecten opercularis* fishery: Research Update 2011

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Second draft

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1. Background

1.1 The fishery

A fishery for queen scallops, *Aequipecten opercularis*, has been prosecuted in the Isle of Man's territorial sea since the late 1960s. Until recently queen scallops were targeted almost entirely with either toothed dredges or skid dredges. However, most Manx vessels now fish for queens with otter trawls, while UK vessels use dredges without teeth. The fishery is governed by several management measures that include areas where dredging is prohibited, a closed season and a minimum landing size (Sea-Fisheries Act 1971. Isle of Man Sea-Fisheries (queen scallop fishing) bye-laws 2010. Statutory document No. 668/10).

1.2 Marine Stewardship Council certification

A precautionary management strategy for the Isle of Man's queen scallop fishery was set out in 2010 and reviewed by a Marine Stewardship Council (MSC) assessment team (Andrews *et al*., 2010). The trawl fishery was MSC certified in April 2011, while the dredge fishery failed to meet the necessary standard due to the negative impact of dredging on benthic habitats (e.g. Hinz *et al*., In press). A key aspect of ensuring the sustainability of the fishery is that management responds to stock status and that the impact of the fishery on the seabed remains limited. Certification of the fishery was made on the basis of nine conditions being met over various timescales and the actions required to meet these conditions were set out in an action plan (Bangor University/DEFA, 2011). These conditions include developing a habitat management strategy and undertaking a formal stock assessment.

1.3 Recent increases in fishing effort

An increase in the demand for queen scallops in 2010 has prompted discussions about the management of the fishery. A meeting between relevant attendees of the UK Scallop Working Group was held on 29th June 2011 in Manchester to discuss concerns over high fishing pressure on queen scallops in the Irish Sea. The possibility of a need for voluntary measures to manage the fishery was raised. A second meeting, held between the Seafish Industry Authority (Seafish) and several scallop processors in Preston on 21st July 2011, identified an increase in demand for queen scallops combined with increased catching capacity. The suggestion of a three day fishing week had wide support within the meeting. However, no management actions were agreed (Seafish, 2011).

1.4 Aims

This report provides the most recent survey results from the Isle of Man. We provide management recommendations in the context of recent concerns raised about the increase in fishing effort within the Irish Sea queen scallop fishery and in relation to the requirements of MSC certification of the trawl fishery. Management recommendations are provided based on the assumption that maintaining viable dredge and trawl based queen scallop fisheries in the Isle of Man's territorial sea is the desired outcome.

2. Methods

2.1 Scallop surveys and abundance index

Despite surveys of the Isle of Man's scallop populations having been undertaken biannually (typically in June or October) since 1992 (Beukers-Stewart *et al*., 2003) most survey stations (Fig. 1) have been visited intermittently, although latterly with increased sampling effort. Survey station name abbreviations are: Bradda Inshore (BRI), Bradda Offshore (BRO), Port St. Mary (PSM), Chickens (CHI), South East of Douglas (SED), East of Douglas (EDG), Laxey (LAX), Ramsey (RAM), Point of Ayre (POA), Peel (PEL) and Targets (TAR). Stations were sampled using the protocol described by Hinz *et al*. (2009a) and Murray *et al*. (2009).

Since not every station has been sampled in every year the mean abundance index may reflect both spatial and temporal variation in queen scallop abundance. Therefore, a Generalized Additive Model (GAM) was used to estimate the abundance at those stations not sampled in some years. These interpolated estimates were used to calculate the mean annual abundance (across survey stations) where stations had been surveyed in some years but not others but were not used to extrapolate beyond the first or last time at which a given station was surveyed. The model used was: log(AI)~s(time, by =station) + station, where AI = Abundance Index, time = years from first survey, and station = survey station (see Fig. 1). Plots of residuals against theoretical quantiles and the linear predictor, residual frequency distribution and responses against fitted values were used to assess distributional assumptions and homogeneity of variance, with these assumptions met in both cases (Appendix 1). Stations at which abundance did not exhibit a significant relationship with time were excluded from the model. The model explained 89.10% of the deviance (n = 116). Abundance showed highly significant (probabilities in brackets) relationships with time at all stations included in the model: BRO (0.0028), CHI (<0.0001), EDG (0.0003), LAX (0.0003), SED (0.0001) and TAR (0.0014). For PSM station there was no significant relationship between abundance and time; however, this station had been surveyed regularly. Thus a moving average was used to estimate abundance for missing surveys at PSM. For BRO, although not a major queen scallop fishing ground, a simple average abundance was taken from all survey years and used for the years before this station was first surveyed.

The most recent survey was conducted in September 2011. The dredges used in the surveys have a belly ring internal diameter of 55 mm and thus do not quantitatively sample smaller queen scallops. To address this issue a 2 m beam trawl, with cod end mesh size of 4 mm and an outer net with a 10 mm mesh, was used at RAM and LAX stations in May 2011 to assess its effectiveness at catching queen scallops, and assess this technique for future surveys to improve estimates of small size categories of scallops.

2.2 Fishery-dependent data

To examine fishing effort and landings throughout the fishing season, logbook data were linked to VMS data following the methodology outlined in Murray *et al*. (2011). Due to changes in the systems used to record logbook data from January 2011 onwards these periods have been examined separately. Fishing effort was estimated in 2009 and 2010 for Manx vessels fishing in the Isle of Man's territorial sea. In 2011, logbook data from UK vessels fishing in ICES statistical rectangles were made available, in addition to logbook data from Manx vessels. Therefore, to estimate an abundance

index based on Landings Per Unit Effort (LPUE) during 2011 a GAM was fitted with live weight landings per hour as the response variable and date, position and vessel (including gear) as the predictors. An identifier (v) using vessel name and gear type (i.e. dredge or otter trawl) was used instead of two separate factors for vessel and gear. Models were fitted with a three-way interaction between latitude, longitude and date (Model 1; log(LPUE)~te(date, lat, lon) + v), using a tensor-product smooth, and a two-way interaction between latitude and longitude (Model 2; log(LPUE)~s(date)+s(lat, lon) + v), using an isometric smooth, with date as a separate term. Plots of residuals against theoretical quantiles and the linear predictor, residual frequency distribution and responses against fitted values were used to assess distributional assumptions and homogeneity of variance, with these assumptions met in both cases (Appendix 2). In both cases a gamma error distribution was used, and $\gamma = 1.4$ to reduce the likelihood of over-fitting. It is important to note that this model was not used to predict abundance beyond the time range of the data and is intended to provide an abundance index that is as recent as possible, given the absence of a recruitment index.

