Bycatch Survey – Isle of Man Queen Scallop Otter Trawl Fishery Summer 2012

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Executive summary

This report provides information and analysis on the bycatch from the queen scallop *(Aequipecten opercularis*) otter trawl fishery in the Isle of Man territorial sea. A scientific survey, conducted onboard commercial fishing vessels between June and September 2012, collected data on bycatch species composition and quantity and examined some of the spatial, environmental and fishing-gear mediated sources of variation in bycatch. The survey data is also compared with an industry-based, self-reporting scheme on bycatch which took place during September and October 2012.

In 2012 the Isle of Man queen scallop season ran from 1st June (although most fishing did not begin until three weeks later) to the 4th of September, when the fishery was closed at the request of the Queenie Management Board. After that date, the only permitted queenie fishing was for the self-reporting scheme, as described later in this report. During the 2012 season, 2,967 tonnes of trawl-caught queen scallops were landed to the Isle of Man (source = DEFA).

The results from the scientific survey showed that the rate of bycatch in the fishery as a whole was relatively low at **7.42% ± 0.52** by weight of total catch, with some variation between fishing grounds. The total non-queenie bycatch for the fishery was estimated to be **309,199 ± 41,191 kg.** There were significant differences found between the four fishing grounds surveyed in relation to mean queenie catch by weight, mean bycatch by weight and bycatch species composition, indicating the importance of the actual ground fished in terms of catch constituents. Although this bycatch rate is higher than previously estimated for this fishery, it is felt that variations in grounds sampled and sampling method can account for much of this variation.

The self-reporting scheme indicated that such a method is feasible, **with 75% of self-reporting tows having a similar biomass to that found by observers**, and can provide quantity and compositional data on bycatch on a far larger scale than would have been possible by scientific observers alone. This may be a model for future bycatch assessments.

Assessment of catch rates with commonly used cod end mesh sizes indicated **no detectable difference in catch size of queenies between 80 mm and 85 mm meshes, whilst the larger mesh did reduce the undersize queenie and teleost fish (roundfish and flatfish) bycatch**. Insufficient data was available for the 90mm mesh size to draw any conclusions.

There are aspects of the design and operation of otter trawls currently used for queenies which minimise fish bycatch without affecting the effectiveness of the nets for the target species. Consideration should be given to prescribing gear design by regulation, so as to maintain the low level of bycatch currently associated with the fishery. This is especially relevant should action be taken to generate an economic return from bycatch, as described below and more fully in this report.

The total amount of the teleost fish bycatch from the 2012 queenies season was **59 tonnes**. **The maximum value of this, if sold for human consumption and bait, was estimated at £48,000.** In order to realise this, however, action would need to be taken on administrative and legislative aspects, as well as the practicalities of collecting, transporting and storing fish in good condition.

Finally, the results of stomach-contents analysis of Dab, one of the most common bycatch species, revealed that discarded, or damaged queen scallops from the fishery may provide a significant dietary component for this fish, **as shown by an increasing occurrence of queenies in Dab stomachs with increasing tow number**. This opportunistic feeding by predators on queen scallops that may be vulnerable or damaged by the catching and sorting process could also indicate that the survivability of discarded undersized queen scallops is lower than previously thought.

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1.0 Introduction

The primary goal of fisheries management is to ensure the sustainable use of natural resources while serving the needs of the present, and to do so without compromising the ability of future generations to use this resource. Of the fish stocks recently assessed by the FAO (2011), almost 30% were estimated to be overexploited, with a further 57% estimated to be fully exploited. The high number of overfished stocks combined with the numerous indirect effects of fishing on marine ecosystems indicates, that in many cases, management has failed in its goal of sustainability (Botsford *et al*., 1997). In recognition of this, there has been a recent and significant attempt to reform the Common Fisheries Policy (CFP), which governs fishing within European Union countries, with changes to be implemented from 2013.

Species targeted by fisheries are typically found in association with other organisms, but due to the unselective nature of many fishing gears these non-target species become incidental catch or bycatch, which is defined as '*incidental catch of non- target marine animals and undersized individuals of target species*' (Crowder & Murawski, 1998; Garcia *et al*., 2003; Davies et al., 2009). Some of the bycatch may be valuable, and is often retained, however, the discarded component, consisting of low value or non-commercial species, are subsequently returned to the sea, often dead or dying (Catchpole *et al*., 2005a). Discarding occurs for a variety of reasons including 1) that the fish are below minimum landing size, 2) the bycatch may have little or no market value and 3) the catch may be damaged or high-graded (i.e. lower-valued individuals or species discarded to maximize profits), or 4) the quota for a species may have been reached (Clucas, 1997).

The method of fishing and type of gear used can have a major effect on the level of bycatch. A survey for the FAO (Kelleher 2005) quantified the maximum rate of discarding recording in various fisheries.

Due to the way that those figures are calculated, a discard rate of 96% refers to the fact that 96% of the total catch is bycatch – ie for every kg of target species landed, 24 kg of bycatch would be caught. Shrimp trawls are particularly destructive in this respect, as they employ small mesh nets in areas of high species diversity.

Table 1: Maximum % rate of bycatch recorded from various types of fishing

Fishing Type	Kelleher (2005)
Shrimp trawl	96
Demersal finfish trawl	93
Pelagic longline	40
Midwater (pelagic) trawl	56
Tuna purse seine	10
Mobile trap/pot	61
Dredge	60
Small pelagics purse seine	27
Demersal longline	57

Environmental conditions have been shown to be a major influence on bycatch/discard quantity and composition in several studies. Seasonality has been found to influence amounts of discards in a number of fisheries (Liggins & Kennelly, 1996; Machias *et al.*, 2001), as well as the species (Trujillo & Pereda, 1997; Castriota *et al.*, 2001; Stratoudakis *et al.*, 2001a) and size composition of discards (Stratoudakis *et al.*, 2001a). A number of studies have also shown that bycatch/discards vary considerably between areas. For example, Murawski (1996) found that species composition and diversity were significantly affected by area, and Bergmann *et al.*, (2002) found significant differences in bycatch composition between samples from the north and south Clyde Sea areas. Water depth has also been found to have a significant influence on discard quantity (Moranta *et al*., 2000; Allain *et al*., 2003; Sánchez *et al*., 2004), species (Blasdale & Newton, 1998; Allain *et al*., 2003), and size composition (Stratoudakis *et al*., 1998). The importance of such environmental conditions is the basic rationale underlying studies that aim to identify 'hot spots' –i.e., areas or times with high bycatch/discard rates (Perkins & Edwards, 1996). Such studies can assist in providing management information to prevent high bycatch and discarding by indicating appropriate seasonal or area closures.

1.1 The Isle of Man Queen Scallop fishery

A substantial fishery for queen scallops (*Aequipecten opercularis)*, known locally as ‘queenies’, has operated in the Isle of Man’s territorial waters since 1969, and is now the second most important after king scallops, with total landings in 2011 to the Isle of Man of 4,529 tonnes and a first sale value of £1.39m. The traditional gear used in the queen scallop fishery was toothed or skid dredges; however, most fishing for queen scallops by Manx vessels is now conducted with otter trawls. There are a number of management measures that govern the fishery within the Territorial Sea, including a minimum landing size of 50mm, a closed season and areas where dredging is not allowed (Sea-Fisheries Act 1971, The Isle of Man Sea-Fisheries (queen scallop fishing) by-laws 2010. Statutory document No. 668/10 (URL 2)). All of these management measures helped the Isle of Man Queen Scallop trawl fishery become Marine Stewardship Council (MSC) certified in April 2011.

An assessment of the queen scallop fishery bycatch completed in 2009, as part of the initial assessment process, found that the levels were relatively low by comparison to other similar fisheries (Duncan, 2009), with the overall rate by weight, relative to target species, being estimated at 3.36%.

The aim of this report therefore was to re-assess the composition of bycatch of the otter trawl queen scallop *(A. opercularis*) fishery in the Isle of Man territorial sea. The study will build upon the bycatch sampling conducted by Duncan (2009), and aims to identify the species composition and quantity of bycatch and discards in relation to the target-catch composition. Furthermore, the spatial variation in bycatch will be examined in order to identify key factors contributing to any observed differences in bycatch abundances and composition. This report will also suggest ways in which the fishery may further reduce and utilise bycatch/discards.

2.0 Materials and Methods

2.1 Location of Activities

The general locations of the fishing grounds on which vessels were observed during the 2012 season are shown in Figure 1.

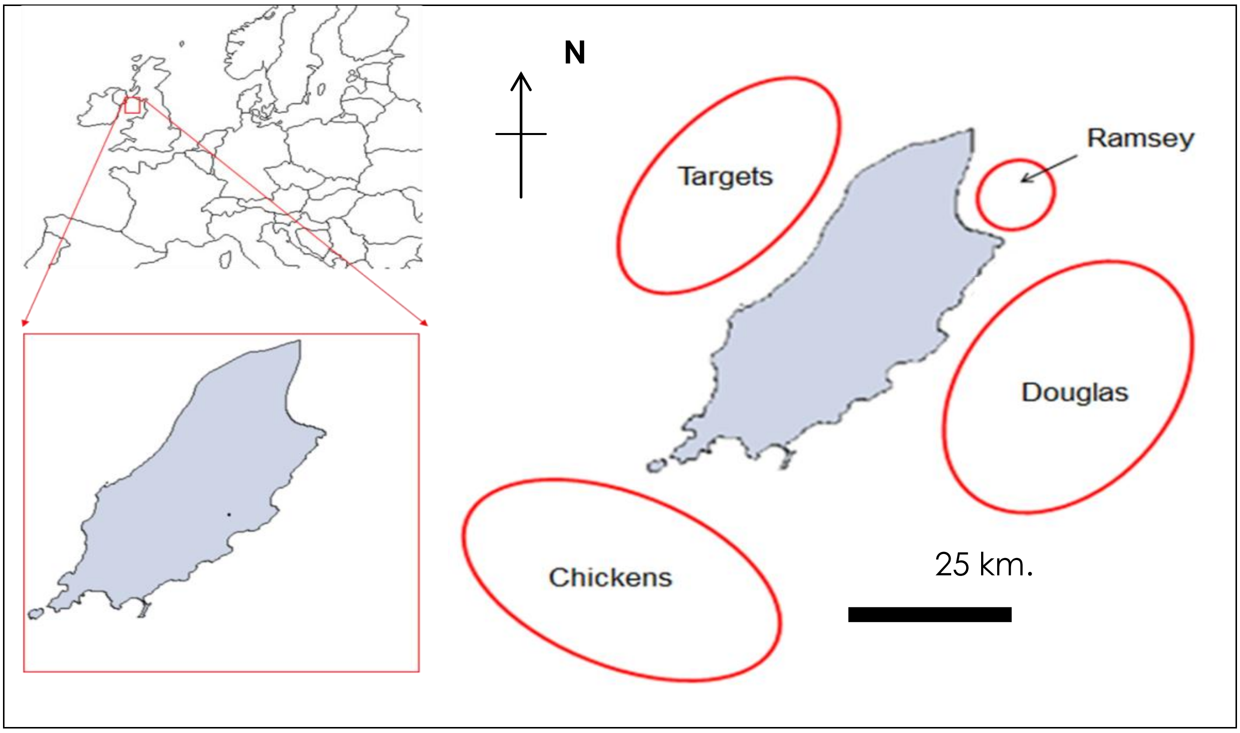


Figure 1: General location of the Isle of Man (left) and indicative locations of studied fishing grounds during this survey (right).

2.2 Data collection

Data were collected at sea from commercial catches of Isle of Man-based vessels using otter trawls to catch queen scallops. The fishing gear used in this fishery is a single net rockhopper otter trawl. A foot rope which holds a number of rubber rollers rolls along the seabed while a head rope is made more buoyant using hollow spherical floats. Occasionally a light tickler chain is used, located in front of the foot rope. The catch is sorted on deck through the use of a mechanical riddle consisting of fixed diameter steel rings and bars. The queen scallops are transferred into the rotating riddle, which removes undersized queen scallops and small bycatch automatically. The undersized catch is forced through the steel rings by a constant stream of seawater into a pipe or chute that flows directly overboard. Queen scallops of sufficient commercial size and larger bycatch which come out are retained and the larger bycatch is then typically removed overboard. No variation to the normal method of fishing was imposed by the observation and sampling programme.

The location of each tow was recorded by means of a handheld GPS unit running continuously in order to record the track, with waypoints entered to identify start and end points of tows. The length (in metres) and duration of tow (in minutes) were extracted from these GPS records.

The mesh size of the cod end and net footrope length were determined from the boat skipper. A net spread factor of 0.75 was assumed (Duncan 2009), in order to calculate the swept area of each tow, i.e. the area of seabed covered by the net during each tow.

After the unsorted catch was deposited on deck a subsample of about 40 kg was collected for the invertebrate analysis, ensuring that it was representative, as it had been observed that animals tended to be aggregated at certain locations in the net. Any fish in the subsample were removed and returned to the bulk of the unsorted catch. The weight of the subsample was recorded.

All queen scallops were removed from the sub-sample, weighed and retained. All non-organic material (stones, plastic etc.) were removed and their weight recorded. All other animals larger than 10 mm in the resultant invertebrate bycatch were retained and sorted. In general, invertebrates were identified to species level, based on Hayward and Ryland (1995), but a few difficult species were identified to a lower taxonomic level. Sorted invertebrates were counted and weighed by species. Weighing on board fishing vessels was by a suspended dial spring balance.

Fish (teleosts (bony fish) and elasmobranchs (sharks and rays)) were collected from the whole catch and sorted by species, counted and weighed. Fish were identified with reference to Wheeler (1978) and Kay and Dipper (2009).

