Predicted impacts of proposed management measures in the Isle of Man's *Pecten maximus* fishery

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SUMMARY

This report examines the likely impacts on the scallop fishing fleet of management measures proposed by the Isle of Man Government. A 221 kW maximum engine power limit would potentially exclude 80 registered scallop dredging vessels from fishing in the Isle of Man's territorial waters. However, only 44 of these are known to have fished in this area during the 2008/2009 scallop season. Bag limits would effectively limit fishing effort and catches when scallop abundance is high. However, this may be difficult to enforce and would also prevent vessels landing catches fished over two or more days to the Isle of Man. A seven dredges a-side limit would have reduced effort by 12.5% on 13% and 34% of vessel days for Manx and UK vessels, respectively. Tow bar length and engine power restrictions alone will be most effective in limiting effort and catches when scallop abundance is lower, by making fishing in the Isle of Man's territorial sea less economically viable. However, a tow bar length, or dredge number, restriction combined with a curfew could be used to limit catches by a fleet of a given size. A curfew of 1800 to 0600, in line with the 0 to 3 nautical mile zone, is recommended with the option to alter this to reduce landings as necessary. A curfew will be easier to enforce than a bag limit and will affect all vessels equally. The combined effect of these measures will be to help ensure that high scallop densities are not depleted rapidly at the beginning of the fishing season, and that fishing effort can be reduced when densities are low. The voluntary closure of areas when scallop abundance becomes very low, as adopted in Ramsey Bay, would also help to prevent over-exploitation. Nevertheless, it is important to consider that there is also enormous latent fishing capacity, which will leave the fishery vulnerable to over-fishing.

1. Introduction

Fisheries management has in most cases failed to achieve sustainable fisheries worldwide due to increasing harvests and uncertainty in predicting critical biological limits (Botsford *et al*., 1997). Fisheries are governed by many management measures, including technical restrictions such as number of dredges or Maximum Continuous Engine Power (MCEP), spatial and temporal limits, and caps on landings. If fisheries management goals are to be attained then in addition to correctly determining appropriate harvest limits it is of prime importance that the likely impacts of specific management measures can be understood. This report aims to address this latter issue with respect to the Isle of Man's great scallop fishery.

Pecten maximus is harvested across northern Europe (Beaumont *et al*., 1992; Beukers-Stewart *et al*., 2003; Fresard and Boncoeur, 2006; Hervas *et al*., 2006). Scallop fisheries receive a great deal of attention partly due to the damage that many of these fisheries cause to benthic species and habitats (Thrush *et al*., 1995; Hall-Spencer *et al*., 2000; Jenkins *et al*., 2001; Morsan, 2009). There are examples of scallop fisheries that have suffered declines including *Chlayms islandica* in Iceland, Greenland and Norway (Garcia, 2006; Jonasson *et al*., 2007) and *Argopecten ventricosus* in the Gulf of Panama (Medina, 2007). Other scallop fisheries have shown increases in stocks following declines, including the *Pecten maximus* fisheries in the Isle of Man (Beukers-Stewart *et al*., 2003; Shephard *et al*., 2010) and the Bay of Brest (Alban and Boncoeur, 2008). In the case of the French fishery the partial recovery has been achieved through a combination of aquaculture and managed wild-capture fishing.

The regulations governing scallop fisheries across the British Isles vary widely. The minimum landing size of scallops in ICES area VIa is 100 mm compared to 110 mm in area VIIa, for instance. Vessels with a MCEP of >221 kW have recently been banned from fishing for scallops in Welsh waters, all vessels banned from fishing within 1 nautical miles the Welsh baseline, and several other restrictions have been placed on vessel size and dredge numbers (The Scallop Fishing (Wales) (No.2) Order 2010). Restrictions on scallop fishing activity may also be imposed by conservation designations such as Special Areas of Conservation (SAC) or other protected areas, one such example being the Firth of Lorn SAC in Scotland (SNH, 2006).

The Isle of Man's *Pecten maximus* fishery is prosecuted from 1st November to 31st May by vessels using toothed, Newhaven, dredges. Management of the fishery differs between an inner 0 to 3 nautical mile zone, and an outer 3 to 12 nautical mile zone, with more stringent regulations in the inner zone. The fishery in the outer zone falls under the jurisdiction of five

authorities, namely the Isle of Man Government, the Welsh Assembly Government, the Scottish Government, the Northern Ireland Executive and DEFRA. Vessels from all of these areas may fish in the Isle of Man's territorial sea. Thus any new management regime may impact upon fishers and processors throughout the British Isles. The aim of this study was to determine the effects of proposed management measures on landings and effort in the Isle of Man's great scallop fishery with reference to the UK and Manx fleets.

2. Methods

The scallop fishery within the Isle of Man's territorial waters is prosecuted by local vessels operating from four main ports in the Isle of Man, and nomadic vessels from the UK. The Isle of Man's territorial sea is divided into two zones for fisheries management purposes. The Isle of Man has exclusive control from the baseline to 3 nautical miles, while from 3 to 12 nautical miles management is shared with the UK administrations. Henceforth, the 0 – 3 zone will be referred to as the inner zone, and 3 – 12 nautical miles as the outer zone. There are several management measures in place that govern the exploitation of the great scallop fishery, (Table 1) and several new measures have been proposed to govern scallop fishing activity (Table 2). All vessels in the fishery use toothed dredges attached to tow bars of varying lengths and diameters, one of which is towed on each side of the vessel.

Table 1. Present management measures within the Isle of Man's *Pecten maximus* fishery.

Management measure	Where the measure is applicable
5 dredges per side	0 to 3 nautical mile zone
8 dredges per side	3 to 12 nautical mile zone
Curfew: 1800 to 0600	0 to 3 nautical mile zone
Curfew: 2100 to 0500	3 to 12 nautical mile zone
≤15.24 m vessel registered length	0 to 3 nautical mile zone
VMS required for all vessels dredging for scallops	0 to 3 nautical mile zone
VMS required ≥15 m overall length	0 to 12 nautical mile zone
Minimum landing size 110 mm	0 to 12 nautical mile zone
Closed season: 01/06 to 31/10	0 to 12 nautical mile zone
Closed areas	Area off Port Erin, and Douglas Bay
Trial scallop ranching areas	Area off Niarbyl, and Laxey Bay
Temporary closure	Ramsey Bay
Maximum of 9 teeth per dredge	0 to 12 nautical miles
Aggregate dredge width of 12.19 m	0 to 12 nautical miles
Minimum tooth spacing of 75 mm	0 to 12 nautical miles
Minimum belly ring internal diameter 75 mm	0 to 12 nautical miles
Minimum dredge net mesh of 100 mm	0 to 12 nautical miles
French dredge prohibited	0 to 12 nautical miles

Table 2. Additional management measures proposed by the Isle of Man Government Department of Environment, Food and Agriculture (DEFA) for the *Pecten maximus* fishery.