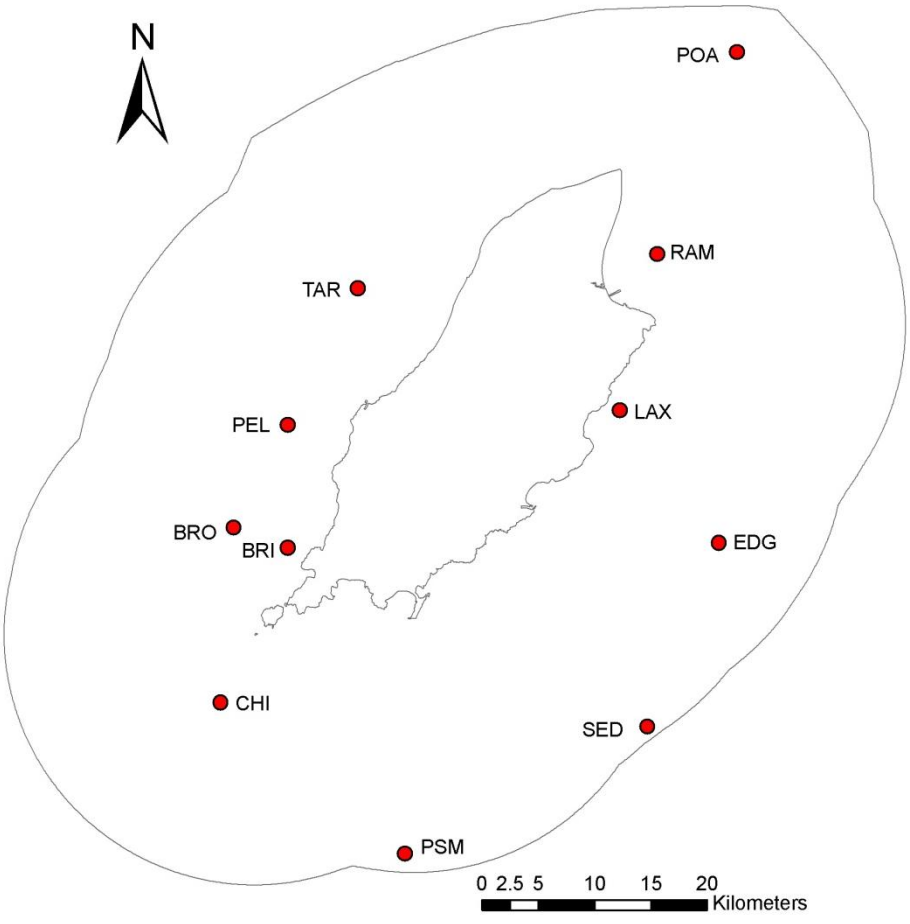

Fig. 1. Survey stations around the Isle of Man.

3. Results

3.1 Relative abundance and landings

The relative abundance of queen scallops reached the highest recorded level since 1992 in October 2010 (Fig. 2a). Since then, abundance has fallen substantially to around the level observed in June 2008. Abundance has declined over the past three May/June surveys. Between October and June the following year there has typically been a slight decrease in abundance (Fig. 2b) with the largest decreases following the two peaks in abundance in 2005 and 2010 (Fig. 2b). Between 2007 and 2010 abundance increased between October and June in all three years. Data from individual survey stations revealed declines in June abundance at BRO, CHI, PSM and TAR, with increases at RAM and at EDG between 2010 and 2011 (Fig. 3 and Fig. 4). PSM and SED exhibited the most restricted size frequency distributions with no queen scallops under 60 mm caught, and hence no evidence of recent recruitment to the fishery (Fig. 5). In contrast, two year classes were evident at both CHI and RAM.

Landings originating from ICES statistical rectangles 36E5 and 37E5 between June 2010 and May 2011 greatly exceeded the recommended TAC of 4000 tonnes (Murray *et al*., 2010; Fig. 6), with around 12000 tonnes landed to the UK and Isle of Man between June 2010 and May 2011. This increase in landings is a response to a high market demand. The result has been a decline in the June abundance estimate for the second year running. This decline was outside the 95% confidence intervals derived from previous surveys, as described by Murray *et al*. 2010 and in accordance with the protocol outlined previously should trigger a proportional decrease in the advised TAC.

There was an exceptionally large recruitment during 2010 and hence it is not deemed necessary to subtract the excess landings between June 2010 and May 2011 from the advisory TAC for June 2011 to May 2012. However, it is important to note that the large recruitment observed in 2010 was unusual. Only in 2005 was a similarly high abundance of queen scallops observed, due to a large recruitment at LAX (Fig. 3). The peak in average abundance in 2010 was due to large increases in abundance at SED and EDG stations.

Average landings from ICES statistical rectangles 36E5 and 37E5 between 2008 and 2010 were 6285 tonnes. Based on the annual surveys, there was a 24% reduction in abundance of queen scallops between June 2010 and May 2011. A decrease in landings proportional to the decrease in abundance would result in an advisory TAC of 4792 tonnes. However, the relatively low impact of landings in 2010/2011 was due to the unusually large recruitment. It cannot be assumed that recruitment will be similarly strong in 2011/2012. It is also important to note that dredging was prohibited within the territorial sea in 2010 until the end of August and might have resulted in lower fishing mortality by the time of the October survey than occurred in previous years. It is therefore recommended that the precautionary TAC set in 2010 should be maintained and that landings do not exceed 4000 tonnes between 1st June 2011 and 31st May 2012 in ICES statistical rectangles 36E5 and 37E5 as it is not possible at present to predict the strength of recruitment to the fishery in 2012.

