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Environmental impacts of demersal otter trawls targeting queen scallops (*Aequipecten opercularis*) in the Isle of Man territorial sea

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Executive Summary

The use of mobile fishing gears is thought to be one of the greatest causes of disturbance to marine benthic communities. These impacts may be direct (removal, burial or crushing), indirect (increased susceptibility to predation), or may take the form of wider biogeochemical implications for the environment. In 2011 the trawl portion of the Isle of Man queen scallop fishery was awarded Marine Stewardship Council (MSC) certification; however the dredge component of the fishery was not certified primarily based on the damaging effects dredges have on the marine environment. With a view to the continued certification of the fishery it is necessary to quantify the impact of fishing activity on benthic habitats within the Isle of Man territorial sea. This report aims to assess what proportion of the territorial sea is impacted at varying levels of fishing intensity and to determine what impact fishing is likely to have had on known areas containing species or habitats of particular conservation concern. Analysis showed that in excess of 85% of the territorial sea is not trawled for queen scallops. While the spatial distribution of effort varied on an annual basis the mean footprint of the fishery was relatively stable at 11.85% ± 0.78% of the area of the territorial sea. From 2011 to 2013 less than 1% of the territorial sea was trawled at an intensity of greater than 0.5km^2 trawled per 1km^2 of seabed. The introduction of a "Queenie Conservation Zone" coupled with a designated dredge box and a specific separate Total Allowable Catch (TAC) for the dredge fishery has led to its footprint being much reduced in the 2013 season to December 31st and has reduced the potential for cumulative impacts of trawling and dredging for queen scallops. For the most part fishing effort was not seen to coincide with the presence of four features of conservation concern identified within Manx waters during the 2008 habitat survey. The exception to this was the presence of *Sabellaria spinulosa* in the extreme south-west of the territorial sea. As the area is heavily dredged trawling activity is likely to have a comparatively minor impact compared to background levels of disturbance. The queen scallop trawl fishery in the Isle of Man is spatially restricted due to the distribution of queen scallops and fortunately trawling activity occurs in areas distinct from many of the Island's more vulnerable marine habitats. Where trawling occurs it does not take place in isolation rather it is set against high background levels of disturbance from the king, and historically, the queen scallop dredge fisheries. As such, with current background and historical levels of disturbance as high as they are, it remains extremely difficult to effectively isolate the impacts of the any one of the fisheries within the territorial sea.

Table of Contents

Table of Figures

Appendices

1. Introduction

1.1. Queen scallops (*Aequipecten opercularis*)

Queen scallops, known colloquially in the Isle of Man as the Manx "Queenie", are one of the smallest commercially exploited scallop species, growing up to 90mm shell height (Schmidt *et al*., 2008). They may be found from 30°N to 70°N in water depths of up to 100m. Generally, however, they are found at between 20m to 45m on firm sand or fine gravel (Brand, 1991; Román *et al*., 1999). Queens scallops, unlike king scallops, do not exhibit recessing behaviour (Jenkins *et al*., 2003) and as a result they may be found in areas where sediment composition is coarser than that required of king scallops. Scallops do not generally distribute themselves homogenously across their available range, rather they tend to form dense aggregations, known as beds, in areas that are particularly suitable in terms of sediment type, flow regime, food availability etc. (Brand, 2006a). Scallop beds may be either permanent or seasonally variable. Permanent beds have well established borders that are generally delineated by areas unfavourable to scallop growth while temporary beds may arise as a result of variations in settlement and the survivorship of both larval and post larval stages. Permanent beds are particularly important as they may be reliably targeted year on year by fishers, effectively reducing the need for prospecting at the start of the season to determine the location of economically viable aggregations of scallops.

Bivalves in general tend to be poor swimmers (Jonsson *et al*., 1991); however, adult queen scallops are proficient swimmers who, having detected approaching danger at a distance of up to 1.5m (Chapman, 1981), exhibit an escape response. This escape response involves a rapid vertical ascent into the water column followed by a short horizontal swim before settlement back to the benthos (Chapman, 1981; Brand, 1991). Jenkins *et al*. (2003) demonstrated seasonal variations in the escape response of queen scallops which tracked changes in water temperature. It is this escape response that allows queen scallops to be fished using trawls, as they are required to leave the seabed and swim into the mouth of the approaching net. In addition, as an escape response is only exhibited above a certain temperature threshold the fishery is effectively limited to the warm summer/autumn months.

1.2. The Fishery

Commercial fisheries exist within Manx waters for two species of scallop, king scallops (*Pecten maximus*) and queen scallops (*Aequipecten opercularis*), with the king scallop fishery being the more valuable; however, the fishery for queen scallops has increased in value and importance in recent years. King scallops are targeted exclusively with dredges while queen scallops may be targeted either with dredges or demersal otter trawls. Manx vessels almost exclusively utilise the otter trawl method during the closed season for king scallops; however, some vessels from outside the Manx fleet, along with a small number of Manx vessels, do still dredge for queen scallops. In 2011 the trawl portion of the queen scallop fishery was awarded Marine Stewardship Council (MSC) certification; however the dredge component of the fishery was not certified primarily based on the damaging effects dredges have on the marine environment. As such this report will focus exclusively on the otter trawl portion of the queen scallop fishery and the effects of otter trawling on the marine environment.

Otter trawling is almost exclusively limited to the months of June to October as the fishery, in requiring the scallops be active, is largely temperature dependent (Jenkins *et al*., 2003). It is during this period that scallops, due to increased water temperatures, are most likely to swim in response to disturbance allowing them to be captured in trawls (Chapman *et al*., 1979). Trawling is traditionally conducted by vessels fishing single rig otter trawls with net openings of 18m to 32m. Regulations related to trawling for queen scallops within the territorial sea include: a minimum mesh size of 85mm, a minimum landing size of 55mm, daily curfews and restrictions on vessel engine size. In addition forthcoming regulations due to come into effect for the 2014 season include a ban on multi-rig trawling and a restriction on the trawl net width of 12 fathoms (21.95m), wing-end to wing-end.