Management measure	Where the measure is applicable
7 dredges per side	3 to 12 nautical mile zone
Tow bar length: 5 m	0 to 3 nautical mile zone
Tow bar length: 7.6 m	3 to 12 nautical mile zone
MCEP ≤221 kW	0 to 12 nautical mile zone
Curfew: 1800 (or 2000) - 0600	3 to 12 nautical mile zone
Temporary bag limit: c. 40 – 50 bags per vessel per day	0 to 12 nautical mile zone

A total of 217 vessels were licensed to fish for scallops within the Isle of Man's territorial waters during the 2008/2009 scallop season (Table 3). Of these vessels, 142 may fish for scallops within the inner zone, although only around 88 are likely to do so. Of the vessels licensed to fish in the inner zone, 78 are not required to carry Satellite Vessel Monitoring Systems (VMS). At present no information on tow bar length is recorded in fishers' logbooks or by officers boarding vessels. Fishers may remove dredges from tow bars to meet restrictions on dredge numbers. Thus larger vessels capable of towing more than 8 dredges per side, may fish within the Isle of Man's territorial sea, and vessels capable of towing more than 5 dredges per side may fish within the inner zone. Reducing the maximum permissible tow bar length would require these vessels to carry multiple tow bars.

VMS data were obtained for vessels ≥15m fishing within 12 nautical miles of the Isle of Man, and all vessels licensed to fish within the 3 nautical mile zone. These data were joined to fisher logbook data and vessel registration details for Manx vessels. Vessels <15 m overall length are not required to carry VMS transceivers to fish in the outer zone. Little information is available on the fishing activity of these vessels; however, these vessels are also less likely to be affected by the proposed management measures than the vessels required to carry VMS. For UK vessels landing to the UK no logbook data was available. Data from UK vessels landing to the Isle of Man requires further processing. Therefore catches of these vessels were estimated from fishing time and catch per unit effort of the Manx fleet. VMS records of fishing activity on muddy sediments to the west of the Isle of Man were excluded as these were assumed to represent *N. norvegicus* trawling.

Fishing time was first estimated by excluding non-fishing activity (<1.2 and >3.4 knots) from VMS records based on vessel speed. The time between the first and last records identified as fishing activity for each vessel within each day was taken as the fishing time. The distance covered in that time was then calculated from the mean vessel speed. Data on the width of fishing gear deployed was available for Manx vessels. Thus the area of seabed swept was estimated.

As the width of fishing gear deployed was unknown for the UK vessels these values were estimated from the relationships between vessel specifications and gear width in the Manx fleet. Therefore, regression analysis was used to examine the relationships between vessel length, breadth, tonnage, MCEP and vessel capacity units (VCU) and both the width of gear deployed in the Manx fleet and total catches per vessel. The minimum, mean and maximum catch rates of Manx vessels were used to estimate the catches of UK vessels based on fishing time derived from VMS records.

The area swept was calculated from the width of gear, mean daily vessel fishing speed and fishing time. Catch data were derived from fishers' logbooks. Catches were reported as number of bags of scallops, and the nominal bag weight. However, bag weight was not always given and was only estimated. Therefore, the number of bags is used as the catch unit in this report. Data was summarized into ten day fishing periods over the 212 days of the fishing season. No UK vessels fished on the final two days of the season, and data from Manx vessels is reported separately for these two days.

The number of vessels, fishing time and catches were calculated for Manx and UK vessels with ≤221 kW and >221 kW MCEP fishing within the inner and outer zones. To estimate whether vessels were landing catches to the Isle of Man at the end of each fishing day the proportion of vessels entering a zone within 250 m of the coastline following fishing during each day was calculated using the Spatial Join tool in ArcGIS 9.2. Regression analysis was undertaken using SigmaPlot; analysis of covariance was conducted using R.

3. Results

221 kW MCEP

Excluding vessels with Maximum Continuous Engine Power (MCEP) of ≤221 kW would prevent up to 80 vessels currently licensed to fish for scallops doing so within the Isle of Man's territorial sea. However, far fewer vessels fished within the territorial sea than were licensed to do so in 2008/2009 (Table 3). The maximum MCEP of any vessel licensed to fish for scallops at present is 1135 kW. A total of 25 Manx vessels, 3 of which had >221 kW MCEP, and 41 UK vessels, 32 of which had over 221 kW MCEP, fished within the territorial sea during the 2008/2009 scallop season. All Manx vessels fished within the outer zone, while 23 fished within the inner zone. Of the UK ≤221 kW vessels 9 fished within the inner zone and 15 in the outer zone. Of UK >221 kW vessels 17 fished in the inner zone and 31 in the outer zone. Up to 16 additional <15 m vessels may have been fishing within the outer zone without VMS; at least two of these vessels were sighted dredging for scallops during the 2008/2009 scallop season, both of which had <221 kW MCEP. VMS records were missing for one >221 kW vessel that was known to be fishing in the outer zone, and two >221 kW vessels (these were not fishing in the territorial sea during the 2007/2008 scallop season).

Table 3. Numbers of vessels licensed to fish in the Isle of Man's territorial sea during the 2008/2009 great scallop season.

Vessel length	≤221kW	>221kW	TOTALS
≤10m overall	74 (24)*	4 (0)	**78** **(24)***
10.01m – 15m overall	36	5	**41**
15.01 overall – 15.24m registered	15	8	**23**
>15.24m registered	12	63	**75**
TOTALS	**137**	**80**	**217**

* All under 10 m vessels (78) are permitted to fish for scallops but only 24 are likely to do so.

The number of UK vessels fishing within the territorial sea declined throughout the fishing season (Figure 1). The relationship between time (t) and vessel fishing days (v) was described by the equation: $v = y_0+(ab)/(b+t)$. In the inner zone v_u declined from 25 at the beginning of the season and approached 0 in the 21st period (Figure 1a; a = 3180, b = -0.008, y_0 = -3177, R^2 = 0.55, p=0.0008). In the outer zone v_u decreased less sharply; however, there was only a weak relationship with time (Figure 1b; a = -427, b = 0.045, y_0 = 432, R2 = 0.33, p = 0.028). In the inner zone v_o decreased over the first 30 days but then remained approximately level (Figure 1a; a = -1126, b = 0.02, y_0 = 1127, R^2 = 0.79, p<0.0001). In the outer zone v_o decreased sharply between the first and second periods, thereafter decreasing slightly (Figure 1b; a = -5355, b = 0.018, y_0 = 5368, R^2 = 0.61, p = 0.0002). There was no clear trend in the number of Manx vessels fishing throughout the season, irrespective of MCEP or zone (Figure 2). During the final two days of the season, when no UK vessels fished for scallops in the territorial sea, there were 3 and 7 Manx vessels fishing, respectively.

