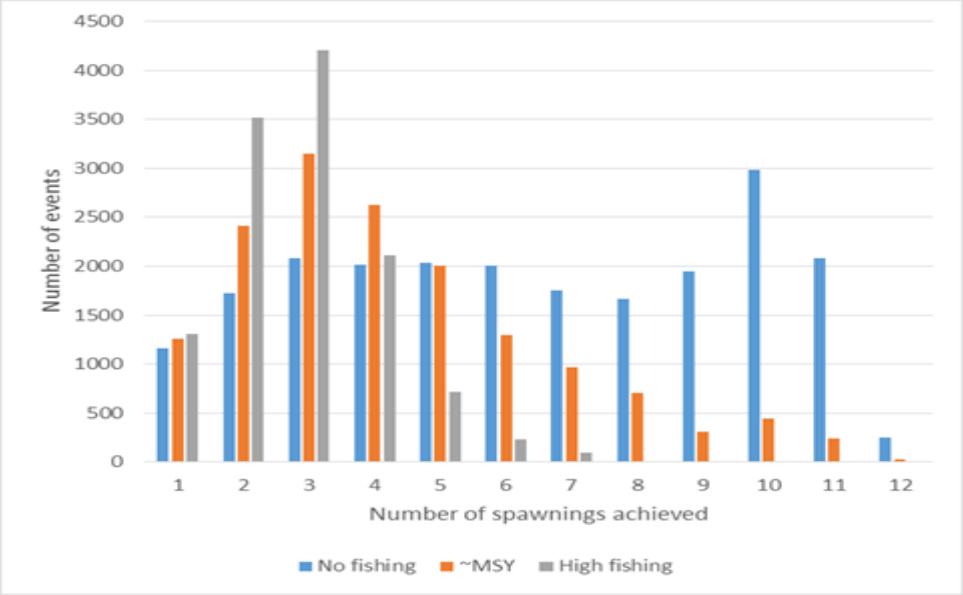
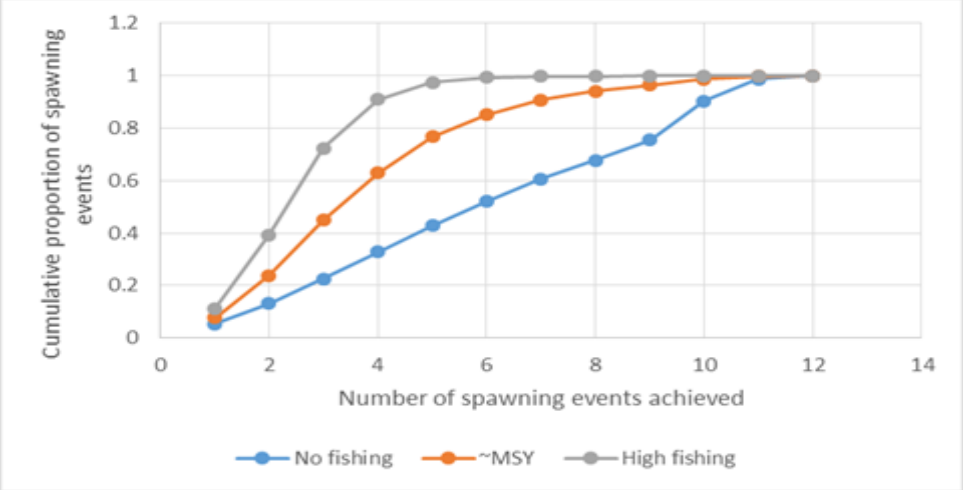
Annex 2 Biological Parameters and Stock Information

Dr Ewen Bell, Senior Inshore Fisheries Advisor at CEFAS was contacted to provide information on brown crab growth, recruitment, spawning and stocks. The following points came out from these discussions:

- When male and female brown crabs reach 140/150 mm they increase their size by approximately 25% per moult i.e. they could grow to 175mm from 140mm in one moult.
- Once they reach approximately 140mm 100% of males and between 90-94% of females should have reached sexual maturity.
- L50 is 110mm meaning that this is the size of sexual maturity where 50% of the population will be have reached sexual maturity.
- Dr Bell uses a spawning event model to calculate/estimate the number of spawning event an individual can go through under different fishing mortalities and sizes. The model starts from 2 year old individuals which are ~75mm. When there is no fishing, about 30% of them will spawn three times over their life time.
- Male and female growth rates are very similar in terms of their shell width at age however for a given shell size males will be heavier so males grow faster in terms of weight.
- Dr Bell was asked the question "how many times should a fish spawn"? He explained that it depends upon what the management is trying to achieve. It might be tempting to think that provided everything can spawn once then everything is fine. L50 (the size at which 50% of the population can spawn once) is an arbitrary measure simply used as a convenient point of comparison between species. For some reason it has entered fishery management regimes as rationale for setting MLS – but there's no scientific reason why it should be L50 rather than, for example, L75 or even L25. In order to understand what level of protection the MLS offers to the stock an exploration of what happens to the stock under a range of fishing mortalities is required.
- Dr Bell explained that he explored this further in the model and realised that he would have to chart the spawning experiences of individuals and therefore see how many times individual animals were spawning. Due to different growth and maturation rates, animals of the same age may experience a range of spawning opportunities. The numbers of animals achieving 1 or 2 spawning opportunities didn't change much even with a large variation in fishing mortality. The results show that you only really get a response to variations in fishing mortality when you look at three or more spawning opportunities. High fishing mortality dramatically reduces the number of spawnings achieved.
- In the model Dr Bell used 10,000 individuals to which reduce the variation on aggregate stats every time it re-calculates) and pushed the age range out a bit. From this:
    a. At NO fishing I get 7% spawning 9 times or more
    b. At MSY fishing I get 1% spawning 9 times or more
    c. At HIGH fishing I get 0% spawning 9 times or more
- In the figures below Dr Bell set the MLS to be 110mm (i.e. around L50). When there is no fishing there is a lot of repeat spawning activity with over 50% of spawning events coming from animals that spawn 4 or more times. At high fishing rates the vast majority of animals get to spawn three or less times. Under high fishing the spawning potential (as measured by SSB) is only 20% of the unfished state. If the MLS is changed to 140mm, then even under high fishing rates, only 35% of the spawning potential is achieved.
- At high fishing rates (fishing mortality =1) most animals in a population will get to spawn three times or less.

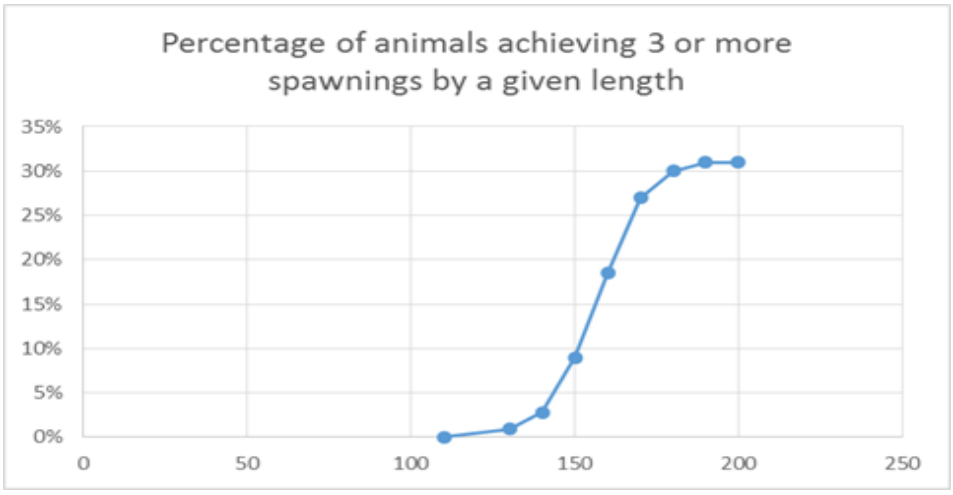
- At 150 mm MCRS with a high level of fishing mortality 30% of animals with have 3 spawning events
- At 140mm MCRS with a high level of fishing mortality 26% of animals will have 3 spawning events
- At little or no fishing mortality the MCRS makes no difference to the percentage of animals that will have 3 spawning events
- By the time a female crab reaches 150mm it is likely to have spawned on average 2.9 times. At 140mm this is reduced to 2.4 times. Therefore if the MCRS is 150mm for female crabs there would be an extra 0.5 spawns per animal which equates to a 20% increase in spawning events if it is left to reach this size.