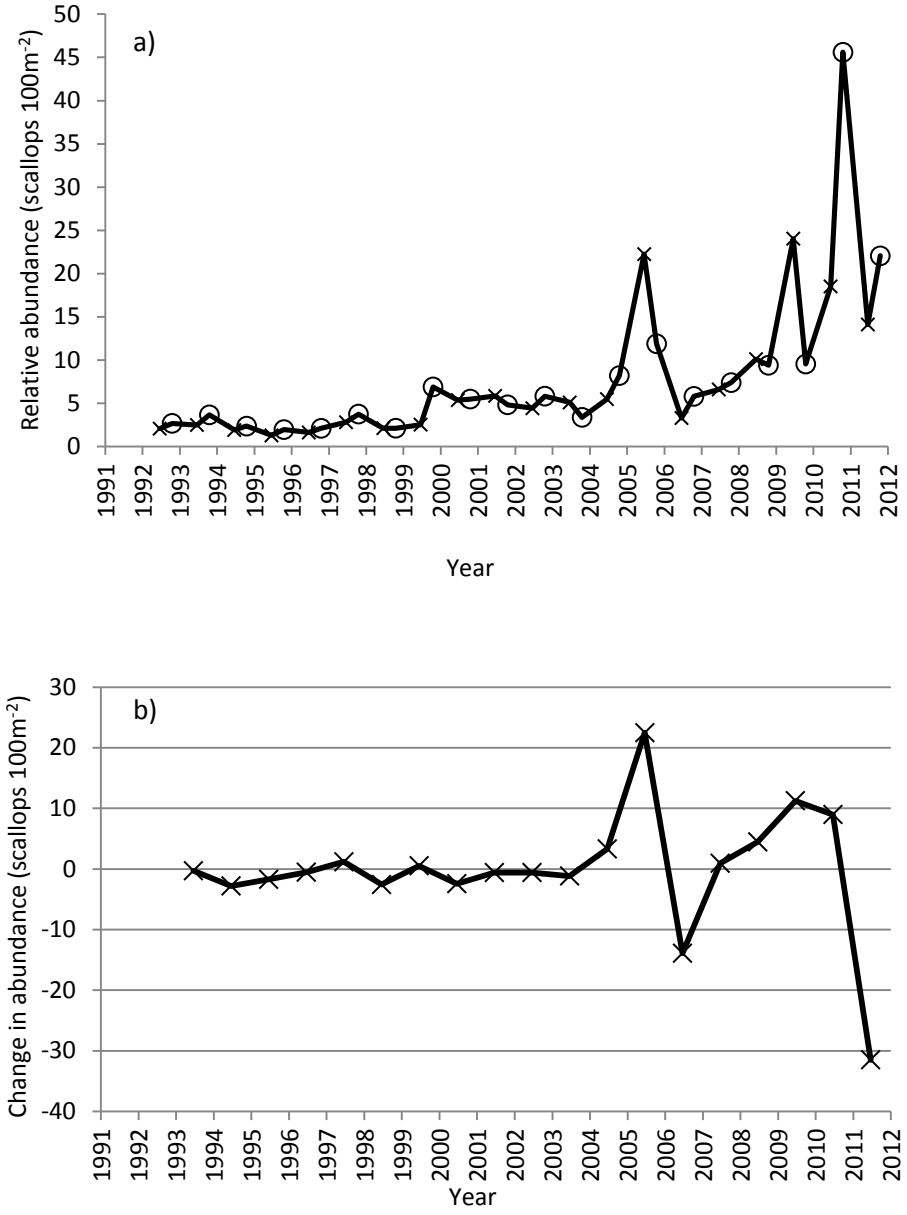

Fig. 2. a) Mean relative abundance of queen scallops in May/June (crosses) and September/October (circles) across all survey stations except PEL, and TAR and RAM (which were surveyed only in recent years) and b) change in abundance between October and May/June the following year.

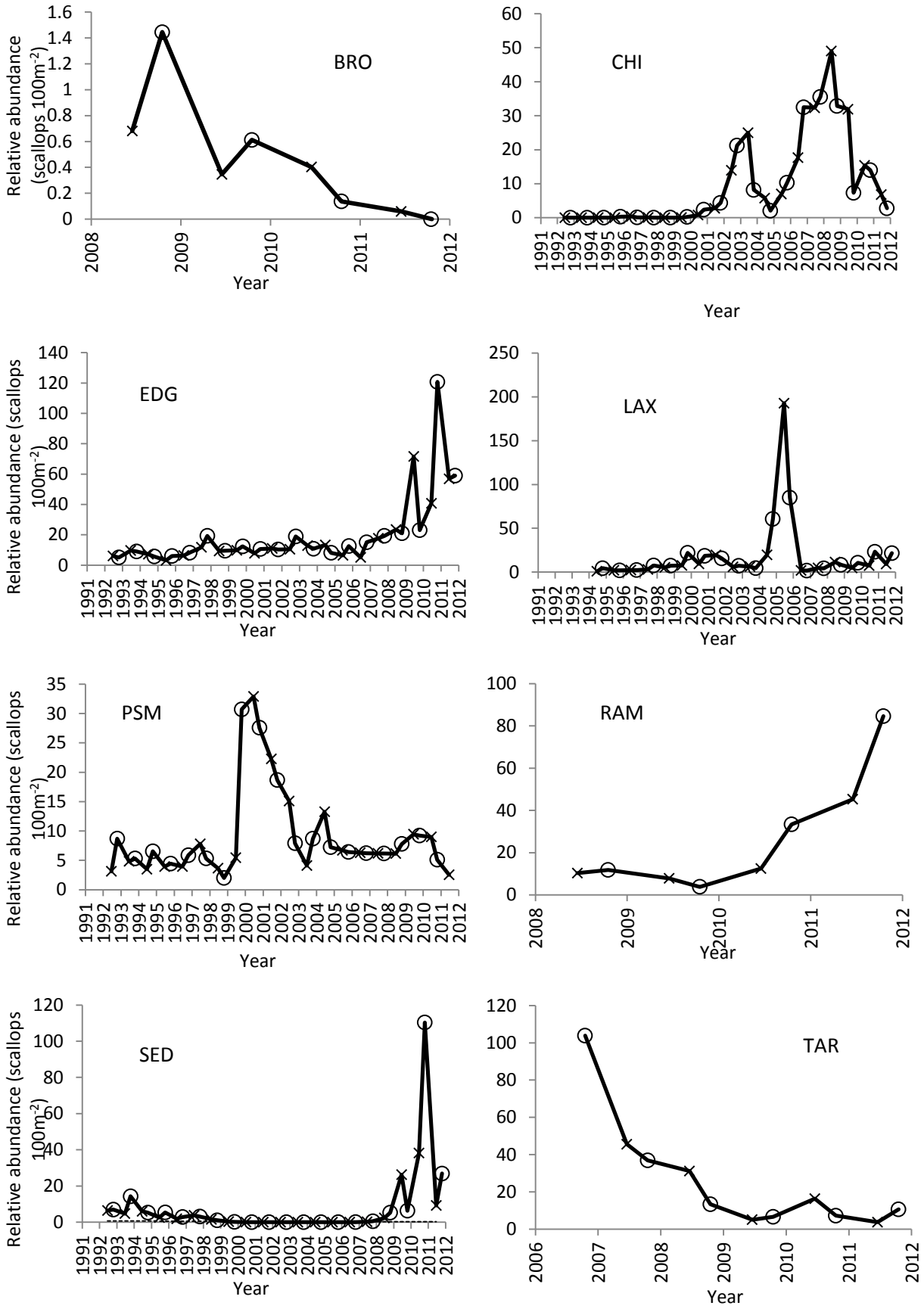

Fig. 3. Relative abundance of queen scallops at survey stations around the Isle of Man in May/June (crosses) and September/October (circles).