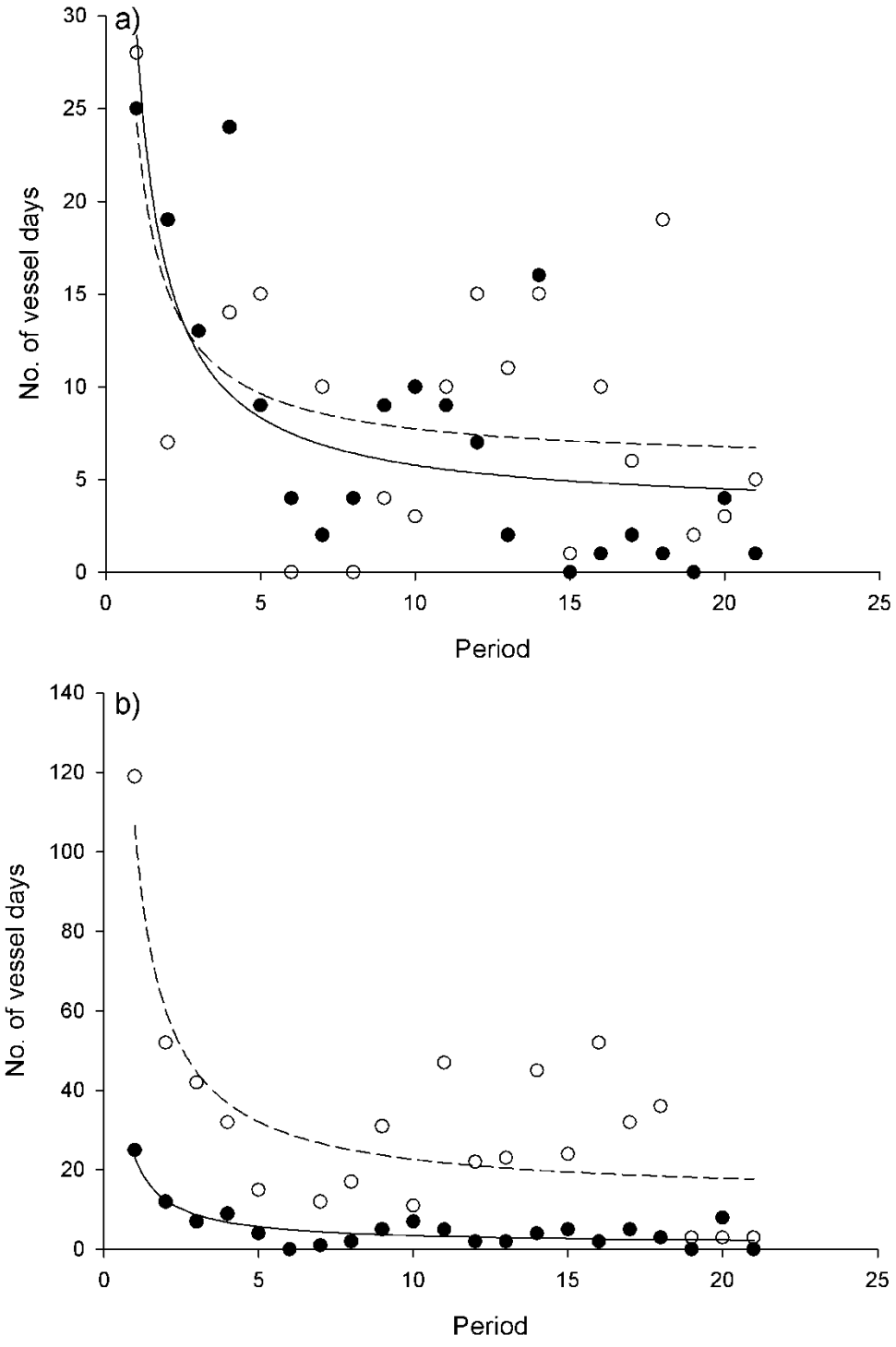

Figure 1. Total number of UK vessel fishing days within the inner zone (solid circles/solid line) and outer zone (open circles/dashed line) with (a) ≤221 KW engine power and (b) >221 kW engine power during each ten day fishing period.

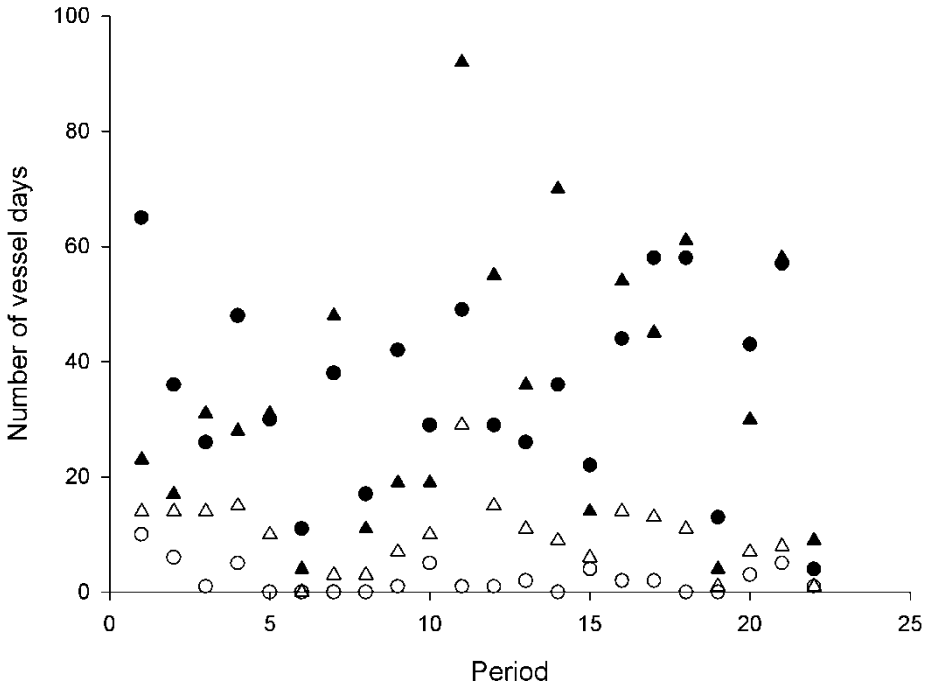

Figure 2. Total number of Manx vessel fishing days within the inner zone (circles) and outer zone (triangles) with ≤221 kW engine power (filled symbols) and >221 KW engine power (open symbols) during each ten day fishing period.