The total length of each individual teleost was recorded to the next lowest whole centimetre using a standard fish board. On the first two days of survey (28 June and 3 July) all teleost fish were transported to a laboratory ashore to be measured more precisely in order to calculate the relationship between length and weight. In the laboratory, total length of fish was measured to the nearest millimetre using a fish board, and individual fish weight was measured to the nearest gram using a laboratory balance. Squid (*Loligo forbesi*) were also measured in the same way as teleosts, except that mantle length was measured.

The total weight of commercial-size queenies retained from each haul was calculated by counting the number of filled standard queenie sacks and multiplying by the weight of a sack. The weight of a filled standard sized sack was checked several times during the course of each fishing day.

After the crew had finished processing the commercial catch, the queenies from the subsample were passed through the grading riddler on the fishing vessel in order to estimate the proportion of size to undersize in the overall catch.

During one haul each day size profiles of the queenies were measured. One hundred queenies were randomly selected from the unsorted catch and one hundred from a bag of sorted queenies. Shell height was measured to the nearest millimetre from hinge to the opposite margin using a specific scallop measuring gauge. Queenie size data were used to examine the effect of different cod end mesh sizes on capture and retention rates.

2.3 Self-reporting trial

In addition to the scientific observations conducted at sea, a trial was also conducted during September (following closure of the fishery on 4th of September) to monitor self – reporting of teleost bycatch by the fishing vessels. For each tow, instructions were provided to separate all teleosts from the total catch and retain in sacks identifying the vessel, tow number and date. Skippers completed a log sheet containing similar information, as well as grounds fished, cod-end mesh size, footrope length, and use of tickler chain. For each tow, coordinates (latitude and longitude), water depth and number of standard size bags of queenies in the total haul (skippers best estimate) and retained (actual count) were requested.

Retained bags of fish were landed with the queenie catch and kept in cold storage by the queenie processor. Subsequently, scientists separated the fish by species for each tow, and recorded the total number and weight for each species to the nearest 10 g using commercial scales.

A total of sixty boat-days were recorded by this method and the results were compared with those obtained during the scientific survey on the same grounds, in order to assess the accuracy of the self-reporting method. In this section 5 fishing grounds where examined as the fleet began fishing in the Laxey Area due to bad weather conditions and the fact that Laxey Bay is quite sheltered.

2.4 Data Processing

2.4.1 Abundance and Biomass data

Each tow was treated as a distinct sample. Abundance and biomass data were standardised to give a value / Ha. (of swept area). These data were initially examined using the PRIMER software suite (Clarke & Gorley, 2006) to examine multivariate factors, with differences and trends then examined using univariate techniques.

Significance of differences was assumed for p values < 0.05, or as calculated by Bonferonni adjustment where applicable.

2.4.2 Teleost Length Weight relationship

The relationship between length and weight for teleost fish was examined using the fit trendline (power relationship) function in Microsoft Excel. This allowed determination of the 'a' and 'b' values for the relationship; 'Fish Weight = a * Fish Length ^{b}. The fit trendline function also generated the R^2 value for the goodness of fit of the projected line to the actual data. For species with insufficient samples to produce a good relationship, the 'a' and 'b' values from Coull *et al* (1989) were used.

2.4.3 Potential values of teleost fish for human consumption or bait use

To determine the potential economic value of teleost bycatch when used for human consumption or as pot-fishing bait, the quantity, length and species of fish from each tow was recorded at sea, then the weight of each fish was estimated from the length: weight relationship described above. The value of each fish for human consumption was then determined using this weight and a price list (Appendix 1) supplied by a local fish merchant (Robinsons Group, Isle of Man) who had expressed an interest in selling retained bycatch. The bait value of fish was based on a price of £ 0.20 / kg., (the price offered by a local fish processor) (Caleys, Peel, Isle of Man). Economic values were expressed per tow, as this has more relevance to those wishing to make use of these particular data.

2.5 Investigation of Dab scavenging behaviour

Preliminary stomach content analysis revealed that the stomachs of several fish species including dab and whiting contained a high proportion of queen scallop meat. It was hypothesised that these species may have been feeding on queen scallops discarded from previous tows throughout the day, as all fish sampled were collected from the last tow of the day, and fishing activity tended to be in a relatively small area in any day of fishing. To test this hypothesis Dab was selected for further study due to its common occurrence in all fishing areas with an average abundance of 18.05 ± 2.77 fish per tow. The samples were collected over five days from the Douglas, Ramsey and Chickens grounds and Dab from each consecutive tow were retained and labelled separately. Fish were then kept in a cool box onboard and immediately frozen on return to shore for later analysis. The total length (TL) was measured to a precision of 1mm, and the total body weight to a precision of 1 g. The sex and maturity stage were verified macroscopically for each fish. The stomachs were removed and weighed, with excess moisture removed by blotting with absorbent paper. Stomach fullness was assessed on a scale of 1 -7:

1. Empty
2. Trace of prey
3. Trace to 25%
4. 25% to 50%
5. 50% to 75%
6. 75% to 100%

7. Stomach distended

Each stomach was then dissected and the contents examined under a stereoscopic microscope. Each prey item was identified to the lowest possible level of taxonomic resolution, counted and wet weight recorded. Thus, we wished to investigate whether the stomach contents, particularly the presence of queen scallop changed throughout the day in relation to tow number.

3.0 Results

3.1 Details of Survey

Tows were observed between 28th June and 6th October 2012 (some being vessels participating in the self-reporting trial). Nine different vessels were involved, some on more than one fishing ground. A total of 81 tows were observed, with a mean duration of 91.9 ± 1.78 minutes and mean speed of 2.72 knots ± 0.019 over the ground. Mean tow length was 7677 ± 161 metres and mean swept area per tow 11.20 ± 0.28 Ha. The total swept area of all the observed tows was 907.44 Ha.

Summary statistics of duration, speed, swept area and depth of all observed tows are shown in Table 2. The depth at which fishing occurs varies more between grounds than within grounds, so the specific values for each ground are more instructive than the overall figure.

Table 2: Characteristics of tows observed on Isle of Man fishing grounds during bycatch sampling June-October 2012.

	Chickens	Douglas	Ramsey	Targets	Overall
Number of tows observed	14	37	13	16	81
Mean duration of tow (minutes)	95.4 ± 4.29	90.3 ± 2.30	90.0 ± 5.12	94.4 ± 4.87	91.9 ± 1.78
Mean speed of tows (knots)	2.54 ± 0.10	2.82 ± 0.04	2.62 ± 0.04	2.68 ± 0.06	2.72 ± 0.02
Mean swept area of tows (Ha)	12.3 ± 0.08	11.2 ± 0.33	10.9 ± 0.94	10.4 ± 0.54	11.2 ± 0.28
Mean depth of tows (m below chart datum)	56.8 ± 1.00	26.9 ± 0.48	14.4 ± 0.14	35.7 ± 0.42	Na
Total swept area observed (Ha)	172.5	413.7	142.2	166.8	907.4
Total Landed Catch Sampled (kg)	11383	28910	7088	8380	56499

Figure 2 shows the start locations of the observed tows. In many cases tows were very close together or overlapped. A typical tow track was an elongated loop, with the start and end points often close together.

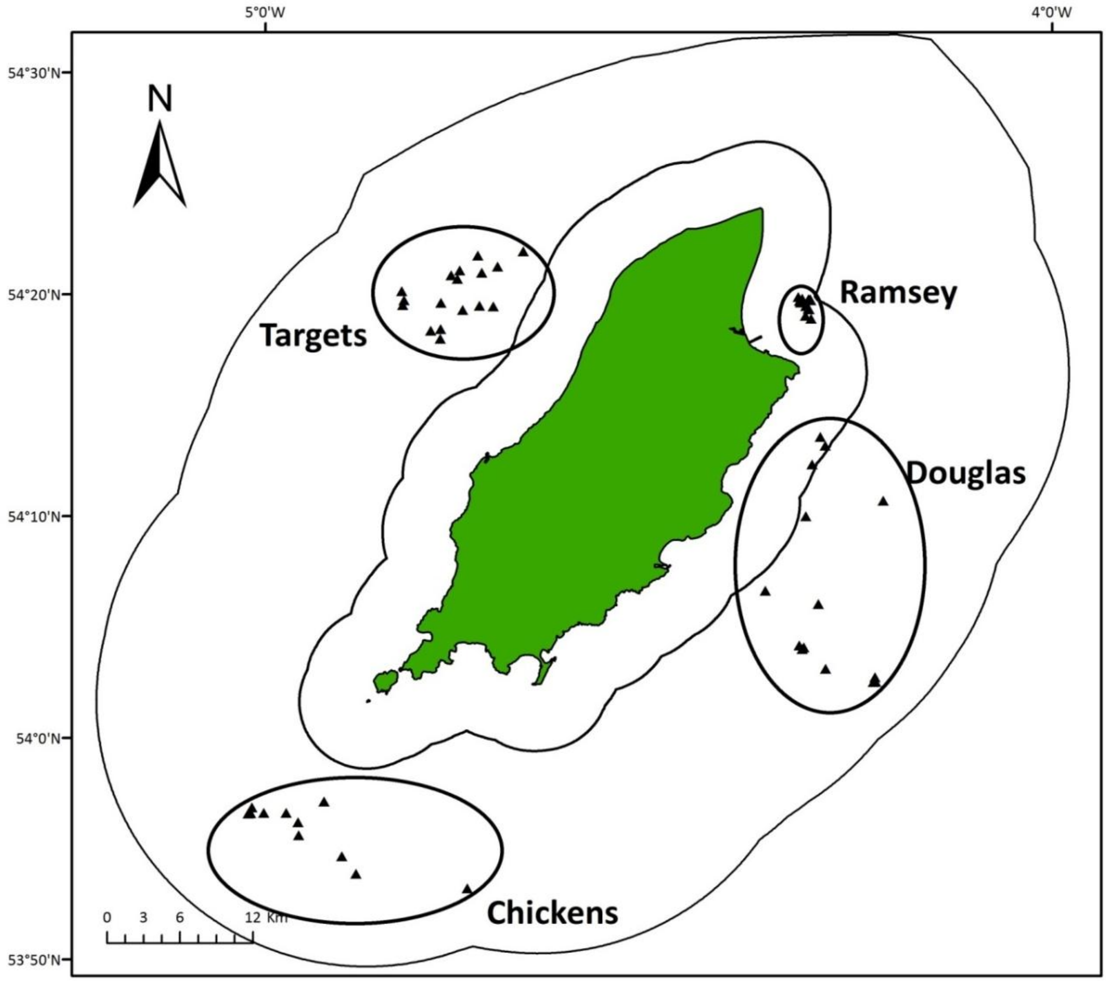


Figure 2: Map of study area, points indicating start position of tows included in the analysis. Approximate boundaries of the fishing grounds used in this study, and the 3 and 12 nautical mile limits are also shown.

3.2 General catch overview of the fishery

For all observed tows combined, the average total catch of queen scallops was 91.69 ± 4.92 kg/Ha (n=64). The average of queenies retained following grading on the boat was 63.94 ± 2.84 kg/Ha (n=81), with an average of 27.51 ± 2.44 kg/Ha (n=64) queenies discarded after grading. There is a slight discrepancy in these figures, due to the different sample sizes. A total of 56,499 kg of queenies were retained during observed tows (n=81). Therefore, the overall average retention rate of queenies was approximately 70% (n=64) of the total queenie catch, or approximately 65% (n=64) of the overall total catch with all bycatch included.

For non-target species catch, averages of 1.26 ± 0.10 kg/Ha (n=75) of teleost bycatch, 1.71 ± 0.16 kg/Ha. (n=71) of elasmobranchs and 3.72 ± 0.51 kg/Ha (n=64) of invertebrates were recorded. In percentage terms, teleosts represent 1.28%, elasmobranchs 1.74% and invertebrates 3.78% of the weight of the total catch (or 1.97%, 2.67% and 5.82% of landed catch respectively). All non-queenie bycatch combined therefore represented 6.80% of the weight of the total catch on deck, or 10.42% by weight of the landed catch (

Table 3). When calculated for the total landed queenie catch of 2967 tonnes for the season June to October 2012, the total amount of bycatch from the 2012 queenie season was estimated at 58 tonnes of teleost fish, 79 tonnes of elasmobranch fish (‘elasmos’) and 173 tonnes of invertebrates (‘inverts’) (Table 3).

Table 3: Constituents of the catch and bycatch of the Isle of Man otter trawl queenie fishery June - October 2012. (A) Observed catch and bycatch all kg/Ha except for % retained queenies). (B) Overall total landed catch and estimated non-queenie bycatch figures (in tonnes) for the 2012 queenie fishing season.

	Total Queenies	Retained Queenies	Discarded Queenies	% retained queenies	Teleosts	Elasmos	Inverts
(A)	91.7 ± 4.9	63.9 ± 2.8	27.5 ± 2.4	69.5 ± 2.9	1.3 ± 0.1	1.7 ± 0.2	3.7 ± 0.3
(B)	na	3000	na	na	58.4 ± 4.6	79.2 ± 7.4	172.7 ± 12.5

3.3 Bycatch abundance and composition by fishing grounds

Figure 3 shows the mean weight of retained queenies, discarded (i.e. undersized) queenies and total bycatch per hectare respectively in each of the four fishing grounds. There was a significant difference in the mean weight per hectare of retained queenies between fishing grounds (ANOVA $F_{3,54}$ = 5.655, p = 0.002) (Figure 3) with the highest value in Douglas, which is significantly higher than both Ramsey and Targets, but not Chickens. There was also a significant difference between the mean weight per hectare of discarded queenies between fishing grounds ($F_{3,54}$ = 4.513, p = 0.007) with the highest value in Ramsey, and significant differences between Ramsey and Targets and Chickens and Targets. The total bycatch for the entire fishery over the entire season, including all fishing grounds, was estimated to be 310,000 ± 41,191 kg, calculated using landings information and the calculated proportion of bycatch to catch from each of the four fishing grounds.

