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Isle of Man crab and lobster fishery consultation evidence document (2)

Minimum Conservation Reference Size (MCRS) changes in the lobster (*H. gammarus*) fishery; expected short-term costs and long-term benefits. Evidence to support the crab and lobster consultation (2020)

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1.0 Introduction

At present, the Isle of Man lobster fishery is subject to a minimum conservation reference size (MCRS) applied to the length of the carapace (CL), and is set at 87 mm. By contrast, other jurisdictions in the Irish Sea have increased the MCRS to 90 mm CL (e.g. Welsh waters) whilst others have set a maximum landing size (e.g. 127 mm CL in the Republic of Ireland, and 155 mm CL in Scottish waters). These changes are associated with a general aim to improve stock status and increasing yield in the fishery. This document considers the likely short-term economic impact on fisheries in the Isle of Man from a similar increase in MCRS, as well as long-term benefits. Size-selective harvesting is a common approach to stock conservation in many finfish and shellfish fisheries. Regulators aim to manage the rate of fishing mortality (F) across the different size-classes of the stock (Beverton & Holt, 1957; Quinn & Deriso, 1999) and is a basic principle of good management for Crustacea (Bannister, 2008).

Lobster increase in size through a process of moulting ('ecdysis'), where moult increments and intermoult period are temporally and spatially variable (Wahle & Fogarty, 2006). The 'growth factor' of an individual is a measurement of proportional growth (% increase in CL) from before and after a moult. For European lobster around commercial size (~80-90 mm CL) a growth factor of ~10% per year has been previously estimated using mark-recapture methodologies (Bennett & Lovewell, 1983; Agnalt, et al., 2007; Wahle, et al., 2013).

In the Isle of Man territorial sea, MCRSs are set for all commercial shellfish species and many have been revised and raised in agreement with scientific advice on biological reference points such as $L_{50 \text{ and}}$ reproductive output (see Hold, et al., 2013; Haig, et al., 2016; Emmerson, et al., 2018) as well as advice based on the economic benefits of harvesting larger animals (e.g. Brand, et al., 1991).

Recent estimates suggest that the size at maturity in some regions of the UK and Ireland is above the current MCRS for that area (see Free et al., 1992; Tuly et al., 2001 and Lizárrage-Cubedo et al., 2003). Regional variability in size at maturity suggests regional application of MCRS is appropriate. In the Isle of Man, maturity analysis based on dissection of the female reproductive organs estimates physiological maturity at 83 mm CL (± 3 mm), which is below the current MCRS. However, onboard observations have also noted that 50% of observed females carry eggs at a size 93 mm CL ('functional maturity'). More information is available on this study in a separate report (see Garratt et al. 2020).

It is important to evaluate the short-term economic impacts of an increase in MCRS, as well as the assumption that an increase will eventually lead to yield benefits after two or three years (Bannister, 2008). Population modelling can assist with devising strategies to increase the efficiency of natural resource management (Sundelöf, et al., 2015). With respect to MCRS changes in fisheries, previous studies have shown some unanticipated consequences to shifts in havesting strategies; for example where increasing MCRS may lead to a significant increase in exploitation rate (Harley, et al., 2000) or decreases in yield when dicard mortality and natural mortality is high (Waters & Huntsman, 1986).

In this study, the potential economic consequences of increasing lobster MCRS to 90 mm CL are explored for the northern Irish Sea population by combining shoreside sampling with growth rates determined from mark-recapture data.

2.0 Materials and Methods

2.1 Data collection

Shore-sampling of harvested lobster took place between February 2018 and February 2019 with samples from all of the main fishing grounds in the Isle of Man territorial sea (Figure 1). The size (CL) and sex were recorded for all individuals and any damage to the animal's appendages noted. A subsample of animals, excluding those with missing limbs, were weighed (0.01 kg) in order to determine a length-weight relationship for the population.