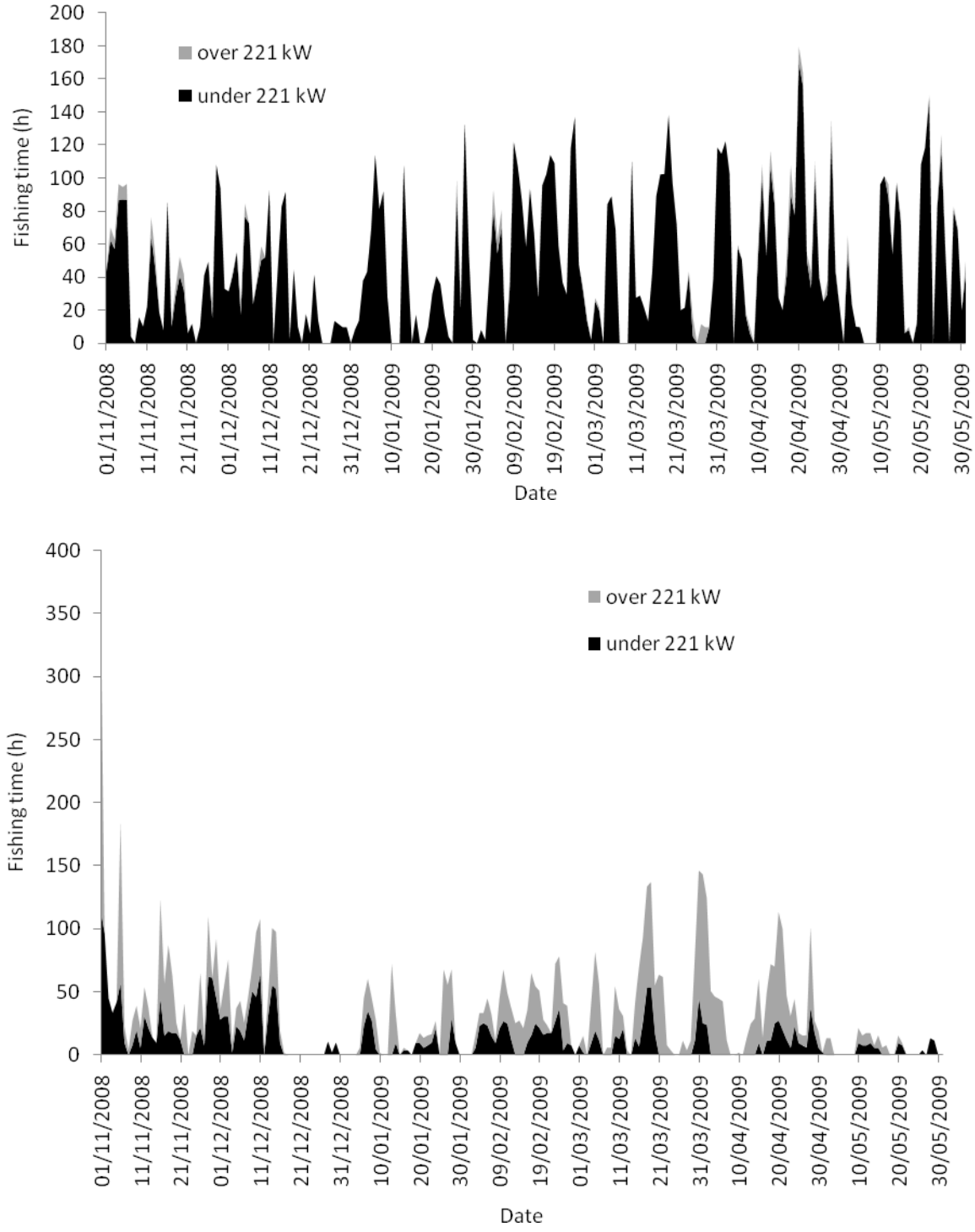

Figure 3. Total daily fishing time of a) Manx and b) UK vessels. Data series are stacked.

Width of fishing gear

VCU (V) exhibited the strongest relationship, compared to length, breadth, engine power or tonnage, with the mean width of dredges deployed (W) by Manx vessels within the territorial sea ($W = 0.034V + 3.157$, $R^2 = 0.797$, $p<0.0001$; Figure 4). However, due to the different limits on dredge numbers within the inner and outer zones, the relationship between V and W might have been different within each zone. Therefore, ANCOVA was used to test for a significant difference in W between the inner and outer zones (Z), with V as covariate. The model W = V x Z was fitted initially; however, the interaction term (V x Z) was not significant ($F = 0.306$, $p = 0.583$). There was also no significant difference between the width of fishing gear deployed within the inner and outer zones. Removing the zone factor did not reduce significantly the variance explained by the model ($F = 1.76$, $p = 0.191$). Therefore, the relationship between V and W can be described by the formula $W = 0.032V + 3.294$; $R^2 = 0.777$, $p<0.0001$, SE = 0.782.

There was a weaker relationship between MCEP and gear width ($y = 0.0217x + 4.5989$, $R^2 = 0.504$) excluding the vessel with the highest MCEP (capable of towing more than eight dredges per side). Therefore, the mean width of gear deployed by vessels with an engine power of 221 kW would be 9.4 m, corresponding to approximately six dredges per side. However, the width of gear towed is clearly not just a function of MCEP. In the Manx fleet a seven dredge a-side limit would have affected 12.3% of vessel days. The effect of this measure would be on larger vessels, predominantly >221 kW MCEP, as evident from Figure 4. Similarly, UK vessels with >221 kW MCEP would be most greatly affected by a seven-a-side dredge limit, affecting an estimated 34% of vessel days. Reducing the number of dredges deployed from 16 to 14 amounts to a 12.5 % decrease in fishing power. There was no significant relationship between MCEP and catch rates measured as bags km^{-2} (Figure 5).

Variance in the number of Manx vessels fishing within the inner and outer zones was heterogeneous (Levene's statistic = 22.928, $p<0.001$). There was no significant difference between the number of Manx vessels fishing within the inner and outer zones (Mood's median, Chi-squared = 0.62, $p = 0.432$). Variance in the number of UK registered vessels fishing within the inner and outer zones was homogeneous (Levene's statistic = 1.211, $p = 0.272$); there was no significant difference in the numbers of vessels fishing in each zone per day (ANOVA, $F_{1,422} = 1.21$, $p = 0.272$).

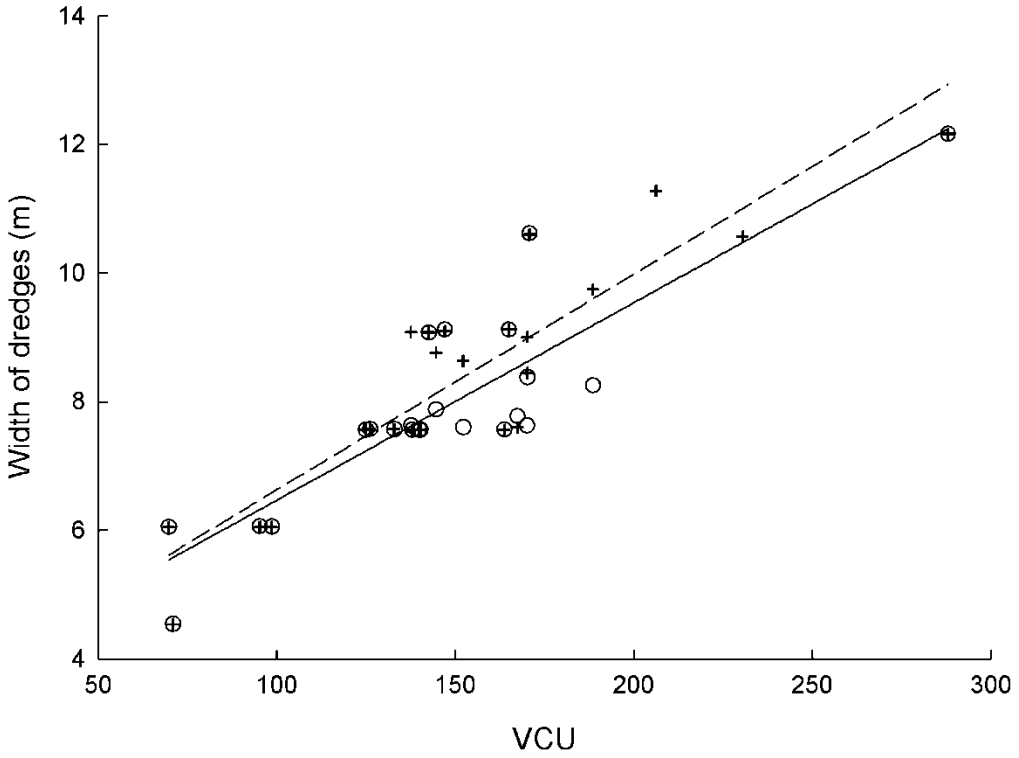

Figure 4. Relationship between Vessel Capacity Units (VCU) and the width of dredges deployed by Manx vessels.