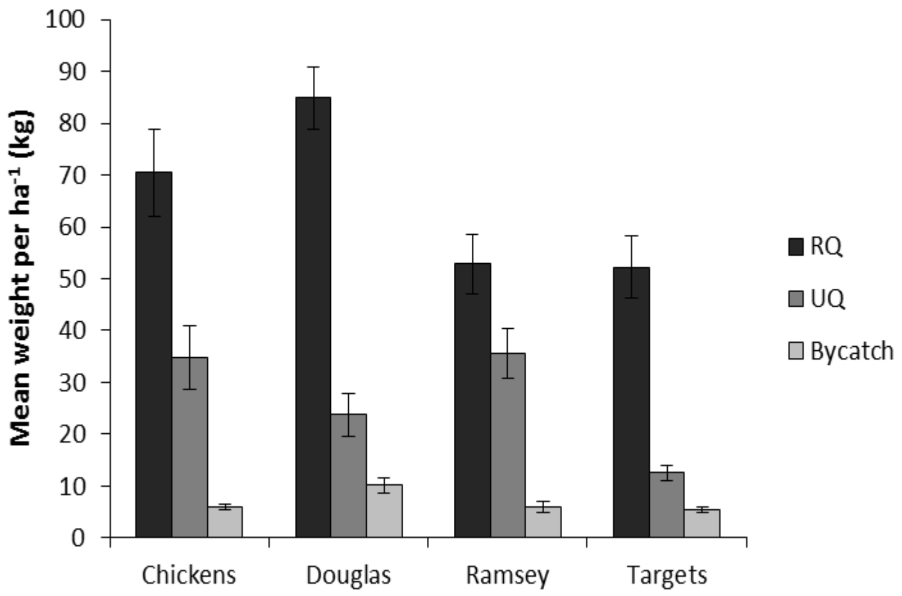


Figure 3: Mean (±SE) weight (kg) of catch components per hectare swept; retained Queen scallops (RQ), unretained Queen scallops (UQ) and other-species bycatch in each of the four fishing grounds. Sample size = 58 tows.

Significant differences were observed in the mean bycatch biomass between fishing grounds (χ^2_3 = 53.202, $p < 0.023$). Figure 4, shows that mean bycatch biomass per hectare swept was highest in Douglas (10.07kg ± 1.49), which differs significantly from Targets (5.05kg ± 0.57), although no other significant differences were found between other areas.

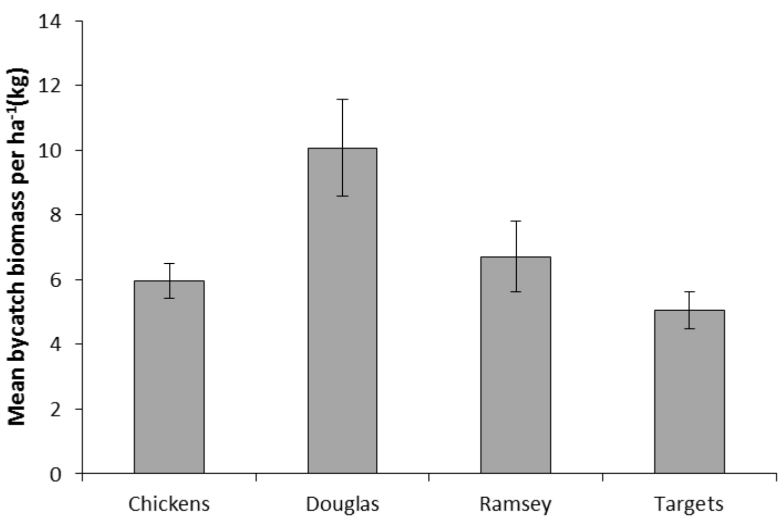


Figure 4: Mean (±SE) bycatch biomass (kg) per hectare swept in each of the four fishing grounds. Sample size = 58 tows.

The mean weight per hectare of teleost fish, elasmobranchs and invertebrates all differed significantly between fishing grounds (ANOVA $F_{3,54}$ = 11.163, p < 0.001; $F_{3,54}$ = 4.156, p = 0.01; χ^2_3 = 21.340 , p < 0.001) (Figure 5). The only pair of grounds that showed a significant difference in mean elasmobranchs caught was between the Douglas (2.35kg ± 0.37) and Targets (0.85kg ± 0.13) areas, with Douglas having a higher value than Targets (Figure 5a). The highest mean weight for teleost fish was found in Chickens (2.59 kg ±0.16), which was significantly higher than Douglas (1.19kg ± 0.1), Ramsey (0.53kg ± 0.09) and Targets (0.92kg ± 0.10)(Figure 5b). Douglas was also significantly greater in mean fish weight caught compared to Ramsey (Figure 5b). Similarly, the mean weight of invertebrates was highest in Douglas (6.53kg ± 1.19) which was significantly greater than that of the Chickens (1.38kg ± 0.16), while the mean weight in Ramsay and Targets was significantly higher than Chickens, but not different from Douglas (Figure 5c).

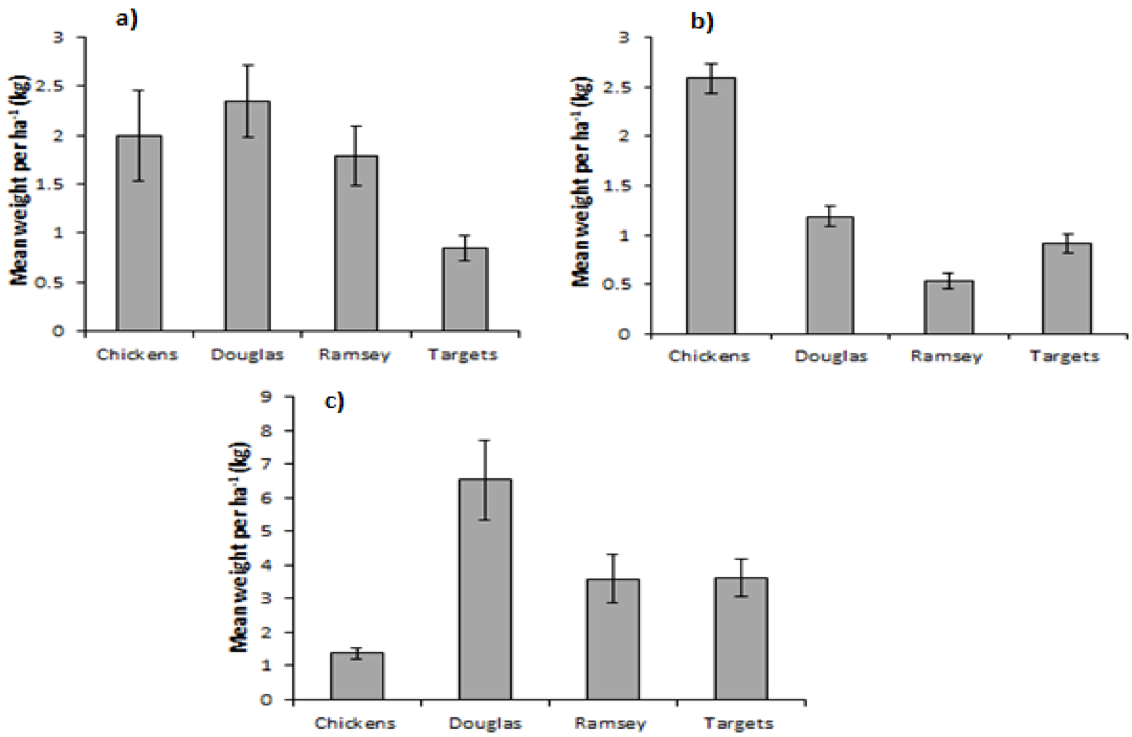


Figure 5: Mean (± SE) weight per hectare of a) elasmobranchs, b) teleost fish and c) invertebrates in each of the four fishing grounds. Sample size = 58 tows.

3.4 Invertebrate bycatch communities

The MDS (in full) plot shown in Figure 6 illustrates the similarity between samples on a two-dimensional ordination where the degree of similarity of tows is represented by the distance between points, with each point representing an individual tow. It is apparent from Figure 6 that there is similarity in invertebrate bycatch communities within fishing grounds, due to the closeness of the points within fishing grounds. Conversely, and despite some variability, there are differences between fishing grounds, seen as greater distance between the points from different fishing grounds.The MDS point is a visual representation of how similar tows are to each other, the closer the points the more similar they are, and the further the points the more dissimilar they are. These observations were confirmed by an ANOSIM analysis of similarities, which revealed significant differences in invertebrate bycatch communities between fishing grounds (ANOSIM, $R = 0.432$, $p = 0.001$). Multivariate pairwise ANOSIM tests showed that all fishing grounds were different from each other, in terms of invertebrate bycatch composition. The abundances of all invertebrate species on each of the four fishing grounds can be found in appendix 3.

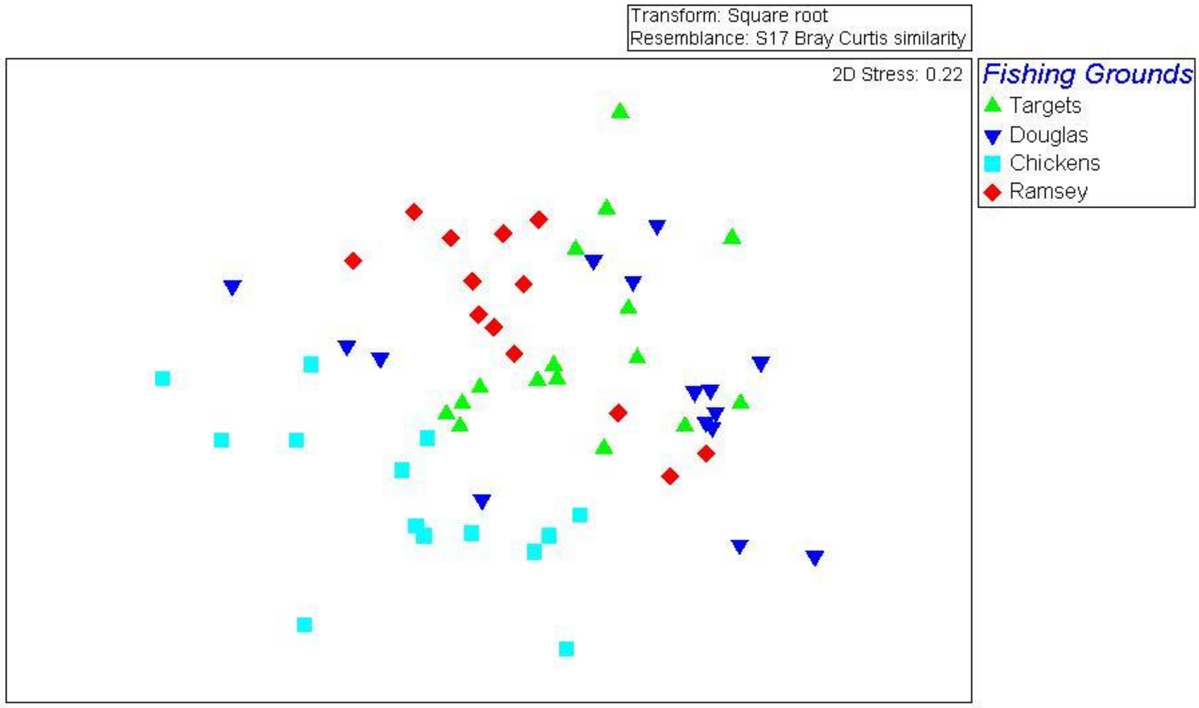


Figure 6: MDS plot of invertebrate bycatch assemblages, within the different fishing grounds (per ha per tow) using abundance data from 58 tows conducted as part of this survey. (Based on Bray- Curtis similarity of square root transformed abundance data).

3.5 Fish and elasmobranch bycatch communities

The MDS plot shown in Figure 7 illustrates the similarity between samples. It is apparent that there is a similarity in fish and elasmobranch bycatch communities **within** fishing grounds and a clear difference **between** fishing grounds, confirmed by ANOSIM analysis of similarities (ANOSIM, $R = 0.544$, $p = 0.001$). Multivariate pairwise ANOSIM tests again showed significant differences between all fishing grounds. The abundances of all fish and elasmobranch species on each of the four fishing grounds can be found in appendix 3.