1.3. Distribution of the fishery

As previously mentioned queen scallops form aggregations and so fishing activity for queen scallops is similarly spatially distributed. The permanence of queen scallop beds means that fishers do not exhibit prospecting behaviour and fish within traditionally defined queen scallop grounds. This lack of prospecting means that fishing impacts on areas that do not sustain commercially viable abundances of queen scallops are limited.

1.4. Impacts of trawls on benthic assemblages

Bottom-trawling, using gears such as benthic otter trawls, beam trawls and scallop dredges, is thought to be one of the greatest causes of disturbance to marine benthic communities. As well as having direct effects on target species through a reduction in abundances trawling has wider biogeochemical impacts on the environment (Kaiser *et al*., 2000). Trawling can impact benthic biota through direct removal, burial or crushing, all of which can lead to increased mortality; be it direct or indirect as a result of increased susceptibility to predation (Jenkins *et al*., 2001b; Kaiser *et al*., 2002; Lambert *et al*., 2011 [see Appendix 2]). The physical characteristics of the seabed may also be altered by the passage of trawls through the creation of tracks in the sediment created by trawl doors and rockhopper gear, which may be clearly visible in some cases with the use of side-scan sonar *(*Hinz *et al*., 2009; Humborstad *et al.,* 2004; Kaiser *et al*., 2002*).* The depth of tracks, which may be up to 5cm deep, is dependent on the composition of the sediment and the size and performance of trawls used; larger trawls and softer sediments both lead to increases in the depth of trawl tracks. The persistence of trawl tracks is dependent on sediment type, current, exposure, and biological activity with tracks taking longer to disappear in either deeper or sheltered areas with fine sediments (Tuck *et al.,* 1998; Smith *et al*., 2000; Humborstad *et al.,* 2004). Repeated passes of fishing gear may lead to smoothing of the sediment and the removal of features such as sand waves. In addition, repeated fishing may lead to the destruction of emergent epifauna and biogenic structures such as tubes and burrows (Schwinghamer *et al.,* 1996) which play an important role in increasing habitat complexity. Increased habitat complexity has the advantage of increasing the range of available niches and has been shown to have a positive impact on biodiversity (Lambert *et al*., 2012 [see Appendix 2]). Fishing activity may also impact the environment through the resuspension and subsequent resettlement of sediment. Changes in sediment regimes in an area have the potential to detrimentally impact biota through interference with feeding mechanisms and the settlement of pelagic larval stages (Kaiser *et al*., 2002; O'Neill *et al*., 2013).

Further information related to the impacts of demersal trawls on benthic habitats may be found in the articles contained in Appendix 2.

1.5. The use of VMS data in the spatial allocation of fishing effort

Vessel Monitoring Systems (VMS) were initially developed to assist fisheries enforcement efforts (FAO, 1988; Deng *et al*., 2005); however, their use has since become more disparate (Drouin, 2001). As vessels behave differently when fishing/steaming VMS data may be partitioned into bouts of fishing and steaming based on vessel speed (Witt and Godley, 2007; Dinmore *et al*., 2003; Bastardie *et al*., 2010 Needle and Catarino, 2011). Therefore VMS, in providing data related to the spatial and temporal distribution of fishing effort (Witt and Godley, 2007**;** Mills *et al*., 2004; Palmer and Wigley, 2009), is increasingly being used by fisheries managers (Dinmore *et al*., 2003; Murawski *et al*., 2005; Lee *et al*., 2010; Rijnsdorp *et al*., 2011). When used correctly VMS provides managers with spatially specific estimates of both the distribution and the intensity of fishing effort and allows rapid responses to changing conditions within a fishery (Guilin, 2005; Deng *et al*., 2005; Murawski *et al*., 2005). The primary advantages of VMS systems are the accuracy with which spatial data is recorded, the near real time availability of data (Saitoh *et al*., 2011) and their autonomous nature. VMS systems in being fully automated remove potential errors resulting from fishers not filing logbook entries consistently or accurately.

1.6. Biotope mapping of the Isle of Man territorial sea

Biotope mapping of the territorial sea was conducted in 2008. Here still and video camera surveys were collected at 154 stations around the Island aboard the RV Prince Madog as described in Hinz *et al*., (2010) and Murray *et al*., (2009) and assigned to recognised biotopes, using the Marine Habitat Classification for Britain and Ireland Version 04.05 (Connor *et al*. 2004), by White (2011). Four main features of conservation concern were identified during the survey namely, maerl, horse mussels (*Modiolus modiolus*), *Sabellaria spinulosa* and the anemone *Edwardsia timida,* with two of the maerl forming species also being separately designated (Table 1).

Table 1. Habitats and species of conservation concern identified by 2008 habitat survey around the Isle of Man. Designating legislation are included as a footnote (Note the Isle of Man is currently in the process of formulating a list of BAP species and habitats specific to the island).

Species/Habitat	**UK BAP[1]**	**Annex I/V[2]**	**OSPAR[3]**
Maerl beds	✓		✓
Phymatolithon calcareum	✓	✓	
Liothothamnium coralloides	✓	✓	
Modiolus beds	✓		✓
Sabellaria spinulosa		✓	✓
Edwardsia timida	✓		

(1) UK Biodiversity Action Plan (BAP) priority habitats/species
(2) Annex V/ Annex I of the EC Habitats Directive
(3) OSPAR priority habitats

1.7. Aims and objectives

The aims of this study were:

1. to assess the distribution and between year variability of fishing effort by vessels trawling for queen scallops within the Isle of Man territorial sea from 1st January 2011 to 31st December 2013
2. to assess what proportion of the territorial sea is impacted by fishing and to what extent
3. to identify areas of the seabed around the Isle of Man that contain either species or biotopes of particular importance from a conservation point of view
4. to assess what impact the trawl fishery has on the species/biotopes identified above
5. to collate empirical evidence related to the known effects of demersal otter trawls on benthic assemblages