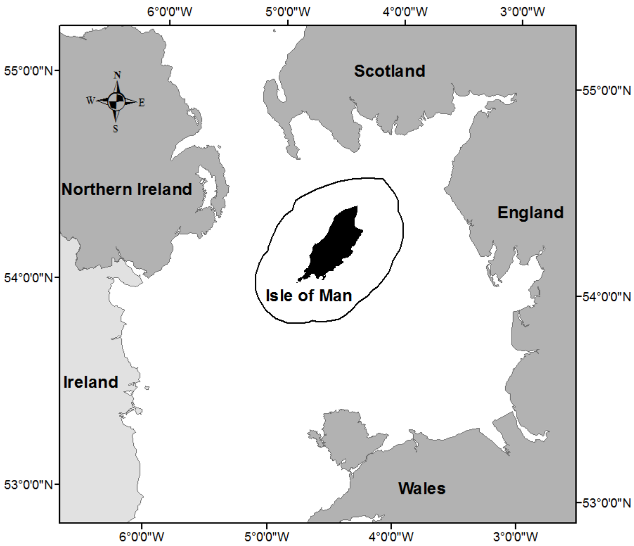

Figure 1. The Isle of Man (black) territorial sea (line) and surrounding fisheries administrations of the United Kingdom (dark grey) and the Republic of Ireland (light grey).

Lobster were also tagged opportunistically as part of a separate study between August 2016 and August 2018 in the Isle of Man. Captured lobster were tagged with a Hallprint© streamer-tag (as used by Agnalt, et al., 2007) with the unique ID attributed to each tag recorded along with the location and time of capture. Biological data including size, sex, damage and reproductive status were recorded prior to release. The time and location of the release site was kept as close to the capture location as possible and recorded electronically. Recaptures underwent the same data collection process and were voluntarily released again under the same procedure, with observations of CL increase (growth) noted.

2.2 Modelling assumptions and methodology

A simulation of the effects of increasing MCRS in the Isle of Man lobster fishery was undertaken in a number of scenarios under a specific set of assumptions that describes a static-environment model. Static-environment assumptions are applied to the recruitment, growth and mortality of the Isle of Man lobster population not affected directly by the MCRS change (i.e. lobsters that are not within the 87-90 mm CL size-class). In other words, the static-environment model assumes that these sections of the population (under 87 mm and above 90 mm) continue to make up the same proportion of the overall harvested population as observed in the shore-sampling data, since recruitment, mortality and growth do not change as a result of the change in MCRS.

With respect to the change in MCRS, the model focuses on the section of the population that measured 87 mm to 90 mm CL. These lobsters undergo a single moult during a season. The moult increment is assumed to be constant for all these individuals and equal to the growth factor determined by mark-recapture observations. The accompanying weight increase as a result of moulting is determined by a size-weight relationship modelled from data collected during shore sampling.

The moult induced mortality ('natural mortality'; M) of this section of the population is unknown, though it is generally accepted to vary between 10% to 20% (Bannister, 1986). A low mortality value supports the idea that short term losses in the fishery brought about through an increase in MCRS will quickly return benefits as a large proportion of animals not captured the previous year are available the following year (Tully, et al., 2006). However, at a certain level, a high mortality rate will mean that the weight increase of those animals that survive is less than the total weight of those that die of natural mortality. In the model used in this study, we look at the effects of different levels of natural mortality, ranging from 0% to 20%.

Other model assumptions include;

- a closed population (i.e. no net-effect of migration on the catchability of lobster)
- effort and catch efficiency of static-gear lobster pots 'creels' in the fishery remains constant each year, and
- economic market conditions for lobsters remains constant between seasons.

The simulation is repeated for two different MCRS implementation scenarios, comparing the effects on recruitment and harvest of i) a single-step introduction of a 90 mm MCRS and ii) a phased-approach, whereby MCRS is raised to 89 mm for a period of one year followed by a second increase to 90 mm in the second year.

3.0 Results

3.1 Population and growth observations

Shore-sampling collected size data from 3,690 lobsters with a sex-ratio of 7:6 (M:F) (Figure 2). A subsample of 16% of individuals were weighed. Regression analysis of log-transformed data determined the length-weight relationship as;

$$W = 0.00034\ CL^{3.16}$$

The estimated weight of an 87 mm and 90 mm CL lobster is 480 g and 510 g respectively, i.e. a 90 mm lobster is 6.2% heavier than a 87 mm lobster.

