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EXECUTIVE SUMMARY

Since 2007, Bangor University has undertaken a programme of research and monitoring of species of fisheries and conservation importance in the waters surrounding the Isle of Man. Much of this research has been focussed on providing evidence for Marine Stewardship Council certification of the queen scallop fishery. This has resulted in the collation of fundamental data that previously was not available for the waters of the Isle of Man. Detailed reports of many of these activities are available via http://www.bangor.ac.uk/~oss801. Research programmes to extend the collection of data relevant to the management of other key fisheries (crab, lobster, whelk) has commenced. Significant advances have been made that enhance the legacy of long-term data from the Port Erin Marine Laboratory.

Fishing activities:

Scallop dredging occurred over most of the areas in which scallops were found. Only on the limit of the 12 nm zone, south of Port St. Mary, did scallops remain unexploited and this area supported the highest density of scallops outside the closed areas. The majority of the queen scallop stock was not fished but market demand for queen scallops during the study period was low. Obtaining archived VMS data is a priority although this is likely to involve additional cost.

Scallop populations:

The following recommendations emerge as a result of the most recent surveys of the scallop populations in Manx waters:

A precautionary approach is recommended to maintain landings of king and queen scallops at the current level or lower. Landings of queen scallops into the IOM and Scotland were 1840 tonnes in 2007; 1806 tonnes of king scallops were landed. It is suggested that total landings in 2009/2010 should not exceed 1900 tonnes each for king and queen scallops. While overall king scallops stocks would appear to have increased, this is entirely attributed to one locality, Targets. In October 2008, 87% of king scallops on the Targets ground were <110 mm. Scallop fishing on the Targets ground should be avoided until next season to avoid damaging undersized scallops.

If the majority of scallops at Targets have not grown to 110 mm by November 2009, it would be propitious to reduce scallop densities at the Targets by moving scallops to other grounds. A decrease in growth rates would be indicative of density dependent effects i.e. individual scallops competing for food. Moving them to less densely populated areas would reduce competition for food and promote growth.

Various stock assessment models are currently being trialled. Surplus production models have not been successful for queen scallop data. A length-tuned model is currently being used which may prove more successful for both queen and king scallop stocks. CEFAS do not undertake scallop stock assessments due to the poor definition of stocks (pers. comm.) and FRS have undertaken stock assessments for some *P. maximus* stocks only (Howell *et al*., 2006). Therefore, although stock assessment models will continue to be investigated it may be that none are appropriate at this stage.

Habitat surveys:

The preliminary results of the towed underwater video and stills surveys to map the seabed around the Isle of Man, demonstrated that remote imaging techniques can provide a valuable tool with which to assess scallop populations and other fauna and habitats, allowing rapid estimation of species distribution and abundance. The full dataset, once processed, will be a vital resource for the future assessment and sustainable management of the fisheries. This data is matched with environmental parameters that will enable us to determine biogeographic zonation that occur in Manx waters.

Mechanical vs hand sorting of scallops:

Queen scallops may be slightly more vulnerable to predators following mechanical sorting due to greater shell damage. However, the survival experiment demonstrated that there is a high likelihood that discarded undersized queen scallops will survive if returned promptly to sea following sorting. In areas of high fishing intensities juveniles may be caught, sorted and discarded several times which may lead to significantly higher stress levels than investigated by this study. However, the use of mechanical sorting seems unlikely to result in a substantially greater mortality of undersized queen scallops.

Lobster escape panels:

The fitting of small and large rectangular escape gaps to lobster traps would allow many lobsters <87 mm to escape with no loss of lobsters ≥87 mm CL. Thus, as a stock conservation measure, limiting juvenile lobster capture and discards can be recommended as a management option. Other studies have indicated that fitting escape gaps might in fact improve the efficiency of traps slightly with respect to catching marketable lobsters. This observation could not be supported by the data collected in the present study.

It is important that lobsters continue to be measured to ensure only lobsters of ≥87 mm are landed as undersized lobsters will continue to be retained in traps with escape gaps. The compulsory use of escape gaps in traps used for hobby fishing may be beneficial for lobster populations as these traps are more likely to be abandoned or hauled only irregularly. As such there may be a case for the compulsory use or larger escape gaps in hobby pots. The results of this study are available in a detailed report (Murray *et al*., 2008).

Management recommendations:

- It would be prudent to restrict scallop fishing activity at the Targets fishing ground to limit damage to undersized scallops, which form the majority of the population in this area.
- Imposing a total allowable catch for king and queen scallops should be considered to avoid the large fluctuations in catches that have occurred in the past.
- Scallop densities in the closed area at Port Erin are higher than in most other areas. However, scallop densities are low around the edges of the area and intensive monitoring of fishing activity in this area is recommended.
- The installation of lobster escape gaps in traps would reduce catches of undersized lobsters without reducing catches.
- Results suggest that RV Prince Madog is a suitable vessel for conducting scallop surveys. Data quality is better and a greater quantity of data can be collected.
- Mechanical sorting of undersized queen scallops is unlikely to cause significantly greater mortality than hand sorting.
- It will be necessary to assess the environmental impacts of scallop dredges used to fish for queen scallops to the east of the island to determine whether the queen scallop fishery can meet the requirements of MSC certification.

- More detailed information on queen scallop fishing activity will be required to allow catches to be traced to particular areas and fishing gear types. This information could be derived if electronic logbooks and additional vessel monitoring systems were introduced.

Preface

The Isle of Man currently supports five main fisheries, these are: king scallops *Pecten maximus*, queen scallops *Aequipecten opercularis*, common lobster *Homarus gammarus*, brown crab *Cancer pagurus* and whelks *Buccinum undatum*. Small-scale fisheries for bony and cartilaginous fish are also prosecuted, and these animals are taken as by-catch in the queen scallop fishery. A year-round fishery for *Nephrops norvegicus* also exists which is exploited predominantly by Irish vessels. This report describes research conducted during 2007 and 2008, building on existing research which has focused on the Isle of Man's scallop fisheries. Time-series data on scallop landings and abundance indices have been updated. The report is written for a non-scientific audience. The terms 'relative abundance', 'relative density' and 'catch per unit effort (CPUE)' have the same meaning and are used interchangeably.

CONTENTS

1. INTRODUCTION

1.1 Scallop fisheries

An estimated 746,263 tonnes of pectinid molluscs were caught worldwide in 2006. *Pecten maximus* and *Aequipecten opercularis* are landed predominantly in France (26,874 t), the United Kingdom (19,036 t) and the Isle of Man (994 t). *Aequipecten opercularis* are landed chiefly in the Faroe Islands (5,237 t), UK (4,868 t) and France (4,614 t). Fisheries for *P. maximus* and *A. opercularis* are prosecuted almost exclusively in the North East Atlantic (FAO, 2007).

In general, only a small proportion of European scallop production (*P. maximus* 57 t and *Aequipecten opercularis* 60 t) comes from cultivation, although extensive cultivation of *P. maximus* has proved viable in France (e.g. Alban and Boncoeur, 2008). Aquaculture can broadly be divided into two types: extensive and intensive. Extensive aquaculture generally relies on the natural productivity of a system to support the cultivated stock, with minimal intervention. This is in comparison to intensive aquaculture, whereby the cultivated stock is artificially fed and environmental conditions controlled within an artificial environment. Extensive aquaculture limits widespread environmental damage, by concentrating fishing effort into a smaller area, and reduces fuel costs and the fishing effort required to harvest economically viable quantities of shellfish. However, all forms of aquaculture require initial financial investment and management must be tailored to local conditions. The deployment of spat collectors, for instance, must be timed precisely and both horizontal and vertical positioning of the collectors will influence their effectiveness (Pearce *et al*., 1996).

Scallops inhabit a wide range of seabed types from sand through to gravel (Brand, 2006) and can be found in rocky crevices. As broadcast spawners, scallop egg fertilisation is more successful when populations occur in high densities (Stokesbury and Himmelman, 1993). *Pecten maximus* larvae have a planktonic phase of two to four weeks (Cragg, 2006). During this time they are sensitive to environmental conditions. The mean depth at which scallop larvae swim in the water column increases with light intensity (Kaartvedt *et al*., 1987), and both temperature and salinity have a strong influence on bivalve larval behaviour (Lough, 1975). For instance, the larvae of the giant scallop *Placopecten magellanicus* aggregate at the thermocline, through which only larger larvae penetrate (Gallagher *et al*., 1996).

Due to the high level of natural variability in shellfish populations, it is often desirable to be able to assess and forecast stock levels but to do so can require substantial data collection. Surplus production models are the simplest method of stock assessment and particularly useful where the catch cannot be aged (Prager, 1994). The data requirements of surplus production models are minimal, requiring only total catch weights, and fishing effort data or an abundance index. The simplicity of production models necessarily means that many processes are ignored or are assumed to occur at a constant level. In contrast, virtual population analysis (VPA) is based on the age-structure of reproductively isolated stocks and, in addition to data on age, requires data on mortality, growth and catchability (Lassen and Medley, 2001). For many shellfish stocks it is difficult to obtain the data (age in particular) necessary to utilise VPA models; this includes lobsters, crabs and some bivalve molluscs. Defining the spatial limits of stocks also remains problematic for many commercially important stocks including scallops and crabs.

1.2 Crab and lobster fisheries

Landings of *C. pagurus* into England and Wales by English and Welsh vessels were 10,157 t in 2006. 9,325 t of brown crab were landed into Scotland. Landings into Ireland amounted to c. 10,000 t. Of catches in the Irish Sea, 244 t were landed into Scotland and 247 t into England and Wales (ICES, 2007). Stock assessments for both lobster and crab stocks are confounded by difficulty aging the animals. Progress has been made recently in determining the age of *C. pagurus* (Sheehy and Prior, 2008). However, the methodologies used are time consuming and relatively expensive making their use in regular surveys unfeasible. As with scallop stocks, defining crustacean stocks is problematic. Crab populations are especially difficult to define. Female *C. pagurus* have been found to migrate >100 km (Bennet and Brown, 1983). By comparison, migrations of up to 6 km are more typical for *Homarus gammarus* (Bannister *et al*., 1994). Given their intrinsically territorial nature, there is restricted genetic exchange between *H. gammarus* populations (Ulrich *et al*., 2001; Jørstad *et al*., 2004).

1.3 Environmental impacts and mitigation

All fishing activity poses a potential threat to the target species but the effect of fishing on habitats and non-target species varies greatly depending on the fishing gear used. While pot fishing for crabs and lobsters is fairly benign in terms of the damage caused to non-target species (Bullimore *et al.* 2001), there are numerous reports on the environmental damage caused by scallop dredging

(Bradshaw *et al*., 2001; Jenkins, 2001; Kefalas *et al*., 2003; Løkkeborg, 2005; Garcia *et al*., 2006; Kaiser *et al.* 2006). Nevertheless, wild-capture dredging remains the most common method of fishing for *Pecten maximus* and *Aequipecten opercularis*. Natural scallop populations are subject to large fluctuations in size and, potentially, collapse (e.g. Alban and Boncouer, 2008). In recent years, increasing fuel prices have also made fishing less profitable.

Seabed habitats are vulnerable to spatial and functional change due to fishing activity, which may be permanent when certain thresholds are crossed (Thrush and Dayton, 2002). These thresholds will vary temporally and spatially due to biogenic and environmental factors. A precautionary approach to limiting habitat damage, similar to that adopted for setting total allowable catch, could be adopted. In practice, this is likely to mean imposing limits on fishing effort, gear restrictions and prohibiting fishing in certain areas - the same measures used to protect the populations targeted by fishers.

Marine Protected Areas (MPAs) have been utilised to achieve a number of different objectives: to protect spawning stocks (Beukers-Stewart *et al*., 2003), as part of a rotational harvesting regime in extensive aquaculture practices (Alban and Boncouer, 2008), and to conserve habitats or endangered species (Jones, 1999). The designation of such areas usually involves excluding some or all fishing and other potentially damaging activities. Regardless of whether protected areas are designated as fisheries MPAs or conservation MPAs they may achieve both functions simultaneously. Genetic diversity is often overlooked when selecting marine nature reserves but should be considered to allow greater resistance to environmental change (Bell and Okamura, 2005) as marine protected areas are likely to become a widely used means of safeguarding exploited shellfish stocks and sensitive habitats.

1.4 Isle of Man fisheries and science

The challenges facing wild capture fisheries are common across many geographic areas, including the Isle of Man. High fuel costs and low market demand for *A. opercularis* were problematic in 2008 and landings of *P. maximus* have fluctuated widely during the past 40 years. Competition for space in Manx territorial waters may increase during the next few years. A marine nature reserve will be implemented by 2012, offshore renewable energy consultations are underway, exploration for aggregates has been undertaken and land will be reclaimed to extended the runway at Ronaldsway airport. Therefore, improving our understanding of the marine environment, exploited fish and shellfish stocks, and the interaction between fishing and marine habitats is becoming increasingly important.

Research into the Isle of Man's fisheries has focused predominantly on *P. maximus* (e.g. Mason, 1957, 1958; Gruffydd 1972, 1974; Brand *et al*., 1980; Beukers-Stewart *et al*., 2003, 2005), and to a lesser extent *A. opercularis* (e.g. Brand *et al*., 1980; Allison and Brand, 1995; Jenkins *et al*., 2003; Vause *et al*., 2007; Philipp *et al.*, 2008). Specific aspects of the biology of *B. undatum* have also been examined (Kideys and Hartnoll, 1991; Kideys *et al*., 1993; Kideys, 1996). In this report, the results of research conducted in 2007 and 2008 are presented. Research into the king and queen scallop fisheries has been continued. In addition to basic data on stock status, the preliminary results of habitat surveys are presented along with oceanographic data. Data from the satellite vessel monitoring system (VMS) has also been processed to allow fishing activity to be mapped. The results of a study into the use of escape gaps are also presented. Management recommendations are made and future areas of research are discussed.

2. DISTRIBUTION OF FISHING ACTIVITY

2.1 Background and aims

It is of particular importance that scallop distributions can be related to fishing activity as stock assessment models require that the spatial limits of populations can be defined. In the case of scallops, the geographical bounds of populations and larval dispersion are unclear. Nevertheless, detailed knowledge of the spatial distribution of fishing effort and stocks can elucidate the impact of fishing on the target population. Data collected by the satellite vessel monitoring systems (VMS) has not been used previously to monitor fishing activity around the Isle of Man. Fishing effort has, however, been estimated from scientific logbooks. The aim of this work was to map fishing activity for king and queen scallops in relation to scallop stocks.

2.2 Methods

VMS data were downloaded for individual vessels. Data for all Manx licensed vessels were downloaded, while for UK vessels sighting reports were used to identify vessels fishing in Manx territorial waters. Logbook data were used to identify vessels targeting king scallops and queen scallops. To identify likely fishing activity, data were filtered by vessel speed based on speed-frequency distributions, with speeds from 1.2 – 3.2 knots classified as fishing. All vessels of >10 m in length fishing for scallops in the 0 – 3 nm zone are fitted with VMS transceivers, while in the 3 – 12 nm zone all vessel >15 m are fitted with VMS. The abundance estimates of king and queen scallops across Manx territorial waters were based on counts made from real-time underwater video images during the August/September surveys (see Chapter 5 for further details). All mapping and geospatial analysis was conducted using ArcGIS 9.2. Scallop density contour plots were generated using inverse distance weighting (IDW). Spatial density of VMS point data was calculated based on the number of points per 1km radius circle; plots were displayed using a 100 m cell size. Natural (Jenks) breaks classification was used to create contour intervals.

2.3 Results

Fishing activity for queen scallops within 12 nm of the IOM took place over an area of 705 km^2, 17.8% of the Isle of Man's territorial waters (Table 2.1). Only 139 km^2 were fished for *A. opercularis* within 3 miles of the IOM, 18.1% of the 3 mile zone. Fishing activity for queen scallops was concentrated on the Targets fishing ground in particular (Figure 2.1). Other concentrations of fishing activity for queen scallops occurred in Ramsey Bay, at Chickens, Point of Ayre, and East of Douglas. Fishing activity for king scallops occurred over 47.8% of the 12 mile zone. There were concentrations of king scallop fishing activity at Targets, Ramsey Bay, Chickens and East Douglas (Figures 2.2). There were also concentrations of king scallop fishing activity off Bradda Head. Fishing activity occurred at a lower intensity between these intensively fished areas; 139 km^2 were fished for *P. maximus* within the 3 mile zone, 84% of this zone. Nevertheless, over the entire territorial sea, large areas of seabed were not fished for *P. maximus*, in particular to the south and north of the island. Fishing activity for prawns (*Nephrops norvegicus*) was restricted to areas with mud sediments to the west of the island.

Table 2.1. Area (km^2) of territorial waters where fishing activity for king scallops, *Pecten maximus,* and queen scallops, *Aequipecten opercularis*, was observed during 2007/2008. Percentage of each zone fished is shown in italics.