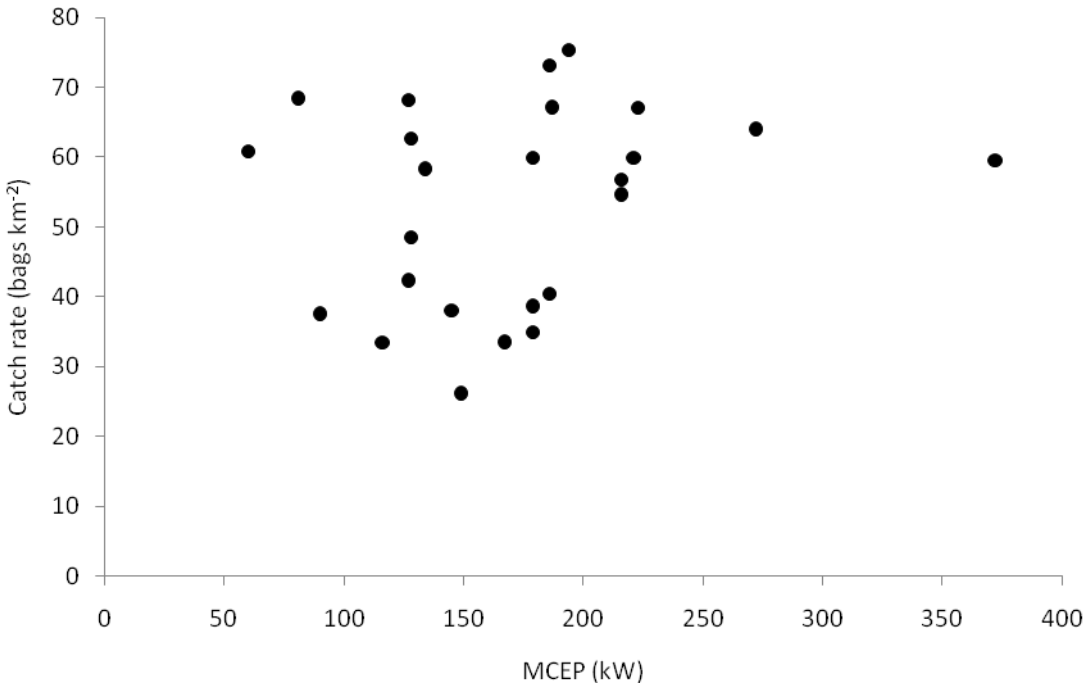

Figure 5. Relationship between Maximum Continuous Engine Power (MCEP) and catch rate.

Bag limit

The majority of Manx vessels caught scallops amounting to between 5 and 20 bags per day (Figure 6). Scallops amounting to over 120 bags were caught on one day but catches of >40 bags per day were rare. Therefore, the impact of a bag limit on Manx vessels, based on the 2008/2009 fishing season, would be small. Vessels >221 kW would be affected to a greater extent (Figure 7). Nevertheless, a bag limit of ≥50 would have almost no impact. For ≤221 kW vessels a bag limit of 35 would have affected 38 fishing days. The relationship between VCU and the mean daily catch of Manx vessels (Figure 8) shows that even the largest vessels, on average, catch fewer than 40 bags of scallops per day. This relationship also indicates that the prevention of larger, more powerful, vessels fishing within the territorial sea would be effective in reducing the landings of the existing fleet.

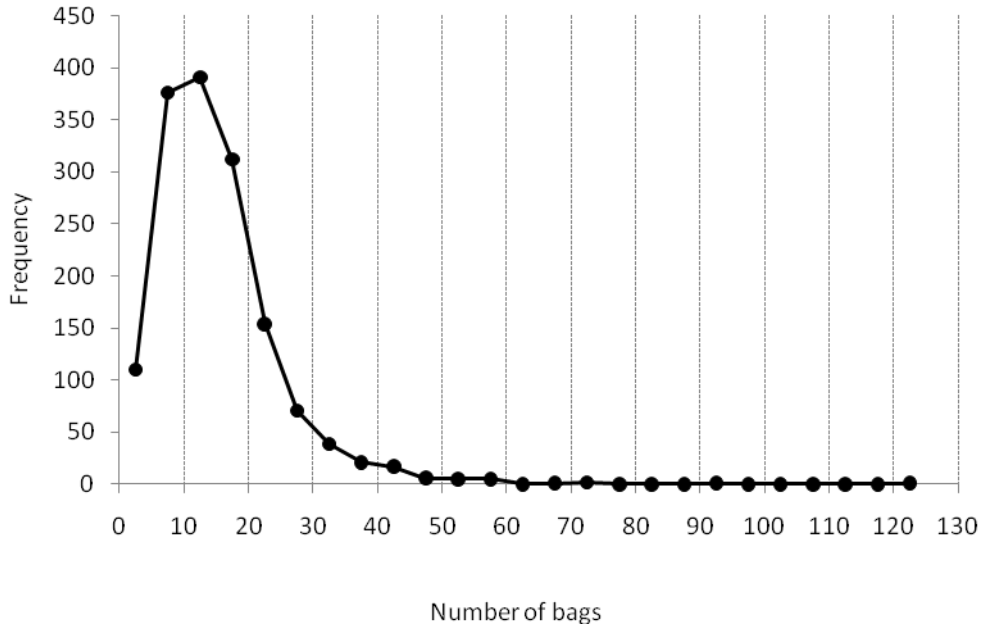

Figure 6. Frequency of number of bags of great scallops landed per fishing trip by the Manx fleet during the 2008/2009 scallop season.

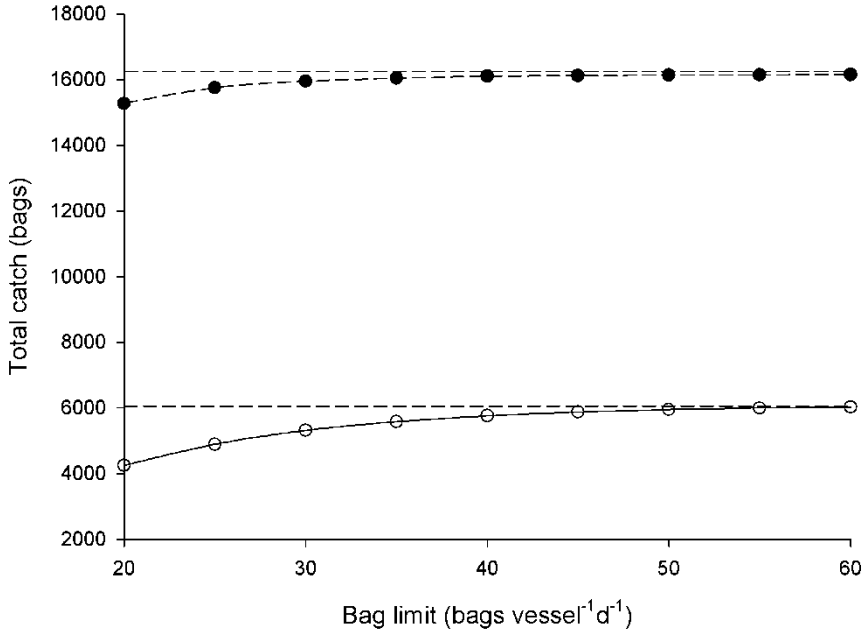

Figure 7. Effect of bag limits on total landings by Manx vessels ≤221 kW (closed circles) and >221 kW (open circles) during the 2008/2009 fishing season. Dashed lines show the actual total catches.