2. Methods

In this study fishing activity was assumed to occur at between 1.2 and 3.4 knots as this has been shown to give an accurate representation of fishing activity (Jenkins, 2001b; Lambert *et al*., 2011; Murray *et al*., 2011). Fishing intensity was calculated based on the number of times an area of $1km^2$ was swept by trawls over the three year period for which VMS data was available. An intensity level of 1 means the entire $1km^2$ area was swept once in the three year period. For each VMS point there is an associated speed and given the two hour polling interval the distance fished represented by each individual VMS point may be approximated. All trawls were for the purpose of this study assumed to have a trawl net opening of 18.3m based on values obtained from vessel logbooks in Lambert *et al*., (2012). Thus the swept area associated with each VMS point was calculated as the product of vessel speed, VMS polling interval and the width of the mouth of the net (0.018m). A $1km^2$ grid of squares, encompassing the entire territorial sea, was created in ArcGIS 10.1 and the total area swept for each calculated based on the sum of the associated swept areas for all the VMS points contained within. While Lambert *et al*., (2011) has previously shown fishing intensity around the Island to be as high as 2.8 yr^{-1}, this was based on both dredges and trawls targeting both king and queen scallops. Here the impacts of queen scallop trawls were considered in isolation giving a lower level of fishing intensity ranging from 0 to 1.16 yr^{-1}. The standard deviation between years was calculated in order to determine which areas of the territorial sea were contributing to the variance in fishing distribution between years.

3. Results

3.1. Area of territorial sea affected by queen scallop trawl fishery

The three year footprint of the fishery shows that the majority of the territorial sea is not trawled for queen scallops (Figure 1). In reality fishing effort is even more densely aggregated than the simple footprint of the fishery would suggest with effort being concentrated in particular areas, the precise location of which may vary between years. Figure 1 shows that the average area of the territorial sea not impacted in a given year is in excess of 85%. Fishers, relying on previous knowledge, target specific areas of the territorial sea with prospecting behaviour being minimal. This historical knowledge related to likely areas of queen scallop abundance has the benefit of increasing efficiency and reducing damage to sensitive areas ill-suited to hosting commercially viable abundances of queen scallops. Less than 1% of the territorial sea is trawled at an intensity of greater than 0.5km^2 trawled per km^2 of seabed and in fact 2011 was the only year in this study where a level in excess of 100% impacted was reached (Figure 3). While the spatial distribution of effort varied on an annual basis the mean footprint of the fishery was relatively stable at 11.85% ± 0.78% of the area of the territorial sea (Figure 2 and Figure 3).

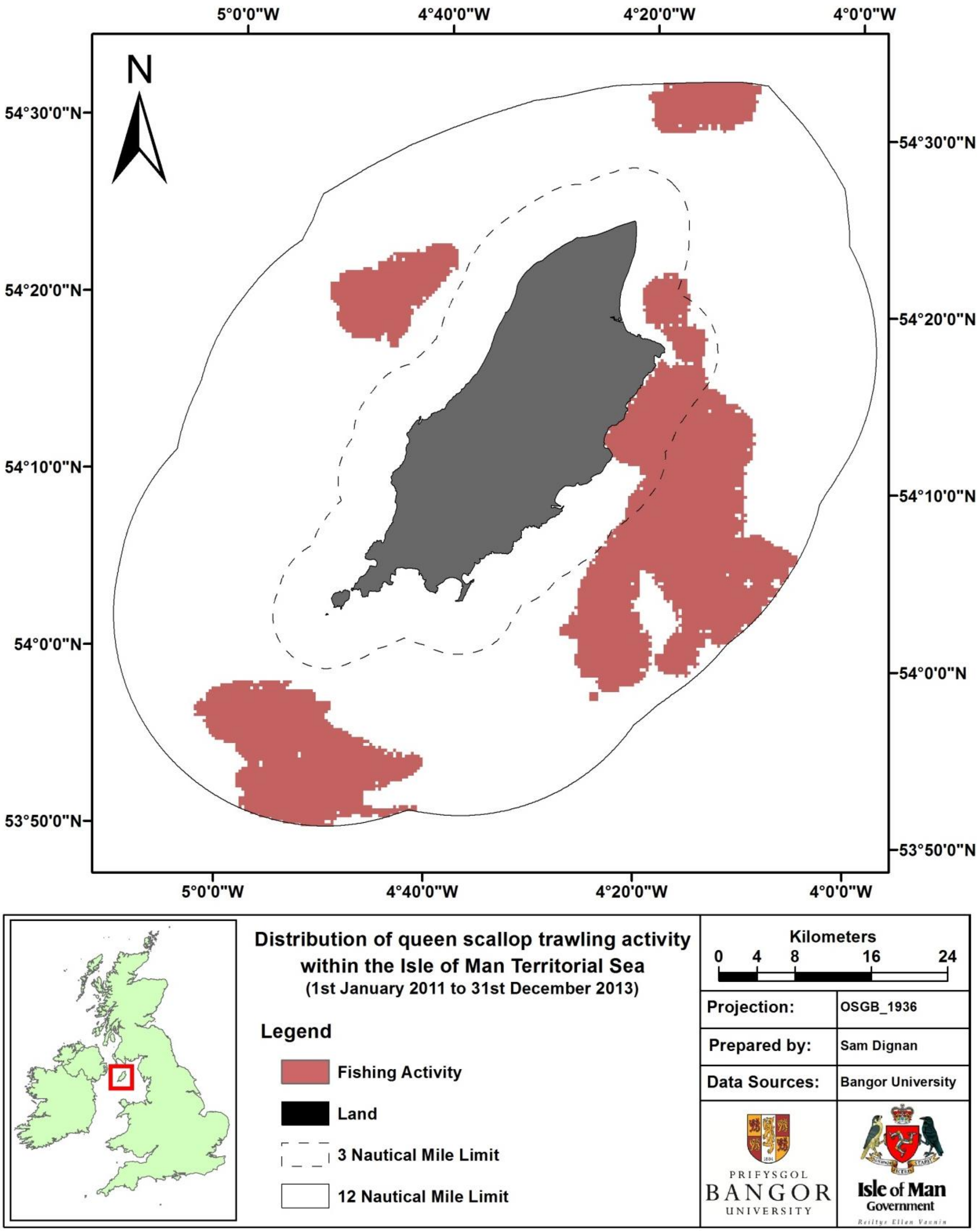

Figure 1. Three year footprint, 1st January 2011 to 31st December 2013, of trawling activity targeting queen scallops in the Isle of Man territorial sea. Fishing extent calculated from VMS and Logbook data.