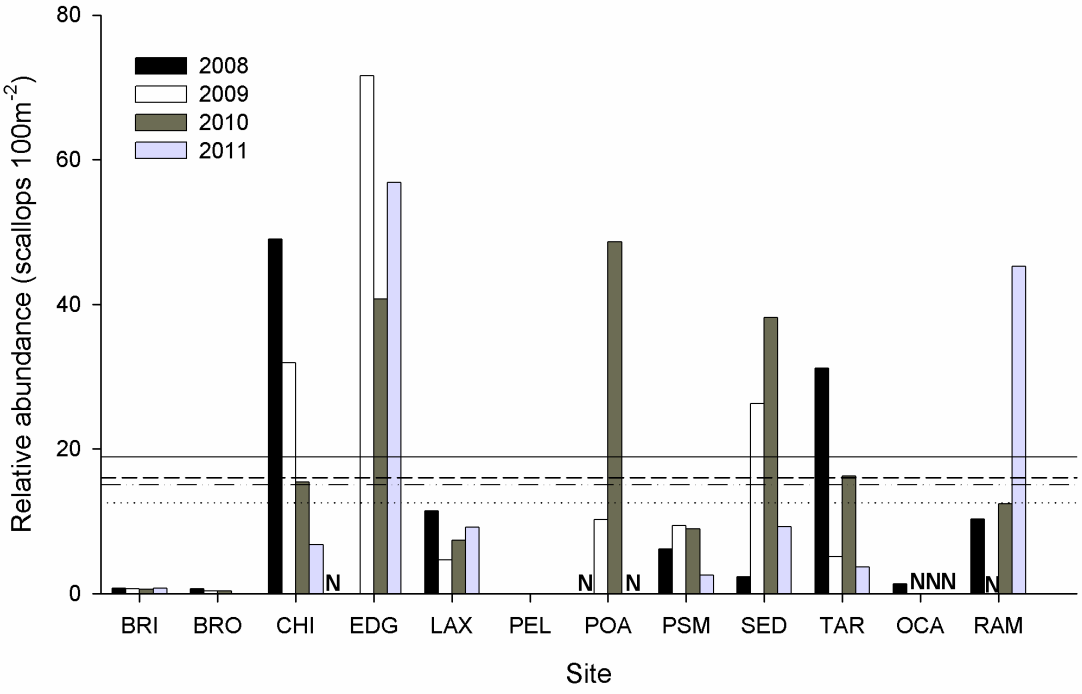

Fig. 4. Mean abundance of queen scallops at survey stations around the Isle of Man. Horizontal lines show mean across all sites surveyed (excluding Peel) in June 2008 (dotted), June 2009 (dashed), June 2010 (solid) and May 2011 (dotted-dashed). N = No sample.

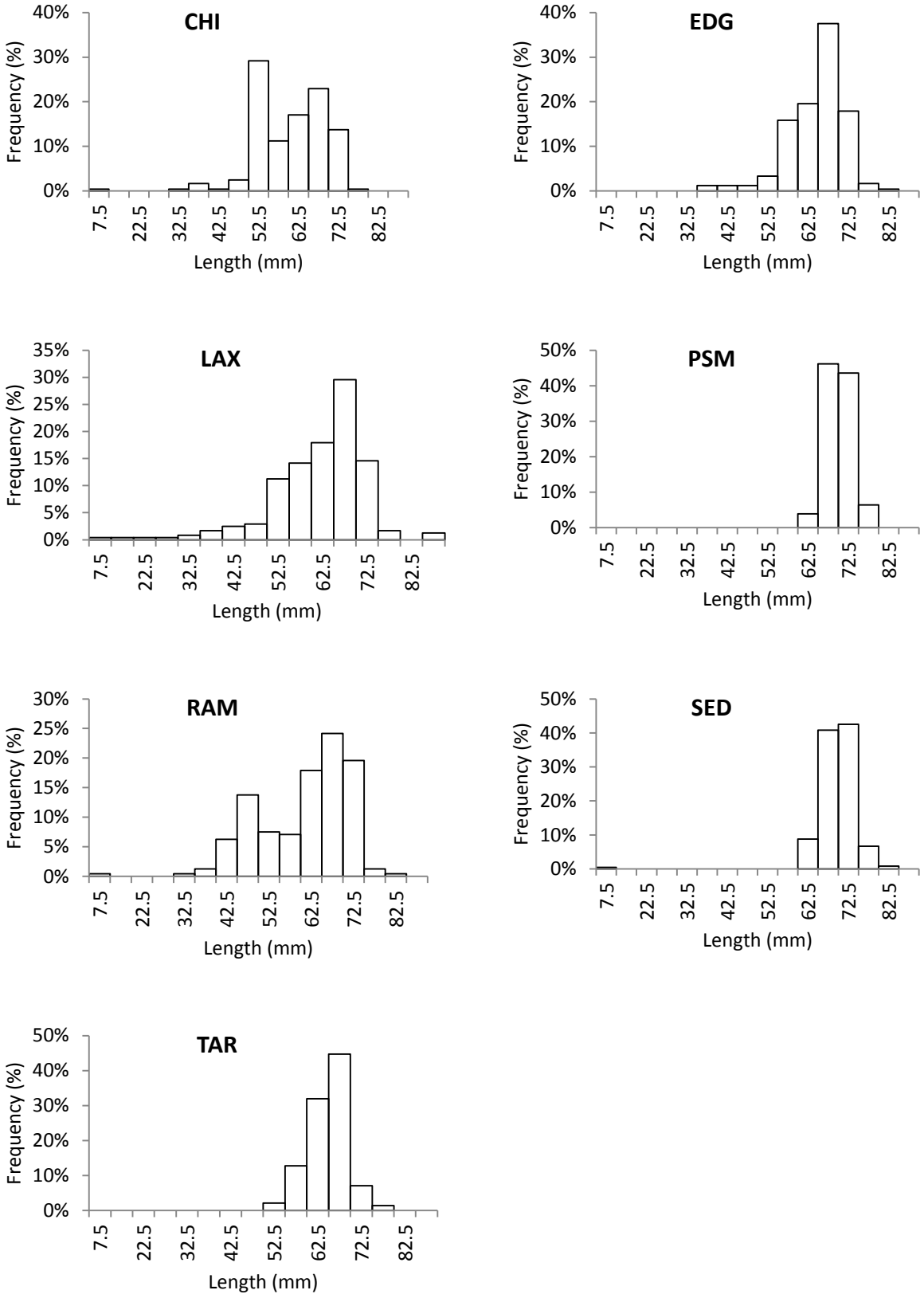

Figure 5. Size frequency distributions of queen scallops from the May 2011 survey.

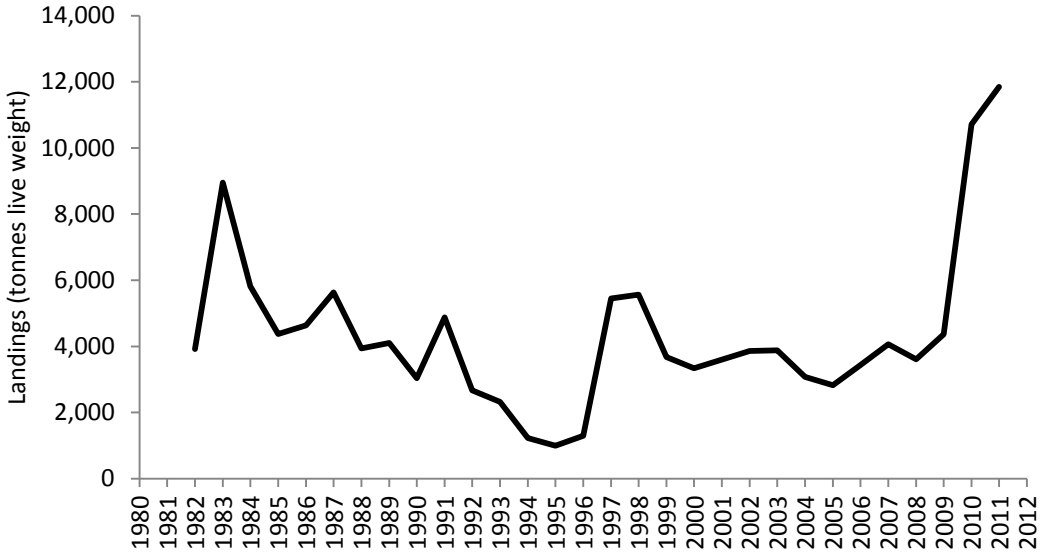

Fig. 6. Landings (live weight) of queen scallops to the UK and Isle of Man. The figure for 2011 is based on reported landings to the end of November 2011. Landings are referenced to ICES statistical rectangles 36E5 and 37E5 (as a proxy for territorial sea landings) where possible. However, Isle of Man landings before 1994 are total landings to the Isle of Man, which are likely to be predominantly from these two statistical rectangles.