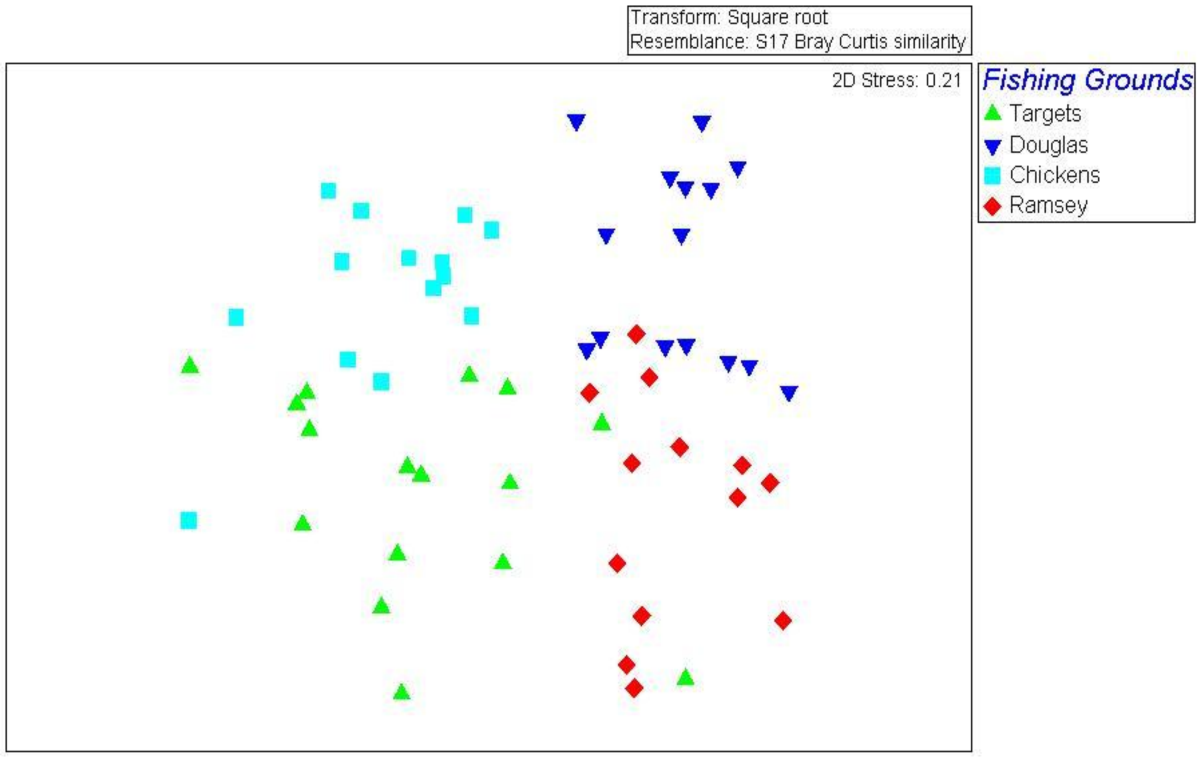
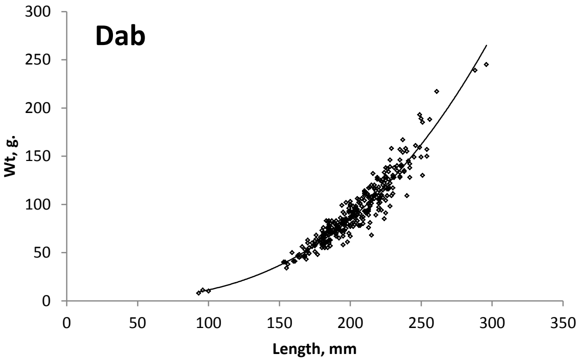


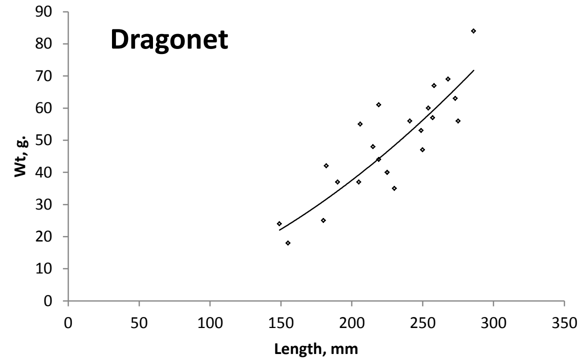
Figure 7: MDS plot of fish and elasmobranch bycatch assemblages, within the different fishing grounds (per ha per tow) using abundance data from 58 tows conducted as part of this survey. (Based on Bray- Curtis similarity of square root transformed abundance data).

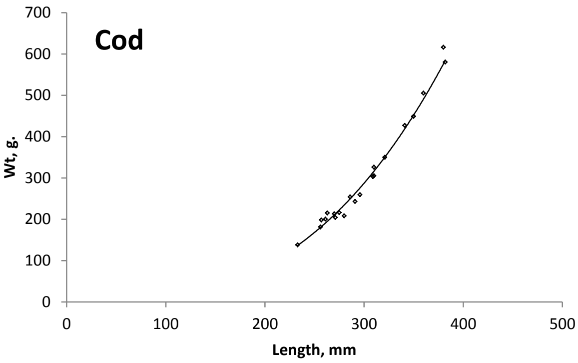
3.6 Teleost fish

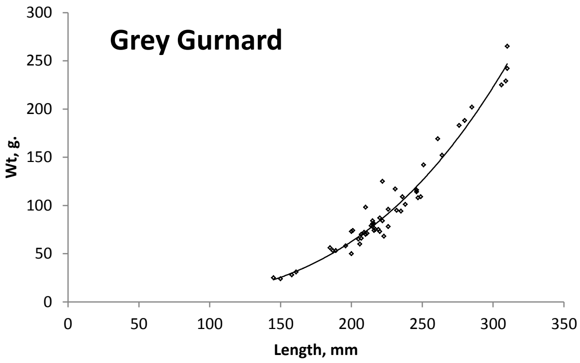
3.6.1 Length/Weight Relationship

Figure 8 shows the length/weight relationship for all the teleost fish species found as part of this survey, for which an adequate number was encountered to produce such a graph. The factors used to produce these curves can be found in appendix 2.


Dab
Wt, g.
Length, mm
0 50 100 150 200 250 300
0 50 100 150 200 250 300 350


Dragonet
Wt, g.
Length, mm
0 10 20 30 40 50 60 70 80 90
0 50 100 150 200 250 300 350


Cod
Wt, g.
Length, mm
0 100 200 300 400 500 600 700
0 100 200 300 400 500


Grey Gurnard
Wt, g.
Length, mm
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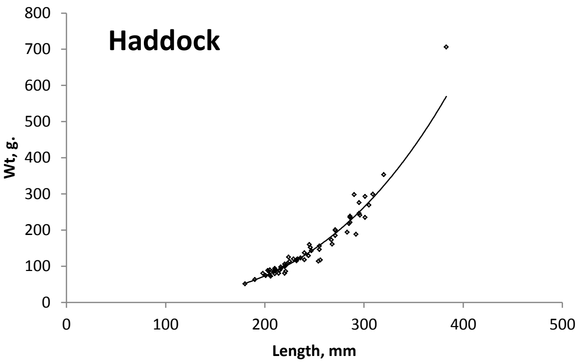
0 50 100 150 200 250 300 350


Haddock
Wt, g.
Length, mm
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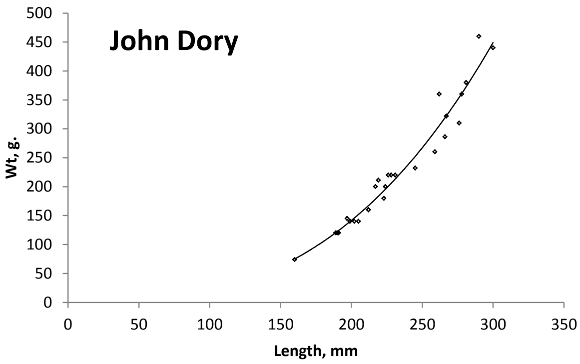
0 100 200 300 400 500


John Dory
Wt, g.
Length, mm
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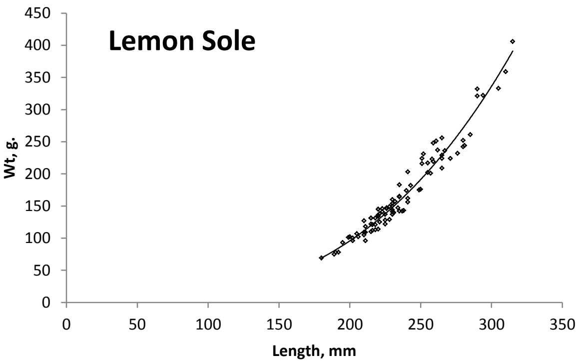
0 50 100 150 200 250 300 350


Lemon Sole
Wt, g.
Length, mm
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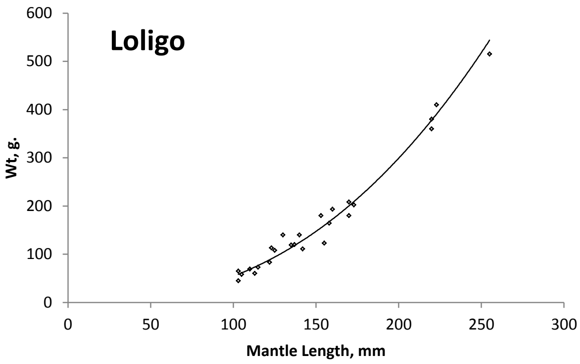
0 50 100 150 200 250 300 350


Loligo
Wt, g.
Mantle Length, mm
0 100 200 300 400 500 600
0 50 100 150 200 250 300

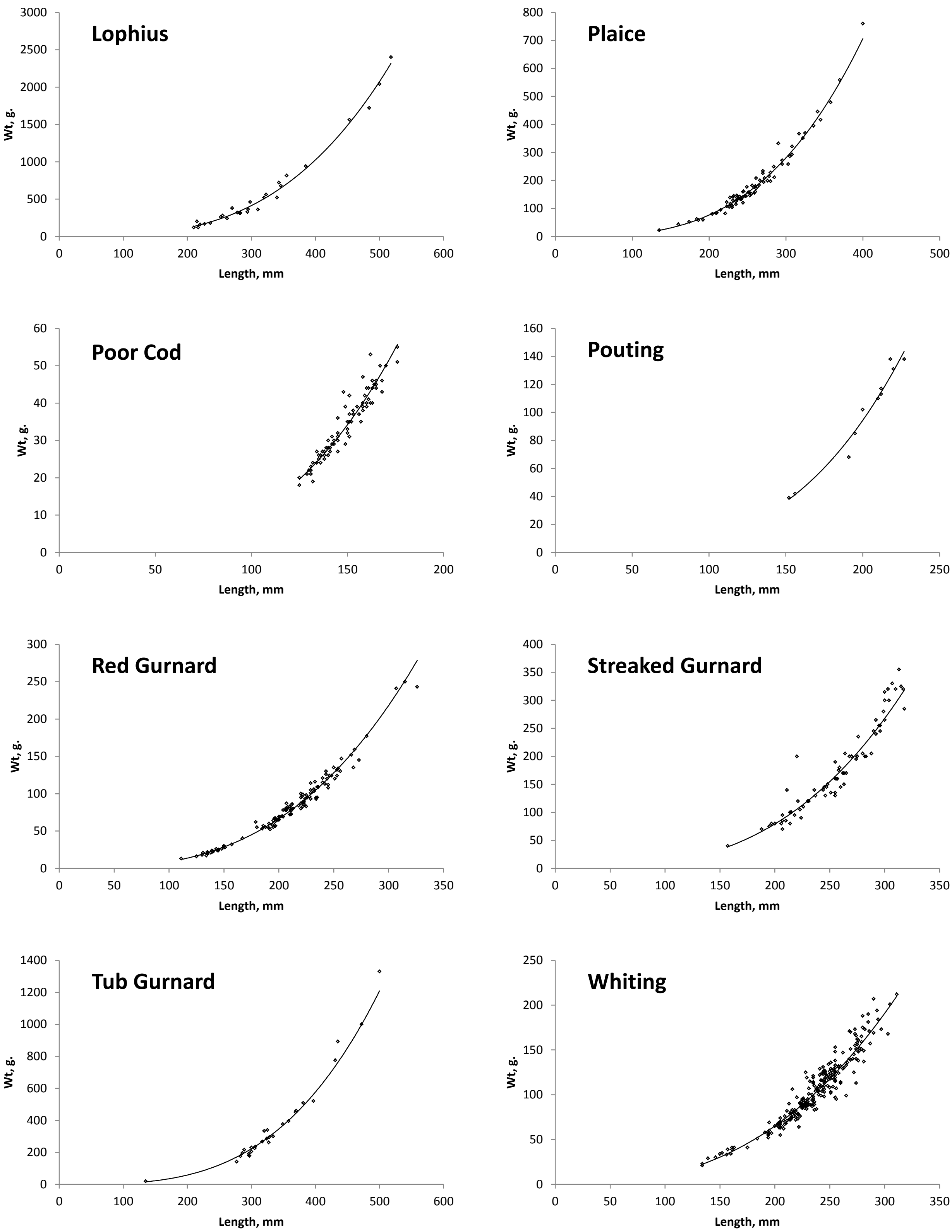


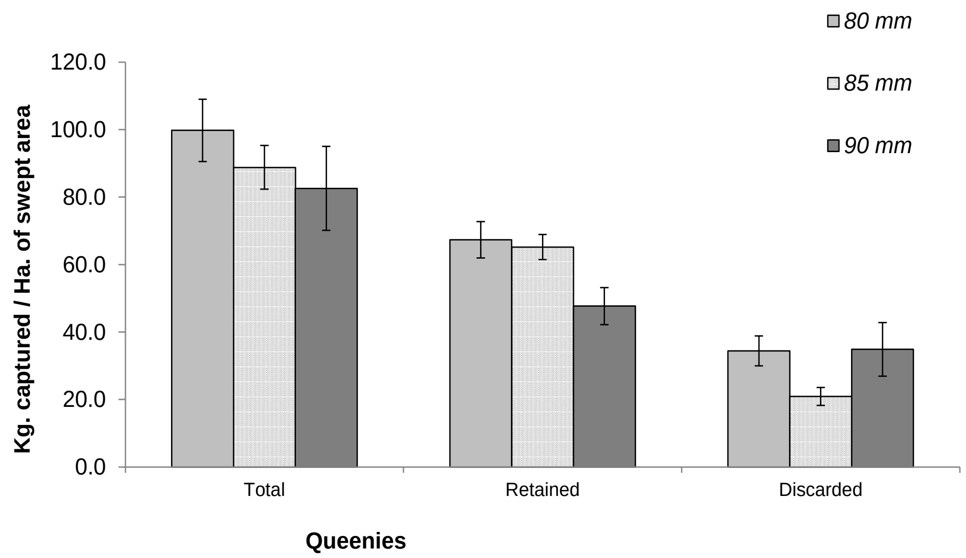
Figure 8: The length (mm)/weight (g) relationship of a number of teleost fish caught as bycatch of the queen scallop fishery.