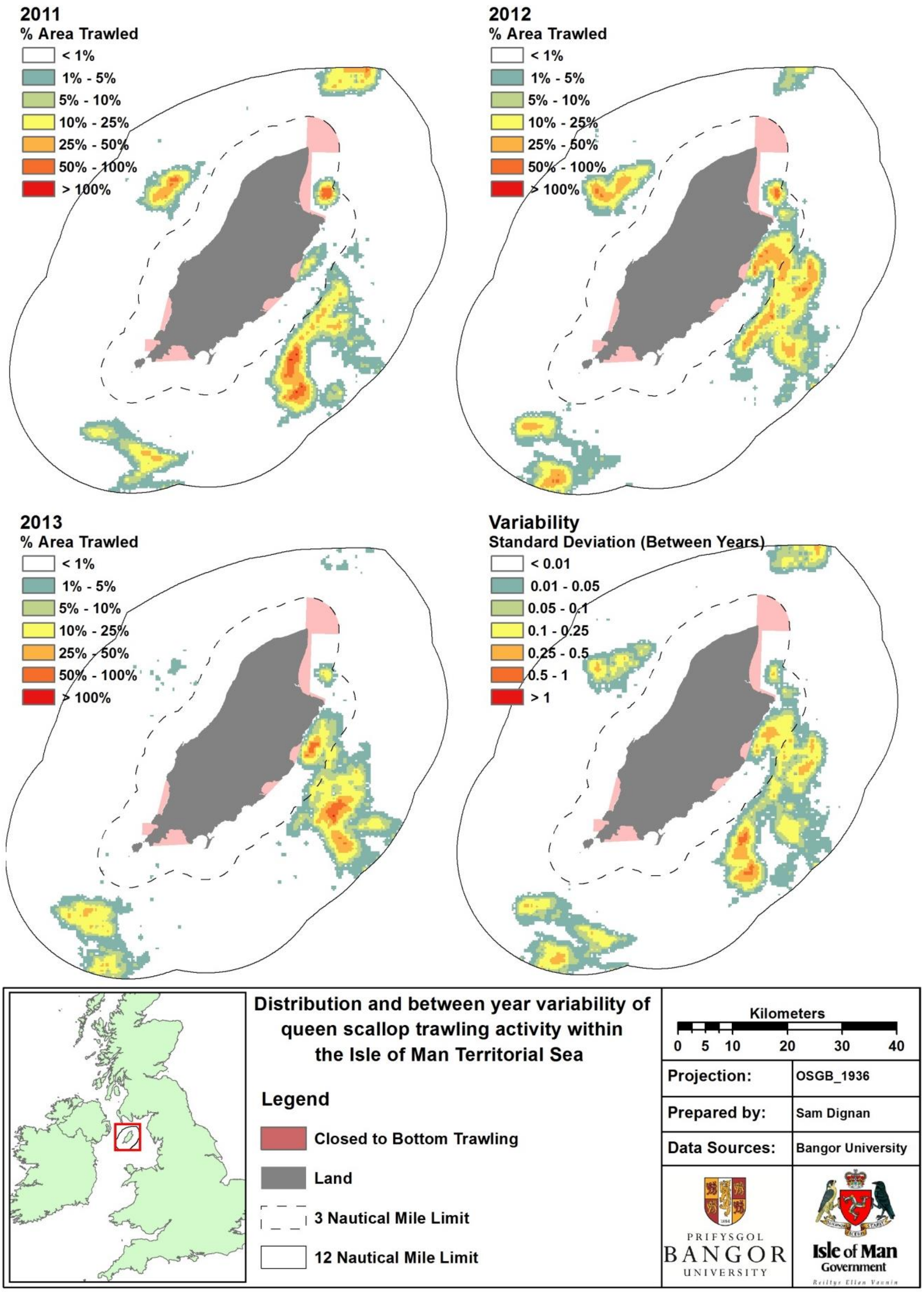

Figure 2. Fishing intensity in the Isle of Man queen scallop trawl fishery calculated from VMS and logbook data. Intensity is based on area dredged with 0% being no fishing activity and 100% being $1km^2$ trawled per $1km^2$ of seabed. Standard deviation between years shows the extent to which fishing activity in particular areas is variable.