3.2 Landings and fishing effort

Landings of queen scallops are referenced to ICES statistical rectangles only. Landings from 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 landings from these two rectangles will be substantially higher than from the territorial sea alone. Landings from Manx vessels in previous years have been spatially referenced to the territorial sea using VMS and logbook data. Logbook data from UK vessels has only recently become available to the Isle of Man for those vessels fishing in ICES rectangles 36E5 and 37E5.

The queen scallop fishery across ICES statistical rectangles 36E5 and 37E5 from June 2010 to May 2011 was predominantly dredge-based (10454 t) with only 2034 t caught by otter trawls. In total, 8956 t were landed to the UK and 3532 t landed to the Isle of Man. In the trawl fishery, which was based almost entirely within the territorial sea, reported landings stood at 3789.7 t by the end of November 2011, 54% higher than landings between June 2010 and May 2011. Reported landings by dredgers had reached 6425.2 t by the end of November 2011 within ICES statistical rectangles 36E5 and 37E5. Landings in 2011 (Jan to Dec) have so far exceeded landings in 2010 (Jan to Dec) by over 1000 t. The area swept by trawlers and landings of queen scallops almost doubled between 2009 and 2010 (Fig. 7). Most trawling does not commence until the third week of June, with effort and landings peaking in the middle of the season (August – September) and levelling off in October. There was an eight-fold increase in the area swept by Manx dredgers when targeting queen scallops and a thirteen-fold increase in landings of queen scallops by Manx dredgers between 2009 and 2010, and an estimated (from VMS records in the territorial sea) 50% increase in dredging for queen scallops by UK vessels in the territorial sea. Data similar to that presented in Figure 7 are also available for Manx dredgers. However, few Manx vessels dredge for queen scallops. Therefore, to

avoid revealing details of individual landings and fishing effort data, these figures have not been included.

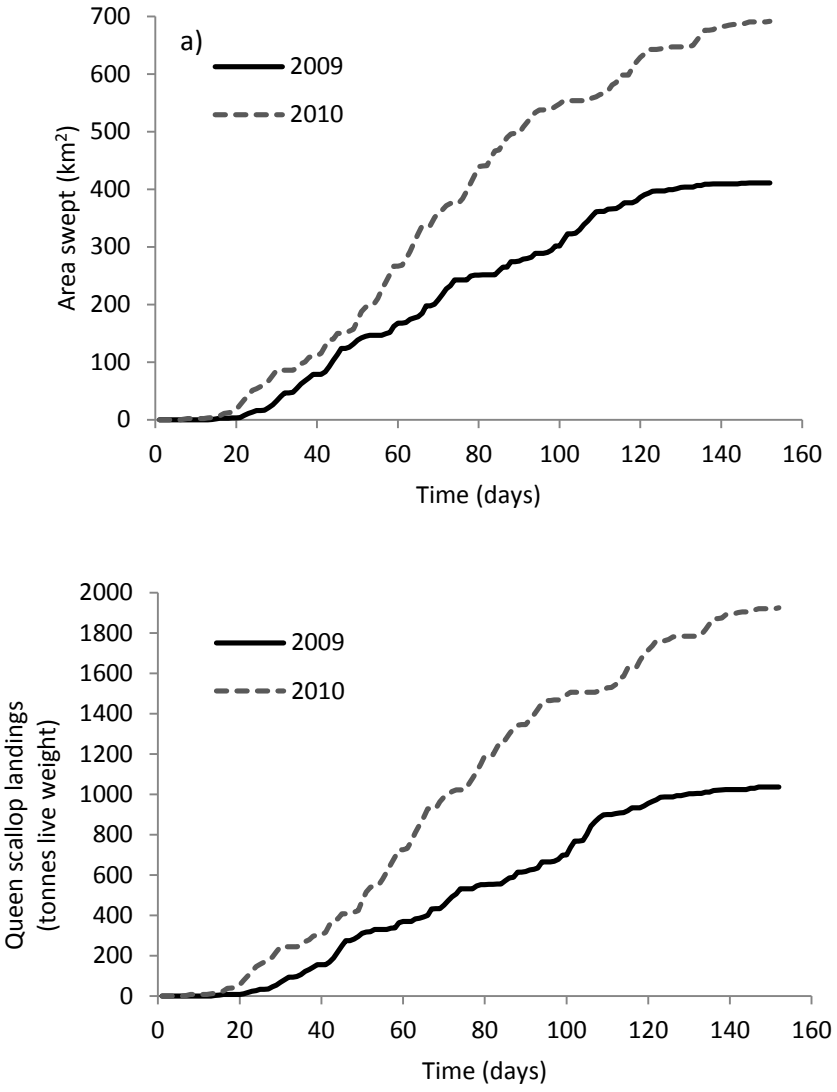

Fig. 7. Cumulative area swept by otter trawlers fishing for queen scallops and landings of queen scallops caught within the Isle of Man's territorial sea in 2009 and 2010 from 1st June (Day 0).

To derive an abundance index for the Isle of Man queen scallop fishery from LPUE data, a GAM was used to standardize data to account for variation in fishing power and efficiency of different vessels, and the location fished. Since fishers target areas with higher abundance, and have been able to maintain catch rates over the year, simply using LPUE data does not provide a valid abundance index. Two models were selected from several candidate models. Model 1 explained 73.8% of the deviance with an Akaike Information Criterion (AIC) score of 20178.86. Model 2 explained 71.4% of the deviance, with an AIC of 20276.8. Analysis of Deviance also suggested supporting Model 1 over Model 2 ($p<0.0001$). The standardized abundance index derived from LPUE data is presented in Figure 8. The abundance index suggests a similar change in abundance to that observed in the research surveys. That is, a large in decline in abundance between the end of 2010 and mid-2011, with similar abundance in May 2011 and September 2011, although the fishery-dependent data suggests a slight decline in abundance over this latter period (Figure 8).