3.7 Cod end mesh size

Catch rates for retained queenies, undersized queenies, and amount of non-scallop bycatch (separated into teleost fish, elasmobranchs and invertebrates) from different cod-end mesh sizes were examined. Sample sizes for both 80 mm (n = 22 to 36) and 85 mm (n = 33 to 48) mesh sizes were considered sufficient to give confidence in the results, but sample size for 90 mm mesh was only nine, so results have reduced confidence.

The mean weight of total queenie catch, size queenies (retained) and discarded queenies per area swept are shown in Figure 9a. There was no significant difference in either total queenies caught or retained queenies between mesh sizes. Both 80 and 90 mm mesh show significantly greater percentage of retained queenies after riddling than does 85 mm mesh, but there was no statistically detectable difference between 80 and 90 mm mesh. These results are considered due to low sample size for 90 mm mesh.

a)



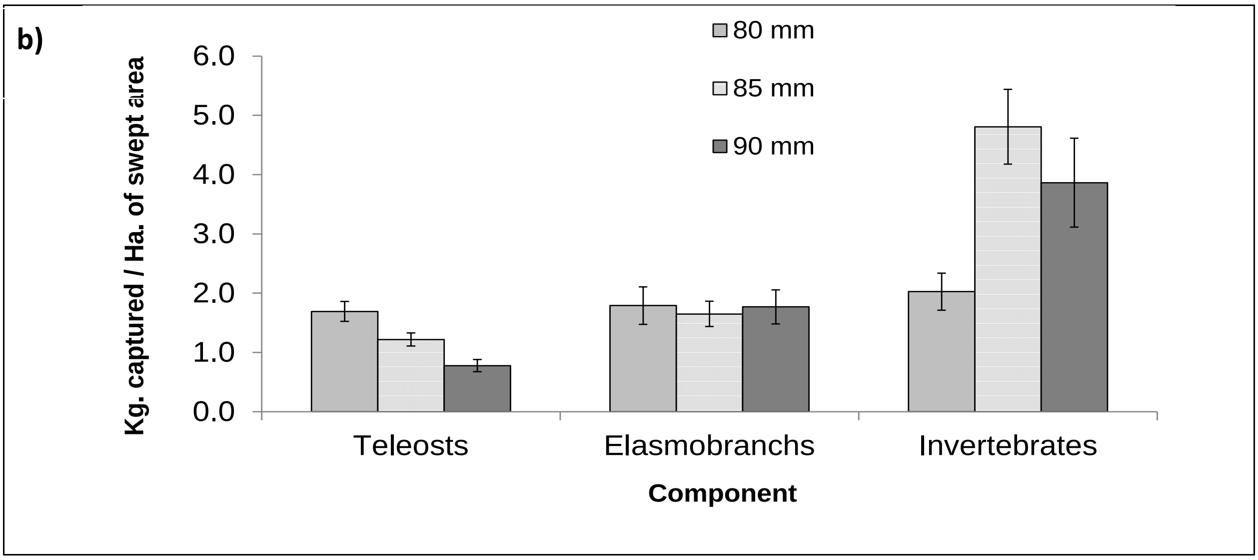


Figure 9: a) Weights of constituents of queenie catch (total, retained and discarded) (kg per Ha of swept area) with different mesh sizes, and, b) weight of non-queenie bycatch retained with different mesh sizes (kg per Ha of swept area).

The size profile ogive for queenie size (Figure 10) shows the proportion of queenies for each mesh size, and in the graded catch ready for landing. The differences between 80 mm mesh, 85 mm mesh and the graded sample are all statistically significant, and indicate that smaller mesh sizes retain more small scallops, and that 85 mm mesh produces a catch closer to the final graded catch The result for 90 mm was not statistically distinguishable from that for 85 mm, probably due to the small sample size, and is omitted for clarity.

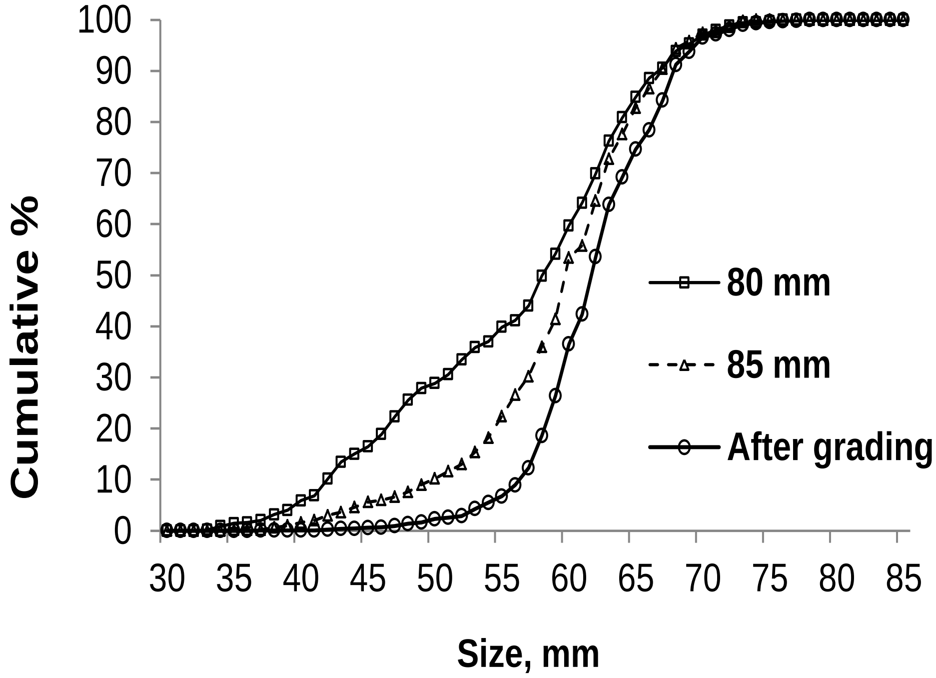


Figure 10: Cumulative % of queenies by size for cod end mesh sizes 80 mm and 85 mm, and for graded queenies. Error bars omitted for clarity.

The results for teleosts show a significantly greater bycatch with 80 mm mesh than both 85 and 90 mm mesh (Figure 9b), between which there is no detectable difference. Overall there is no significant difference between mesh sizes for elasmobranchs, but when considered by individual grounds larger mesh sizes retain greater biomass of elasmobranchs. This is considered more fully in “Discussion”.

The invertebrate bycatch indicates higher capture with 85 and 90 mm mesh than with 80 mm mesh. However, this appears to be an anomalous result, caused by disproportionate sampling with 85 mm mesh on the Douglas fishing grounds, where there are higher levels of invertebrate bycatch than on any other ground. No other mesh sizes were sampled on this ground, so useful comparisons are not possible. When the effect of mesh size is examined taking account of the ground, there are no significant differences between the three mesh sizes for invertebrate bycatch rate.

3.8 Discard utilisation

In addition to the value calculated as described above for fish destined for human consumption, a further value was calculated based on the assumption that all fish would go for use as bait. These values are referred to as "human consumption" and "bait" respectively.

There are large value differences between grounds (Figure 11), with Chickens being significantly higher than any other ground for both human consumption and bait bycatch. This is due to the larger amount of fish caught overall, and also to their relatively higher value status, e.g. haddock, rather than gurnard species which predominate on other grounds. On all grounds, the capture of relatively small amounts of high-value species such as Brill, Dover sole, John Dory or monkfish / anglerfish (*Lophius* sp.) increased the value of a catch for human consumption appreciably, whilst having little effect on the value for bait.

Averaged over all tows, on all grounds, the value for the teleost bycatch for human consumption was **£11.38 ± 1.45 per tow**, and for bait was **£3.19 ± 0.34 per tow**.

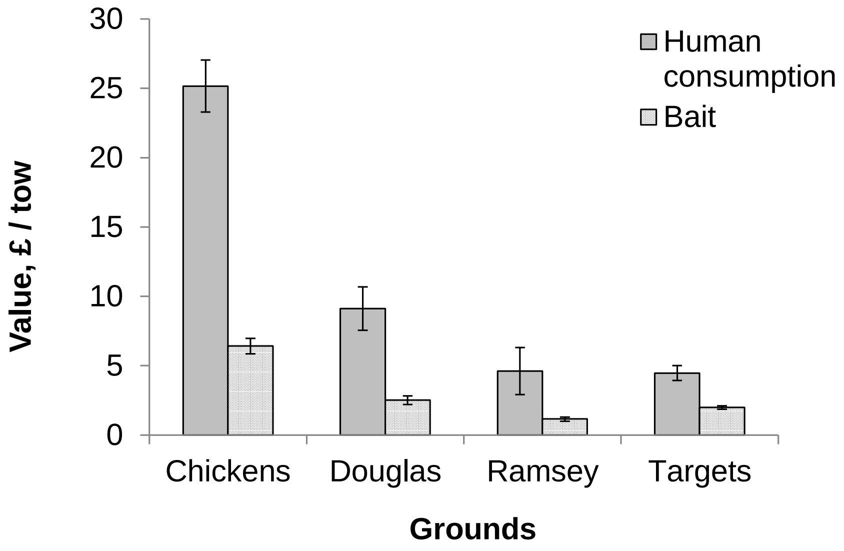


Figure 11: Potential value, £ per tow, of teleosts if used for human consumption or bait from each fishing ground.

The total amount of teleost bycatch from the 2012 Isle of Man queenie season was calculated as 58.45 ± 4.64 tonnes, and the total potential value of this calculated as **£48,311 ± 6403** if used for human consumption or **£13,522 ± 1513** if used entirely for bait.

3.9 Observer Vs. self-reporting of bycatch

Using multivariate analysis (ANOSIM) to compare the biomass of teleost fish species composition recorded by observers against those reported and landed by fishermen, it was found that two of the five areas had significant differences, in some cases lower and some higher for self-reporting than for observed tows. Alternatively, three of the five grounds showed no differences in biomass of teleost fish species composition between observer's data versus "self-reporting" data (Table 4).

Table 4: ANOSIM results of comparisons of observer Vs. self-reporting of biomass of teleost fish species between 5 fishing grounds. Using 62 tows observer and 223 tows self- reporting.

Fishing Ground	P value
Chickens	**0.002**
Douglas	0.225
Ramsey	0.386
Targets	**0.001**
Laxey	0.666

Due to differences in fish communities found between fishing grounds (see section 3.5) the comparisons of observer data against self-reporting data was done on a ground by ground basis, i.e. between observed tows from Chickens against self-reporting tows from Chickens etc. In the majority (75%) of tows tested the mean biomass of teleost fish recorded from self-reporting was found to be similar to the mean biomass of teleost for the tows recorded by observers. Figure 12 shows the mean biomass for the 5 areas with observer recorded tows and the 16 vessels which took part in the self-reporting scheme. There were significant differences in the mean biomass of teleost between observer data and self-reported data from some vessels fishing in Chickens, Targets, Douglas and Laxey. However, the majority (75%) of self- reporting tows had levels of teleost biomass close to values found by observers.

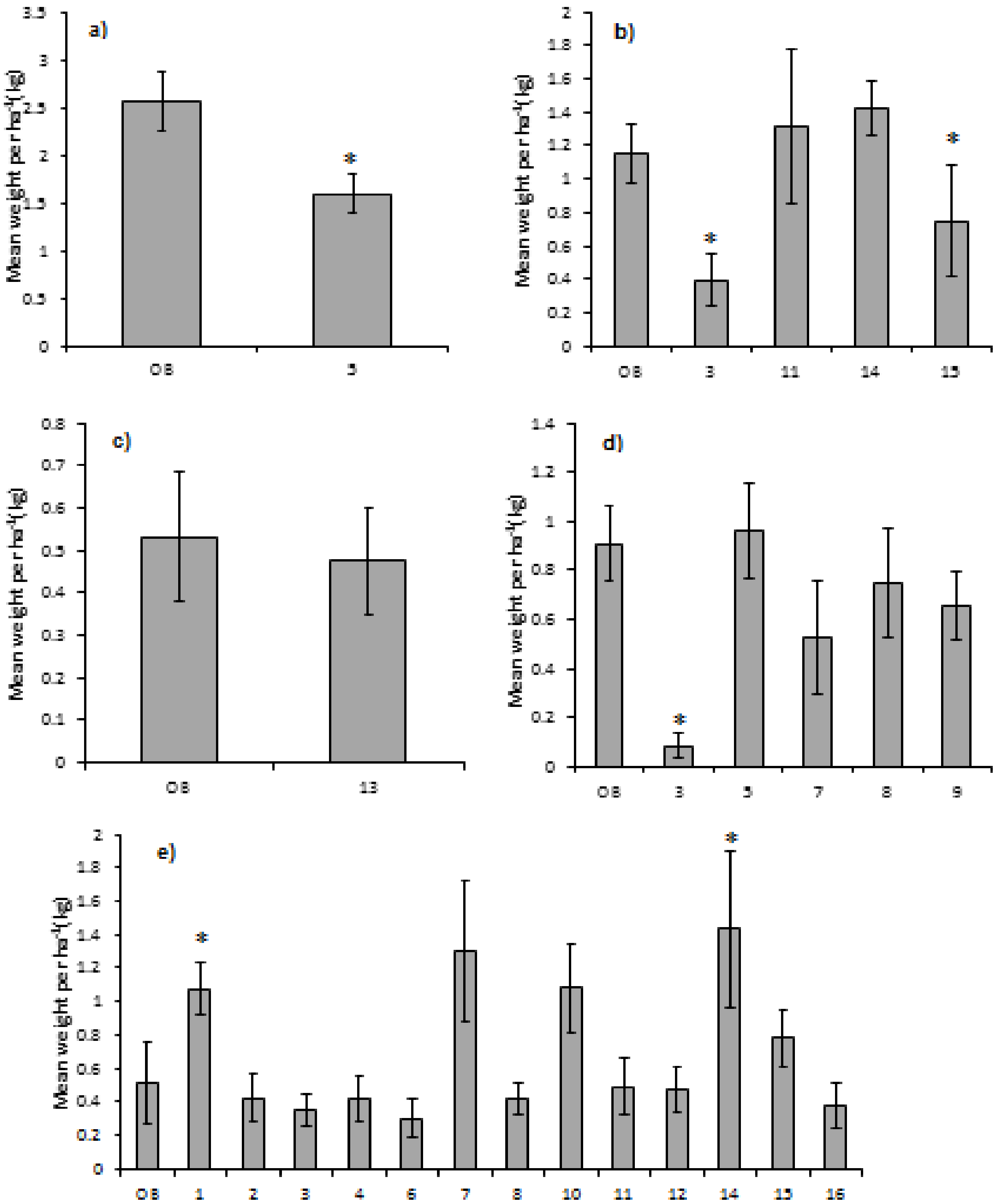


Figure 12: Mean (± SE) biomass of teleost fish at a) Chickens, b) Douglas, c) Ramsey, d) Targets and e) Laxey. OB represents the data from tows directly observed and each number represents tows from a given vessel in a given fishing ground from self-reported data. Numbers have been randomly assigned to protect vessel identity. Significant difference between observer and self-reported means are indicated by a *.