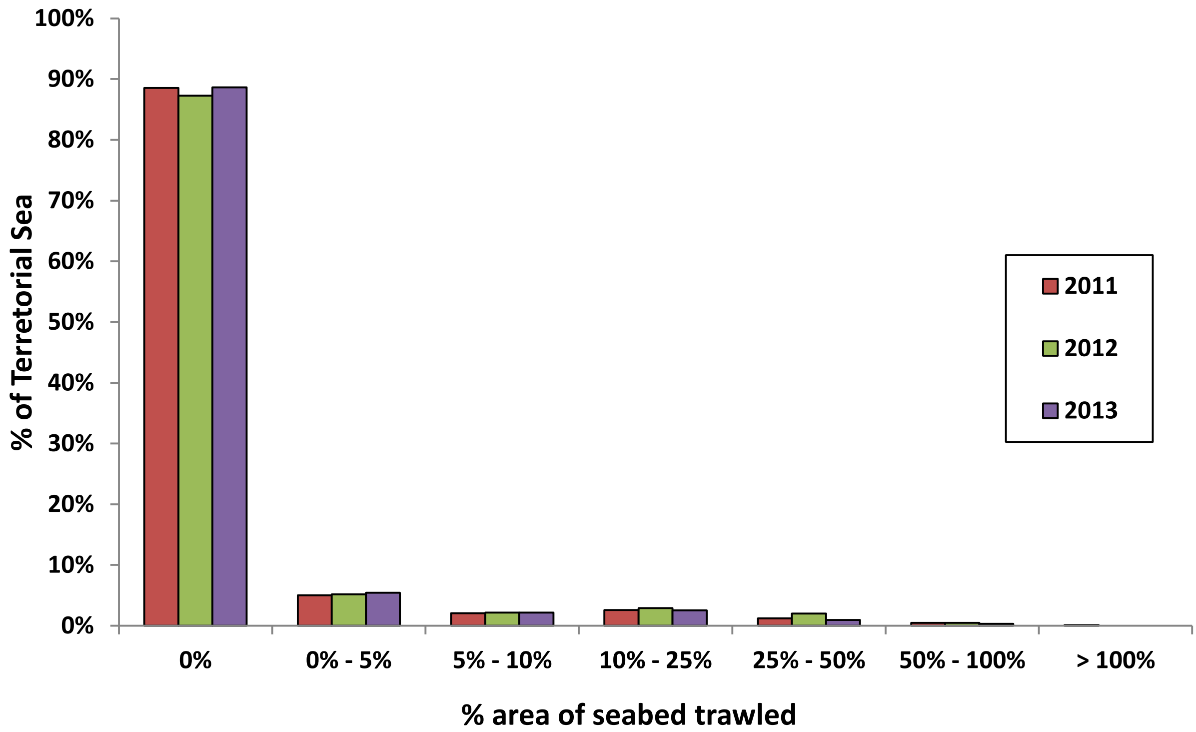

Figure 3. Frequency distribution of fishing intensity in the Isle of Man queen scallop trawl fishery by % area of Manx territorial waters in 2011, 2012 and 2013. Intensity is based on area fished with 0% being no fishing activity and 100% being $1km^2$ trawled per $1km^2$ of seabed.

3.1. Interaction with dredge fisheries and the potential for cumulative impacts

The potential for cumulative impacts of trawling and dredging for queen scallops has been lessened by the exclusion of dredging for queen scallops from much of the territorial sea. Figure 4 shows the extent of queen scallop dredging in the 2011, 2012 and 2013 fishing season. The introduction of a "Queenie Conservation Zone" coupled with a designated dredge box and a specific separate Total Allowable Catch (TAC) for the dredge fishery has led to its footprint being much reduced in the 2013 season to December 31st. The potential does, however, remain for cumulative impacts of king scallop dredges and queen scallop otter trawls to have disproportionately damaging effects compared to one or the other in isolation. The cumulative impacts of fishing activity are difficult to quantify and in the Isle of Man the issue is further complicated by historical fishing activity. With there being little or no pristine areas of habitat capable of sustaining commercially viable abundances of scallops it is difficult to find comparable areas of exploited and unexploited habitat to compare. However, with scallops trawls shown to be much less damaging to the marine environment when compared with scallop dredges (Hinz *et al.*, 2012 [see Appendix 2]), it may be inferred that the effects of queen scallop dredging are minor in relation to background levels of disturbance from the king scallop fishery; which also covers a much wider area of the territorial sea.