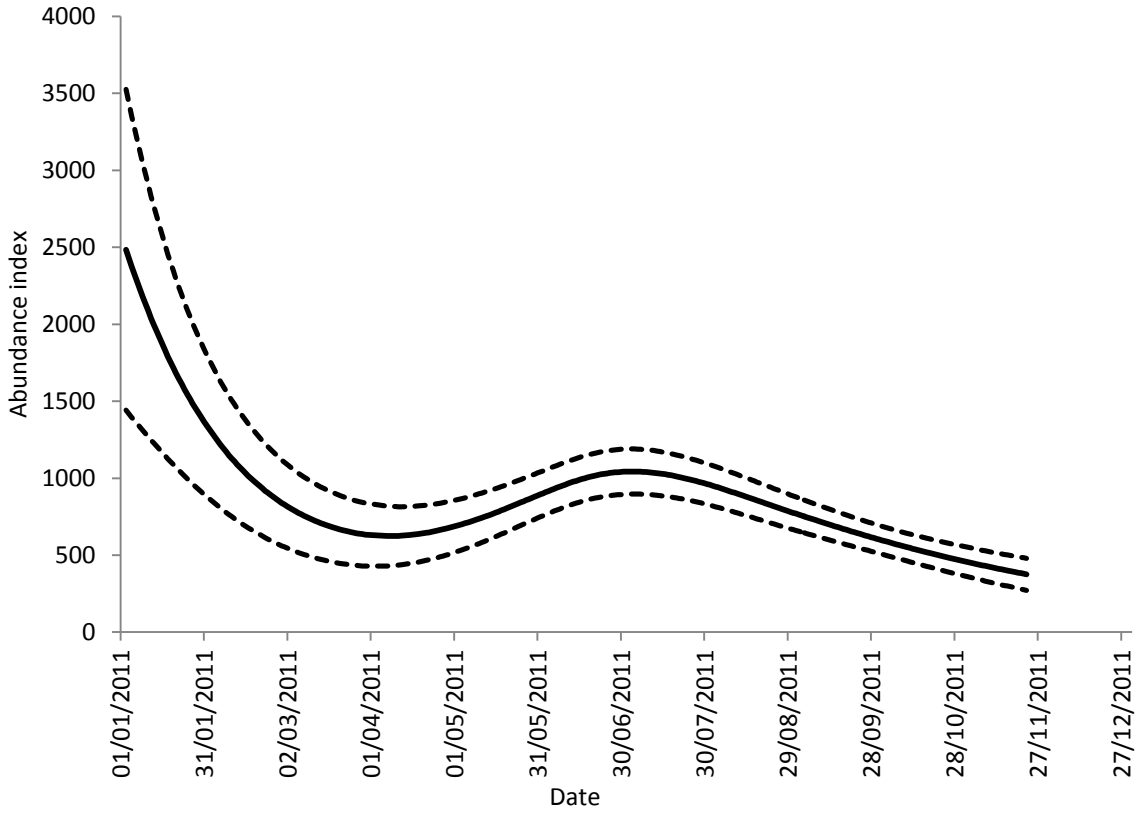

Figure 8. Abundance index derived from LPUE data in 2011. Dashed lines indicate ±1 standard error (n = 1381).

3.3 Improving queen scallop sampling

In May 2011 a 2 metre beam trawl was used to sample queen scallops at two of the stations visited in the annual surveys. The beam trawl sampled smaller queen scallops much more effectively than the queen scallop dredges (Fig. 9 Cf. Fig. 5). The relative size frequency distributions of queen scallops caught were significantly different between gears in both Ramsey and Laxey (ANOSIM, R>0.59, p=0.029; Clarke and Gorley, 2001). In September 2011 further stations were surveyed with the 2 m beam trawl; the results of this work will be presented in future reports. It is intended that surveys will be undertaken annually using the beam trawl and it is hoped this will allow forecasts to be made for the fishery.

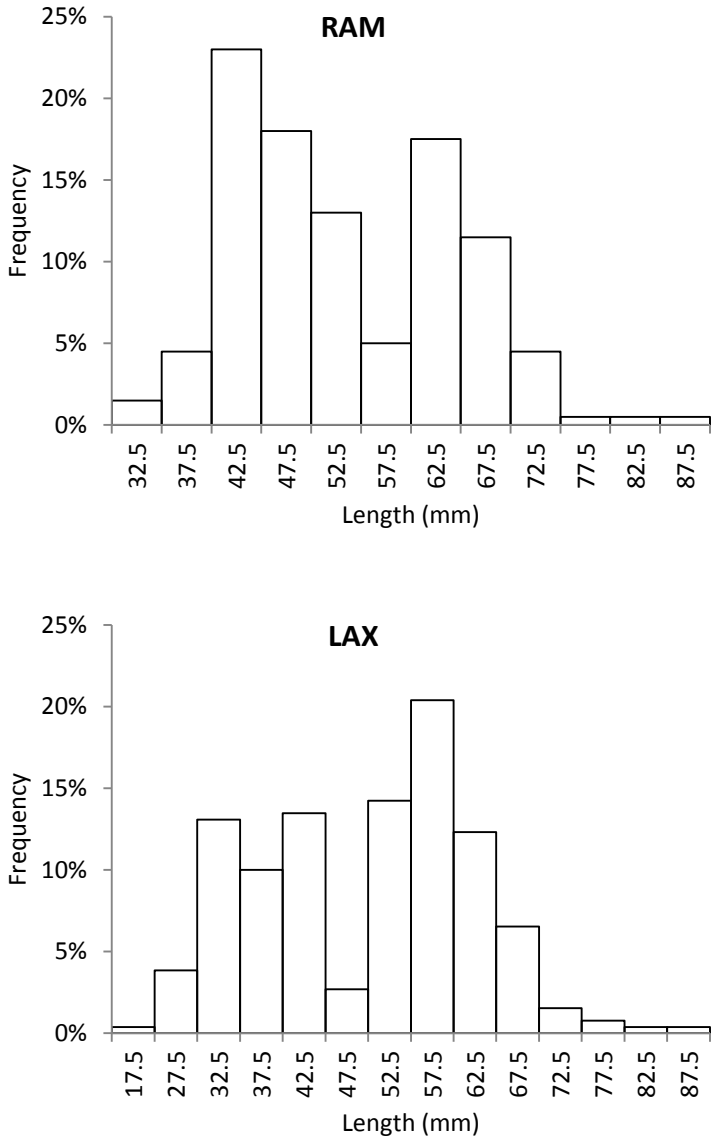

Fig. 9. Size frequency distribution of queen scallops caught at the Ramsey and Laxey survey stations (see Fig. 1) using a beam trawl in May 2011 (Cf. Fig. 5).

4. Discussion

4.1 Abundance

When scallop surveys commenced around the Isle of Man in 1992 queen scallop abundance was around seven times lower than in May 2011 and remained at this low level until 1999. Landings declined steadily between 1983 and 1992. However, relatively low exploitation levels during the past decade have allowed abundance to increase from the low levels observed in the past. The reason for the long period of low abundance is unclear but one possibility is that successful reproduction is dependent on the presence of queen scallops at a particular density as a result of Allee effects (Gascoigne *et al*., 2009). Scallop egg fertilisation success is likely to be higher when adults are present at higher densities (Stokesbury and Himmelman, 1993; Claereboudt, 1999). Therefore, maintaining sufficient densities in at least some areas may be important to the long-term viability of the fishery.