Zone (nm)	King	Queen	King only	Queen only	King+ Queen
3	648.9	139.5	531.5	22.1	117.4
	84.3	*18.1*	*69.0*	*2.9*	*15.2*
12	1895.0	705.3	1335.2	145.5	559.8
	47.8	*17.8*	*33.7*	*3.7*	*14.1*

Fishing did not occur in all the locations inhabited by king or queen scallops. Fishing for queen scallops was restricted to Targets, Chickens, south of Port St. Mary, Point of Ayre, Ramsey Bay, Maughold and East of Douglas (Figure 2.1). None of these areas harboured high densities of queen scallops relative to the maximum of >500 ind. $100m^{-2}$; however, at Chickens and East Douglas densities were >200 ind. $100m^{-2}$. Fishing for king scallops occurred over most of the areas were *P. maximus* was present (Figure 2.2). Only at the southern limit of the 12nm zone did *P. maximus* remain unexploited; densities were highest in this area, at 22 ind. $100m^{-2}$. Fishing activity was most intensive at Targets, Ramsey Bay, Bradda Inshore, Chickens, outside Laxey Bay, and immediately south of Port St. Mary.

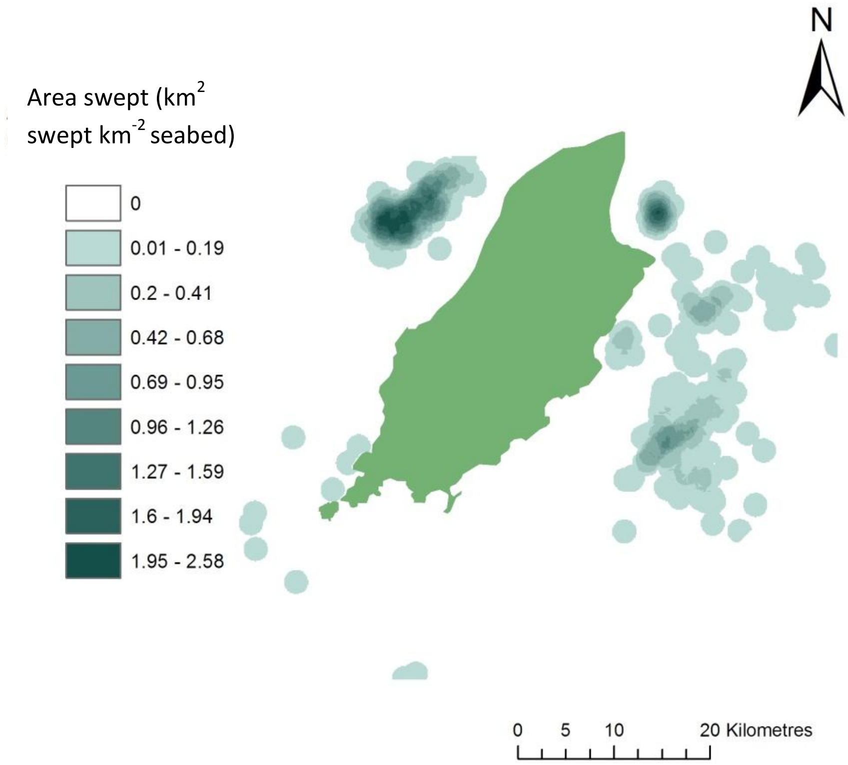


Figure 2.1. Estimated area of seabed swept by Manx vessels targeting *Aequipecten opercularis* from November 2007 to May 2008.

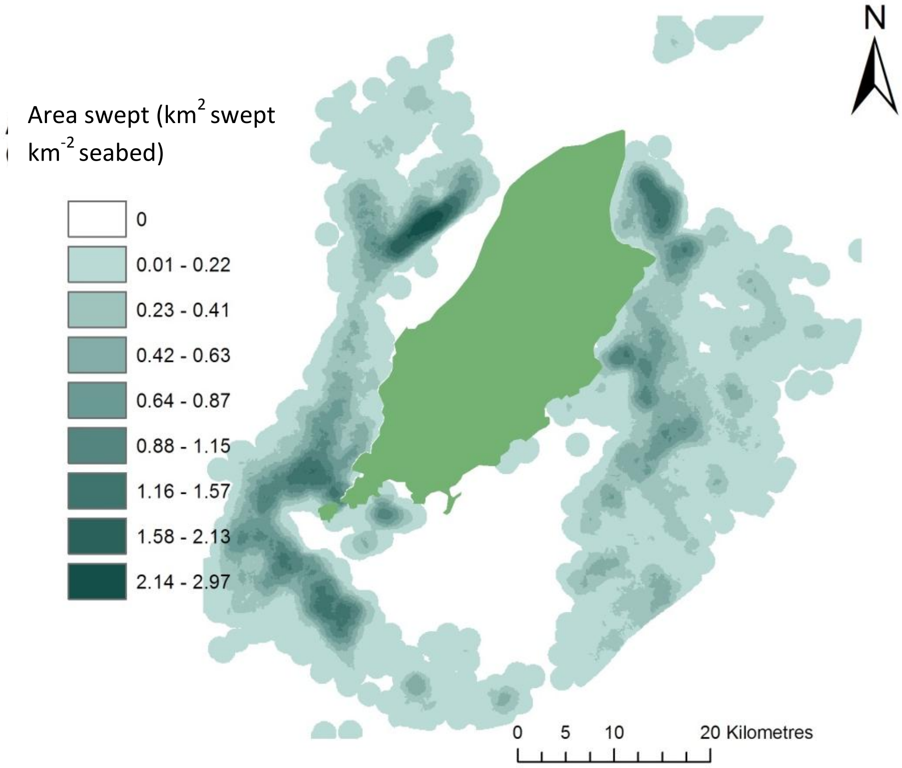


Figure 2.2. Estimated area of seabed swept by Manx vessels targeting *Pecten maximus* from November 2007 to May 2008.

2.4 Discussion

The satellite VMS provides a valuable tool with which to monitor fishing activity. Prior to the results presented in this report no use has been made of VMS data in the Isle of Man beyond use for day-to-day fisheries enforcement. Monitoring the spatial extent of fishing activity is essential in order not only to allow for successful fisheries management but for spatial management of all uses of Manx territorial waters. There are potential difficulties in using VMS data for scientific purposes as it does not include records of gear type, and fishing activity must be identified from vessel speed (Dinmore *et al*., 2003). These issues are less problematic in the Isle of Man due to the comparatively small area under study, the limited size of the fishing fleet, and only three species are targeted with mobile fishing gear. Both queen scallops and king scallops are fished at 2 – 3 knots and fishing activity is thus clearly distinct from steaming activity. Moreover, VMS data has been used in conjunction with benthic production models to assess the impact of trawling on benthic communities in the North Sea (Hiddink *et al*., 2006), and to predict the impacts of fishing activity on habitats with different sensitivities (Hiddink *et al*., 2007).

Under current legislation all vessels fishing for scallops within the 3 nm zone are fitted with VMS transceivers; however, in the 3 – 12 nautical mile zone only vessels >15 m are fitted with VMS. Consequently, the level of fishing activity in the 3 – 12 nautical mile zone will be underestimated. Vessels <15 m in length are known to fish in the 3 – 12 nautical mile zone and further data will need to be obtained on this sector of the fishing fleet if possible.

VMS data from vessels fishing *Aequipecten opercularis* indicates that fishing activity from November 2007 to November 2008 was restricted to small areas of the territorial sea. Visual habitat surveys (see Chapter 5) showed that *A. opercularis* was present over much of the territorial sea. The impact of fishing for queen scallops on by-catch species, seabed habitats and the scallop stocks will be limited by the spatial extent of fishing activity. Even without any regulations in place to restrict fishing for queen scallops, the impacts of this fishery, over the past year at least, are spatial limited by market demand. Queen scallop landings during this period were relatively low, at c. 1000 tonnes. Fishing is likely to occur over a greater area should stocks decline or landings increase. The impacts of the fishery will necessarily be increased under either scenario. During the 2007/2008 fishing season, fishing activity for queen scallops at Targets, Ramsey and Chickens was conducted solely by otter trawlers. Queen scallop dredgers, using toothless dredges, were the predominant type of fishing vessel to the east of the island.

The Douglas Bay closed area covers an area of 4.1 km^2, while the Port Erin closed area covers 3.5 km^2. The two closed areas together represent only 0.2% of the Isle of Man's territorial waters and 1% of the 3 nautical mile zone. By comparison, in the past year 83% of the 3 mile zone, and 48% of the 12 mile zone, was dredged for scallops. Fishing activity for queen scallops was much more concentrated, focusing on Targets and East Douglas, with 18% of both the 3 and 12 mile zones fished for queen scallops. In this study, fishing was identified as having occurred where at least one vessel was fishing within a 1 km radius of any given point during the year; it has been assumed that anywhere in that radius can be considered as fishing ground. In the areas identified as being fished, some areas of seabed will have been swept by fishing gear many times while only a small proportion of the seabed will have been swept in other areas. Even once the width of fishing gear and tow length have been considered it is only possible to estimate the area of seabed fished as many areas will be swept repeatedly, particular in heavily fished areas such as Targets.

The abundance of queen scallops was generally much higher than the abundance of king scallops. As with king scallops, densities were greatest south of Port St. Mary on the edge of the 12 mile zone, at >500 ind.$100m^{-2}$. No fishing activity for king scallops occurred in this area and fishing activity for queen scallops was low. The majority of fishing activity for both king and queen scallops occurred on Targets and this fishing ground will thus be especially vulnerable to a rapid decline in stocks following any poor recruitment to the fishery. The current high densities of king scallops at Targets attract high fishing effort. However, queen scallops are more abundant elsewhere and Targets may simply offer a convenient fishing area.

It has not been possible to obtain VMS data from before June 2007 at this stage. VMS data collected from November 2007 to November 2008 may not be representative of longer-term fishing activity. Fishing activity for queen scallops was affected by lack of market demand, the low value of the catch, and high fuel prices. In 2007, catches were double those found during the study period and the extent of fishing activity may also have been greater. The next stage of this work will be to randomly sub-sample VMS data to cross-reference fishing activity with fishing logbook data. This will allow the area of seabed swept to be calculated and the distribution of gear types to be estimated. This is particularly important for the queen scallop fishery as the environmental impacts of dredges and otter trawls are very different.

2.5 Conclusions

Scallop dredging occurred over most of the areas in which scallops were found. Only on the limit of the 12 nm zone, south of Port St. Mary, did scallops remain unexploited and this area supported the highest density of scallops outside the closed areas. The majority of the queen scallop stock was not fished but market demand for queen scallops during the study period was low. Obtaining archived VMS data is a priority although this is likely to involve additional cost.

3 STATUS OF THE FISHING EXCLUSION ZONES

3.1 Background and Aims

Towed video surveys were conducted using the fisheries patrol vessel 'Barrule' to investigate the status of stocks within the fishing exclusion zones at Port Erin and Douglas. Port Erin has been a scallop no take zone since 1989, and Douglas Bay was designated as a scallop no take zone in 2008. Laxey Bay was surveyed as, along with Douglas Bay, it was proposed as a closed area in 2008. Scallop densities were estimated in Douglas Bay to provide a baseline against which to monitor the effectiveness of the no take zone designation at increasing scallop densities.

3.2 Methods

During February and March 2008 visual surveys were undertaken in Douglas Bay, Laxey Bay and the Port Erin closed area. A sledge was fitted with a video camera with live-feed to the surface vessel. Video footage was recorded to DVD. A Canon EOS 400D camera also took a 10 mega-pixel digital photograph every 9 seconds along each transect of c.300 m. Each still image covered a seabed area of 0.302 m^2. Sixty images were extracted at random from each series of images. The number of *Pecten maximus* and *Aequipecten opercularis* were counted in each image to ascertain abundance in Port Erin closed area, Douglas Bay and Laxey Bay. All mapping and geospatial analysis was conducted using ArcGIS 9.2. Scallop density contour plots were generated using inverse distance weighting (IDW).

3.3 Results

There were <2 queen scallops 100m^{-2} throughout most of Douglas Bay; however, up to 22 individuals 100m^{-2} were found along the 20 m depth contour. King scallops were absent from the middle of Douglas Bay but up to 38 ind. 100m^{-2} were found towards the southern end of the bay, largely on rocky areas which cannot be dredged. Scallops were also found at densities of 10 ind. 100m^{-2} along the northern boundary of Douglas Bay. Both king and queen scallops were restricted to the outer edges of Laxey Bay at ≥15 m depth. King scallops were observed at densities of up to 1.5 ind. 100m^{-2} in Laxey Bay, while queen scallops were present at densities of only 0.2 ind. 100m^{-2}. In the closed area at Port Erin, queen scallops were found in increasing numbers with increasing depth, while king scallops were found in increasing numbers with decreasing depth. King scallop densities were lowest in the north-eastern end of the Port Erin closed area, at <8 ind. $100m^{-2}$, but the mean density was high, and over 100 ind. $100m^{-2}$ were found in the south-eastern end of the closed area.

3.4 Discussion and conclusions

The abundance of scallops in the Port Erin closed area was around five times greater than the maximum observed anywhere else around the island. Densities reached 22 ind. $100m^{-2}$ south of Port St. Mary. The abundance of scallops in Douglas Bay also was also relatively high, reaching a maximum of 38 ind. $100m^{-2}$. The closed area at Port Erin appears to have successfully protected high numbers of scallops in the near-shore area. However, the densities of scallops found around the edges of the area are no higher than at Chickens, East Douglas, South of Port St. Mary and Targets. The densities of scallops found in Douglas Bay were higher than were found at most other areas around the island. The highest densities of scallops in Douglas Bay were found on rocky areas that cannot be dredged. The addition of 25,000 scallops of 2.5 years in age to Douglas Bay in April 2008 will have increased densities by 0.625 scallops $100m^{-2}$. This value will have decreased due to natural mortality, which following seeding of the closed area at Port Erin was found to be high (Brand *et al*., 2005).

4. STOCK STATUS OF KING AND QUEEN SCALLOPS

4.1 Background and Aims

Allison (1993) undertook comprehensive studies of *P. maximus* and *A. opercularis* around the Isle of Man from 1987 to 1989. Murphy (1998) also conducted a detailed investigation into the population dynamics of *P. maximus*. Since then, king and queen scallop stocks around the Isle of Man have been monitored biannually, during surveys in June and October. Additional monitoring of scallop populations in the Port Erin closed area has also been undertaken. Beukers-Stewart *et al*. (2003) found that total mortality of *P. maximus* was almost 3.5 times greater outside the Port Erin closed area than within it. The aim of this work was to update scallop survey size and abundance data and to collate scallop landings data from fishing logbooks. Detailed results are presented for the most recent scallop surveys.

4.2 Methods

Scallop surveys 2008

Survey sites visited historically around the Isle of Man (Figure 4.1) are as follows (abbreviations in brackets): Bradda Offshore (BRO), Bradda Inshore (BRI), Peel (PEL), Targets (TAR), Point of Ayre (POA), Ramsey (RAM), Maughold (MAG), Laxey (LAX), East Douglas (EDG), South East Douglas (SED), 15 Miles South of Port St. Mary (PSM) Chickens (CHI) and Outside Closed Area (OCA). These sites are located in some of the areas commonly fished by Manx and UK fishers. Although it is common to refer to traditional fishing 'grounds' many of these grounds are adjoining, particularly for *A. opercularis*. The distribution of fishing activity is at least partly influenced by proximity to the fishing ports of Douglas, Port St. Mary, Peel and Ramsey. However, both *P. maximus* and *A. opercularis* are fished out to the 12 nautical mile limit of the Manx territorial sea and beyond.

Scallop surveys were undertaken in June and October 2008. The surveys followed the protocol adopted in previous surveys (see Brand and Beukers-Stewart, 2001; 2005; Beukers-Stewart *et al*., 2003). In June, a gang of four scallop dredges was towed from one beam and a gang of four queen scallop dredges from the other beam of FV Cair Vie on the eastern side of the island and of FV Genesis on the western side. Scallop dredges were fitted with nine teeth of 110 mm in length, while queen dredges were fitted with ten teeth of 60 mm in length. RV Prince Madog is being considered as a possible platform for future survey work. Therefore, in October a ship comparison was undertaken between a commercial fishing vessel (FV Genesis) and RV Prince Madog (see Chapter 8 for further details). Consequently, two scallop and two queen dredges fitted alternately on a single tow bar were towed from RV Prince Madog, and an identical set of gear was towed from the fishing vessel.

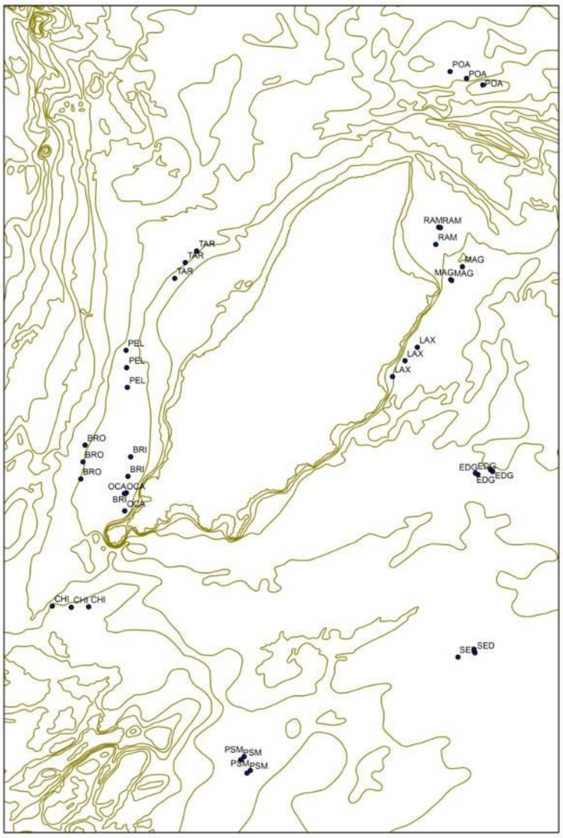


Figure 4.1 Positions of dredge survey sites around the Isle of Man.