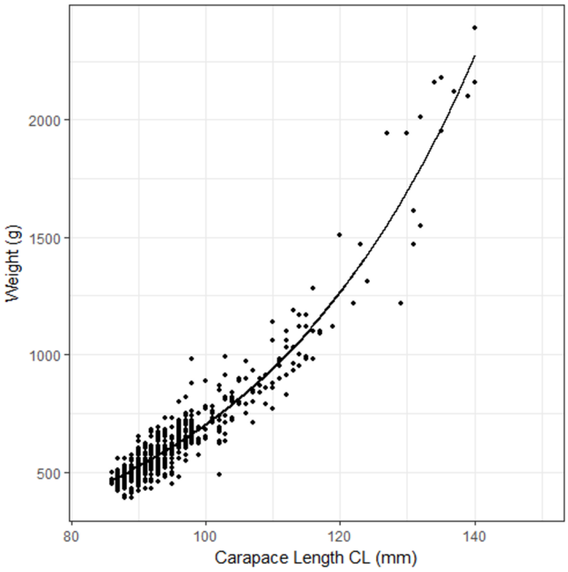

Figure 2. The size – weight relationship for lobster (H. gammarus) sampled in the Isle of Man 2018/19.

A total of 321 lobster were tagged during the period. A recapture rate of 31% was achieved (n = 97) with 26 observations of CL increase due to moulting. An average annual growth factor of 13%, was observed. This means that an 87 mm CL lobster will grow approximately 11.3 mm during the moult, and have a postmoult CL of 98.3 mm, and an estimated weight of 696 g (47% increase).

3.2 Model simulation: single step-change (87 mm to 90 mm)

Under a single step-change in MCRS from to 90 mm, lobsters between 87 mm and 90 mm CL would be excluded from the harvest in Year 1. The model estimates such a change would reduce the total landed weight by 12%, relative to 'Year 1: Status Quo' when the MCRS was 87 mm (Figure 3c). As the forgone catch in Year 1, i.e. individuals that were between 87 mm and 90 mm, moult and recruit into the fishery the next year, they will have increased in both size and weight. The model predicts that when natural mortality is 0%, the harvested weight in Year 2 is 6.5% greater than the status quo (Figure 3 b,d).The additional harvest weight of Year 2 relative to status quo will however decrease if an estimate of natural mortality rate is included in the model (as a portion of the unfished stock die). This means that harvest improvements reduce from +6.5% (with no natural mortality) to +4.1%, +3.2% and +2.4% when natural mortality rate is modelled at 10%, 15% and 20% respectively (table 1).