Despite high quantities of queen scallops being landed since May 2011, LPUE has shown only slight declines indicating that recruitment to the fishery has been strong during this period. Earlier in the year, when water temperature was lower, LPUE declined markedly. Consequently, queen scallop biomass will be much lower at the beginning of 2012 than at the beginning of 2011. If queen scallop mortality and recruitment to the fishery are similar in 2012 to that observed in 2011 then queen scallop biomass will be depleted to almost nothing. However, reduced catch rates are likely to prevent landings reaching the levels observed this year. Landings in 2012 will depend heavily on the level of recruitment to the fishery over the period, particularly during spring and summer.

4.2 Impact on benthic habitats

In addition to the direct impact on the target species there are secondary effects that could lead to reduced larval settlement in the future. Trawling is generally considered to be less damaging to benthic habitats than dredging (Kaiser *et al*., 2006). Consequently, the queen scallop dredge fishery failed to achieve MSC certification due to its impact on benthic habitats (Andrews *et al*., 2010). Of particular relevance to the fishery is the fact that the habitats that support queen scallops may be damaged by excessive fishing activity. For example, there is a positive relationship between the presence of macroalgae and maerl and the abundance of juvenile scallops (Howarth *et al*., 2011) and *Aequipecten opercularis* have been found to settle on bryozoans and hydrozoans (Lambert *et al*., 2011). Within the territorial sea the greatest increase in effort is in the trawl fishery, while over the wider area dredging constitutes a much greater proportion of the area of seabed swept and landings. At fishing intensities prior to 2010 benthic conditions were clearly suitable to allow large settlement of queen scallop larvae, as evidenced by the increase in abundance. Therefore, this level of fishing activity may provide an indicator of an appropriate, sustainable, level of fishing in relation to benthic habitats.

4.3 Assessing stocks

Quantifying the various influences on queen scallop stock biomass is likely to be challenging. As well as numerous environmental variables that may affect the reproductive success and mortality of queen scallops there have been many changes in the fishery itself. The fishing gear used to target

queen scallops has changed over time and the dredgers and trawlers are potentially targeting different sizes of scallops. The impact of the various fishing gears on benthic habitats is different and catchability of queen scallops varies between gears (Hinz *et al*., 2009b). Catchability of queen scallops is also temperature dependent (Jenkins *et al*., 2003). Management of the fishery has changed substantially during the past year. The introduction of closed areas, increased minimum landing size (50 mm) and a closed season will all impact on the queen scallop populations. The accuracy of historical landings data is unknown but is almost certainly subject to large errors. Therefore, a great deal more research over many years is needed. Nevertheless, there is sufficient information to allow the fishery to be managed to sustain or increase yields.

In 2008 the Scottish Government established an independent panel to examine the future of fisheries management in Scotland. In the report of the independent panel it was deemed more likely that in stock assessments, rather than there being greater precision, there would be greater recognition of the uncertainty in the future. Consequently, it was concluded that where there is additional risk, due to imprecision or uncertainty, a rational management system would take a more cautious approach, by setting a TAC at a very low level, for instance (Anonymous, 2010). Such an approach is appropriate in the case of the Isle of Man, and Irish Sea, queen scallop fishery. Large increases in fishing effort over a short period of time, as have been observed, represent a high-risk strategy to managing the fishery if the objective is to maintain stocks at current levels. However, to fully understand the risks of increasing fishing effort the management objectives for the Irish Sea queen scallop fishery must first be identified. Within the Isle of Man, maintaining or increasing queen scallop abundance has been identified as an objective in managing the fishery; a pragmatic approach to limiting fishing effort through an advisory TAC based on previous abundance and landings has been proposed to help meet this objective until broader scale management can be implemented (Murray *et al*., 2010).

Basing targets and limits on historical stock size and productivity levels is potentially advantageous since they are not based on model assumptions, and this approach is entirely consistent with the aim of preventing loss of yield (Hilborn and Stokes, 2010). Formal stock assessment will not necessarily lead to better management of the fishery than a pragmatic approach but is necessary if exploiting the fishery to maximum sustainable yield is a management goal. Until a formal approach can be adopted we recommend following a precautionary strategy in order to avoid overfishing. The consequences of failing to safeguard queen scallop stocks will be much more damaging in the long-term than taking a more cautious approach and moderating fishing effort and landings. Therefore, we recommend that the queen scallop fishery is closed in the Isle of Man's territorial sea with immediate effect until 1st June 2012.

4.4 Wider-scale issues

Queen scallops within the Irish Sea are generally thought to consist of a single stock (Beaumont, 1982; Macleod *et al*., 1985). Therefore, ideally, the Irish Sea fishery would be managed as a single stock with management advice provided based on data collected across the Irish Sea. There is also a need to achieve a management strategy that can allow viable trawl and dredge fisheries to continue. Additional research undertaken around the Isle of Man will contribute to achieving this but is less likely to succeed without investment in research into queen scallop fisheries in other areas of the Irish Sea and around the British Isles in general.

5. Summary

- Landings of queen scallops from ICES statistical rectangles 36E5 and 37E5 during 2010 reached the highest level since 1982 at 10716 t and were higher still in 2011.
- The increase in landings corresponded with a large increase in abundance at South East of Douglas and East of Douglas survey stations with average abundance reaching the highest levels since 1992 (46 scallops $100m^{-2}$).
- There was a decrease in average abundance between June 2009 and June 2010, and June 2010 and May 2011.
- The advisory TAC is held at 4000 t on the basis that increases in abundance have occurred while landings have occurred at or below this level.
- It is important that management of the fishery responds to stock status both in terms of maintaining a viable fishery and retaining MSC certification. Consequently, unless action is taken to limit landings the MSC certified status of the trawl fishery is threatened.
- We recommend that the queen scallop fishery is closed within the Isle of Man's territorial sea with immediate effect until 1st June 2012.