Time-series data

The relative abundance of *A. opercularis* from 1992 to 1998 was estimated based on numbers recorded at four sites which were: LAX, EDG, PSM and TAR. Continuous biannual monitoring of scallop abundance at all of these, or other, sites would be necessary to provide the most reliable index of abundance over time. However, none of these or other sites has been monitored annually over the entire period from 1992 to 2008, with some sampling periods represented by only one site, or with no data. Consequently, the relative abundance time-series data includes both spatial and temporal variation. Therefore, trends in relative abundance data were estimated based on a two-year moving average to ensure that each sampling period is represented by more than a single site. The effect of this process is to spread spatial variability across a greater period of time, in effect smoothing the data. Landings data from 2004 to 2008 were extracted from fishing logbooks. Data on landings from 1969 to 2003 were obtained from records kept by DAFF.

Catch and effort data from scallop dredgers and trawlers has been collected from a sample fleet from 1982 to 2004 (see Brand *et al*., 2005). From 2005 onwards catch and effort data for the entire Manx fleet is available. Relative abundance was estimated from the logarithmic relationship between survey CPUE (relative abundance) and fishing CPUE from 1992 to 2004 when data series overlapped:

$$C_i = y_0 + a \cdot \ln(A)$$

Thus,

$$A = e^{\left(\frac{C_i - y_0}{a}\right)}$$

Where, C_i = CPUE (dredge or trawl), y_0 = intercept, a = constant, and A = relative abundance. Fisheries dredge CPUE was therefore raised to give relative density estimates from 1982 onwards.

4.3 Results

Scallop surveys 2008

The relative density of scallops in October 2008 was greatest at Targets and to a lesser extent at the Bradda Inshore and Offshore (Figure 4.2a). The number of scallops recruited to the fishery was also greatest at Targets but as most scallops were <110 mm in length the relative density of recruits was only slightly greater than at other sites (Figure 4.2b). The relative density of queen scallops was greatest at East Douglas (11 ind. $100m^{-2}$) and the number of queen scallops ≥55 mm was also greatest at this site (Figure 4.3a). Relative abundance of all queen scallops and those ≥55 mm was lowest at Bradda Inshore and Offshore (1 ind. $100m^{-2}$) (Figure 4.3b). The relative abundance of queen scallops ranged from 1 scallop $100m^{-2}$ at Bradda Inshore and Offshore to 13 scallops $100m^{-2}$ at East Douglas (Figure 4.4). The percentage of queen scallops ≥55 mm ranged from 33%, at Ramsey, to 95%, at Bradda Inshore. King scallop dredges caught between 7 and 41% of the amount of queen scallops caught by queen scallop dredges. The relative abundance of scallops at Targets was an order of magnitude higher than at other sites.

Queen scallops as small as 25 mm were found at Targets, Bradda Inshore, Point of Ayre and Bradda Offshore (Figure 4.6). Individuals as small as 15 mm were present at Maughold. Only scallops of ≥45 mm were found at Laxey. The largest queen scallops found were 85 mm in height and were present at all sites except Ramsey. At Targets, 94% of scallops were ≥55 mm in height, while at Bradda Offshore only 39% of scallops were ≥55 mm in height. At least two year classes of king scallops were found at all sites except Targets, within queen dredges (Figure 4.7). A relatively large year class of 60 – 75 mm scallops was found at Point of Ayre. The largest scallops (165 mm) were also found at Point of Ayre. At East Douglas, Ramsey, Maughold and Point of Ayre >75 % of *P. maximus* catches in queen scallop dredges were ≥110 mm in length. At Targets only 20% of scallops were ≥110 mm in length. Catches with king dredges at Ramsey and Point of Ayre did not include the younger year classes found with queen dredges (Figure 4.8). At Point of Ayre, 84% of king scallops caught in king scallop dredges were ≥110 mm in length, while at Targets only 16 % were ≥110 mm.

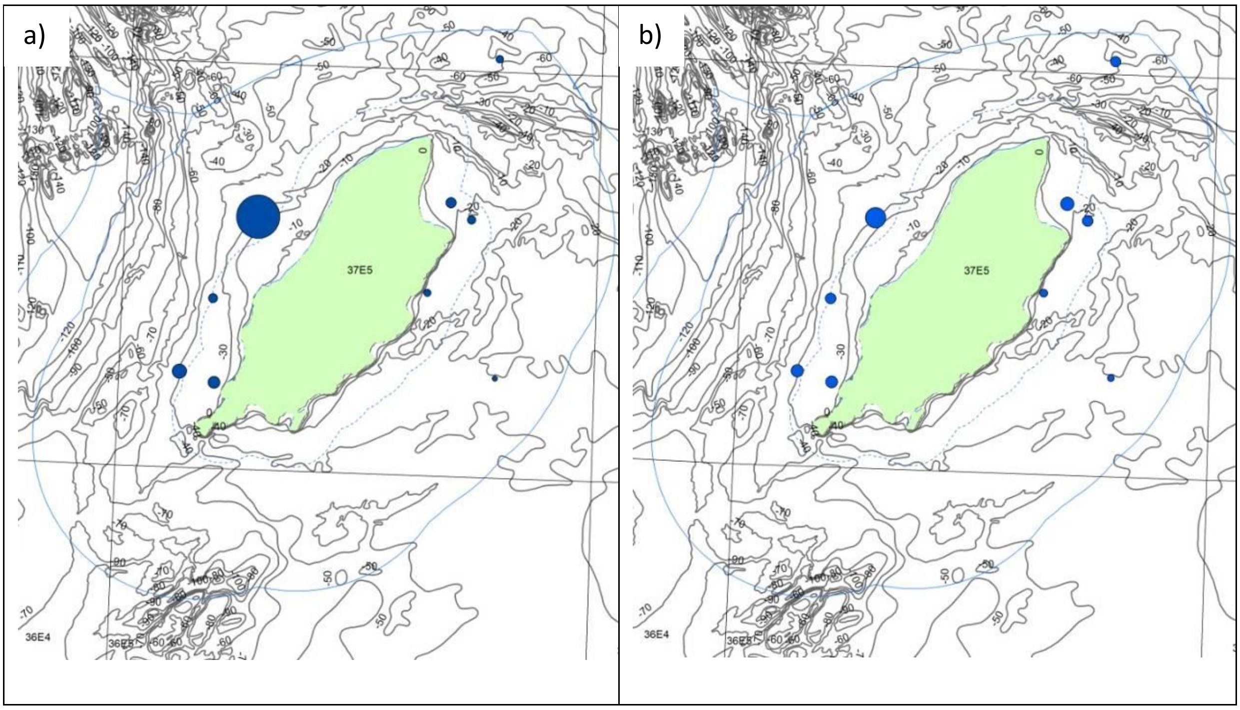


Figure 4.2 Relative total density (a) and relative number of *Pecten maximus* ≥110 mm (b) recorded from surveys conducted during October 2008 using queen scallop dredges. NB. Size of circles represents the proportion of the total across all sites surveyed.

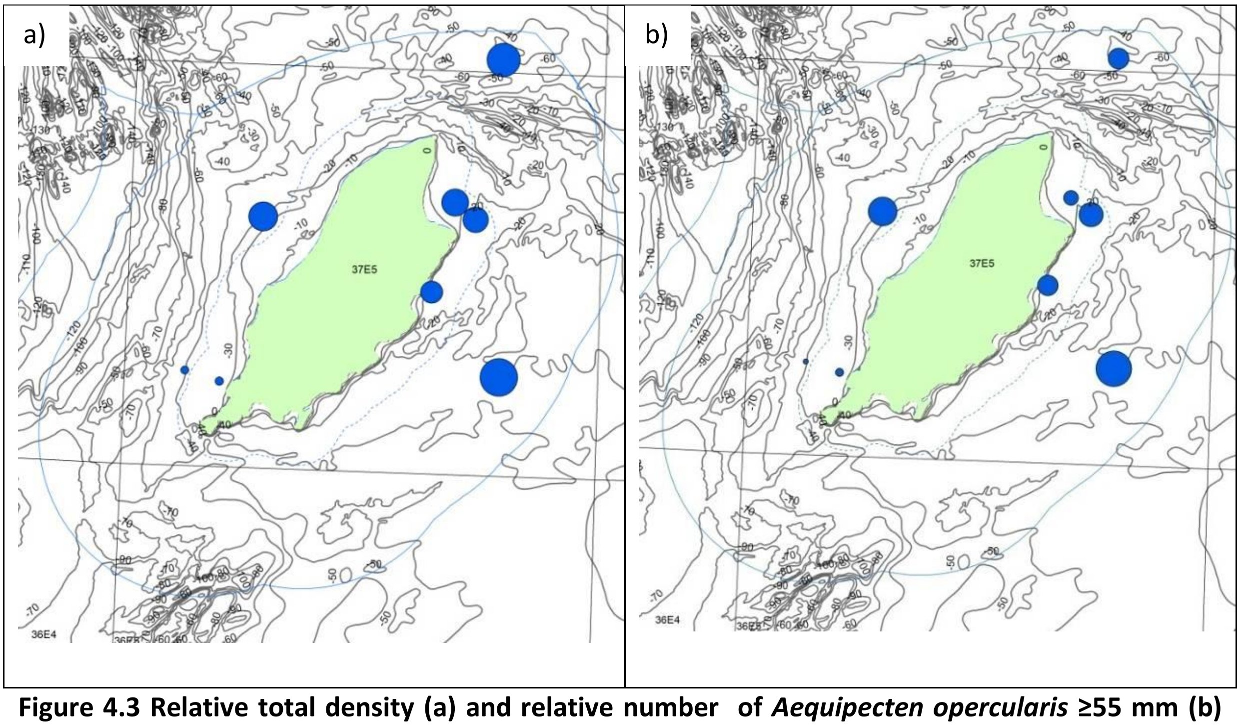
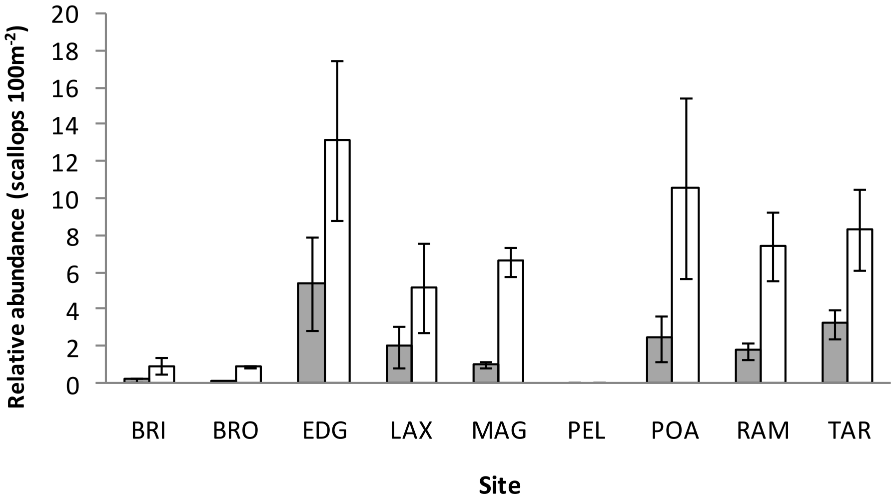


Figure 4.3 Relative total density (a) and relative number of *Aequipecten opercularis* ≥55 mm (b) recorded from surveys conducted during October 2008 using queen scallop dredges. NB. Size of circles represents the proportion of the total across all sites surveyed.



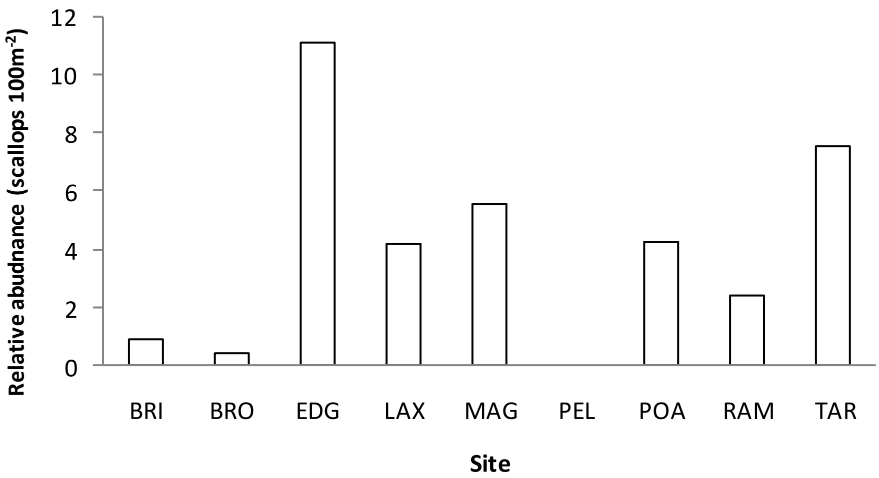


Figure 4.4 Relative total abundance (top) and abundance of *Aequipecten opercularis* ≥55 mm (bottom) at sites around the Isle of Man during October 2008. Shaded bars: catch in king scallop dredges; open bars: catch in queen scallop dredges.

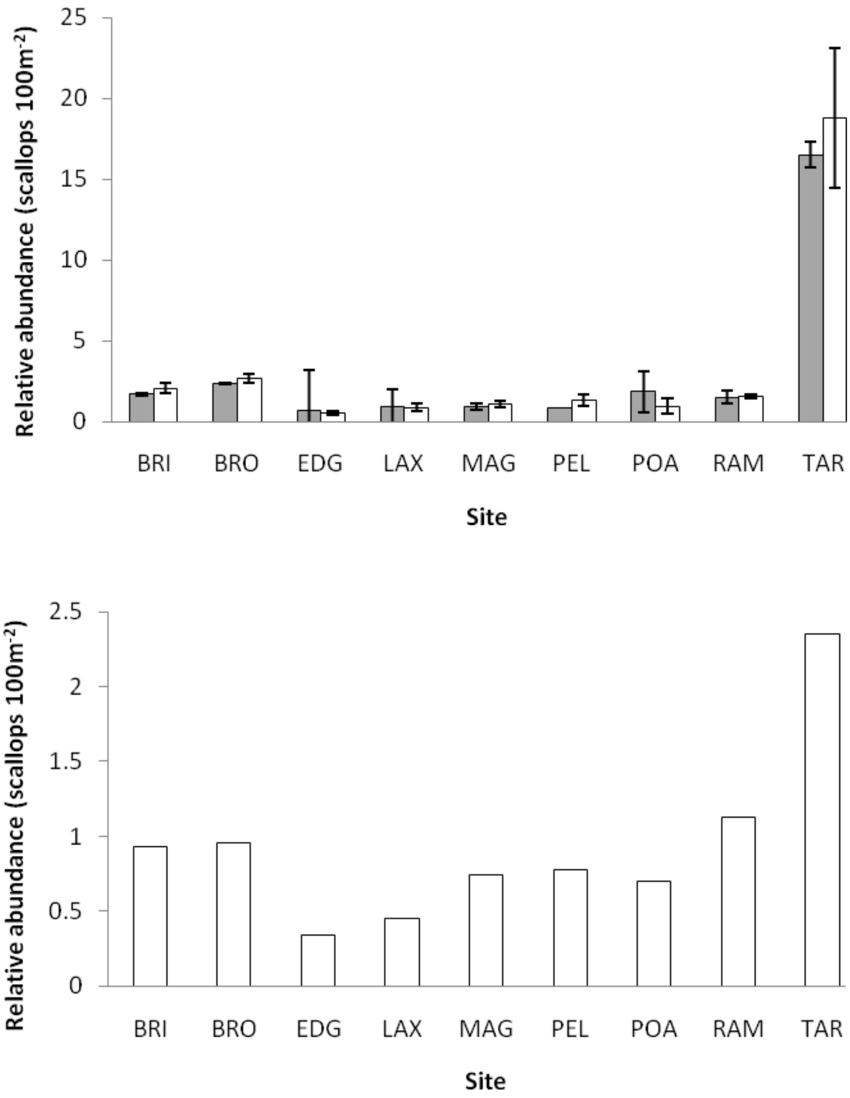


Figure 4.5 Relative total abundance (top) and abundance of *Pecten maximus* ≥110 mm (bottom) at sites around the Isle of Man during October 2008. Shaded bars: catch in king scallop dredges; open bars: catch in queen scallop dredges.