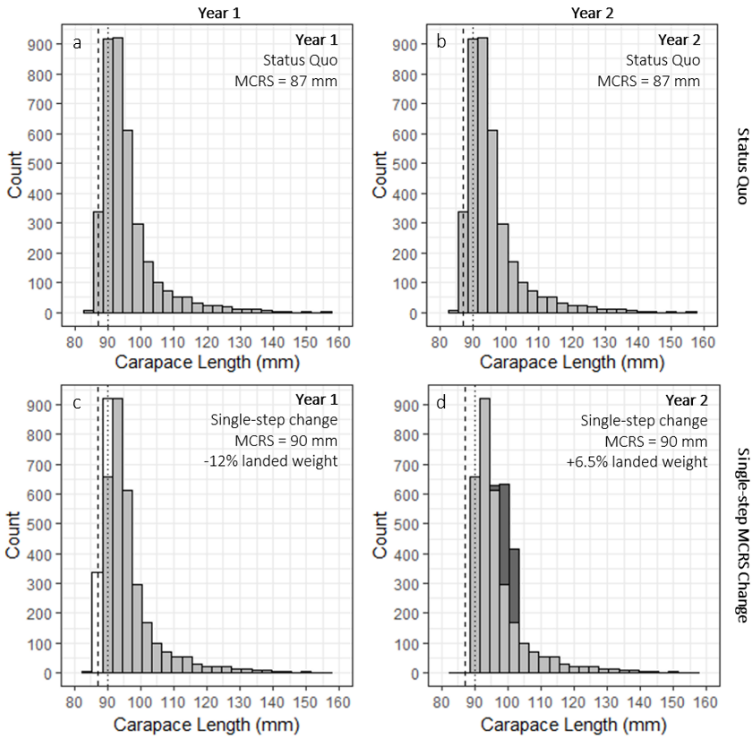

Figure 3. The data in these graphs are based on the size distribution of lobster (*H. gammarus*) sampled in the Isle of Man in 2018/19, which for the purpose of these models has been assumed to represent a standard year's harvest (i.e. for the purpose of this model it is assumed that, if fished under status quo conditions, the size distribution of harvested lobsters will remain constant among years) : (a) 'Year 1 Status Quo': which reflects the size distribution of harvested lobster for Year 1 under a status quo scenario (i.e. MCRS of 87 mm); (b) 'Year 2: Status Quo' which reflects the size distribution of harvested lobster for Year 2 under a status quo scenario (i.e. MCRS of 87 mm); (c) 'Year 1: Single-step MCRS Change' reflects the size distribution of harvested lobster for Year 1 assuming a single step increase in the MCRS from 87 to 90 mm (white bars represent forgone catch between 87 and 90 mm resulting from MCRS increase, which equates to -12% biomass relative to the status quo, under a natural mortality assumption of 0%); (d) 'Year 2: Single-step MCRS Change' shows the distribution of harvested lobster in Year 2 assuming a continued MCRS of 90 mm (dark grey bars represent the recruitment of the foregone lobster catch in Year 1 assuming a 13% growth factor and a natural mortality assumption of 0%, which equates to a + 6.5% increase in biomass relative to the status quo).

3.3 Model simulation: phased increase (87 mm to 89 mm to 90 mm)

Under a two phase step-change in MCRS to 89 mm (Year 1) and to 90 mm (Year 2) only lobsters under between 87 mm and 89 mm CL would be excluded from the harvest in Year 1, and additionally lobsters 89 mm to 90 mm in Year 2. The model estimates such a change would reduce the total landed weight by 6.7% , relative to 'Year 1: Status Quo' where the MCRS was 87 mm (Figure 5a).

In Year 2 (Figure 4e), the forgone harvest from Year 1 (i.e. lobster under 89 mm, Figure 4d) recruit into the fishery with postmoult increases in size and weight contributing to increased yield relative to status quo. The additional yield decreases as natural mortality increases, i.e. fewer individuals survive the additional moult (Figure 4e, 4f show the recruitment in dark grey when mortality = 0%).

In Year 2, there is a also a reduction in yield as a result of the second phase of MCRS increase from 89 mm to 90 mm CL (white bars in Figure 4e). The net effect of recruitment, mortality and increased MCRS on harvest in Year 2 relative to status quo ranges between -1.7% and -3.9% depending on mortality (see table 1). In Year 3, when MCRS is 90 mm, the increase in yield relative to baseline is the same as if the fishery had undergone a single-step increase in MCRS (see section 3.2).