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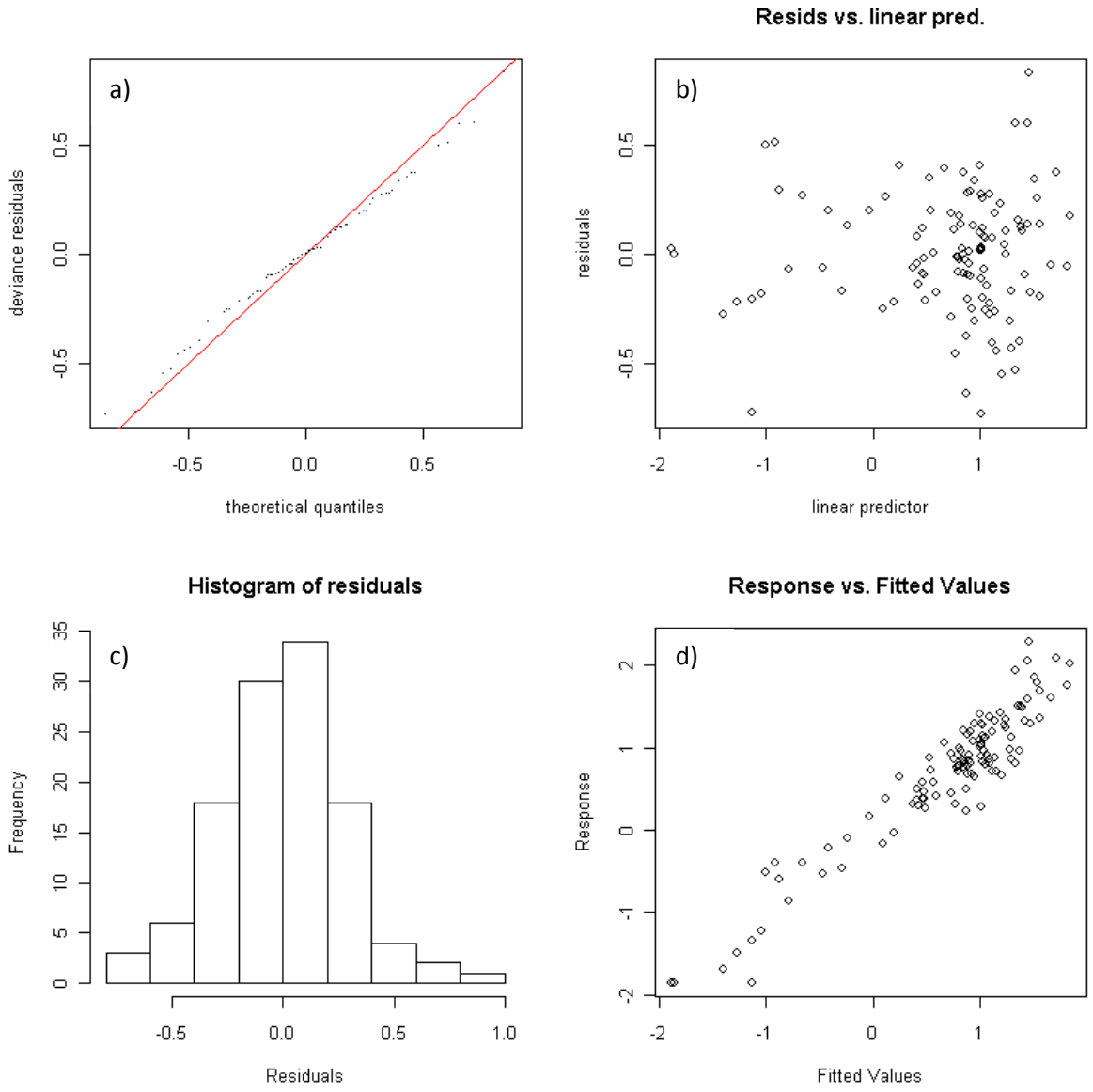
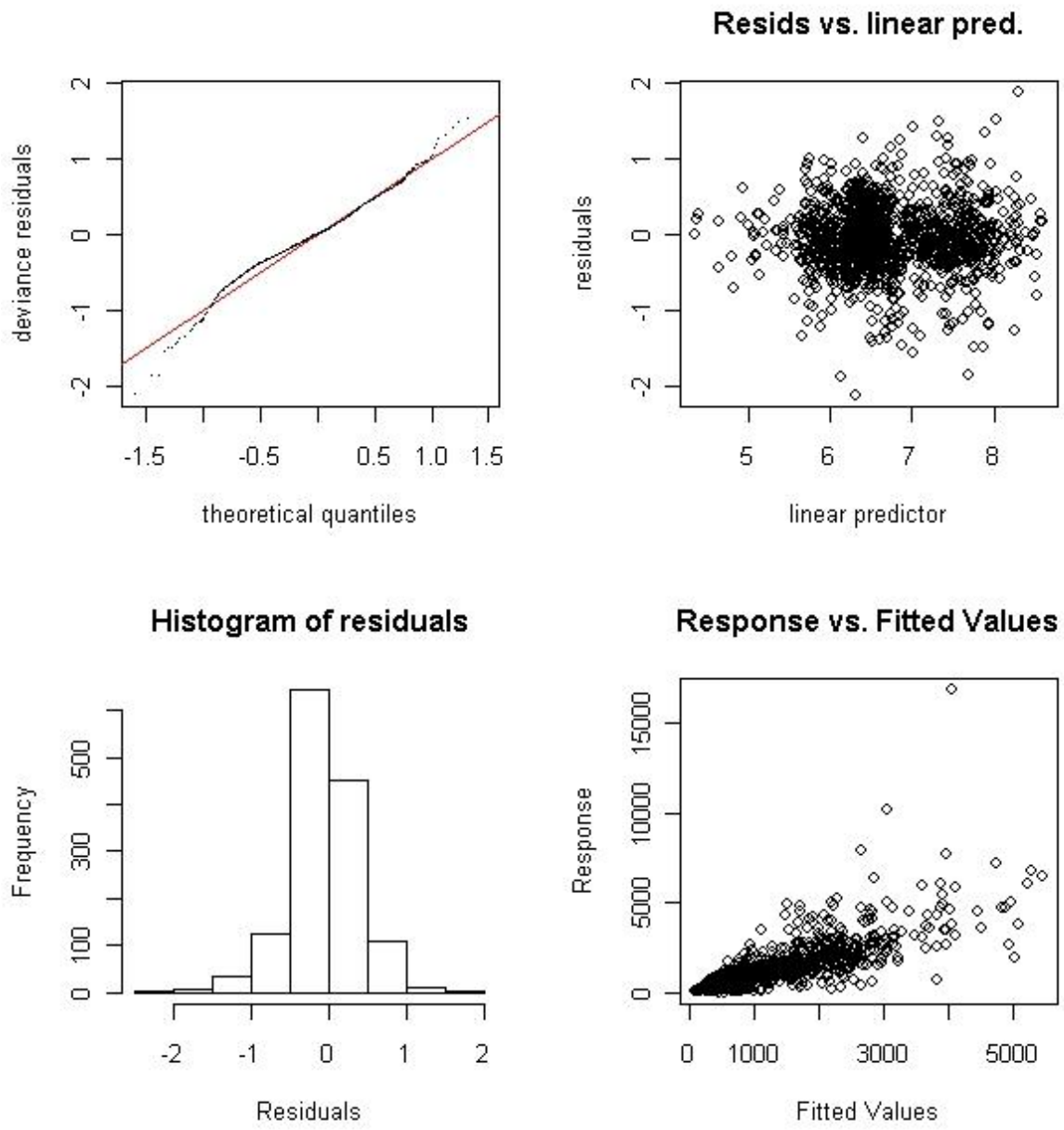


Appendix 1. Model checking plots used to assess the Generalized Additive Model fitted to survey data in order to estimate abundance at survey stations not sampled in some years.



Appendix 2. Model checking plots used to assess the Generalized Additive Model fitted to fishery-dependent data in order to estimate abundance throughout 2011.