3.10 Dab feeding behaviour

A total of 106 Dab were included in this section of the study, of which 96 were female and 10 were male. The mean stomach fullness of dab was found to be significantly different between tows (χ^2_4 = 14.679, p = 0.005). The tow number indicates the number of tows by a particular vessel on a particular day, with tow 1 being the first of a fishing trip. The mean stomach fullness was found to increase with increasing tow number (Figure 13).

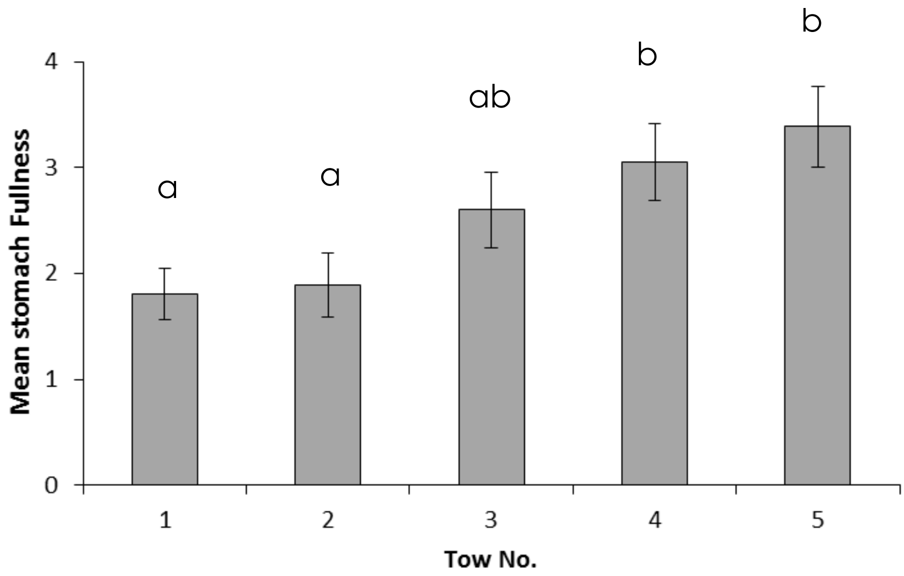


Figure 13: Mean (± SE) stomach fullness of dab (*L.limanda*) against the tow number. Common superscripts indicate no significant difference (Anova, P>0.05)

Post hoc tests revealed that there were significant differences between tows 1 and 4, 1 and 5, 2 and 4, and tows 2 and 5. This demonstrates a gradual increase in the stomach fullness as the tow number increases or as the day progressed.

The term, Weighted Resultant Index (*%R_W*) is a function of the % occurrence and the % weight of a particular prey item, giving a proportional measure of importance of that prey item in a diet. The prey item that accounts for the highest $\%R_W$ in the stomach contents of Dab from all 5 of the tow groups is queen scallops, and ranged from 74-95 %.

The $\%R_W$ of Queen scallops increased with tow number, indicating increasing importance over time (of the fishing day). A linear regression found that there was a significant positive relationship between stomach fullness of dab and the $\%R_W$ of Queen Scallops ($R^2 = 0.628$, $p < 0.001$) (Figure 14). For details of analysis and further information regarding this section please see “Spatial variation in by-catch and energy subsidies generated by a trawl-caught queen scallop *(Aequipecten opercularis*) fishery” (Boyle 2012).

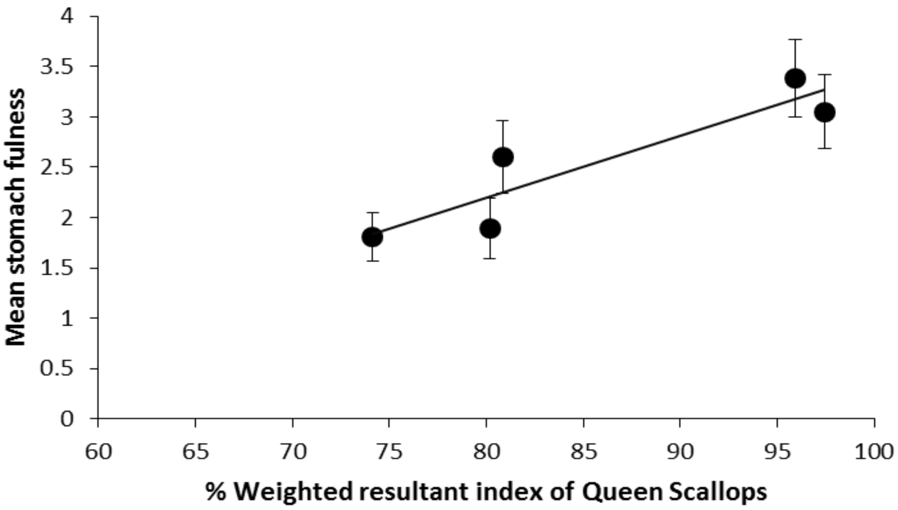


Figure 14: The mean (±SE) stomach fullness of dab from each tow against the %Rw of queen scallops for that tow.

4.0 Discussion

4.1 Survey Overview

A study by Duncan (2009) contributed to the MSC certification of the Isle of Man otter trawl fishery for queen scallops, and the current study continues that work. It is instructive to compare the results of the two surveys, insofar as is possible (Table 5).

Table 5: Comparison of results of tow characteristics and bycatch components from Duncan (2009) and the current study. Figures are means and one standard error, where available. Figures in bracketed italics are estimates only.

	Current Study	Duncan (2009)
Length of tow, minutes	91.9 ± 1.78	69.75 ± 2.10
Length of tow, m.	7677 ± 161	5445 ± 194
Swept area of tow, Ha.	11.20 ± 0.28 Ha	7.46 ± 0.004 ha
Total queenies. Kg / Ha	91.7 ± 4.9	108.26
Landed queenies, kg / Ha	63.9 ± 2.8	87.45 ± 4.51
Discarded queenies. Kg / Ha.	27.5 ± 2.4	20.80 ± 1.82
Discard rate queenies, %	30.5%	21%
Total bycatch kg / Ha	6.69 ± 0.53	4.79 ± 0.36
Teleost bycatch kg / Ha	1.26 ± 0.10	*(2.07 kg / Ha)*
Teleost bycatch No / ha	8.86 ± 0.52	14.55
Elasmobranch bycatch kg / Ha	1.71 ± 0.16	*(1.55 kg / Ha.)*
Elasmobranch bycatch No / Ha	2.68 ± 0.24	2.43
Invertebrate bycatch kg / Ha.	3.72 ± 0.27	***(1.17 kg / Ha.)***
Total bycatch % of landed queenies by weight	10.46%	About 4% (several figures given)
Total bycatch as % of total catch brought on deck	6.80%	3.36 %

Differences are indicated in the mean length of tows (both in time and distance), and swept area, all of which are greater in the 2012 study. The total queenies / Ha figures are similar, but retention and therefore landing rates are lower in the 2012 study.

The total bycatch kg / Ha. recorded by Duncan (2009) is lower than the current study and this in combination with the higher landings of queenies / Ha swept area from 2009 produce a figure of bycatch expressed as a percentage of landed queenies which is below the current study. There are some challenges in comparing the two studies in more detail, as the figures for biomass / Ha swept area for components of the bycatch are not readily accessible in Duncan (2009). Comparisons of the numbers of teleosts and elasmobranchs / Ha swept area indicates that the studies are in agreement for elasmobranchs, but that the 2009 study recorded more teleosts. The current study has examined the variation in bycatch between grounds, and found significant differences for numbers and biomass of teleosts, elasmobranchs and invertebrates between grounds. Specific grounds fished varies from year to year, depending on the perceived return to the fishing vessels for effort on the various grounds, and sampling effort of bycatch observers is generally determined by where the fleet is fishing. The fishery in 2009 was not fishing the same grounds as in 2012, and Duncan (2009) therefore examined different grounds to those in the current study.

If the mean weight of a teleost and an elasmobranch is assumed to be the same for 2009 as found in 2012, then the figures indicated in bracketed italics can be calculated. Subtracting the combined teleost and elasmobranch figures from the total bycatch kg / Ha swept area gives an assumed figure of 1.17 kg of invertebrates / Ha. swept area for the 2009 study (shown in bold bracketed italics), cf. 3.72 kg / Ha swept area for the 2012 study. The 2009 study did not sample on Douglas grounds, which is the location where the current study found a significantly greater biomass of invertebrate bycatch than on any other ground.

Duncan (2009) attempted collection of all the invertebrate bycatch within a haul of queenies, whereas the current study used a sub-sampling method. In addition, Duncan (2009) was completed with a single observer, and the current study used two observers.

Further work is needed to determine if the differences between studies represents real change in the quantitative and qualitative makeup of the bycatch, or if this is a function of the known variability between areas sampled, or due to differences in sampling methods, or a combination of these factors.

4.2 Bycatch abundance and composition by fishing grounds

In this present study, the catch composition between the four areas was found to be different, with tows from Douglas and Targets having the highest percentage of retained queen scallops at 73.45% and 72.96% respectively. Despite this, these two areas also had the highest percentage bycatch 8.41% and 8.10%, but the lowest percentage of discarded queen scallop 18.14% and 18.94%. By contrast, Ramsey attained the lowest catch rate of retained queen scallops (57.14%), the highest rate of discarded queen scallops (36.57%) and the lowest bycatch rate (6.30%). This variation between areas is somewhat expected as it is often observed that catch rates vary both spatially and temporally (Hutchings, 1996; Walters, 2003; Poos & Rijnsdorp, 2007; Rijnsdorp *et al.*, 2011).

In terms of biomass per hectare, all three components of the catch differed significantly between fishing grounds, therefore where a vessel chooses to fish may have major impact on the commercial efficiency of a fishing vessel and subsequently could have major implications for the amount of bycatch caught and the amount of seabed impacted upon by fishing activity. These results suggest Douglas to be the preferred fishing ground, a suggestion borne out by fishery preference during the surveyed season and can be seen from Figure 15 which shows this area had the largest concentration of fishing effort. However, there is evidence suggesting that relative abundances of queen scallops in the different fishing grounds in Manx waters varies considerably from year to year (Murray & Kaiser, 2011), and therefore the preferred fishing ground changes with each fishing season. As a largely recruitment- dependant fishery, it would be expected that the focus of the fleet effort would move depending on where the last good settlement occurred. This annual ground selection will clearly also influence the bycatch, as its quantity and composition also vary significantly by area, and confirms the importance of long-term sampling to provide a true picture of the fishery bycatch.