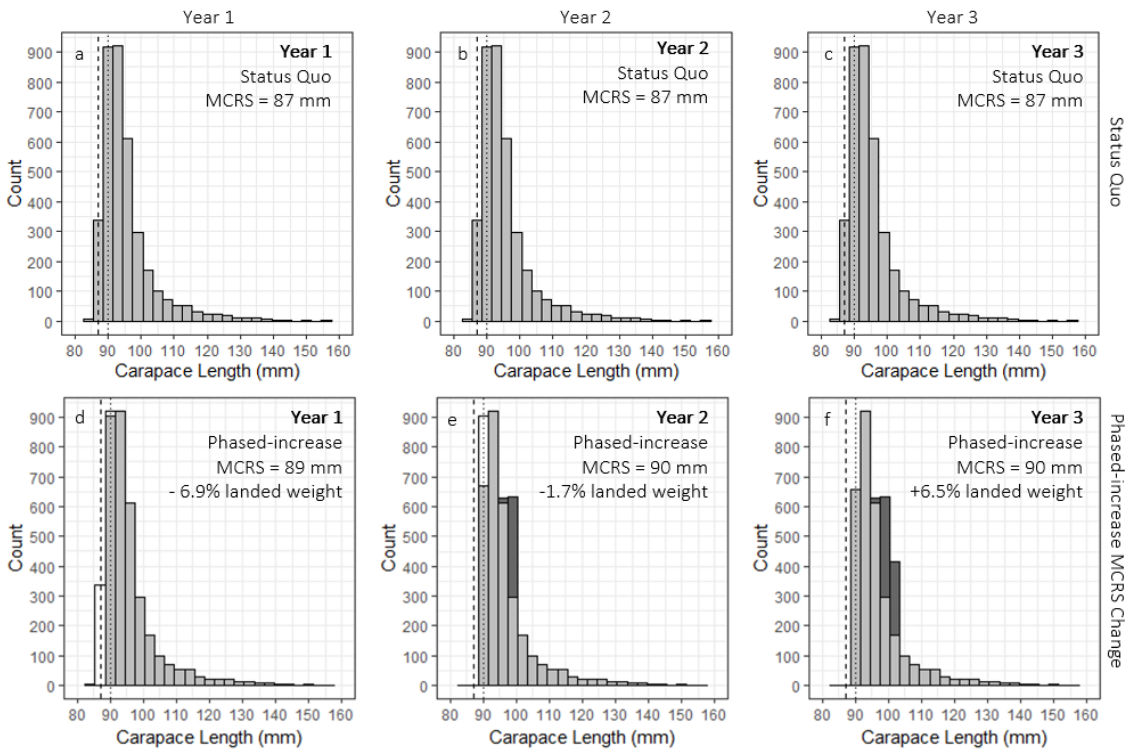

Figure 4. The data in these graphs are based on the size distribution of lobster (*H. gammarus*) sampled in the Isle of Man in 2018/19, which for the purpose of these models has been assumed to represent a standard year's harvest (i.e. for the purpose of this model it is assumed that, if fished under status quo conditions, the size distribution of harvested lobsters will remain constant among years) : (a-c) 'Year 1 Status Quo': which reflects the size distribution of harvested lobster for Year 1-3 under a status quo scenario (i.e. MCRS of 87 mm); (d) 'Year 1: Phased-increase MCRS Change' reflects the size distribution of harvested lobster for Year 1 assuming a step increase in the MCRS from 87 to 89 mm (white bars represent forgone catch between 87 and 89 mm resulting from MCRS which equates to -6.9% biomass relative to the status quo, under a natural mortality assumption of 0%); (e) 'Year 2: Phased-increase MCRS Change' shows the distribution of harvested lobster in Year 2 assuming a second increase in MCRS to 90 mm (white bars represent forgone catch between 89 and 90 mm resulting from MCRS increase from 89 mm to 90 mm. Dark grey bars represent the recruitment of the foregone lobster catch in Year 1 assuming a 13% growth factor and a natural mortality assumption of 0%. The net-effect of forgone lobster (white bars) and recruitment + growth (dark grey bars) equates to -1.7% decrease in biomass relative to the Year 2 status quo); (f) Year 3 where MCRS is 90 mm and lobster 87-89 mm and 89-90 mm have recruited into the fishery, which equates to a +6.5% biomass relative to Year 3 status quo.

Table 1. A summary table showing the short-term economic impact on harvest.

	Single-step				**Phased-approach (89 mm)**			
Natural mortality estimate	0%	10%	15%	20%	0%	10%	15%	20%
Year 1 compared to status-quo	-12.0%				-6.7%			
Year 2 compared to status-quo	+6.5%	+4.1%	+3.2%	+2.4%	-1.7%	-2.8%	-3.3%	-3.9%
Year 3 compared to status quo	+6.5%	+4.1%	+3.2%	+2.4%	+6.5%	+4.1%	+3.2%	+2.4%
Number of years for net-benefit to be achieved	2.8	3.9	4.8	6.0	3.3	4.3	5.1	6.4

Using the above data, we can also estimate that if natural mortality ≈ 31% (i.e. 31% of the forgone lobsters die before they recruit into the fishery at an increased MCRS), there would be zero benefit to an increase in MCRS and only a short-term loss, i.e. the weight gained by individuals that moult and survive is equal to the weight of the lobsters that do not survive.

4.0 Conclusion

The simulated changes in MCRS to 90 mm for the Isle of Man lobster population suggest that, depending on the approach taken and the rate of mortality in the population;

- it could take between 2.8 and 6.4 years for the cost of the transition to be recovered in the new harvesting regime (i.e. reach a net-benefit),
- opting for a phased-approach reduces the initial negative impact but increases the time in which a net-benefit could be realised by approximately 0.5 seasons,
- in the long-term, annual yield is estimated to increase between 2.4% and 6.5% compared to baseline (current harvests) depending on mortality rates, unless mortality exceeds 31% at which point there is no benefit to MCRS change.

<u>As an example scenario;</u> a phased approach is adopted, and mortality rate is 10%:

- in the long-term, annual yield would increase 4.1% compared to status-quo after the population has been given chance to grow and recruit to the new harvesting regime, and
- it would require 4.3 seasons for the increase in MCRS to equate into an overall net benefit in the fishery

5.0 References

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