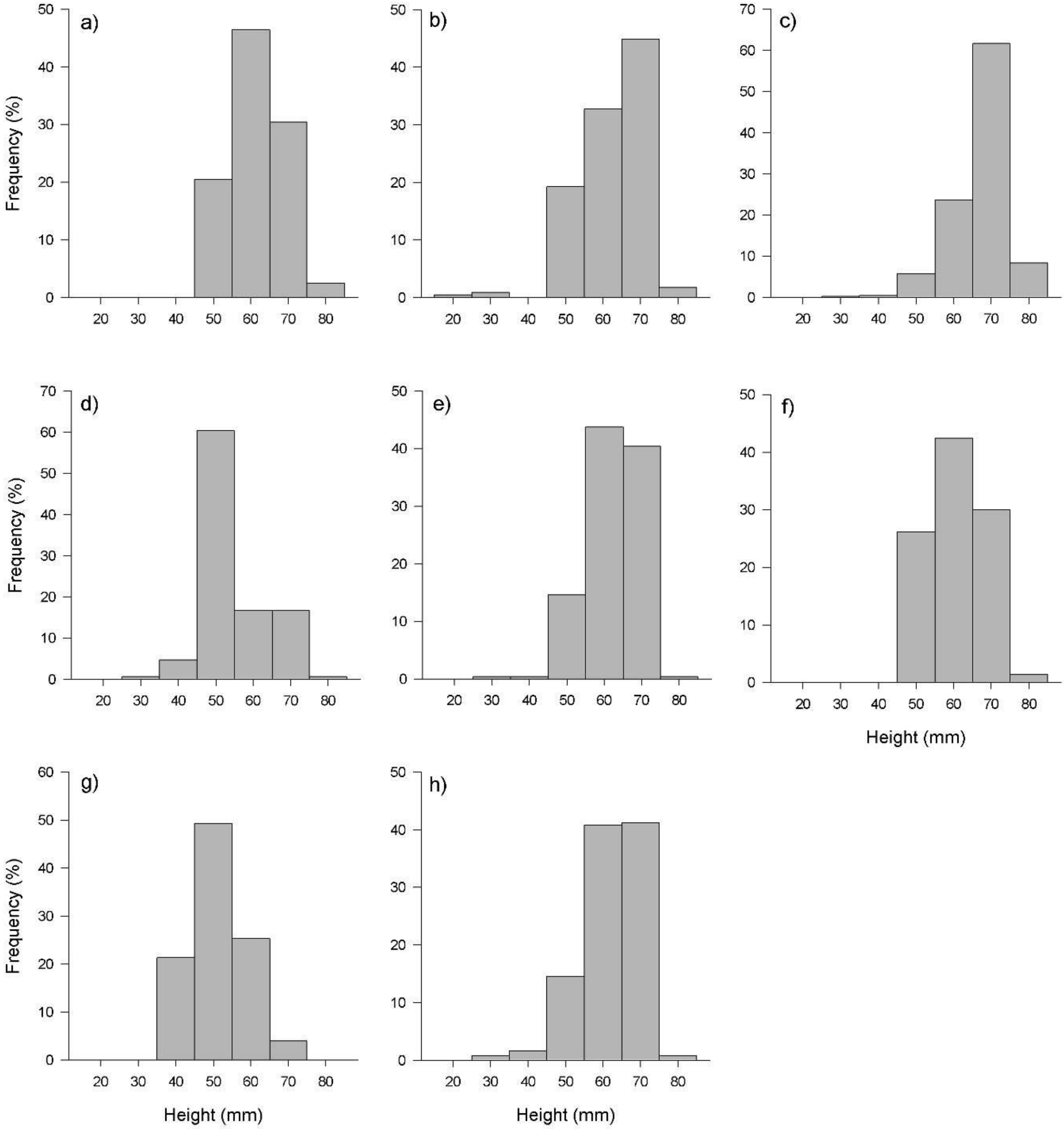


Figure 4.6 Height of *Aequipecten opercularis* collected with queen scallop dredges from sites around the Isle of Man. a) Laxey, b) Maughold, c) Targets, d) Bradda Inshore, e) Point of Ayre, f) Ramsey, g) East Douglas, and h) Bradda Offshore.

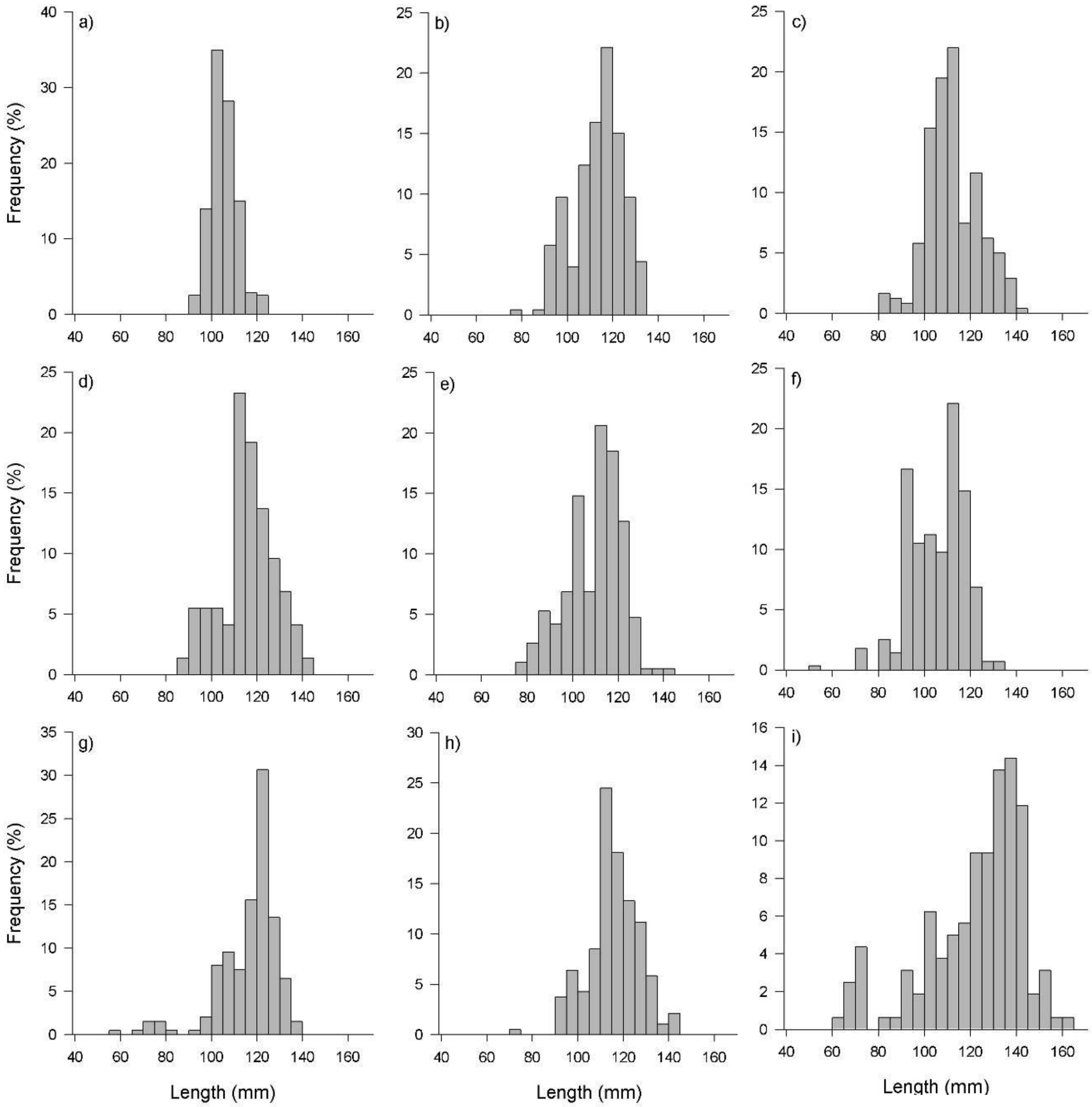


Figure 4.7 Length of scallops *Pecten maximus* collected with queen scallop dredges from sites around the Isle of Man. a) Targets, b) Peel, c) Bradda Inshore, d) East Douglas, e) Laxey, f) Bradda Offshore, g) Ramsey, h) Maughold, and i) Point of Ayre.

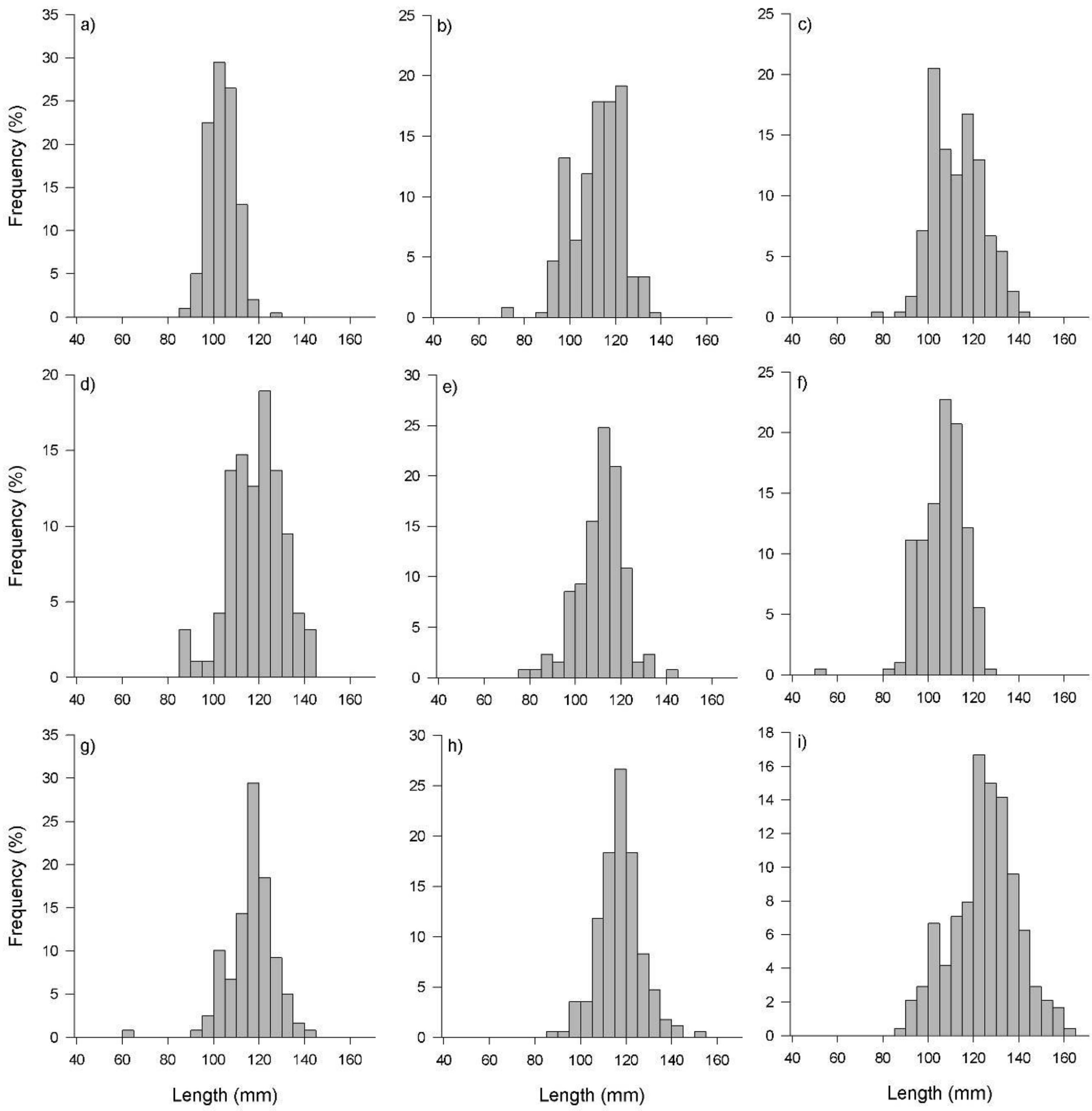
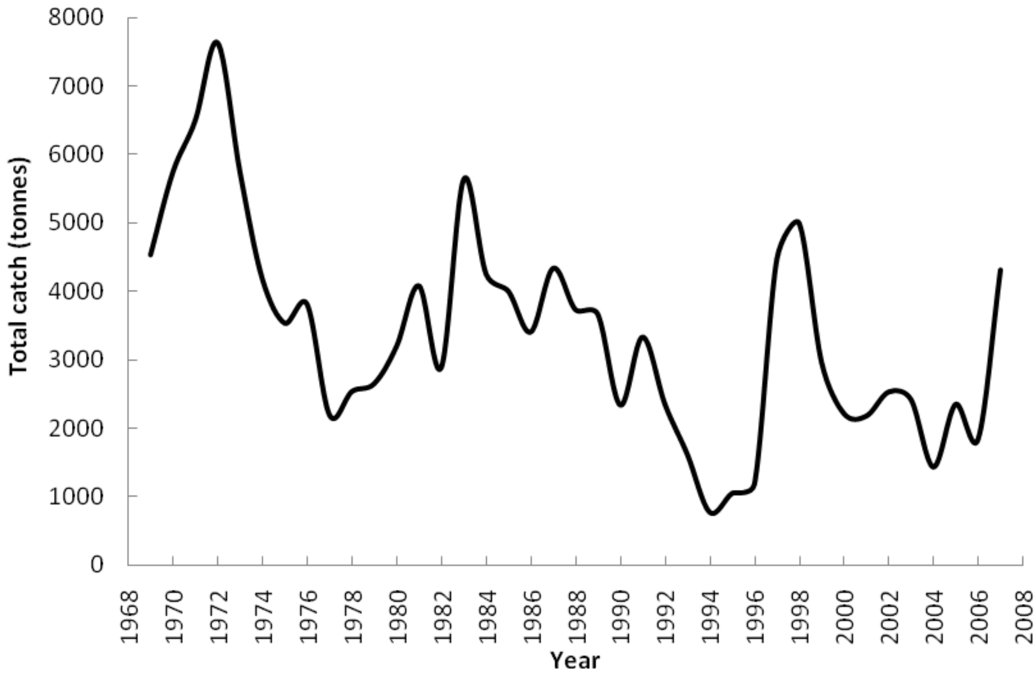


Figure 4.8 Length of *Pecten maximus* collected with king scallop dredges from sites around the Isle of Man. a) Targets, b) Peel, c) Bradda Inshore, d) East Douglas, e) Laxey, f) Bradda Offshore, g) Ramsey, h) Maughold, and i) Point of Ayre.

Scallop landings

Landing of queen scallops in the Isle of Man fell from a maximum of 7,600 tonnes in 1972 to 770 tonnes in 2008 (Figure 4.9). Landings have remained between c. 1000-2000 tonnes for the past 14 years. Landings into Scotland from ICES squares 37E5 and 36E5 peaked in 1997. From 2000 to 2008 landings into Scotland and the Isle of Man have remained similar. Landings of king scallops into the Isle of Man in 2007 were 1,200 tonnes (Figure 4.10). Landings into Scotland from ICES squares 37E5 and 36E5 have increased steadily from 1992, currently standing at 590 tonnes. Scallop landings into the Isle of Man from 37E5 and 36E5 have fluctuated from a low in 1972 of 470 tonnes up to 2,400 tonnes in 1985 before declining to 570 tonnes in 1994. From 1994, landings increased to 2,100 tonnes in 1999 and have since declined to 1,800 tonnes. Most of these fluctuations are due to changes in landings in to the Isle of Man. King scallop landings into Scotland increased steadily from 1992 to 2007. Queen scallop landings have shown even greater fluctuations, both through landings into Scotland and the Isle of Man although there is general trend of declining landings. There was an unusually high peak in landings into Scotland in 1998.



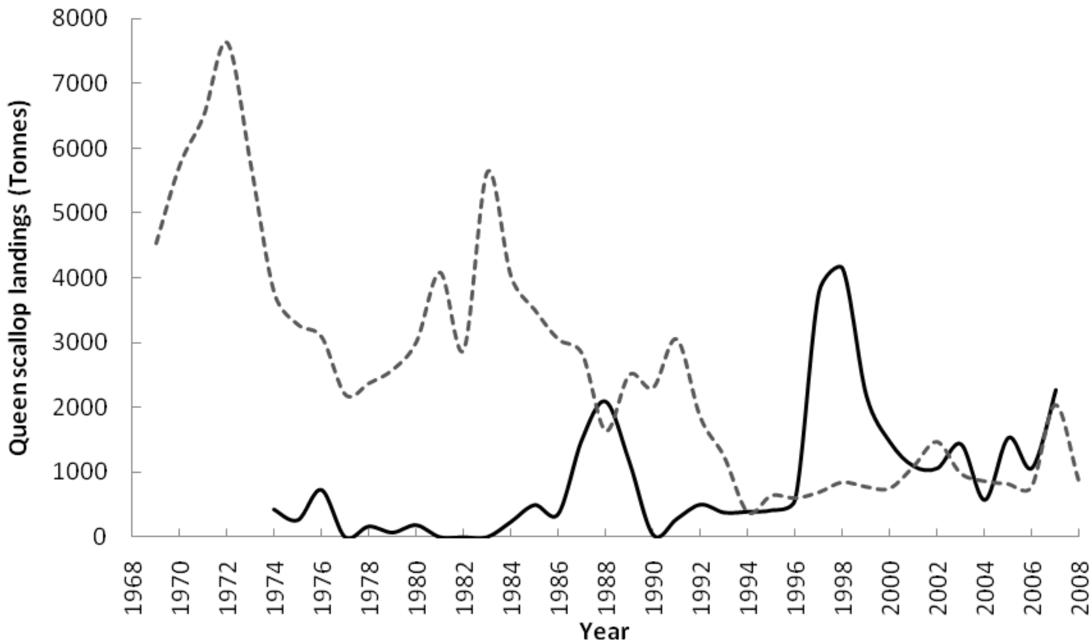


Figure 4.9 Total annual landings of queen scallops (*Aequipecten opercularis*) into Scotland and the Isle of Man (top), and landings into Scotland (solid line) and Isle of Man (dashed line) independently (b). Landings are those fished by vessels of any nationality and caught in ICES statistical rectangles 37 E5 and 36 E5.