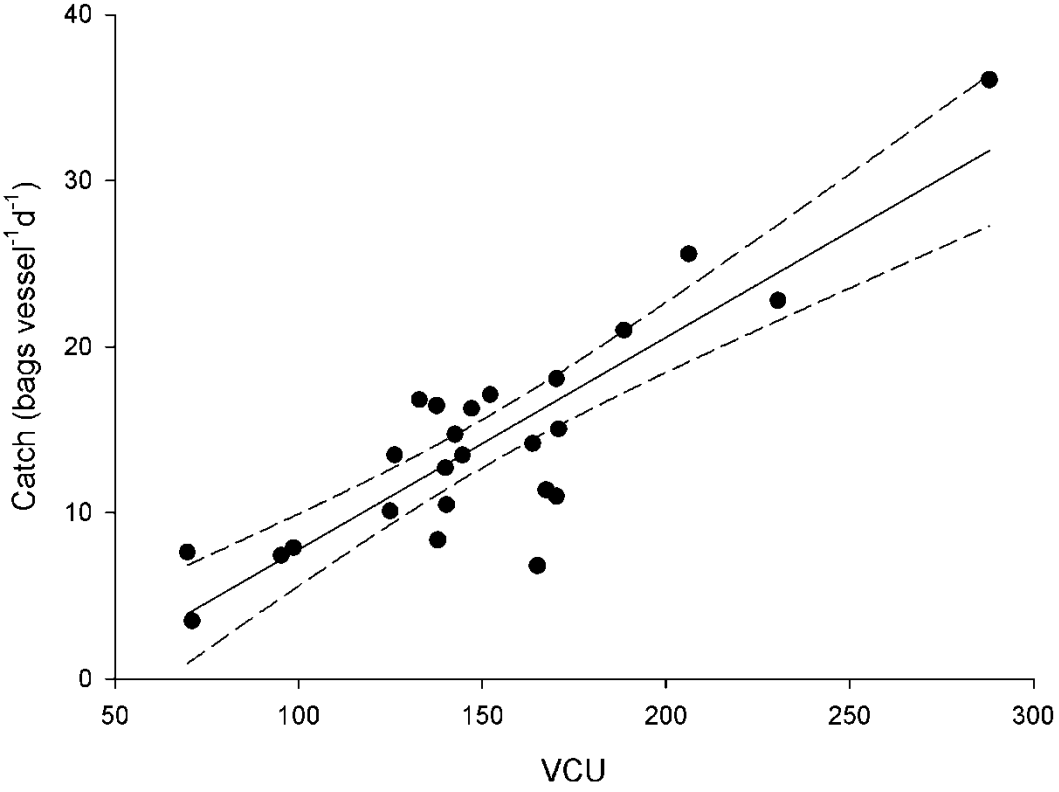

Figure 8. Relationship between Vessel Capacity Units (VCU) and mean catches of Manx vessels ($a = 0.0128$, $y_0 = -5.025$, $R^2 = 0.745$, $p<0.0001$). Dashed lines show 95% confidence interval.

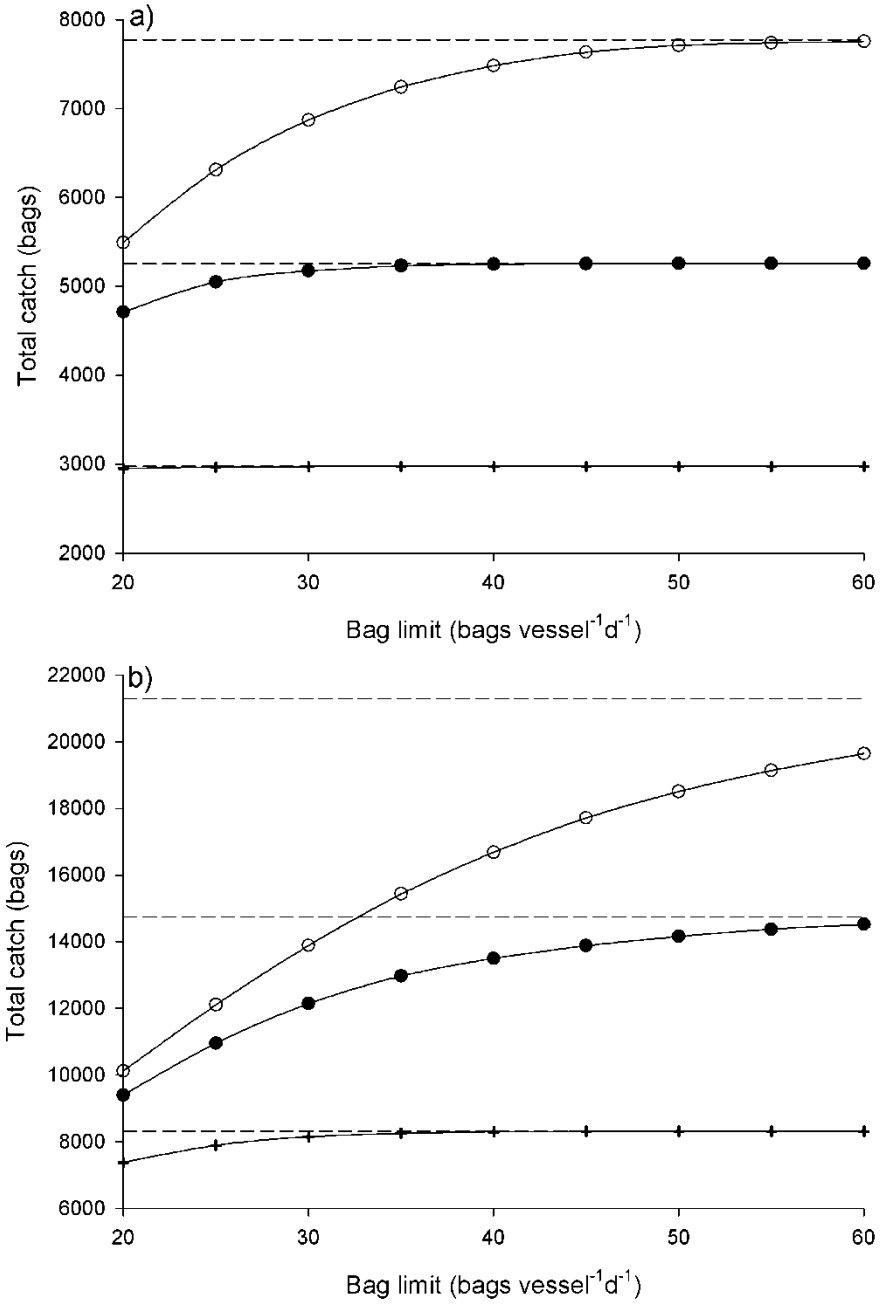

Figure 9. Effect of bag limits on total landings of UK vessels a) ≤221 kW and b) >221 kW fishing within the Isle of Man's territorial sea. Dashed lines show predicted total catches of the UK fleet based on minimum, maximum and mean catch per unit effort of the Manx fleet, and UK fishing effort derived from VMS records. Data points and solid lines show the catches with bag limits imposed where CPUE was at the maximum (open circles), minimum (crosses) and mean (solid circles).