Further question were asked of Dr Bell and his responses are as follows:

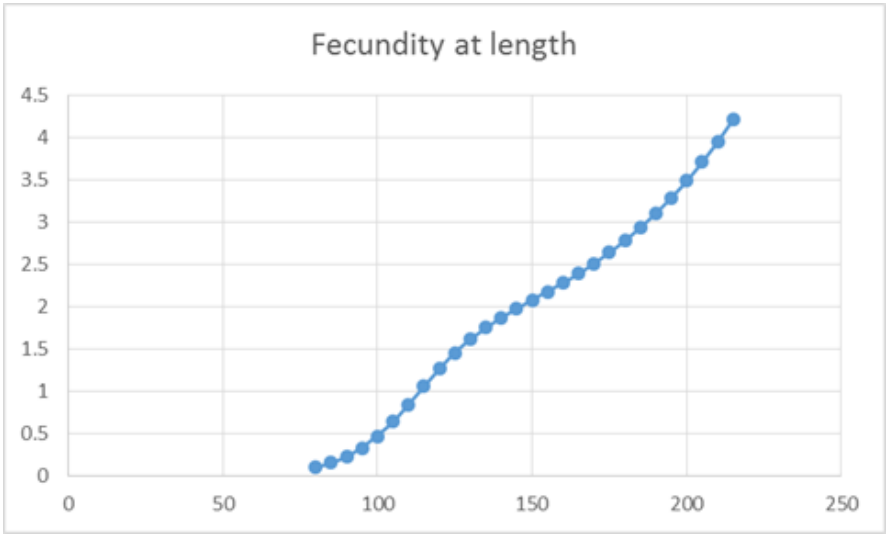
1. What %age of animals will have 3 spawning events at 150mm, 140mm and 130mm if there is no fishing mortality?



2. Can you define high fishing mortality? – i.e. relate it to coverage on the ground or number of pots per km?
   A. Unfortunately not - We have no reliable effort data to start linking pots on ground to realised fishing mortality. In the "high" fishing mortality examples outlined here I have used a fishing mortality rate of 1 – which would be about three times higher than MSY and has been historically observed in UK crab assessments.

3. How old is a hen crab of 140mm? 150mm too?
   A. According to our continuous growth models a 140mm hen crab would be 4.6 years old and a 150mm hen would be 5.2 years old. Of course growth isn't continuous and a crab observed to be 140 would subsequently grow to be ~175 at the next moult. Due to variability in individual's growth rates, there is a strong possibility that a 140mm crab is the same age as a 150mm crab.

4. What size of hen crab is most fecund? – does this increase with age/size?
   A. I've plotted up the fecundity function which is a combination of weight-length and maturity functions and comes out almost linear. It certainly doesn't seem to be asymptotic and is steeper than 1. This means that as crabs get larger (and older) their reproductive output increases faster than their size. Put simply, big crabs output more eggs per kg than small crabs!



5. At what age/size is their natural mortality for both sexes?
   A. In an unfished situation, and starting to account for mortality from age 2 onwards, the average age of death is 5.25

6. Is 9 spawning events the maximum number in a crab's life history? If not what is this figure?
   A. This was a function of how far out I had pushed the model – I've now pushed it out further (to age 13) and there are still a handful of animals that are still alive out here in an unfished situation, however it's very few. <7% of animals in an unfished population achieved this and we've got no accounting for senescence in here, so are probably over-estimating.

7. If left on the ground at 140mm how many times does a hen crab moult in a year – or how often do they moult when they reach a size of 140mm?
   A. Moult frequency is the area of growth we know the least about. According to the growth models, animals are likely to have slowed to moulting every two years, but it's an area we'd like to undertake more research on.

8. What is the spawning output of a 140mm and 150mm hen crab? How many eggs are likely to recruit into the fishery at these two sizes?
   A. A 150mm crab is supposed to output 11% more eggs despite being only 7% bigger. We have no information regarding the likelihood of eggs recruiting to the fishery (i.e. no stock-recruit relationship).

9. Can you provide more information about the mating size limitation i.e. what size of a male crab can mate with a 140mm / 150 mm hen crab?

10. Can you explain the brown crab spawning in the channel as they move east to west? Is there only one spawning event in that time?
    A. From the tagging experiments done recently we have observed that female crabs have sequentially moved westwards, spawning on multiple occasions as they move through the channel. This was evidenced by a total lack of movement through the winter as the female brooded the eggs, followed by another migration and then another period of stasis.