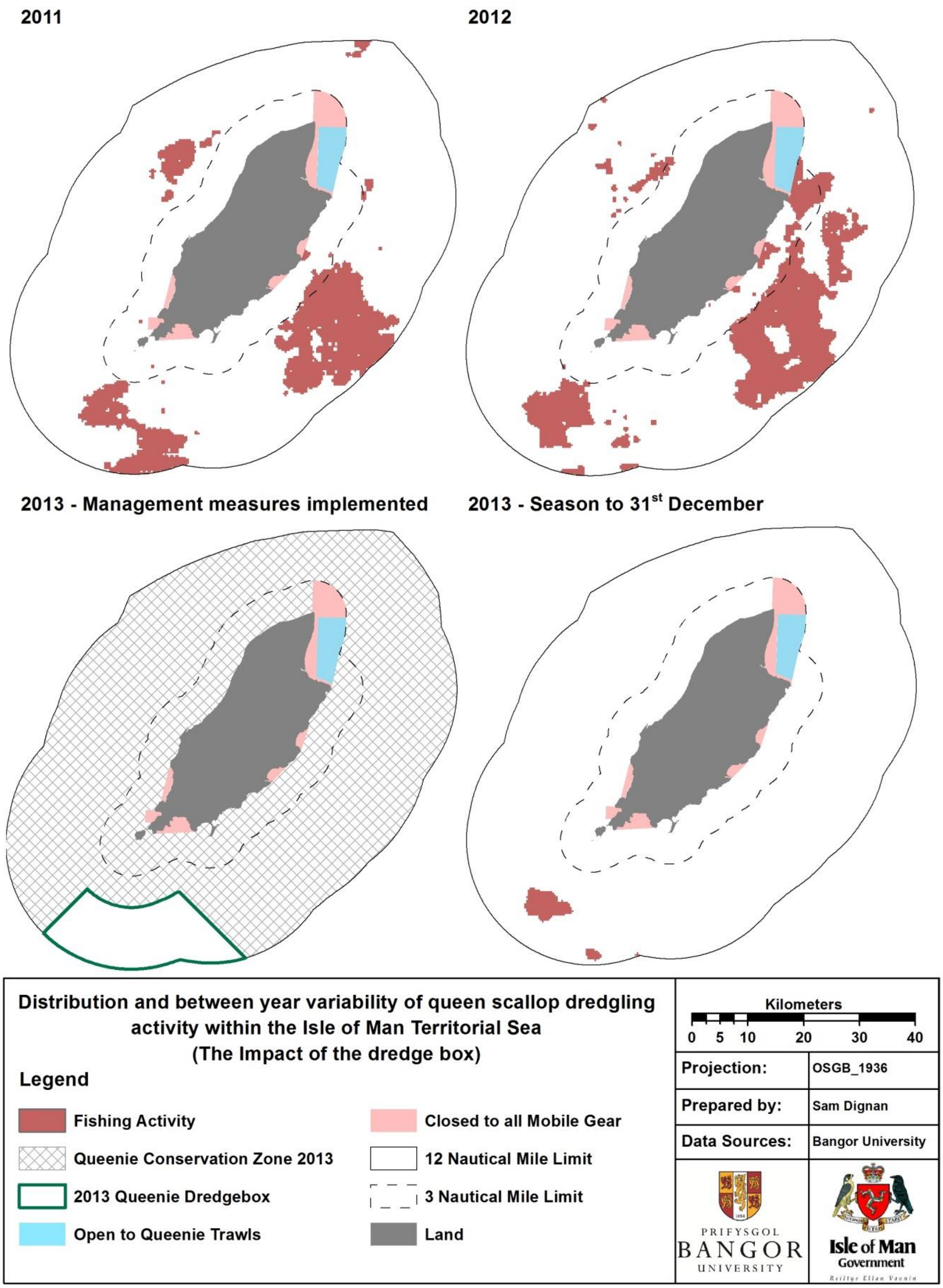

Figure 4. Footprint of dredging activity targeting queen scallops for the 2011, 2012 and 2013 fishing seasons (e.g. 2011 season runs from 1st June 2011 to 31st May 2012) in the Isle of Man territorial sea. Fishing extent calculated from VMS and Logbook data. Also location of queen scallop conservation zone and dredge box implemented for 2013 season.

3.2. Species and Biotopes of Conservation Concern

For the most part fishing effort was not seen to coincide with the presence of the four features of conservation concern identified within Manx waters during the 2008 habitat survey. The exception to this was the presence of *Sabellaria spinulosa* in the extreme south-west of the territorial sea. The *Sabellaria spinulosa* identified in the survey was not seen to be reef forming and rather was present in disparate clumps (White, 2011). Historically, the area in question is heavily dredged for both king and queen scallops and studies have shown this method of fishing to be much more destructive to benthic habitats than trawling (Kaiser *et al*., 2006; Collie *et al*., 2000). In addition substrata suitable for scallops tend to be mobile in nature and may be subject to natural cycles of disturbance which render them ill-suited to supporting structurally complex benthic assemblages.

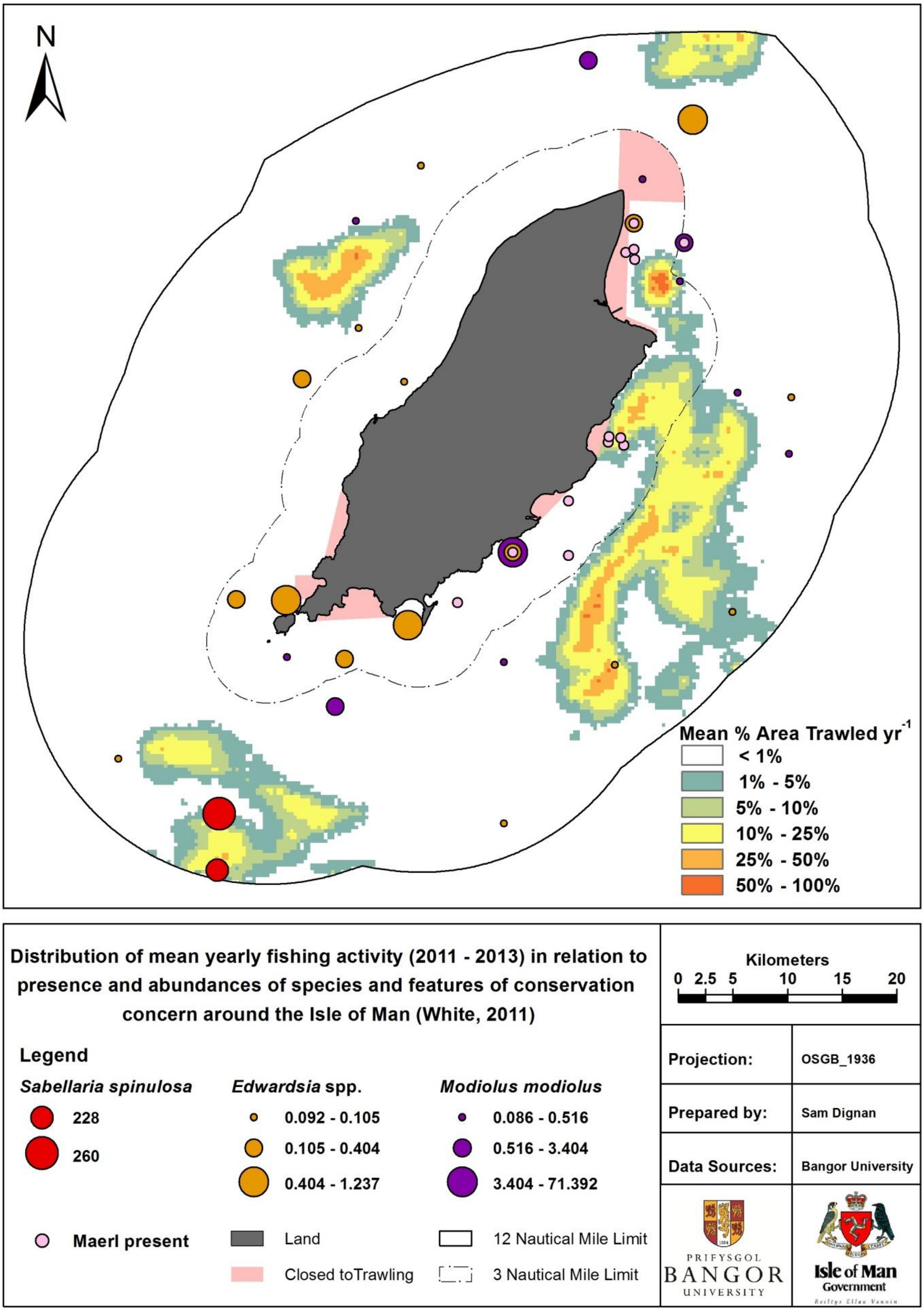

Figure 5. Distribution of species and features of conservation concern, *Sabellaria spinulosa, Edwardsia* spp. *Modiolus modiolus* and maerl in relation to mean yearly aggregations of fishing effort in the Isle of Man queen scallop fishery (2011 to 2013).