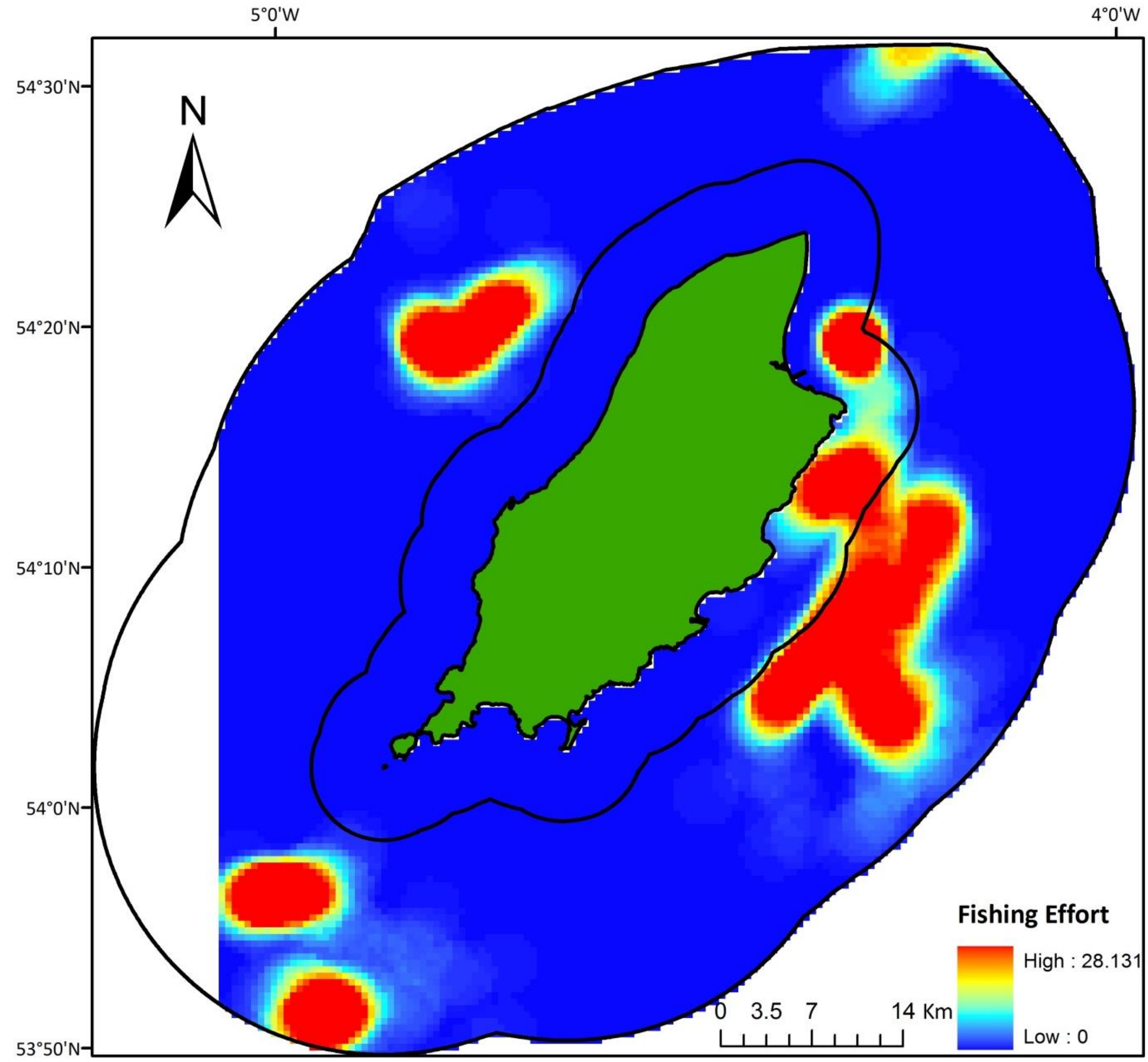


Figure 15: 'Heat' map of the Isle of Man showing the fishing effort (hr/km^2) of queen scallop boats from June to October 2012. 3 and 12 mile limits are also shown. Data provided by Murray.

4.2 Invertebrate bycatch assemblages

The Invertebrate by-catch obtained also differed according to the location of the tow. Statistical analysis revealed clear patterns in invertebrate bycatch assemblages, with distinctly different patterns in community composition between fishing grounds, all with high levels of similarity within fishing grounds, but dissimilarity between grounds. Some species identified as causing the similarity within fishing grounds such as *Alycyonium digitatum*, hydroids, ascidiacea and *Diodora graeca* are known to be associated with or attached to queen scallops in the Isle of Man (Bradshaw *et al*., 2003). Similarly scallop spat have been reported to settle on hydroids and bryozoans and are considered important for recruitment (Eggleston, 1962; Brand & Hoogesteger, 1980; Dare & Bannister, 1987), so their common presence on queen scallop fishing grounds is not surprising.

Figure 6 shows slight overlap of samples (points) from Targets, Douglas and Ramsey, but there is a clear separation of the samples from Chickens. This may be due to the location of Chickens in much deeper waters than the other three fishing grounds. These results imply that depth has some influence on the invertebrate assemblages. It is well known that depth influences species communities and a number of studies have found that depth influences invertebrate bycatch communities (Probert *et al*., 1997; Bergmann *et al.*, 2002).

4.3 Fish and elasmobranch bycatch communities

Fish and elasmobranch species communities showed similar patterns to that of invertebrate species communities. There were clear distinctions between fishing grounds, with no two fishing grounds being the same.

4.4 Cod end mesh size

Results show no reduction in landed (retained queenies) catch of the target species with increasing mesh size. The sample size of 80 mm and 85 mm mesh allow confidence in results for those mesh sizes; the small sample size for 90 mm mesh allows less confidence. The size profile of queenies caught by 80 mm compared to those caught by 85 mm mesh shows the larger mesh is not catching the smaller queenies, and that the profile of those caught by 85 mm mesh more closely matches the profile for riddled queenies, with relatively few (10.2%) below the minimum legal landing size of 50 mm, and only 22.4% below 55 mm. The result is that in effect the 85 mm mesh grades queenies on the seabed, rather than them being brought on board and graded on deck. This avoidance of capture stress and potential damage from handling and riddling should aid survival of the undersized queenies (although it must be noted that there may well be some stress caused by the capture by, and subsequent escape from the net on the seabed) (Montgomery 2008). In addition, there are time and effort-saving benefits to the fisherman of not bringing on deck, handling and riddling queenies which will then be returned to the sea. The profile of riddled queenies shows very few indeed (2.3%) below 50 mm, and relatively few below 55 mm (6.71% by number) (Figure 5).

Table 6: Overall mean percentage of queenies below specified sizes when caught with 80 mm or 85 mm mesh, plus post- grading profile.

	Mesh Size		
Queenie Size	**80 mm**	**85 mm**	**Graded Queenies**
50 mm	28.9 %	10.2 %	2.3 %
55 mm	39.9 %	22.4 %	6.7 %
60 mm	59.7 %	53.4 %	36.5 %

A statistically significant reduction in the biomass of teleost bycatch was shown with an increase in mesh size from 80 mm to 85 mm, but there is no significant difference between 85 mm and 90 mm, although the trend is downwards. When the different mesh sizes are considered on one ground, in order to remove the effect of varying abundances of teleosts on different grounds, this trend remains. It is likely that those teleosts which escape larger mesh size are small individuals of species which are of commercial interest, or species which do not attain a large body size at all. In both cases, it is desirable that these fish are not captured – in the former to aid sustainable fisheries management by allowing the survival of juvenile fish, and in both cases because these small fish have little or no value for either human consumption or bait (being too small to be retained in the pots).

The elasmobranchs bycatch was dominated in all tows by small spotted catshark (lesser spotted dogfish). When examined by ground, all results of statistical significance indicate increasing bycatch of elasmobranchs with increasing mesh size. The body size of the vast majority of these does not allow escape through the mesh of any of the nets observed, so it is not surprising that bycatch of elasmobranchs did not decrease with increasing mesh size within the range examined. It may be that the increasing catch with increasing net size is due to some other confounding factor. Should it be determined that this is an important consideration, further targeted work will be needed to identify and quantify reasons. As explained in the results section, the results for invertebrates do not show any detectable differences between mesh sizes when considered by grounds.

4.5 Discards Utilisation

The European Union has formulated plans to implement a ban on the discarding of teleost fish by the end of 2016 (url 4). As the Isle of Man follows EU fishing regulations, such a ban will also apply to fisheries on the island. The issue of discarding has attracted public and legislative concern, including high profile media campaigns (url 5). There seems to be a widely held public perception that discarding in connection with sea fisheries involves the dumping at sea of large sized, quite high value species, simply because the fisherman does not have quota to land such fish. As this study indicated, the true picture is more likely to be that many of the discarded teleosts are fish below minimum legal landing size, or fish of a size or species which are not of major interest to consumers. That notwithstanding, this present study did identify that from the nearly 60 tonnes of teleosts estimated to have been caught by the queenie fishery during the 2012 season, approximately £50,000 could have been realised at first sale, if there was a system in place to effectively collect, handle, process and pay for the fish – some for human consumption, and those not suitable, as bait for the island's pot fisheries.

Discussion with a major fish merchant on the Isle of Man revealed that they consider it possible to handle such an amount of fish. This company has retail sales of approximately £1.1 million per year for wet fish (including crabs, lobsters and salmon), so the amounts likely to be generated by a discards ban would not be overwhelming – indeed, any locally caught fish which becomes available at the moment is eagerly bought by local consumers and hotels. The merchant did point out that should there be a large amount of one species, then it may be necessary to invest in some form of processing facility, and also that the administrative aspects of the scheme would need to be well defined. (pers. com. Matthew Nelson, Robinsons)

This exercise highlighted the fact that there are legislative aspects which must be considered. It was necessary to address aspects of the sale and handling of fish below minimum legal landing size, the "Registration of Buyers and Sellers", and electronic logbooks before all teleosts could be retained for examination. The pragmatic solution was for the scientists to be formally appointed agents for both the fishing vessels and the merchants handling the fish, with the scientists then responsible for supplying information on the landings to DEFA. DEFA also administered and issued permits for all those involved in the scheme – fishing vessel skippers, scientists, merchants and potting boats using the bait – to be in possession of undersized fish for the purposes of the trial.

It seems likely that it will be necessary to incentivise the fishing industry for this scheme to work. Certainly over the summer of 2012 there was greater acceptance of the idea of fishing vessels retaining teleost bycatch when there were incentives in place (the ability to conduct fishing for queenies to support the collection of teleost bycatch) than when not. A concern arises that once the retention of teleost bycatch is incentivised, such fish may then become a target species rather than a bycatch. At the moment, the efficiency of the queenie otter trawls as fish catching devices is low, due to aspects of the design of the gear –

- There are no warp bridles leading from the net to the otter doors, nor wings extending the central netting section to give a wider fished width; the doors are attached directly to the mesh section of the net material.
- The nets are low – when constructed they are approximately 1.8 m. from headrope to footrope when measured along the net (pers. comm. Davey Faulkner, Isle of Man

net constructer), but it is considered that in operation the headrope is only some 30 cm. in vertical distance above the footrope (Duncan 2009). Trawls designed to catch fish operate with a much greater vertical opening of the net.

- Queenie nets are designed with little or no “overhead” – the amount by which the headrope precedes the footrope when the net is fishing. A fish trawl will typically have a headrope which is approximately two thirds of the length of the footrope, whereas the headrope length for a queenie trawl will be at least 85% of the length of the footrope (pers. comm. Davey Faulkner). The low height and reduction or elimination of overhead allow finfish to escape by swimming upwards out of the path of the queenie net far more easily than would be the case with a net designed to catch finfish.
- Queenie nets are short from footrope to the cod end of the net, compared to finfish nets. This results in less of a “tunnel” in the net, which allows any finfish which do enter the net to swim out far more easily than would be the case in the much deeper finfish trawls (pers. comm. Davey Faulkner).

Nets designed to the principles above operate sufficiently well as queenie nets to support the existing fishery, and have proven to be as effective at catching queenies as modern dredges, and more so than old pattern “Newhaven” toothed dredges (Hinz, Murray & Kaiser 2009). At the same time, they take only relatively small amounts of teleost fish as bycatch. Consideration should be given to prescribing gear design by regulation, so as to avoid evolution into more efficient fish catchers once any scheme is in place which could potentially incentivise the capture and retention of teleost fish. Sound fisheries management should as a priority attempt reduction of bycatch, with utilisation of unavoidable bycatch as a secondary goal.

In addition to the monetary value to be derived from teleost bycatch, continued monitoring of the bycatch will build up a time series dataset which could be useful in following trends in abundance. The variation in abundance of species on different grounds must be considered, but providing that records are kept of the location of bycatch samples useful data will be developed.

4.6 Observer Vs. self-reporting

The results of the self-reporting scheme would indicate that in general it was a successful method of gaining data of the amount and composition of the teleost bycatch of the fishery. The ANOSIM results show that 3 of the 5 areas tested had similar species composition for the self-reporting to that of observed data. However, the two areas that showed significant differences namely Chickens and Targets, may have shown this due to lack of comparable data; in Chickens the number of self-reporting tows was only 4 and in Targets the observer tows were recorded in the earlier months of the season which may indicate some form of seasonal variation. Also the mean biomass of teleost fish in the majority of self-reporting cases had levels similar to that of observer data. These results suggest that this “self-reporting” of teleost bycatch may be an appropriate manner for monitoring the bycatch of the fishery in future, especially if funding for observers is limited. However, the variation in areas fished from year to year could result in large differences in results between this year’s study and subsequent years and therefore there is need for continued observer monitoring perhaps on a bi-yearly basis. To quantify the impact of the trawl fleet with any given year sampling areas should be matched with where the fleet is fishing, due to the significant differences found in bycatch between grounds. However, sampling across the fishing grounds will be necessary to determine whether these differences between grounds are consistent over time.

4.7 Dab feeding behaviour

The results of this study suggest that dab scavenge on discarded queen scallops. It has been shown in other studies that dab are one of the first scavengers to aggregate in areas recently disturbed by trawling (Kaiser & Spencer, 1996), and have shown an increase in their intake of prey in trawled areas compared to that of undisturbed areas (Kaiser & Ramsay, 1997a). The results from this study show that there is a significant increase in the intake of prey and in particular queen scallops as the number of tows in an area increases. Perhaps indicating that repeated tows over an area result in the accumulation of gaping or damaged queenies. However, these results may be influenced by the fact that dab are day feeders (De Groot, 1964) and the fishing activity in an area increased as the day progressed.

There is a clear increase in the stomach fullness of dab as the presumed availability of discarded queen scallops increases. These results would indicate that survivability of discarded queen scallops could be affected by abundances of predators in the area.

A combination of the energy used, and stress induced by the trawling process, on deck sorting and air exposure pose a significant challenge to the survival of queen scallops, and may make them more susceptible to predators once returned to the seabed. A previous study on the effect of on-deck sorting processes on the survival of undersized queen scallops found that post-capture queen scallops took up to 79 minutes to show any signs of response to predators (Montgomery 2008). Both damaged and undamaged queen scallops have been shown to attract up to seven times more scavengers than are present under normal conditions (Veale *et al*., 2000), suggesting that the survivability of discarded undersize queen scallops may be affected to some extent by post-release predation activity.