The effect of a bag limit on the daily landings of UK vessels would vary greatly depending on CPUE and the vessel's MCEP. Vessels ≤221 kW would be least affected, with no impact at the lowest CPUE (Figure 9a). There would be a reduction in landings by vessels >221 kW with bag limits of ≤60 at mean CPUE (Figure 9b). Even a bag limit of 60 would result in around 2000 bags a year less being landed at the highest CPUE (Figure 9b). However, at mean CPUE a bag limit of 40 – 50 would have no effect on ≤221 kW vessels (Figure 9a). A bag limit of 40 would reduce landings by fewer than 2000 bags at mean CPUE. However, these values do not account for the fact that many fishers may not land their catch every day, fishing for two or more days. It is estimated that fishers with vessels ≤221kW landed their catch on 73% of the days on which they fished, while those with vessels >221 kW landed on 70 % of the days on which they fished.

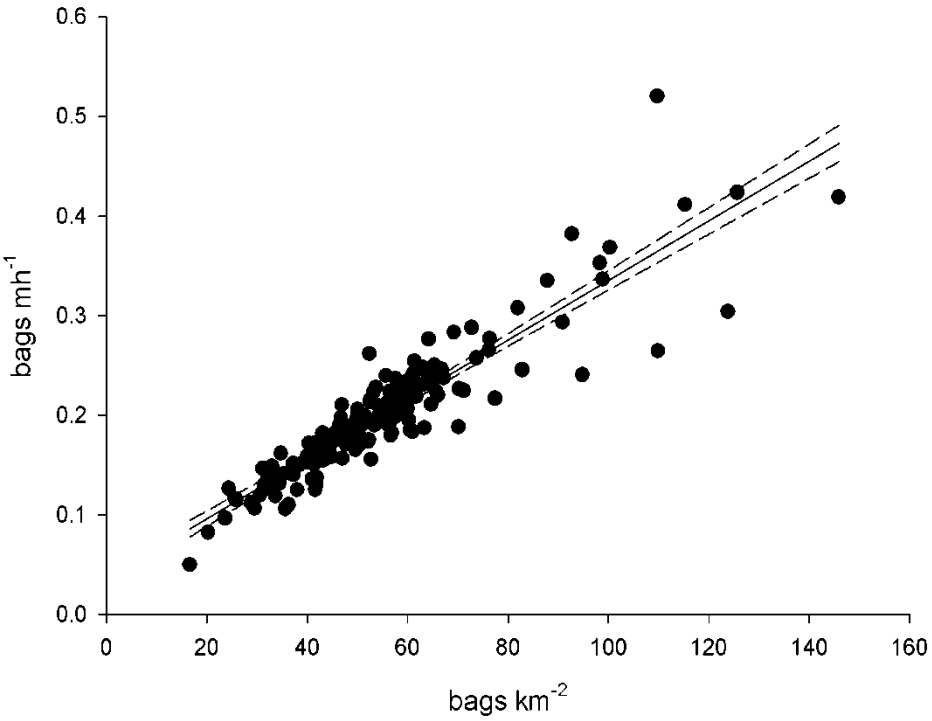

Figure 10. Relationship between catch per area and catch per metre hour.

Curfew

An 1800 to 0600 curfew would have resulted in a 2% reduction in fishing time in UK vessels ≤221 kW, and an 8% reduction in fishing time in UK vessels >221 kW. Increasing the curfew in the outer zone to 2000 to 0600 would have decreased UK ≤221 kW fishing time by less than 0.5%, while for UK >221 kW vessels there would be a 2.5% reduction. Of 32 UK >221 kW vessels, 29 fished for more than 12 hours on at least one day. Of 12 ≤221 kW vessels, 9 fished for over 12 hours on at least one day. Seventeen >221 kW vessels fished for more than 14 hours on at least one day. Four ≤221 kW vessels fished for more than 14 hours on at least one day. An 1800 to 0600 curfew would have resulted in a 3% reduction in fishing time in ≤221 kW Manx vessels, but had no effect on >221 kW Manx vessels, presumably as they spent more time fishing outside of the territorial sea. Increasing the curfew to 10 hours would have decreased ≤221 kW Manx vessel fishing time by 1.5%.

A curfew combined with a dredge limit or tow bar length limit can achieve the same goals as a bag limit. A curfew could be set at a level to limit the total number of bags landed:

$$T = \frac{B}{NWC}$$

Where,

T = Maximum daily fishing time per vessel
B = Total number of bags of scallops landed per day
N = Number of vessels fishing
W = Mean width of fishing gear deployed (m)
C = Catch per metre hour (mh)

For vessels where W is unknown then the value can be estimated using the relationship between VCU (V) and gear width (W = 0.032V + 3.294). N can be determined from VMS data. There was a significant linear relationship between catch rate measured as bags km^{-2} and catch rate measured as bags mh^{-1} (Figure 10); the effect of vessel speed was more apparent at higher catch rates. C can be estimated from fisher logbooks (gear width) and VMS records (fishing time) – this will be facilitated by the introduction of electronic logbooks – so that a maximum fishing time can be set. For example, at a mean catch rate of 0.5 bags mh^{-1}, with 30 vessels fishing and deploying a mean gear width of 10.64 m, then fishing for 12 hours would yield 1915 bags of scallops. To reduce the number of bags of scallops landed to 1500 a reduction in fishing time to c. 9.5 hours would be required.

4. Discussion

Data limitations

This report provides estimates of the impacts of management measures proposed by the Isle of Man Government. These estimates are based on VMS records, fishers' logbooks and vessel registration details. Fisher logbook returns were available from all Manx vessels but not UK vessels; therefore, the width of dredges deployed by UK vessels had to be estimated. The width of gear deployed was found to be highly correlated with boat size and engine power in English Channel beam trawlers (Pascoe and Coglan, 2002). This was also the case in the Isle of Man scallop fishery. Landings of the target species by UK vessels could only be estimated. It has been assumed that the relationships between VCU, width of gear towed and catches are the same for UK vessels as for Manx vessels. As VMS is required only on vessels >15 m fishing in the outer zone, no VMS data on fishing activity by vessels between 10 and 15 m fishing in the outer zone but not the inner zone is available. As with most data used in fisheries management, many parameters will be subject to large errors (Caddy and Mahon, 1995) and the results must be interpreted with this in mind.

Dredge limits

Current limits on dredge numbers appear to be ineffective in limiting fishing effort by the Manx fleet within the Isle of Man's territorial waters. Therefore, tow bar length restrictions would also have little impact on the Manx fleet unless reduced to prevent 5 dredges and 8 dredges per side being deployed in the inner and outer zones, respectively. A 221 kW MCEP limit would correspond to approximately six dredges per side based on the gear width deployed by the Manx fleet. However, vessels may have deployed fewer dredges than they were capable of towing. The dimensions of the vessels also influence the width of gear that can be used. Therefore, the greatest impact of a seven dredge a-side limit would be on vessels >221 kW MCEP. However, a seven a-side restriction would also impact on vessels not affected by the >221 kW MCEP restriction, as some vessels with ≤221 kW MCEP were able to tow more than seven dredges a-side. Overall, the seven-a-side limit applied alone would reduce the effort of one third of the UK fleet and 13% of the Manx fleet by around 12% unless fishing time was increased to compensate.

Engine power

Vessels in the Dutch beam trawl fleet can be divided into two main groups, those ≤221 kW typically deploying 2 x 4 m beam trawls, and those >221 kW typically deploying 2 x 12 m beam trawls (Piet *et al*., 2007). This clear division does not apply to the scallop dredgers in the Isle of Man fishery where there was a linear relationship between engine power and gear width deployed, and a stronger relationship still between VCU and gear width. Therefore, the 221 kW value is not of particular relevance although prohibiting vessels of >221 kW in the Isle of Man's territorial sea would clearly reduce fishing effort. The 221 kW threshold is also likely to be familiar to fishers.