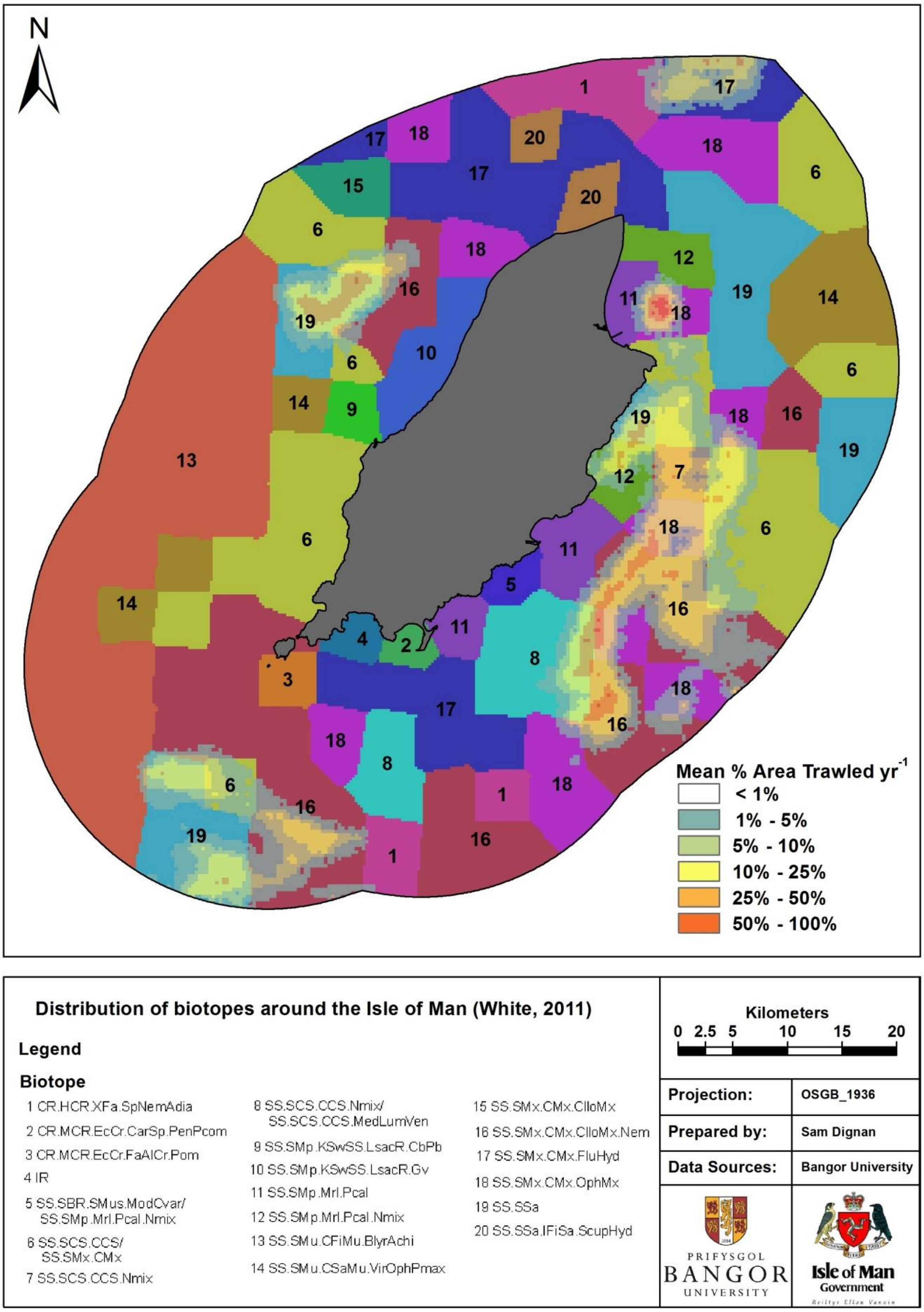

Figure 6. Distribution of biotopes corresponding with significant community groupings identified in benthic habitats around the Isle of Man by White (2011) overlaid with mean fishing intensity per year. Classification based on the Marine Habitat Classification for Britain and Ireland Version 04.05 (Connor *et al*., 2004). For further descriptions of biotopes see Appendix 1.

4. Conclusion

The queen scallop trawl fishery in the Isle of Man is spatially restricted due to the distribution of queen scallops, with the majority of the territorial sea being untouched; as a result large areas are effectively closed to trawling (Figure 1). Fortunately, due to an absence of the target species rather than any explicit management measures, trawling activity occurs in areas distinct from many of the Island's more vulnerable marine habitats (Figure 5 and Figure 6). Habitats likely to be typical of much of the queen scallop fishing areas represent, whether naturally or as a result of years of fishing effort, areas that are relatively robust to the impacts of fishing. While fished areas may potentially represent biotopes that would not have occurred naturally around the island and whose characteristics have by now been irreversibly altered, the fact remains that they are well suited to hosting abundances of scallops of both types and effectively act to limit prospecting behaviour elsewhere in the territorial sea. However, while the extremely concentrated nature of the resource infers advantages in terms of the spatial distribution of the impacts of fishing, there is also the potential that, with increased effort and high catch efficiencies, queen scallop abundances may rapidly become depleted.

Where trawling occurs it does not take place in isolation rather it is set against high background levels of disturbance from the king, and historically, the queen scallop dredge fisheries. Efforts to exclude queen scallop dredging from much of the territorial sea should be successful in reducing the potential for the accumulation of impacts between gear types targeting queen scallops (Figure 4). Unfortunately as no commercially viable methods of capture for king scallops less destructive to the marine environment than dredging are available at present these high levels of background disturbance from the king scallop dredge fishery look set to continue. With current background and historical levels of disturbance as high as they are it is very difficult to isolate the impacts of the trawl fishery. The forthcoming ban on multi-rig trawls and further restrictions on net sizes will have additional benefits in restricting potential future impacts to seabed. As well as this, any gear improvements which reduce bottom drag, such as lighter net construction, will have the dual benefits of decreasing both the impact on benthic biota and fuel use within the fishery and so should be fully supported.