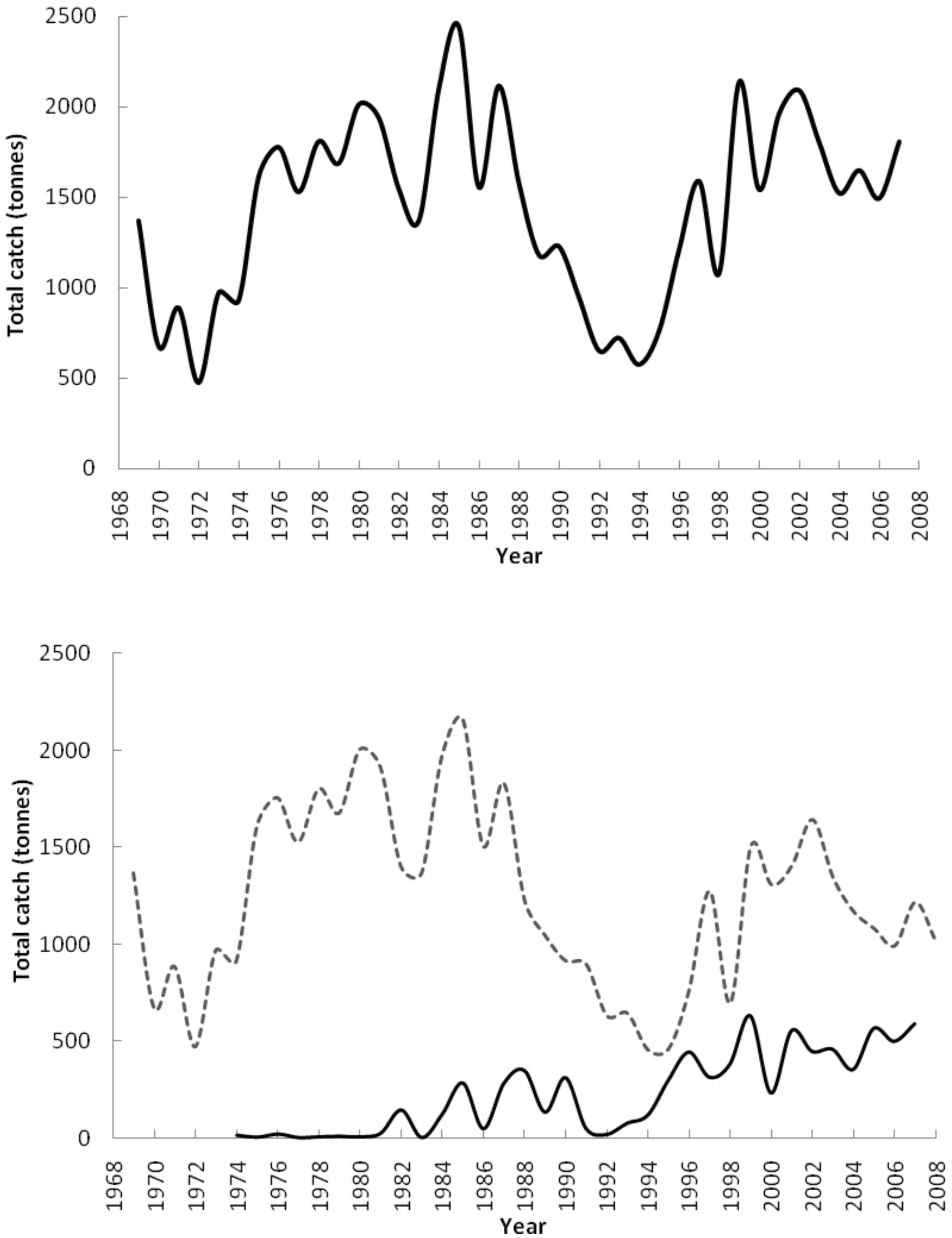


Figure 4.10 Total annual landings of king scallops (*Pecten maximus*) into Scotland and the Isle of Man (top), and landings into Scotland (solid line) and Isle of Man (dashed line) independently (b). Landings are those fished by vessels of any nationality and caught in ICES statistical rectangles 37 E5 and 36 E5.

Scallop survey time-series data

Pecten maximus

Most of the increase in relative scallop abundance since 2004 (Figure 4.11) was due to the large increase in numbers at Targets (Figure 4.12). The mean relative abundance of scallops at Targets increased from <2 ind. $100m^{-2}$ to 27.2 ind. $100m^{-2}$ in 2007. Densities then fell to 18.8 ind. $100m^{-2}$. When Targets was excluded from the average for all sites, scallop abundance was 1.5 ind. $100m^{-2}$in October 2008 (Figure 4.13), compared to 4.4 ind. $100m^{-2}$ when Targets is included. Relative abundance, excluding Targets, in October 2008 was of a similar level to that found since 2004 and in the latter half of the 1990s. Recruitment to the *P. maximus* fishery was greatest during the October surveys (Figure 4.14). Recruitment has shown a general increase although from 2004 onwards this increase is due entirely to the large recruitment at Targets. Mean recruitment in October 2008 was over seven times that observed in October 1993. Fishing effort was consistently greater for vessels landing scallops into the Isle of Man than into Scotland (Figure 4.15). Effort of vessels landing into the Isle of Man was greatest in 2002 and lowest in 1994, coinciding with the maximum and minimum landings during the period (Figure 4.10). Fishing effort of vessels landing into Scotland increased from almost zero in 1992 to 0.3 [effort index] in 1996; from 2001 to 2006 effort remained level (Figure). There was a strong positive correlation between the relative abundance of undersized scallops (<110 mm in length) and landings within the same year ($y = 797.1x^{0.822}$, $R^2 = 0.644$; Figure 4.16). Landings closely followed relative abundance (Figure 4.17).

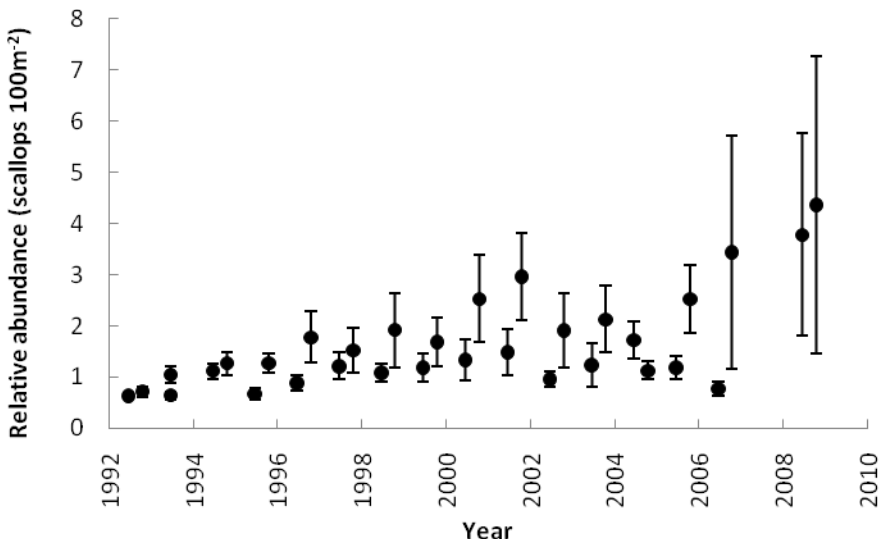


Figure 4.11 Mean relative abundance ±1 S.E of *Pecten maximus* across all sites surveyed.

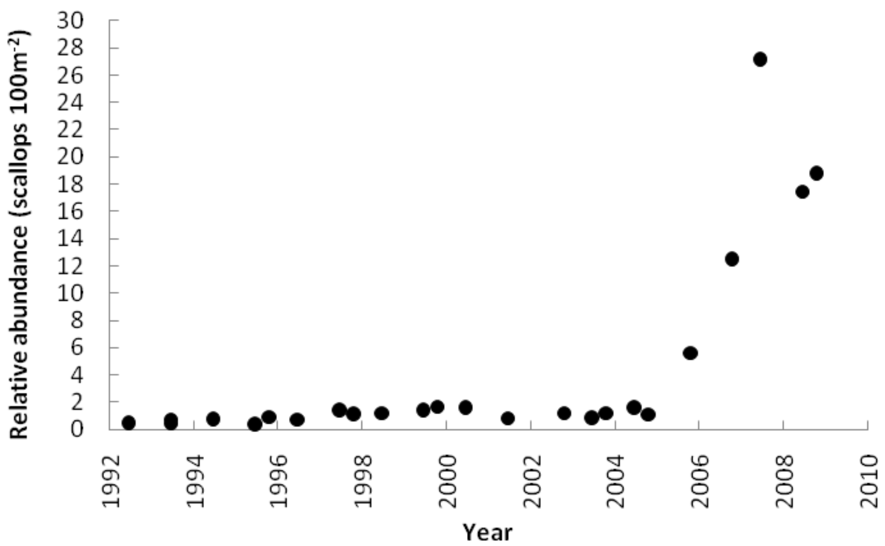


Figure 4.12 Relative abundance of *Pecten maximus* at Targets.

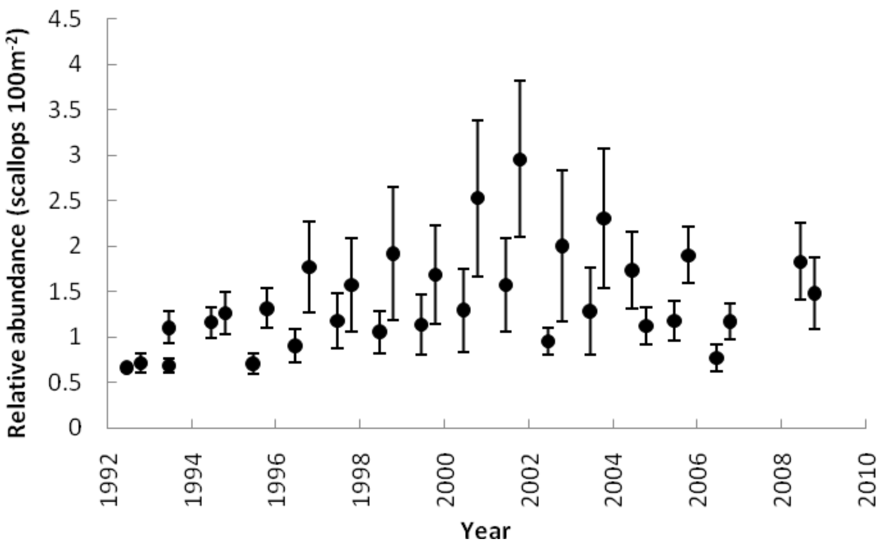


Figure 4.13 Mean relative abundance of *Pecten maximus* across all surveyed sites excluding Targets.

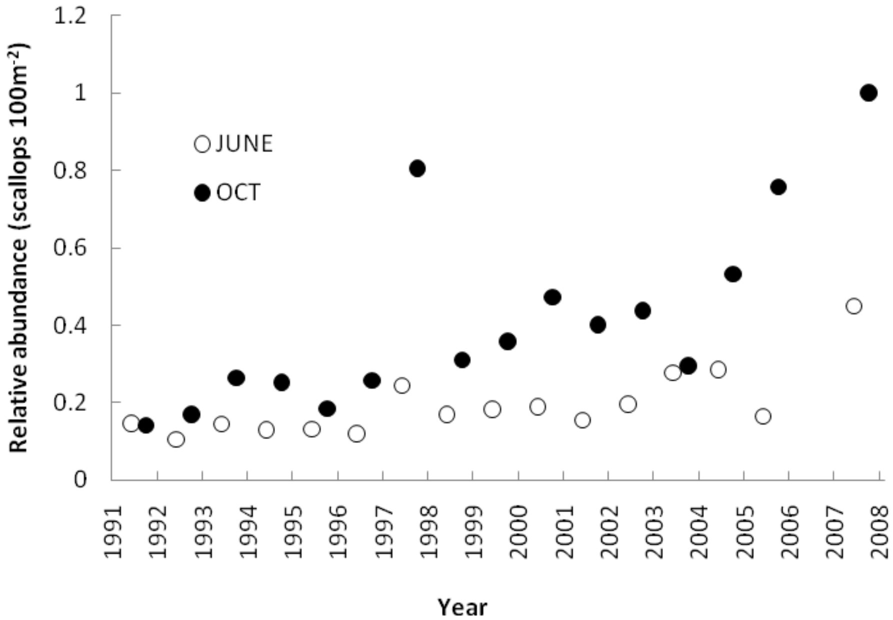


Figure 4.14 Mean estimated recruitment (no. of scallops 110 – 120 mm) of *Pecten maximus* to the scallop fishery in the Isle of Man.

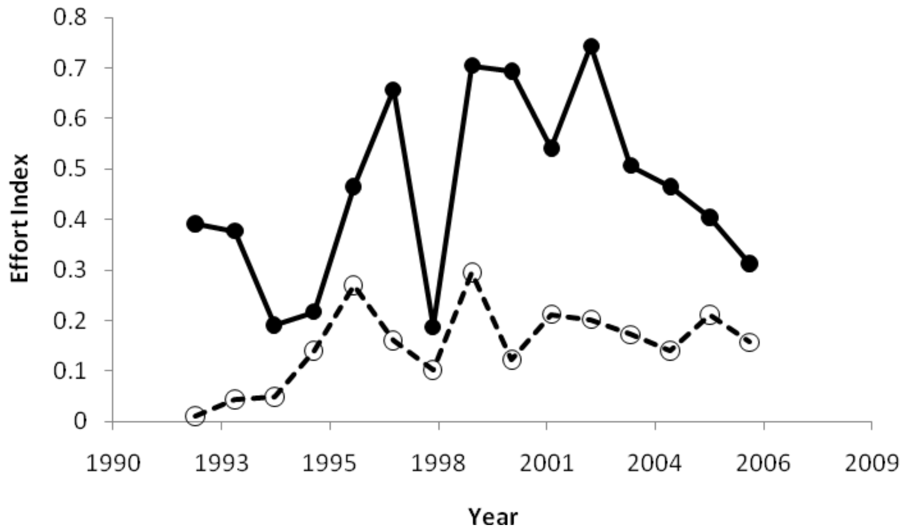


Figure 4.15 Relative fishing effort for *Pecten maximus* from vessels landing into the Isle of Man (solid circle) and Scotland (open circle).

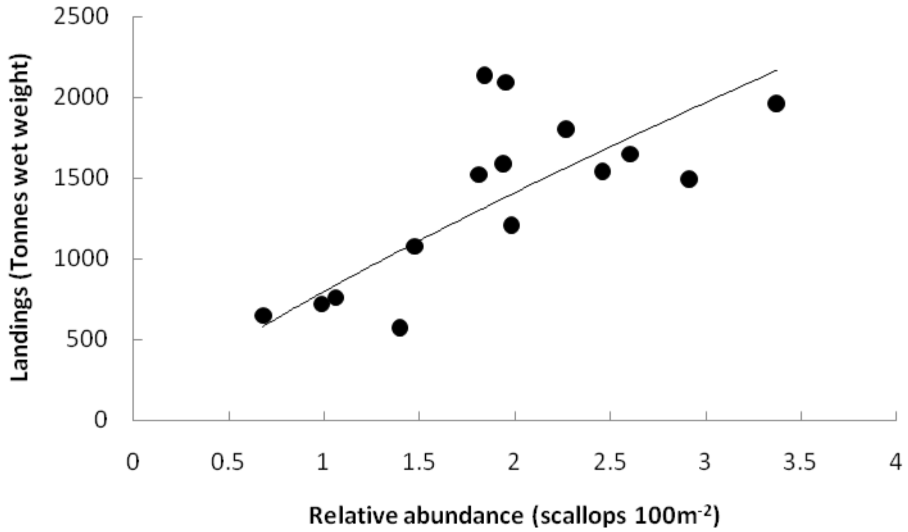


Figure 4.16 Relationship between the relative abundance of undersized king scallops (<110 mm in length) caught in queen scallop dredges and landings into the Isle of Man and Scotland.