There is a positive relationship between engine power and catch rates in the Dutch beam trawl fleet (Rijnsdorp *et al*., 2000). This is not the case in the scallop fishery when catch rates were measured as catch per area dredged. Although engine power is related to the width of gear carried, VCU is a better index of fishing power than kW. VCU also explained 70 – 80% of the variation in earnings of Scottish trawlers (Pascoe *et al*., 2003). Although VCU is now redundant in respect of vessel licensing it remains a useful measure of a vessel's catching power, as is evident in the results of this study.

It is important to note that vessel owners may de-rate engines to comply with limits on MCEP. Vessels are advised by the Maritime and Coastguard Agency that MCEP should not be reduced by more than 25% when de-rating engines; however, there is no maximum on the reduction in MCEP (MCA, 2007). As with tow bar length, whether vessel owners opt to make changes will depend upon a number of variables. The importance of the fishery within the Isle of Man's territorial sea and the catches necessary for a vessel to function profitably will be major determinants. Larger vessels may require greater catches to be profitable making the use of shorter tow bars or de-rating engines unfeasible. However, the inherent weakness of both of these measures is that they can be circumvented, and the viability of doing so will be a function of scallop stock size. Thus, these measures may be effective in reducing effort at low scallop abundances, but less so where the species is more abundant.

<u>Bag limits</u>

Eggleston (2008) suggested that where a fishery is not exploited to saturation, such that fishers are able to increase catches with increasing target species abundance, then measures to reduce catch rates would be more effective. A recent study of the Manx scallop fleet (Murray *et al*., submitted) indicates that limiting landings would presently be the most effective means of reducing fishing mortality. A bag limit would restrict the number of bags or weight of scallops a vessel could have onboard at any given time. Thus the effect would be not only on what could be caught in a single day but how much could be caught over an entire fishing trip. Bags of

nominal 40 kg capacity are most commonly used. A daily catch limit of 2000 kg per vessel would reduce catches at the highest CPUE without reducing landings at average or low CPUE. This measure would therefore help to achieve one of the goals identified by the Isle of Man Government, namely to prevent the intense concentration of fishing effort at the beginning of the season. The Isle of Man Government's current proposal is to implement the bag limit only when the market is at risk of becoming over-supplied. As this limit, if set appropriately, would have little effect when scallop densities were lower it may be preferable to implement this measure on a permanent basis.

The data shown in Figure 9 is based on fishing activity within the Isle of Man's territorial waters only. Vessels will fish across the boundary of the territorial sea. With a bag limit in place it is likely fishers staying at sea for more than one day would fish up to the bag limit within the territorial sea first, before moving outside of the limits. Vessels would not then be permitted to re-enter the territorial sea with more than the maximum weight of scallops onboard. These large catches would therefore have to be landed outside of the Isle of Man. Alternatively, fishers may choose to land smaller catches in the Isle of Man. This measure could prove detrimental to Isle of Man processors and have a disproportionally negative effect on fishers wishing to stay at sea for more than one day.

Curfew

Larger, >221 kW, vessels tended to fish for longer and were more likely to stay at sea for more than one day. Increasing the curfew by 2 hours would have reduced fishing time by up to 2.5% for these vessels but would have reduced fishing time of ≤221 kW vessels by 0.5% or less. Increasing the curfew by 4 hours would have reduced ≤221 kW fishing time by 2% and is unlikely to make fishing uneconomical for these vessels. An 1800 to 0600 would also standardize the curfew across the territorial sea, making enforcement easier. VMS also makes enforcement of curfews relatively straightforward. Therefore, it is recommended that curfews, with a decrease in the maximum number of dredges, are used to limit effort and landings where necessary.

Changes in fleet composition

It is possible that where the scallop fishery in the Isle of Man's territorial sea generates a substantial proportion of a fisher's income, making changes to a vessel to meeting new legal requirements would be worthwhile. In particular, de-rating engines just above 221 kW is often straightforward. A more extreme case would be the replacement of a larger vessel with two or more smaller vessels, which could nullify any intended effect of new management measures.

Following the exclusion of >221 kW MCEP vessels from Welsh water, the same restriction in the Isle of Man may make downsizing of vessels more desirable.

General recommendations

It would be extremely valuable to the Isle of Man government to have access to landings data from UK vessels fishing within the territorial sea either by participation in the UK system or by requiring the submission of log sheets by all vessels fishing within the territorial sea. Similarly, it would presumably be of value to UK authorities to obtain detailed landings data from Manx vessels fishing within the territorial sea. Without knowledge of the catches of most of the vessels the status of the fishery and the effectiveness of management measures will be less certain. Given the uncertainty about the status of the fishery, the proposed measures should be used in conjunction with spatial management measures. The closed area at Port Erin has benefitted scallop stocks (Beukers-Stewart *et al*., 2005) and the temporary closure of Ramsey Bay, together with the Douglas Bay closed area, will also help to minimize unnecessary damage to the scallop fishery and benthic habitats. However, most of the measures discussed in this study apply to fishing for *Pecten maximus* only. There is no upper limit on MCEP, dredge numbers, total width of fishing gear or tow bar length in the *Aequipecten opercularis* fishery. Queen scallops are therefore vulnerable to over-exploitation if latent fishing capacity becomes active in the Isle of Man's territorial sea. Consideration should be given to applying the proposed measures, or similar, to the *A. opercularis* fishery.

Conclusions and management recommendations

A bag limit would be effective in limiting landings when scallop abundance was high. However, such a limit may require fishers to change fishing patterns and landing ports. Therefore, any such restriction would best be implemented on a permanent basis, as once it becomes apparent that the market is becoming flooded it may be too late to impose the bag limit. It may also encourage a 'race to fish' before the limit is imposed. It would also prevent vessels fishing outside of the Isle of Man's territorial waters landing large catches to the Isle of Man, and result in discarding of catches. A bag limit would also be more difficult to enforce than a curfew and dredge number/tow bar length limit, which if implemented correctly would achieve the same goals.

Tow bar length restrictions and engine power limits will be most effective when scallop abundance is lower. Beyond the short-term these measures may become ineffective as fleet composition changes. Based on 2008/2009 fishing activity, the proposed extension of the curfew by 2 hours in the outer zone would have almost no impact. An 1800 to 0600 curfew

would have the greatest impact on >221 kW vessels, and would thus be largely negated by a 221 kW vessel ban. An 1800 to 0600 curfew would make enforcement simpler and reduce the required patrol hours. The curfew would also be much easier to enforce than a bag limit and combined with dredge and tow bar length limits could effectively cap effort in the current fleet. It is recommended that the option of increasing the curfew period is available to cap landings as necessary.

The proposed management measures would help to reduce fishing effort in the Isle of Man's scallop fishery whilst ensuring the fishery remained economically viable to fishers. The measures will be effective in reducing effort in the short-term but should the fleet adapt then further restrictions or changes to this legislation will be required. Even with the proposed legislation in place there will remain an enormous latent effort in the fishery. We have not recommended specific catch or effort limits in this report as these measures go beyond the scope of the Isle of Government's current consultation. However, without a cap on the number of licensed vessels or on landings the scallop fishery will remain vulnerable to over-fishing.

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