5.0 Conclusions

This study has confirmed that bycatch levels in the Isle of Man queen scallop otter trawl fishery are relatively low, although slightly higher than the previous equivalent study. Differences in sampling area distributions may account for much of this difference, emphasising the importance of long-term data collection. Indeed, this study showed that there are clear differences in catch and bycatch rates between geographically locations.

Assessment of catch rates with commonly used cod end mesh sizes indicated no detectable difference in catch size of queenies between 80 mm and 85 mm meshes, whilst the larger mesh did reduce the undersize queenie and teleost fish (roundfish and flatfish) bycatch. Insufficient data was available for the 90mm mesh size to draw any conclusions.

There are aspects of the design and operation of otter trawls currently used for queenies which minimise fish bycatch without affecting the effectiveness of the nets for the target species. Consideration should be given to prescribing gear design by regulation, so as to maintain the low level of bycatch currently associated with the fishery. This is especially relevant should action be taken to generate an economic return from bycatch.

The results of the self-reporting scheme indicated that such a method of data collection is feasible, with 75% of self-reporting tows having a similar biomass to that found by observers, and can provide quantity and compositional data on bycatch on a far larger scale than would have been possible by scientific observers alone. This may be a model for future bycatch assessments. This study has shown that the discards from the queen scallop fishery have a major impact of the diet of bycatch fish species, and indicated that the survivability of undersized discarded queen scallops may be of a lower level than previously thought when on-bottom fish-predation is taken into account. An investigation into the extent of this scavenging behaviour may be an avenue for further study.

Web Resources

url 1	:http://ec.europa.eu/fisheries/reform/docs/discards_en.pdf
url 2	http://www.gov.im/lib/docs/daff/Fisheries/queeniebyelawfinal07aug2010.pdf
url 3	http://www.msc.org/documents/scheme-documents/msc-scheme requirements/msc-certification-requirements-v1.2/view
url 4	http://ec.europa.eu/fisheries/cfp/fishing_rules/discards/index_en.htm
url 5	http://www.fishfight.net/

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Appendices

Appendix 1 Price List – First Sale price for fish destined for human consumption

CODE	**SPECIES**	TOTAL	PRICE	**VALUE**
BLL	brill	kg	£ 6.00	
BLL	cod large	kg	£ 2.60	
CLL	cod small	kg	£ 0.85	
CLL	cod sprag	kg	£ 1.90	
CLL	codling	kg	£ 0.94	
POK	coley	kg	£ 0.60	
DAB	Dabs	kg	£ 0.40	
SOL	dovers large	kg	£ 7.00	
SOL	dovers medium	kg	£ 6.80	
SOL	dovers prime	kg	£ 9.00	
SOL	dovers slips	kg	£ 4.00	
GUX	gurnard large	kg	£ 0.80	
HAD	haddock large	kg	£ 1.80	
HAD	haddock small	kg	£ 0.94	
HKE	hake large	kg	£ 2.90	
HKE	hake medium	kg	£ 2.50	
HKE	hake small pins	kg	£ 1.25	
HER	herring	kg	£ 0.78	
JOD	john dory	kg	£ 5.00	
LEM	lemon sole med	kg	£ 2.00	
LEM	lemon sole small	kg	£ 0.70	
LIN	Ling	kg	£ 0.80	
MAC	mackerel	kg	£ 0.64	
ANF	monk tails	kg	£ 4.90	
ANF	monk whole	kg	£ 3.00	
MUR	Mullet Red	kg	£ 5.00	
PLE	plaice med	kg	£ 1.70	
PLE	plaice small	kg	£ 0.70	
POL	pollack large	kg	£ 1.89	
POL	pollack small	kg	£ 1.33	
DGS	rock salmon / spurdog	kg	£ 0.94	
BSS	Sea Bass	kg	£ 8.00	
SKA	skate whole large	kg	£ 1.30	
SKA	skate whole sml	kg	£ 1.00	
SKA	skate wings	kg	£ 2.40	
SQC	squid	kg	£ 2.50	
TUR	turbot	kg	£ 7.50	
WIT	Witch	kg	£ 0.80	
WHG	whiting	kg	£ 0.40	
		kg	TOTAL	

Appendix 2

Table of factors a and b (for use in calculation of teleost length weight relationships) determined within this study, R^2 values for goodness of fit of these factors to observed samples and number of samples n on which the determination of the factors is based.

	Factor			
Species	**a**	**b**	**R^2**	**n**
Cod	1.49 E-05	2.94	0.98	21
Dab	1.75 E-05	2.91	0.92	324
Dragonet	2.55 E-03	1.81	0.76	23
Grey Gurnard	3.89 E-06	3.13	0.96	53
Haddock	3.95 E-06	3.16	0.96	66
John Dory	4.02 E-05	2.85	0.97	27
Lemon Sole	7.20 E-06	3.10	0.95	93
Loligo	6.50 E-04	2.46	0.96	25
Lophius	6.20 E-06	3.16	0.97	28
Plaice	3.21 E-06	3.21	0.98	80
Poor Cod	7.77 E-06	3.05	0.92	93
Pouting	2.09 E-06	3.33	0.98	11
Red Gurnard	1.20 E-05	2.93	0.99	119
Streaked Gurnard	9.87 E-06	3.00	0.92	75
Tub gurnard	1.36 E-06	3.32	0.98	29
Whiting	5.11 E-05	2.65	0.94	248

Appendix 3

Mean Abundances (± SE) per hectare of the fish bycatch species in each of the four fishing grounds.

	Chickens	Douglas	Ramsey	Targets
Limanda limanda	2.41 ± 0.88	1.98 ± 0.49	1.18 ± 0.23	1.14 ± 0.25
Eutrigla gurnardus	0.39 ± 0.09	1.22 ± 0.40	0.20 ± 0.09	0.5 ± 0.14
Melanogramus aeglefinus	3.73 ± 0.72	0.29 ± 0.29	-	1.42 ± 0.40
Microstomus kitt	2.28 ± 0.36	0.26 ± 0.08	-	0.53 ± 0.11
Pleuronectes platessa	0.77 ± 0.15	1.88 ± 0.55	0.30 ± 0.07	0.33 ± 0.06
Aspitrigla cuculus	3.32 ± 0.58	2.73 ± 0.37	1.13 ± 0.33	0.68 ± 0.13
Trigla lucerna	0.15 ± 0.04	0.42 ± 0.08	0.34 ± 0.07	0.13 ± 0.05
Merlangius merlangus	1.53 ± 0.59	0.08 ± 0.04	0.42 ± 0.11	1.80 ± 0.41
Callionymus lyra	0.09 ± 0.06	0.23 ± 0.06	0.07 ± 0.03	0.24 ± 0.08
Liophius piscatorius	0.20 ± 0.04	0.09 ± 0.03	0.02 ± 0.01	0.02 ± 0.01
Trisopterus minutus	0.14 ± 0.08	0.08 ± 0.08	-	0.37 ± 0.22
Gadus morhua	0.07 ± 0.03	0.04 ± 0.02	0.07 ± 0.04	0.08 ± 0.04
Merluccius merluccius	0.03 ± 0.01	-	-	0.01 ± 0.01
Molva molva	-	-	-	0.01 ± 0.01
Scophthalmus rhombus	0.01 ± 0.01	0.01 ± 0.01	-	-
Solea solea	-	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Trigloporus lastoviza	-	0.13 ± 0.11	0.05 ± 0.03	-
Zeus faber	0.09 ± 0.03	0.04 ± 0.01	0.04 ± 0.02	0.01 ± 0.01
Ammodytes tobianus	-	0.01 ± 0.01	-	-
Agonus cataphractus	0.01 ± 0.01	0.02 ± 0.01	-	-
Trisopterus luscus	0.01 ± 0.01	0.13 ± 0.12	-	0.06 ± 0.03
Microchirus variegatus	0.03 ± 0.02	0.03 ± 0.01	-	0.03 ± 0.02

Mean Abundances (± SE) per hectare of the Elasmobranch bycatch species in each of the four fishing grounds.

	Chickens	Douglas	Ramsey	Targets
Scyliorhinus canicula	2.6 ± 0.62	3.26 ± 0.57	2.51 ± 0.47	1.39 ± 0.24
Scyliorhinus stellaris	0.19 ± 0.06	0.03 ± 0.02	0.01 ± 0.01	0.01 ± 0.01
Mustelus mustelus	0.01 ± 0.01	0.01 ± 0.01	-	-
Mustelus asterias	0.05 ± 0.02	0.03 ± 0.02	0.02 ± 0.02	0.01 ± 0.01
Raja naevus	0.02 ± 0.02	0.06 ± 0.02	-	0.07 ± 0.03
Raja clavata	-	0.08 ± 0.02	0.01 ± 0.01	0.01 ± 0.01
Raja brachyura	0.01 ± 0.01	-	-	0.02 ± 0.01
Raja montagui	-	0.01 ± 0.01	-	0.03 ± 0.02

Mean Abundances (± SE) per hectare of the invertebrate bycatch species.

	Chickens	Douglas	Ramsey	Targets
Alcyonium digitatum	30.47 ± 8.39	112.52 ± 34.78	49.26 ± 17.64	59 ± 21.93
Ophiura	13.37 ± 3.92	3.30 ± 0.89	20.73 ± 5.23	6.97 ± 1.84
Ophiothrix fragilis	9.61 ± 3.75	37.78 ± 24.05	1.35 ± 0.44	0.69 ± 0.34
Psammechinus miliaris	1.21 ± 0.49	19.08 ± 5.14	57.87 ± 25.25	24.74 ± 11.86
Ascidiacea	15.70 ± 3.76	13.47 ± 2.74	3.19 ± 1.50	6.81 ± 1.97
Archidorispse udoargus	8.43 ± 4.21	0.82 ± 0.43	0.94 ± 0.53	5.24 ± 0.96
Diodora graeca	-	10.51 ± 3.28	0.35 ± 0.24	-
Hydroid	4.69 ± 2.51	0.56 ± 0.45	7.65 ± 2.77	3.61 ± 1.93
Inachus dorsettensis	3.95 ± 1.54	0.11 ± 0.11	6.18 ± 1.49	3.32 ± 1.14
Suberite domuncula	0.48 ± 0.34	2.58 ± 0.86	5.23 ± 1.74	0.29 ± 0.17
Asterias rubens	1.99 ± 0.43	31.38 ±4.49	19.12 ± 4.26	24.56 ± 2.47
Crossaster papposus	0.17 ± 0.17	8.09 ± 2.27	0.58 ± 0.28	-
Buccinum undatum	-	4.90 ± 1.47	-	0.32 ± 0.24
Luidia ciliaris	1.65 ± 0.73	-	-	3.23 ± 0.84
Henricia sanguinolenta	2.91 ± 0.91	3.07 ± 1.04	1.28 ± 0.38	1.14 ± 0.32
Porania pulvillus	0.80 ± 0.39	-	-	-
Anseropoda placenta	-	0.25 ± 0.20	0.10 ± 0.10	-
Astropecten irregularis	0.17 ± 0.17	1.44 ± 0.67	-	0.99 ± 0.34
Stichastrella rosea	-	0.12 ± 0.12	-	-
Echinus esculentus	0.46 ± 0.35	4.47 ± 1.04	1.01 ± 0.39	0.95 ± 0.50
Aphrodite aculeata	-	0.20 ± 0.20	-	0.47 ± 0.22
Pagurus bernhardus	0.21 ± 0.15	2.29 ± 0.92	0.63 ± 0.36	0.17 ± 0.12
Pagurus prideaux	0.40 ± 0.28	6.44 ± 1.66	1.21 ± 0.56	6.95 ± 1.80
Macropodia sp	-	0.19 ± 0.19	0.19 ± 0.19	0.45 ± 0.28
Liocarcinus depurator	-	-	0.49 ± 0.26	0.55 ± 0.33
Necora puber	-	-	-	0.12 ± 0.12
Atelecyclus rotundatus	-	-	-	0.84 ± 0.46
Hyas sp	0.34 ± 0.34	0.13 ± 0.13	0.42 ± 0.28	0.14 ± 0.14
Munida rugosa	-	-	-	0.20 ± 0.15
Galatheid	-	-	-	0.10 ± 0.10

Homarus gammarus	0.01 ± 0.01	0.05 ± 0.02	0.05 ± 0.03	0.21 ± 0.14
Cancer pagurus	0.06 ± 0.02	0.01 ± 0.01	-	0.04± 0.02
Neptunia antiqua	-	0.50 ± 0.35	-	-
Scaphander lignarius	-	-	0.23 ± 0.23	-
Capulus ungaricus	0.16 ± 0.16	-	-	-
Calliostoma granulata	3.28 ± 1.73	-	1.30 ± 0.66	0.23 ± 0.16
Glycymeris glycymeris	0.17 ± 0.17	0.42 ± 0.29	0.61 ± 0.32	-
Anomia ephippium	-	1.71 ± 1.18	0.44 ± 0.44	0.12 ± 0.12
Pecten maximus	-	0.15 ± 0.15	0.35 ± 0.30	0.13 ± 0.12
Modiolus modiolus	-	-	0.23 ± 0.23	-
Loligo forbesi	1.10 ± 0.33	0.23 ± 0.08	0.10 ± 0.04	0.02 ± 0.01
Eledone cirrhosa	0.05 ± 0.02	-	0.03 ± 0.02	0.13 ± 0.12
Alloteuthis subulata	-	-	-	0.02 ± 0.01
Nemertesia	1.09 ± 1.09	4.15 ±2.67	-	4.18 ± 1.26
Sponges	-	-	1.13 ± 0.78	-
Maerl	-	-	1.99 ± 1.46	-
Flustra foliacea	-	-	-	8.18 ± 1.86