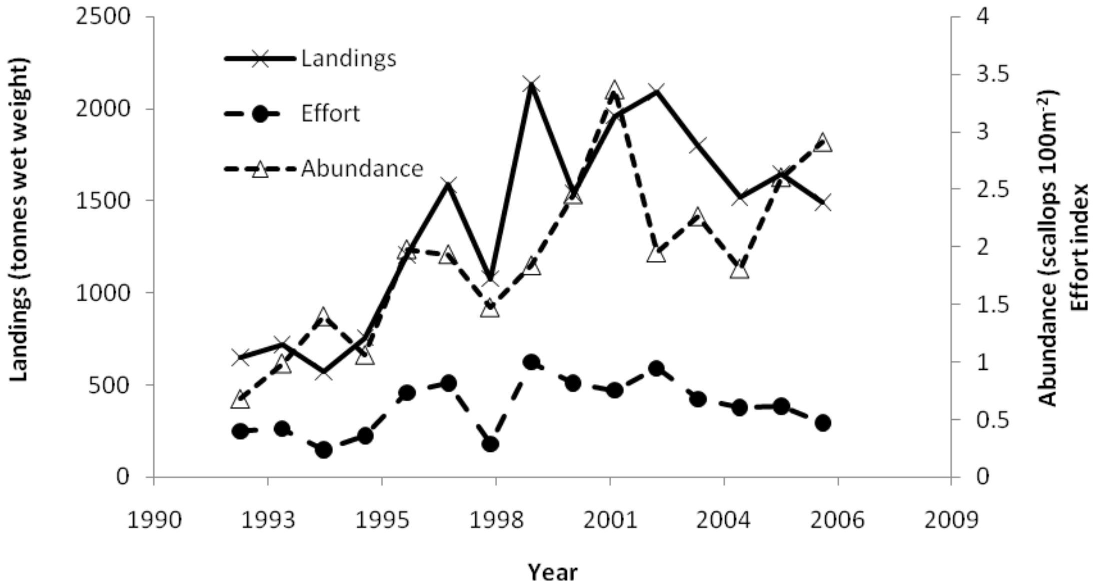


Figure 4.17 Total landings into the Isle of Man and Scotland, relative abundance of <110 mm king scallops and effort index.

Aequipecten opercularis

The relative abundance of queen scallops has shown an overall linear increase during the past 14 years (Figure 4.18). The number of queen scallops ≥55 mm has also increased over the same period (Figure 4.18); however, the percentage of queen scallops ≥55 mm in the population has declined (Figure 4.19). From 1992 to 1997 the relative abundance of *A. opercularis* remained between 1 and 5 individuals $100m^{-2}$. In 1998 relative abundance fell almost to 0 before increasing to between 5 and 10 ind. $100m^{-2}$ from 1999 to 2003. There was a large increase in abundance in 2003 due predominantly to an increase in numbers of queen scallops at Laxey. Relative abundance fell to 4 ind. $100m^{-2}$ and has since has since increased to around 10 ind. $100m^{-2}$ in 2008. The relative number of recruits (55 – 65 mm height) has been highly variable, peaking in 2000, at 12 ind. $100m^{-2}$, but currently recent recruitment was only 2 ind. $100m^{-2}$ (Figure 4.20). There were significant relationships between relative abundance as measured in surveys and trawl CPUE ($y = 0.0439 \ln(x)+0.0422$, $R^2 = 0.611$, $F_{1,11} = 17.29$, $p = 0.002$) and dredge CPUE ($y = 0.2947 \ln(x) +0.0416$, $R^2 = 0.6853$, $F_{1,10} = 21.7786$, $p = 0.0009$) derived from scientific logbook and fishing logbook data (Figure 4.21). Therefore, relative abundance was estimated from fisheries dredge CPUE data from 1982 – 2007. There was no clear correlation between abundance and landings. Relative abundance fluctuated from <1 to 14 ind. $100m^{-2}$, and in 2008 was 5 ind. $100m^{-2}$ (Figure 4.22).

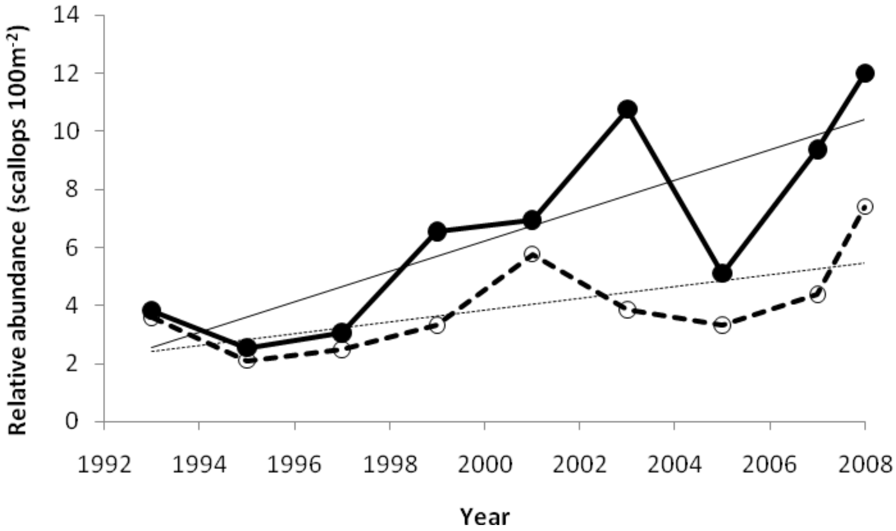


Figure 4.18 Two-year moving average of relative abundance of all queen scallops caught during surveys (solid line) and those ≥55 mm (dashed line).

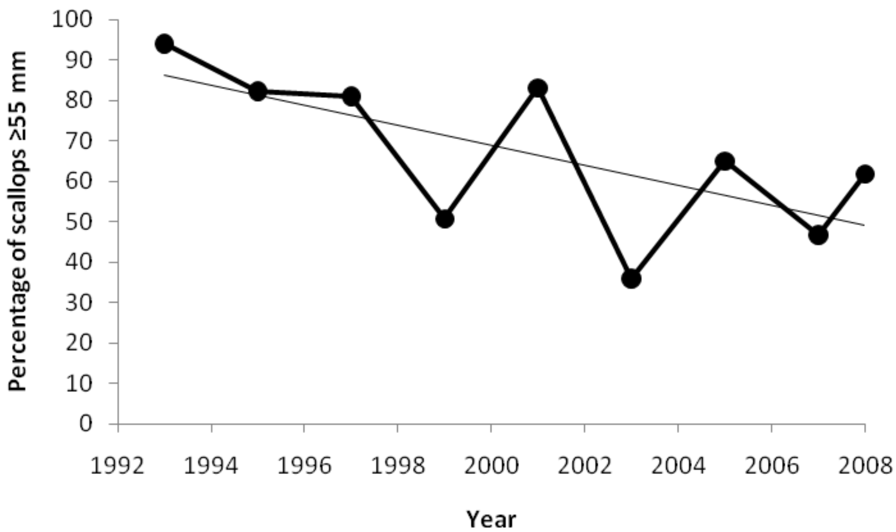


Figure 4.19 Percentage of *Aequipecten opercularis* ≥55 mm in height.

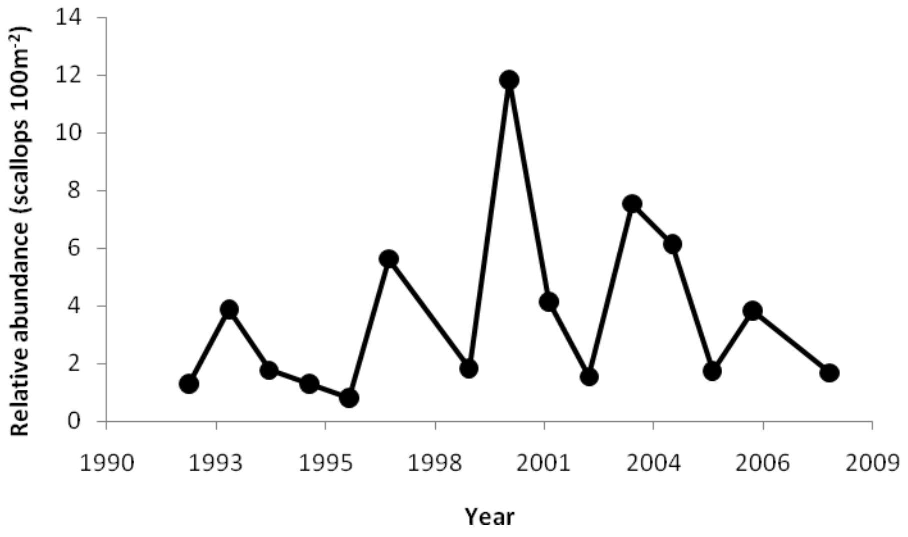


Figure 4.20 Mean number of *Aequipecten opercularis* recruits (55 – 65 mm) around the Isle of Man

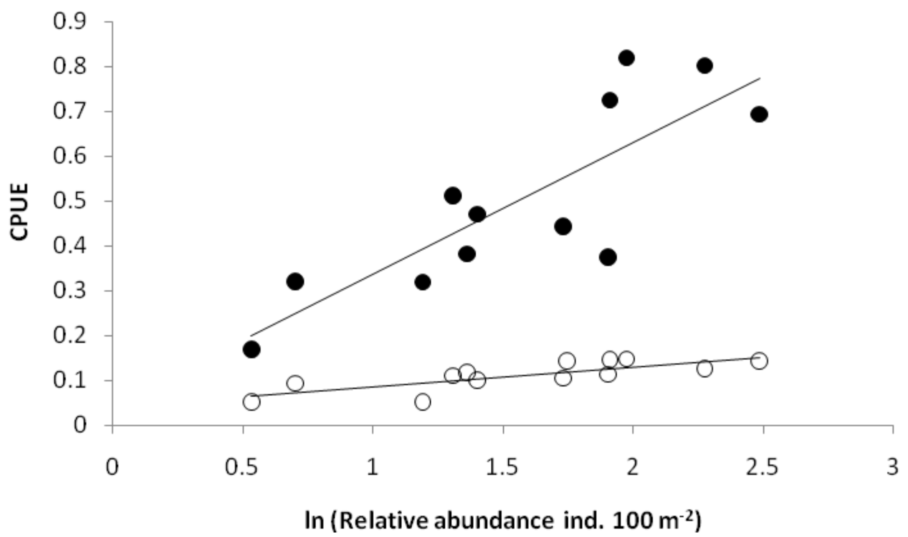


Figure 4.21 Relationships between relative abundance measured during surveys and CPUE from dredges (solid circles) and trawls (open circles).

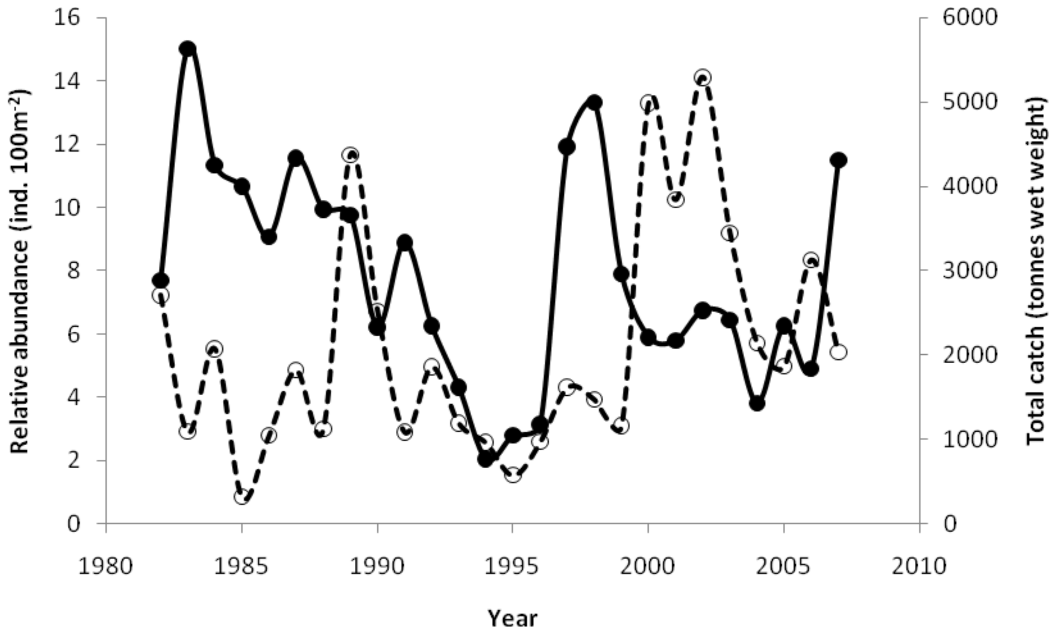


Figure 4.22 Relative abundance (open circles) and total landings (solid circles) of *Aequipecten opercularis* in Manx waters.

4.4 Discussion

Stock status

Landings of both king and queen scallops have shown large fluctuations which may have been due to changes in market demand, fishing effort or stock abundance. Currently there has been a slump in demand due to cheaper products from overseas. *P. maximus* landings show the characteristics of a boom and bust cycle, which is also typical of deep-water fisheries whereby extended periods of over-fishing are followed by declines in stocks (Koslow *et al*., 2000). High catches of scallops from 36E5 and 37E5 in the early 1980s were followed by a decline in landings, reaching a minimum in 1994. Abundance was relatively low during the early 1980s but increased sharply in 1989.

The strongest correlations between abundance and landings of king scallops were for king scallops <110mm. Scallops dredging is undertaken for five months before the June Survey. Thus, it could be hypothesised that the density of scallops ≥110 mm at t_y will show a positive correlation with landings at t_{y+1}, although some scallops would be removed in the last two months of t_y. However, the density of <110 mm scallops will be altered less by fishing activity and is likely to be correlated with the total population size. Reorganisation of landings data to run from November to October would be necessary to better assess the relationships between abundance and landings. Nevertheless, it is clear that abundance has a strong influence on both total catches and fishing effort.

Although abundance data was only collected from 1992 onwards it is possible to infer abundance prior to this from fisheries CPUE data for *P. maximus*. However, there is no clear relationship between abundance of queen scallops and landings. Initial trials of stock assessment methods have focused on surplus production models. These models require total catch data and an index of abundance or fishing effort. Such models depend on there being a large change in fishing effort over time, and that fishing mortality is proportional to fishing effort (Prager, 1994); this has not been the case for queen or king scallops during the past 26 years. Increasing abundance does not appear to have occurred due to decreasing fishing effort. Indeed both landings and effort have increased during much of the study period, which may suggest a sustained period of stock recovery. Moreover, without clear definition of discrete scallop populations, stock assessment models may be ineffective. It would be valuable if data on catches of scallops fished from Manx waters and landed into England, Wales and Northern Ireland could be obtained. However, it is likely that a high proportion of landings into England and Wales caught within 36E5 will have been caught outside of Manx territorial waters.

The relative abundance of both the queen and king scallop stocks has generally increased during the past 15 years. Surveys in 2008 found a particularly large increase in numbers of king scallops. However, this increase is due predominantly to greater scallop numbers at the Targets fishing ground. Numbers of king scallops on the Targets ground are around 10 times higher than on any other ground. However, the number of scallops ≥110 mm is only twice that found on other grounds. At Targets, 28% of king scallops were between 105 and 110 mm in length. Scallops grew by c. 1 cm between June and October 2008; assuming growth continues, the majority should reach 110 mm by November 2009. No new cohort of king scallops was detected at the Targets ground. Consequently, once the existing cohort has been fished out, probably in 2009/2010, catches will be low until a new cohort is recruited, which will be in the 2010/2011 season at the earliest. The next surveys, in June and October 2009, will help to identify whether a new cohort of king scallops is likely to enter the Targets fishery during the next few years.

4.5 Recommendations

- A precautionary approach would be to maintain landings of king and queen scallops at the current level or lower. Landings of queen scallops into the IOM and Scotland were 1840 tonnes in 2007; 1806 tonnes of king scallops were landed.
- In October 2008, 87% of king scallops on the Targets ground were <110 mm. Scallop fishing on the Targets ground should be avoided until the 2009/2010 season to avoid damaging undersized scallops.
- If the majority of scallops at Targets have not grown to 110 mm by November 2009, it would be propitious to reduce scallop densities at the Targets by moving scallops to other grounds. A decrease in growth rates would be indicative for density dependent effects i.e. individual scallops competing for food. Moving them to less densely populated areas might thus enable scallops to feed and grow more efficiently.

4.6 Future developments

Various stock assessment models are currently being trialled. Surplus production models have not been successful for queen scallop data. A length-tuned model is currently being used which may prove more successful for both queen and king scallop stocks. CEFAS do not undertake scallop stock assessments due to the poor definition of stocks (pers. comm.) and FRS have undertaken stock assessments for some *P. maximus* stocks only (Howell *et al*., 2006). Therefore, although stock assessment models will continue to be investigated it may be that none are appropriate at this stage.

5. HABITAT MAPPING

5.1 Background and aims

In August 2008 we undertook an extensive 10 day towed video and still camera survey of the seabed up to the 12 mile limit of the Manx territorial sea (see Figure 4.1). The scientific aims of the survey were threefold: (1) to map and describe sea-bed habitats and their faunal communities, (2) to provide stock estimates of fished species, and (3) to identify relationships between environmental parameters measured and species distributions.

Previous to this survey, no comprehensive assessment of seabed habitats existed in the Isle of Man. In order to understand the extent of fishing grounds and the potential impacts of fishing and other activities (i.e. renewable energy developments, aggregate extraction etc.) on the seabed, it is essential to map the different types of seabed communities. Habitat maps form the basis for marine spatial planning and can provide crucial information for decision makers. The status of marine habitats within Manx waters, with respect to fishing impacts is uncertain. With the present data collected in conjunction with Vessel Monitoring System (VMS) data it will be possible to assess the relationship of fishing disturbance and environmental status. Understanding this link will be vital to set environmental baselines which will be required for MSC certification of the Manx fisheries.