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6. Appendix

Appendix 1. Conservation designations corresponding with each biotope classification defined for the benthic communities identified around the Isle of Man are presented according to the correlation table accompanying the Marine Habitat Classification for Britain and Ireland Version 04.05 on the JNCC website (Joint Nature Conservation Committee, 2010a). Comments regarding the applicability of the designation to the Isle of Man are also presented. Annex I habitat "Sandbanks which are slightly covered by sea water all the time" may be applicable to sandy habitats which occur at <20 m depth. Table taken from White, (2011).

Biotope	UK BAP Habitat	Annex I Habitat	OSPAR Priority habitat	Applicability to Isle of Man
CR.HCR.XFa.SpNemAdia	-	Reefs	-	Rocky reef seemed most applicable to stations 208 and 211.
CR.MCR.EcCr.CarSp.PenPcom	-	Reefs	-	Applicable
CR.MCR.EcCr.FaAlCr.Pom	-	Reefs	-	Applicable
IR	-	Reefs	-	Applicable
SS.SBR.SMus.ModCvar/ SS.SMp.Mrl.Pcal.Nmix	Horse mussel beds/Maerl beds	Reefs (Modiolus) Sandbanks which are slightly covered by sea water all the time (Maerl)	*Modiolus modiolus* beds/ Maerl beds	-"Beds" applicable, "Reefs" potentially applicable. -"Sandbanks" potentially applicable as station 23 was close to the appropriate depth, however the substratum at station 23 was likely too coarse to be considered a sandbank.
SS.SCS.CCS/SS.SMx.CMx	Subtidal sands and gravels (SS.SCS.CCS)	Sandbanks which are slightly covered by sea water all the time (SS.SCS.CCS)	-	-Sands and gravels applicable -"Sandbanks" potentially applicable, but most stations characterized by these biotope complexes occurred at depths greater than 20 m.
SS.SCS.CCS.Nmix	Subtidal sands and gravels	Sandbanks which are slightly covered by sea water all the time (SS.SCS.CCS)	-	-Sands and gravels applicable -"Sand banks" potentially applicable, but the station represented by this classification occurred at a depth greater than 20 m.

Table 5 continued.

Biotope	UK BAP Habitat	Annex I Habitat	OSPAR Priority habitat	Applicability to Isle of Man
SS.SCS.CCS.Nmix/ SS.SCS.CCS.MedLumVen	Subtidal sands and gravels	Sandbanks which are slightly covered by sea water all the time (SS.SCS.CCS)	-	-Sands and gravels applicable -"Sandbanks" unlikely as stations represented by this classification occurred at depths greater than 20 m and were characterized by gravelly substrata.
SS.SMp.KSwSS.LsacR.CbPb	May occur in "tide-swept channels"	-	-	Potentially applicable
SS.SMp.KSwSS.LsacR.Gv	-	-	-	-
SS.SMp.Mrl.Pcal	Maerl beds	Sandbanks that are slightly covered by seawater all the time	Maerl beds	-Maerl applicable, though not all maerl habitats exhibited thick beds -"Sandbanks" unlikely as the substrata which occurred at the stations represented by this biotope had coarse components, including stones and shells, and may not be characteristic of sandbanks.
SS.SMp.Mrl.Pcal.Nmix	Maerl beds	Sandbanks that are slightly covered by seawater all the time	Maerl beds	-Maerl applicable, though not all maerl habitats exhibited thick beds "Sandbanks" is potentially applicable to stations 22, 409, 410, and 411. The substrata at the other stations represented by this biotope may have been too coarse.
SS.SMu.CFiMu.BlyrAchi	Mud habitats in deep water	-	-	Applicable
SS.SMu.CSaMu.VirOphPmax	Mud habitats in deep water	-	-	Applicable
SS.SMx.CMx.ClloMx	-	-	-	-

Table 5 continued.

Biotope	UK BAP Habitat	Annex I Habitat	OSPAR Priority habitat	Applicability to Isle of Man
SS.SMx.CMx.FluHyd	-	-	-	-
SS.SMx.CMx.OphMx	-	-	-	-
SS.SSa	Subtidal sands and gravels	Sandbanks which are slightly covered by sea water all the time (for sub-types within this broad habitat)	-	-Sands and gravels applicable -"Sandbanks" potentially applicable as some stations that were characterized by sand occurred at depths < 20 m.
SS.SSa.IFiSa.ScupHyd	Subtidal sands and gravels	Sandbanks which are slightly covered by sea water all the time (for sub-types within the biotope complex SS.SSa.IFiSa.ScupHyd)	-	-Sands and gravels applicable -"Sandbanks" potentially applicable to station 72, as this station occurred at < 20 m. "Sandbanks" is unlikely for station 112 as this station occurred deeper than 20 m and had both shells and stones on the sediment surface, which might not be characteristic of a sandbank habitat.

Appendix 2. Relevant research articles published on the impacts of scallop fishing in the Isle of Man.

Article 1:

Hinz, H., Murray, L. G., Malcolm, F. R., and Kaiser, M. J. (2012). The environmental impacts of three different queen scallop (*Aequipecten opercularis*) fishing gears. *Marine environmental research*, 73, pp. 85-95.

Article 2:

Lambert, G. I., Jennings, S., Hiddink, J. G., Hintzen, N. T., Hinz, H., Kaiser, M. J., and Murray, L. G. (2012). Implications of using alternative methods of vessel monitoring system (VMS) data analysis to describe fishing activities and impacts. *ICES Journal of Marine Science: Journal du Conseil*, 69(4), pp. 682-693.

Article 3:

Lambert, G. I., Jennings, S., Kaiser, M. J., Hinz, H., and Hiddink, J. G. (2011). Quantification and prediction of the impact of fishing on epifaunal communities. *Marine Ecology Progress Series*, 430, pp. 71-86.