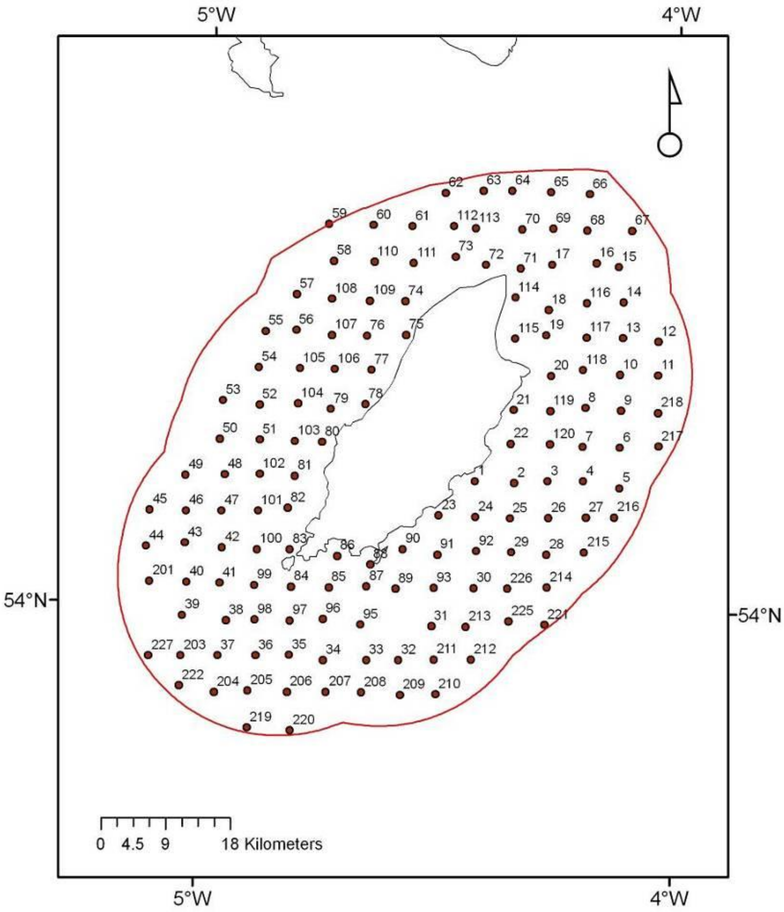


Figure 5.1 Map of the stations surveyed with video and stills camera tows

5.2 Methods

Towed video and high-resolution digital stills imagery was collected at 142 survey stations. Real-time counts of mega-fauna were made during video tows with concomitant photographs of the seabed every 9 seconds. In addition, several environmental parameters were measured including sediment grain sizes, temperature, salinity, chlorophyll fluorescence and benthic chlorophyll concentrations at 119 stations. Currently the data from this survey is being processed. While for some data processing has been completed, several other parts of the data will become available over the next two years (Table 5.1).

Table 5.1 Overview of the data collected and status of processing

Data	Status	Estimated time of completion
CTD (temperature surface & bottom, salinity)	Processed	Completed
Abundance estimates of target species from video tows	Processed	Completed
Chlorophyll levels in surface & bottom water	Processed, needs to be integrated into GIS	February 2009
Chlorophyll levels in sediments	Partly processed	March 2009
Sediment grain size analysis	Partly processed	March 2009
Abundance estimates of faunal assemblages from stills images	Processing will commence in February 2009	June - August 2009

5.3 Results

The temperature data showed that different hydrographic zones exist around the island (Figure 5.2a). Bottom temperatures were generally higher on the north eastern side of the island ranging between 14.6-15.8^{o}C, while in the south west temperatures were lower ranging between 12.6-14.9^{o}C. Temperature is a relevant factor governing growth rates of organisms.

Vertical temperature profiles which were recorded during the survey can reveal the position of stratified and mixed waters. The degree of stratification of the water column can be expressed as the potential energy anomaly (PEA) measured in Joules m^{-3}. The higher the PEA, the more stratified the water column. The transition between stratified and mixed water often leads to the creation of thermal fronts which are important areas of primary and secondary production. Transition Zones were mainly located in the south and southwest of the Island (Figure 5.2b).

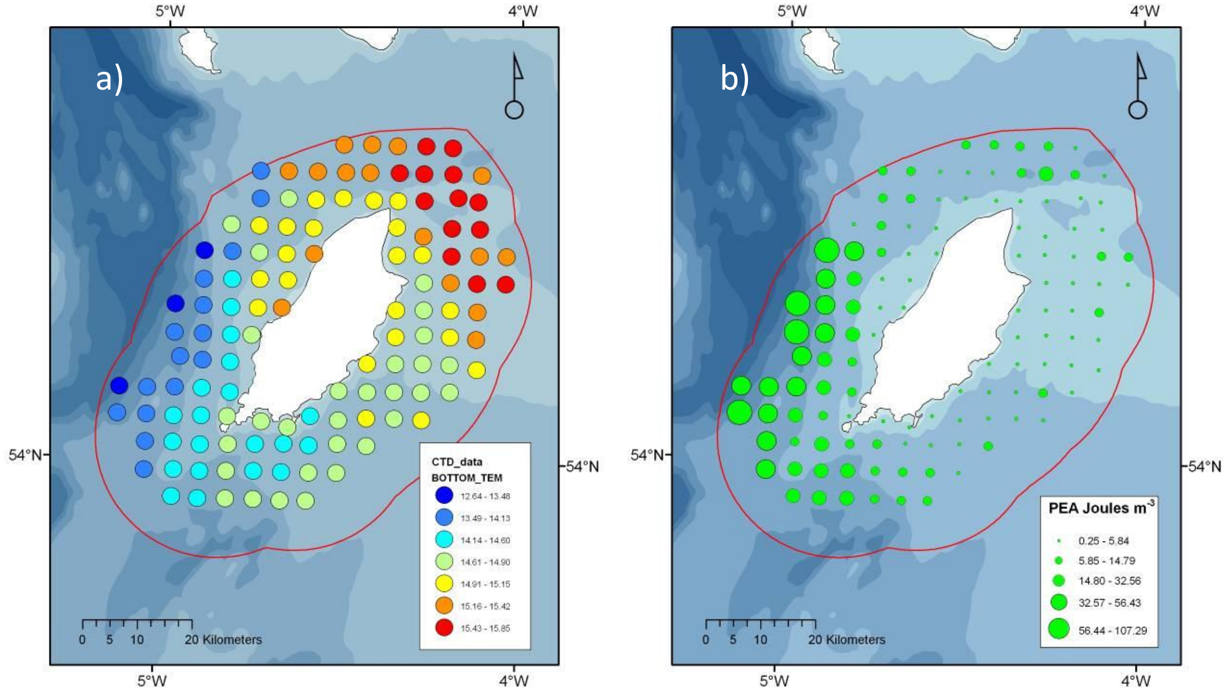


Figure 5.2 Map a)showing the temperature distribution and b) Potential energy anomaly (PEA). Joules m^{-3} a measure of water temperature stratification.

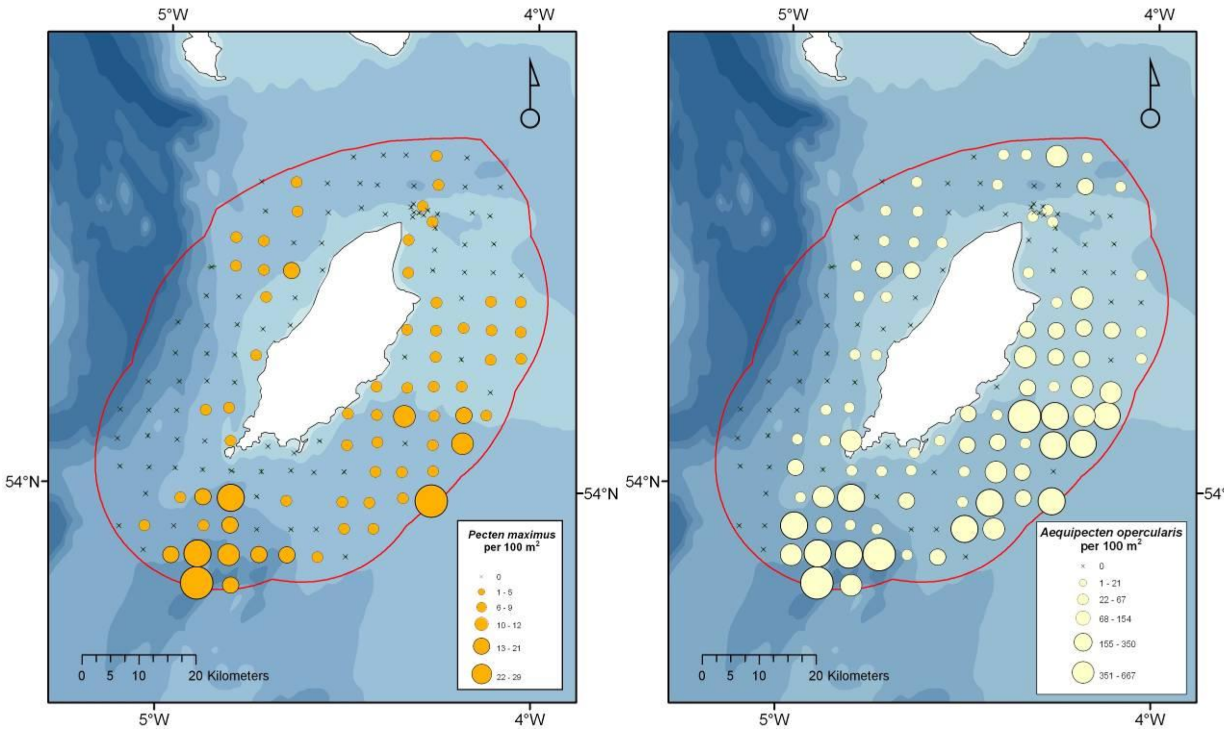


Figure 5.3 Maps of a) King scallop (*Pecten maximus*) distribution and b) Queen scallop (*Aequipecten opercularis*) distribution as ascertained from video camera surveys.

The mean abundance of *Pecten maximus* (king Scallops) was 0.8 ±0.2 individuals.100m^{-2} (Figure 5.3a); *Aequipecten opercularis* (queen Scallops) was more common, with a mean abundance of 16 ±6 individuals.100m^{-2} (Figure 5.3b). *P. maximus* was found from close inshore out to the limits of the survey area although their distribution was patchier on the west coast. *A. opercularis* was the most ubiquitous of the fished species, and was found in four distinct but extensive areas. *B. undatum* occurred predominantly over small areas to the south-east and north of the Isle of Man. *Nephrops norvegicus* was only present to the west of the island on muddy sediment in deeper water.

5.4 Conclusions

The seabed imagery collected will allow habitats to be mapped and associations between these habitats and fauna to be identified. The preliminary results of the towed underwater video and stills surveys demonstrated that they can provide a valuable tool with which to assess scallop populations and other fauna, allowing rapid estimation of species distribution and abundance. The full dataset once processed will be a vital resource for the future assessment and sustainable management of the fisheries.

6. QUEEN SCALLOP SORTING AND DISCARD SURVIVAL

6.1 Aims and methods

There are two major components of indirect fishing mortality to undersized, which in practice is <55 mm, queen scallops; the mortality of individuals that are damaged by the fishing gear and remain on the sea floor and animals that are being caught and die due to damage and stress induced by the sorting process and discarding (Jenkins and Brand, 2001). As indirect mortality may be significant it needs to be quantified and consider in fisheries management. It is particularly important that potential recruits to the fishery are protected (Gruffydd, 1972).

Within an experimental study the consequences of indirect stress factors from different sorting processes on damage, survival and the escape response of discarded queen scallops was investigated. The effects of hand sorting versus mechanical sorting, which is the current standard for sorting queen scallops in Manx waters, was compared. The damage to undersized queen scallops was estimated by assigning a damage score from 1 (no damage) to 4 (lethal damage) and escape response was measured by counting the number of valve closures at different time intervals after the sorting procedure. Survival of damaged and undamaged mechanically and hand sorted scallops was monitored in aquaria.

6.2 Results

Mechanically sorted animals showed relatively low but significantly greater damage levels compared to hand sorted animals (Figure 6.1). The escape responses to a predator stimulus following either sorting method were not significantly different (Figure 6.2). Two hundred scallops were kept in aquaria following either hand or mechanical sorting to monitor their survival rate through time. Damaged and undamaged scallops were kept in separate groups during this experiment. None of the 200 animals, damaged or undamaged, died over a two week period.

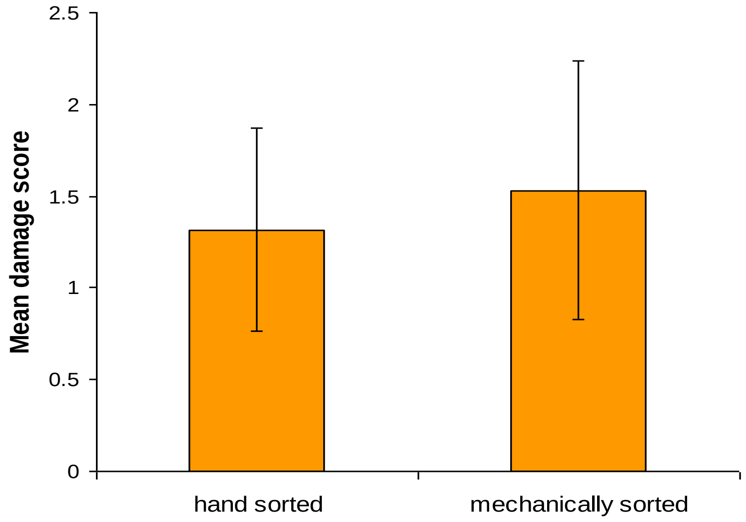


Figure 6.1 Mean damage sore of hand sorted and mechanically sorted queen scallops. Error bars ±S.D.

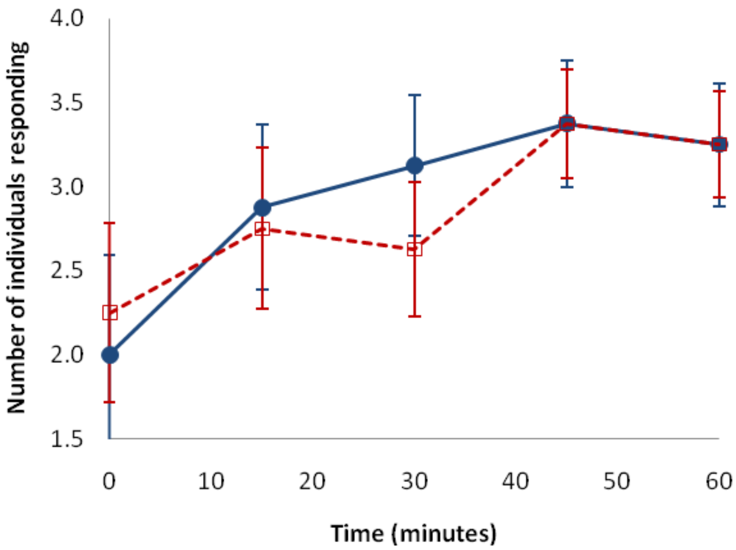


Figure 6.2 Mean number (±1 S.E.) of queen scallops responding to predator stimuli after mechanical (dashed/open) or hand (solid) sorting (n = 5).

6.3 Conclusions

In conclusion, queen scallops may be slightly more vulnerable to predators following mechanical sorting due to greater shell damage. However, the survival experiment demonstrated that there is a high likelihood that discarded undersized queen scallops will survive if returned promptly to sea following sorting. In areas of high fishing intensities juveniles may be caught, sorted and discarded several times which may lead to significantly higher stress levels than investigated by this study. However, the use of mechanical sorting is unlikely to result in substantially greater mortality of undersized queen scallops.

The full results of this study are presented by Montgomery (2008).

7. LOBSTER ESCAPE GAPS

7.1 Background and aims

The lobster traps currently used in the Isle of Man retain all undersized lobsters (*Homarus gammarus*) and brown crabs (*Cancer pagurus*) which enter them. Providing an escape gap by means of a plastic panel with a rectangular hole allows smaller lobsters and crabs to escape and avoids unnecessary stress through capture and discarding. It is important that the size of escape gap used enable most undersized lobsters to escape while retaining lobsters of or above the minimum landing size (MLS). In a review of the use of escape gaps in Newfoundland, Canada, Templeman (1958) notes that the advantages of increasing lath spacing, by allowing juvenile American lobsters, *Homarus americanus*, to escape, were recorded as early as 1890 and a minimum lath spacing of 1 ¾ inches was required under law from 1893 in Newfoundland. Although fishers are required to return undersized lobsters to the sea, in the Isle of Man and elsewhere, Brown (1979) suggested discarded lobsters would be more likely to return to known refuges when allowed to escape on the seabed rather than being discarded after traps are hauled.

7.2 Methods

Three sets of traps were deployed, one in Ramsey Bay, one at Port St. Mary, and one at Dalby. At Ramsey and Port St. Mary, three strings of c. ten traps were set, one set with no gaps (N), one set with gaps of 80 x 45 mm (small, S) and one set with 84 x 46 mm (large, L) gaps. At Dalby, ten traps with each escape gap size were set individually rather than in strings. Traps with and without gaps were not used within the same string to prevent lobsters entering and leaving traps with gaps and then entering traps with no gaps. Traps in Ramsey were deployed on six different days, on four different days in Port St. Mary, and on eight days at Dalby. Soak times varied from 1 to 6 days for all but one trial where traps were left for 12 days due to bad weather. However, soak time was consistent within each trial. The carapace length (CL) of all lobsters was measured to the nearest millimetre from behind the eye to the base of the carapace. The study was conducted during October and November 2008.

7.3 Results

Results demonstrated that there was no significant effect of escape gaps on catching marketable lobsters ≥87 mm. Thus indicating that fitting lobster pots with escape gaps should not have any negative effect on catch revenues. Fitting small and large escape panels proved effective in limiting the capture of juvenile undersized lobsters <87 mm (Figure 7.1). Catches from lobster pots with no escape panels were composed of 75% undersized lobsters (<87 mm). In lobster pots fitted with small escape gaps catches of juveniles were reduce to about 50%. Large escape gaps were most effective in limiting capture of undersized lobsters and catches only contained 25% undersized lobsters.

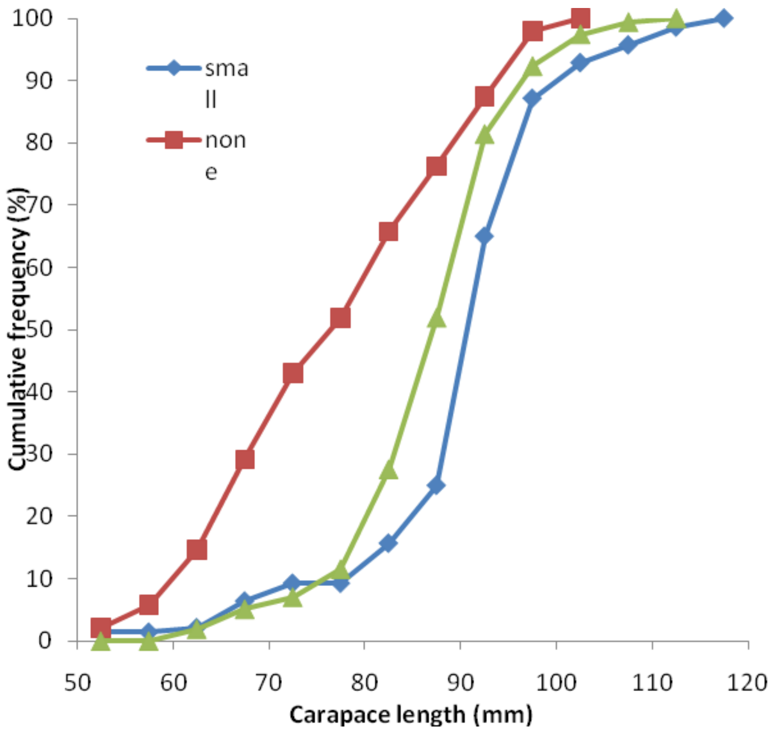


Figure 7.1 Cumulative size-frequency distribution of lobsters caught in traps with small, large or no escape gaps.

7.3 Conclusions

The fitting of small and large rectangular escape gaps to lobster traps would allow many lobsters <87 mm to escape with no loss of lobsters ≥87 mm CL. Thus, as a stock conservation measure, limiting juvenile lobster capture and discards can be recommended as a management option. Other studies have indicated that fitting escape gaps might in fact improve the efficiency of traps slightly with respect to catching marketable lobsters. This observation could not be supported by the data collected in the present study.

It is important that lobsters continue to be measured to ensure only lobsters of ≥87 mm are landed as undersized lobsters will continue to be retained in traps with escape gaps. The compulsory use of escape gaps in traps used for hobby fishing may be beneficial for lobster populations as these traps are more likely to be abandoned or hauled only irregularly. As such there may be a case for the compulsory use or larger escape gaps in hobby pots. The results of this study are available in detailed report (Murray *et al.*, 2008).

8. SHIP COMPARISON WITH RESPECT TO FUTURE SURVEY WORK

8.1 Background and aims

To investigate if the Research Vessel Prince Madog could be used for future stock assessment work instead of local fishing vessels, a ship comparison trial was undertaken in October 2008. Similar ship comparison trials have been carried out by CEFAS in the English Channel to ensure commercial catches and catches made by research vessels can be compared (Dare et al. 1994). There are several advantages to using a research vessel over commercial fishing boats. Foremost is the ability to increase the number of scientific personnel for processing and sorting of scallop samples. The Prince Madog has space for 10 scientists and can work 12 hour days, increasing not only the speed and number of stations (fishing grounds) which can be visited during a working day, but also increasing the potential for taking additional samples. In the past various, relatively small, commercial fishing vessels have been used for stock assessment work. As the Prince Madog is considerably larger in size, concerns existed that the Prince Madog could exhibit significantly different catch efficiencies which could lead to a bias in stock assessment data if not quantified.

8.2 Methods and results

The scallop dredger 'Genesis' was used for this comparison. Dredging trials commenced at 5 different grounds, namely: East of Douglas, Laxey Bay, Maughold, Ramsey and Point of Ayre. At each ground three tows were made with vessels fishing in alternating order following approximately the same trawl lines. Each vessel was fishing with one tow bar equipped with two Newhaven king scallop dredges and two queen scallop dredges in alternating order. Catches onboard the Genesis were sorted by 2 – 3 scientists kneeling on deck while on RV Prince Madog 8 scientists sorted catches on sorting tables.

Preliminarily results showed that no clear differences in the abundance of king scallops caught within king scallops dredges with either vessel existed. However, considerable variation of catches among sites and vessels were noted (Figure 8.1). For queen Scallops caught by queen dredges significant differences between the two vessels became apparent. At most sites Prince Madog catches were higher compared to Genesis (see Figure 8.2).

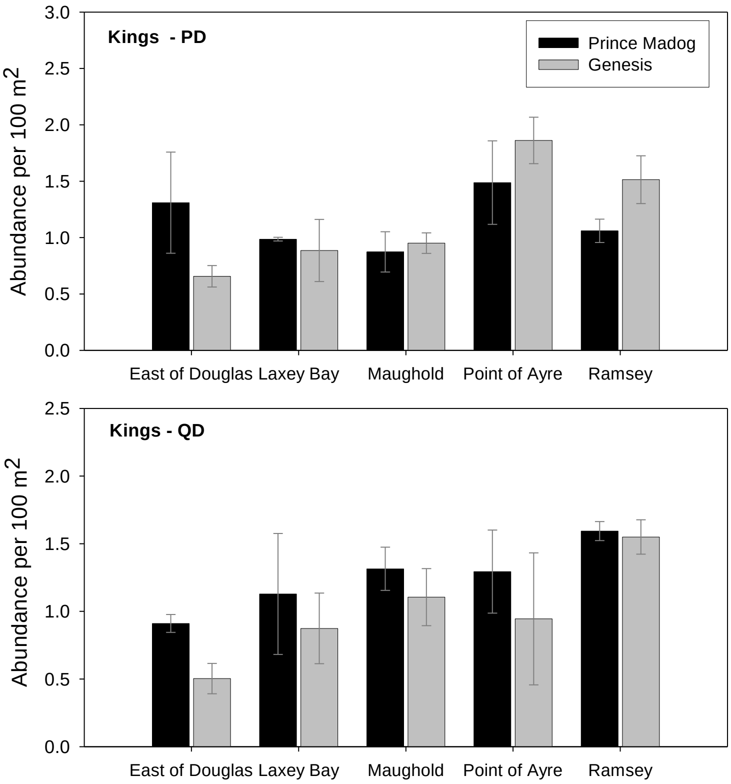


Fig 8.2 King scallop catches of RV Prince Madog and Genesis from five different fishing grounds made with different gears [Pecten dredges (PD), Queen dredges (QD)].

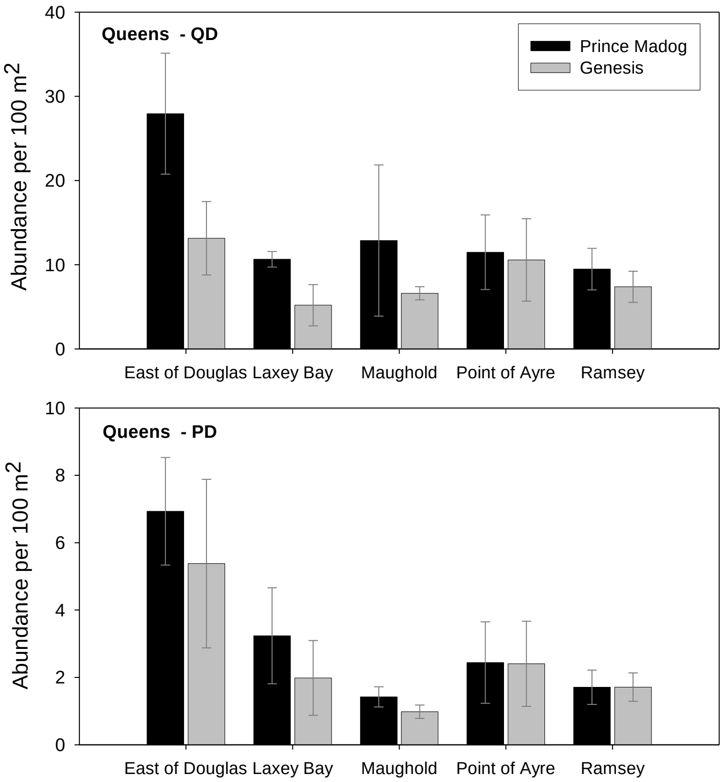


Fig 8.1 Queen scallop catches of RV Prince Madog and Genesis from five different fishing grounds made with different gears [Queen dredges (QD), Pecten dredges (PD)].

8.3 Conclusions

The analysis showed that at least for queen scallops considerable differences between commercial and research vessel catches existed. Nevertheless, we assume that these differences were not related to the catch efficiencies of the vessels used, but due to a more thorough sorting procedure onboard the Prince Madog. We assume that many of the smaller queen scallops were overlooked by personnel working on Genesis due to a limit in personal space and time, leading to a relatively consistent bias in the data. If the Prince Madog were to be used in future surveys this bias would need to be considered within future stock assessments by adjusting historic records. The main concern that catch efficiencies of the Prince Madog would be lower compared to a commercial vessel could not be verified by this study. It can be concluded that the Prince Madog will be a suitable vessel for assessment of stock status and that the bias introduced due to differences in sorting efficiency can be addressed.

Conducting scallop surveys from the same vessel in the future should allow for the collection of more consistent and higher quality data. In the past various vessel have been used for scallop surveys which inevitably will have introduced additional variability into past data. The results of this study are available in a detailed report (Hinz *et al*., 2009).

9. CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The benefits of the fishing exclusion area at Port Erin beyond the immediate surrounding area have yet to be demonstrated conclusively. However, Neill and Kaiser (2008) identified the Port Erin closed area as a potential source of larvae to the Targets fishing ground towards the north-west. Larvae from Douglas Bay are predicted to be transported eastwards towards the East Douglas and South-East Douglas fishing grounds. The particle tracking model used in this study does not incorporate larval behaviour which will have some influence on the area of settlement. The initiation of a study of scallops genetics may better elucidate the dispersion of scallop larvae.

Although landings of scallops fished from Manx waters have fluctuated from 500 t up to 2000 t per annum during the past 40 years, there has not been a complete collapse of the fishery as occurred in the Bay of Brest (Alban and Boncoeur, 2008). The comparative success of the fishery may be ascribed to several factors. Rocky areas of seabed may provide an important area of habitat for *P. maximus*, affording natural protection to spawning stocks, as was identified in Douglas Bay. Increasing abundance of *P. maximus* has been identified from 1993 onwards (Beukers-Stewart *et al*., 2003) which may be attributable to seawater warming (Shephard *et al*., submitted). Furthermore, as a minimum landing size of 110 mm is imposed, fishing becomes uneconomical when scallops of ≥110 mm form a small proportion of the population, making the complete removal of scallop populations unlikely.

However, the Isle of Man queen scallop fishery is heavily reliant on the recruitment of two year olds, and to a lesser extent three year olds (Vause *et al*., 2007). Consequently, the fishery is vulnerable to collapse due to even a single year of poor recruitment. Due, in part, to the closed season for king scallop fishing, most fishers target king scallops from November to May and queen scallops from June to October and are therefore are especially vulnerable to the decline in abundance of any one species.

Progress and future research

The main developments in our understanding of the Isle of Man's scallop populations during the past two years have come through data collected during the visual and oceanographic surveys conducted from RV Prince Madog, and from VMS data. These areas of research will allow us to better understand the impact of fishing on benthic habitats in Manx waters, and the distribution of fishing effort in relation to scallop populations. Stock assessment models are being trialled and a separate report on the results of these trials will be produced in the coming months. Table 9.1 outlines planned research and progress to date.

Attempting to meet the requirements of the Marine Stewardship Council for certification of the queen scallop fishery will require a great deal of research during the next year. The principal scientific requirements will be assessment of the impacts of fishing gear used to exploit queen scallop stocks, including by-catch monitoring, and developing stock assessments to set appropriate reference levels. It will be necessary to implement effective management systems to impose effort or catch limits as necessary.

The introduction of extensive scallop aquaculture to the Isle of Man has been proposed by DAFF. At the date of publication of this report we are awaiting any expression of interest from the Manx Fish Producers' Organisation to pursue scallop ranching in the Isle of Man. Should extensive scallop aquaculture trials be conducted, monitoring of growth and mortality will need to be undertaken during a two to three year period commencing in summer 2009.

Tissue samples have been collected from scallops imported to the Isle of Man from Skye during April 2008 and from scallops ≥6 years old in February 2009. Analysis of these samples will be conducted during the next year to try and identify genetic markers distinguishing the Scottish scallops from the Manx scallops.

At-sea sampling from fishing vessels will be undertaken during 2009 or 2010 to gather data on lobster and crab populations. Crab numbers, sex and size will be collected during dredging surveys in June and October. Lobster escape gaps were trialled and effectively allowed undersized lobsters to escape from traps with minimal loss of larger lobsters.

Table 9.1 Major tasks completed and planned research

Item	Task	Completed ?	Date of completion/estimated date of completion
1.	Stock assessment of *Pecten maximus* and *Aequipecten opercularis* stocks	**N**	April 2009
2.	Collect data on scallop populations in closed areas	**Y**	March 2008
3.	Download and process VMS data	**Y**	Completed for 2007/2008
4.	Collect data on habitats, scallop populations and physical oceanography in Manx waters	**Y**	September 2008
5.	Analysis of video footage of seabed in Manx waters	**Y**	October 2008
6.	Analysis of digital stills seabed imagery	**N**	Summer 2009
7.	Analysis of chlorophyll and sediment samples	**Y**	March 2009
8.	Queen scallop fishing gear comparison	**N**	Summer 2009
9.	Collect preliminary data on lobster populations	**N**	On-going from March 2009
10.	Assess effectiveness of lobster escape gaps	**Y**	November 2008
11.	Undertake survey versus fishing vessel comparison and subsequent data analysis	**Y**	March 2009
12.	Continue biannual monitoring of scallop populations in Manx waters	**-**	Completed for 2008 and on-going
13.	Dissemination of scientific information to stakeholders: i.e. calendar, newsletter, public meetings	**-**	On-going
14.	Monitoring of scallop ranching trials: Pending decision from MFPO/fishing industry	**-**	Commencing summer 2009
15.	Collect scallop tissue samples for genetic analysis	**Y**	February 2009

Key findings and management recommendations

- It would be prudent to restrict scallop fishing activity at the Targets fishing ground to limit damage to undersized scallops, which form the majority of the population in this area.
- Imposing a total allowable catch for scallops should be considered to avoid the large fluctuations in catches that have occurred in the past.
- Scallop densities in the closed area at Port Erin are higher than in most other areas. However, scallop densities are low around the edges of the area and intensive monitoring of fishing activity in this area is recommended.
- The installation of lobster escape gaps in traps would reduce catches of undersized lobsters without reducing catches of marketable lobsters.
- Preliminary results suggest that RV Prince Madog would be a suitable vessel for conducting scallop surveys. A detailed report on this subject is available.
- Mechanical sorting of undersized queen scallops is unlikely to cause significantly greater mortality than hand sorting.
- It will be necessary to assess the environmental impacts of scallop dredges used to fish for queen scallops to the east of the island to determine whether the queen scallop fishery can meet the requirements of MSC certification.
- More detailed information on queen scallop fishing activity will be required to allow catches to be traced to particular areas and fishing gear types. This information could be derived if electronic logbooks and additional vessel monitoring systems were introduced.
- Toothed dredges used to fish for queen scallops are unlikely to meet the requirements of the MSC for certification of the queen scallop fishery and their use to fish for queen scallops should be banned in Manx territorial waters.
- It is essential that fishing for queen scallops can be stopped if safe biological limits of the stocks are reached. No such mechanism is currently in place to do this.

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