Fisheries & Conservation Science

Sustainable Use of Fisheries Resources in Welsh Waters: Progress report and future knowledge needs

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Executive summary

Background

The Sustainable Use of Fisheries Resources in Welsh Waters (SUFRWW) European Fisheries Fund (EFF) project began in May 2012 and will be completed in May 2015. This report briefly outlines progress in the project as of August 2014 and provides an overview of future work that we have identified as important. Subject to consultation with the Welsh fishing industry and Government, this work will form part of a bid for funding under the European Maritime and Fisheries Fund (EMFF).

What have we achieved?

Fishers' knowledge

- Compiled a database of fishers' knowledge
- Undertaken an economic questionnaire of the fleet
- Have completed a model on Welsh fleet economic performance

Scallop dredging impact on epifauna and infauna

- We have mapped out the habitats in an experimental area in the Cardigan Bay SAC (with videos and side scan) and produced a report
- We have assessed the impact of scallop dredging on the main Welsh scallop grounds. We have defined thresholds relating fishing effort to changes in epifauna and infauna.
- We have estimated the catchability of scallop dredgers

Sea bass population biology

- Collected data on length, weight, sex, maturity stage, capture location and fishing gear have been collected for a total of about 2000 bass from 33 areas around Wales.
- The catch at age matrices per fishing gear have been developed and differences between line and gillnet have been detected.
- Identified a significant difference in the sex ratio between North (0.28 ± 0.27SD) and South Wales (0.57 ± 0.43SD) for fish caught with line.
- The spawning period of bass for the season 2013-2014 has been identified (January-May) with the maximum GSI occurring in March. Preliminary results also indicate that there has been a decrease in the size at maturity of female bass to 40 cm from what?.
- A recruitment index of 0 group bass (abundances of 0 group bass) has been developed for 2013 and 2014.

Thornback ray population biology

- Sex ratio, size at maturity, growth curve and other life history parameters are currently under analysis.

Scallop stock assessment

- We have conducted three comparable surveys and compared the outputs of different sampling methods (i.e. stills camera, video and dredge)
- We have determined the population dynamics parameters of scallops around Wales and estimated densities in fished and unfished areas
- We found in 2013 that the scallops seemed to spawn at different times between Cardigan Bay, the Llyn Peninsula and north of Anglesey
- Developed a weekly sampling programme involving three fishers at two locations in Wales and are compiling data on scallop weights (gonad, soft tissue, muscle) and age as well as gonad maturity stages.
- Collected gonad samples from mature scallops at different ages to store for future analysis of egg quality and fecundity. Gonad samples have been stored in Davidson's solution with the aim of carrying out histological analysis.

Crustacean on-board camera development

- Built a prototype video camera system which was trialled on six different fishing boats.
- The relationship between the real measured size and the size estimated from the video footage indicates that this method is a reliable means of collecting population data in the field and could replace observers at sea.

Baseline lobster fisheries data

- Monthly on-board observer data from 2013 until end of project in May 2015.
- On-board observer data includes CPUE, size frequency, sex ratio, proportion of berried females and by-catch.
- Water temperature data from multiple sites around Wales which provides insights into environmentally driven changes in CPUE.

Lobster reproductive genetics

- Genetic samples of female lobsters and their eggs have been collected from 4 sites across north and south Wales.
- DNA extraction protocols for female tissue and egg batches have been developed.
- Microsatellite multiplex PCR protocol developed.

Lobster fecundity and egg quality

- Collected egg mass samples from lobsters in North Wales and Pembrokeshire.
- Fecundity counts from north Wales are completed.
- Laboratory work for egg size, dry weight and CHN analysis is on-going for north Wales.

Lobster size at maturity

- Over 2000 lobsters measured for morphometric relationships.
- Over 20 fishing trips sampled to estimate the proportion of berried females.

- 50-100 Pleopod samples taken every two weeks from April 2014 – September 2014 for cement gland analysis (archived at present) to enable the determination of functional maturity.

Lobster escape hatch study in Cardigan Bay

- Conducted morphometric measurements on lobsters and brown crabs to determine the appropriate size escape hatches to trial
- Installed on-board cameras on four vessels in Cardigan Bay
- Data has been collected but is awaiting analysis

Potting bycatch

- Completed collection of whelk bycatch
- Ongoing collection of lobster, brown crab, and prawn fisheries bycatch
- Designed a camera system mounted above a lobster pot which films what is happening inside the pot.

Brown crab population biology

- Developed a monthly sampling programme involving multiple fishers from north, mid and south Wales and have compiled data on length, sex ratio, moult stage and black spot prevalence
- Collected morphometric data (multiple measurements of body size) and some moult increment data on juvenile and adult crabs to identify inflection points for maturity.
- Identified important habitat variables for juvenile crab populations

Scallop stock structure

- We have used a pre-existing model of larval dispersal and re-developed it to predict the larval dispersal of scallops
- We have shown which areas were self-sustained (sink and source) and which areas were either mostly source or sink

Scallop population genetics

- Two populations of Welsh scallops (Liverpool Bay and Cardigan Bay) were analysed using 14 microsatellite markers and were compared to populations previously studied around Europe to look for genetic stock structure.
- Initial results show that there is low connectivity between Cardigan Bay and Liverpool Bay and between the Welsh sites and other populations studied in the Irish Sea and further afield.

Work proposed under EMFF

Fishers' knowledge

- Any management scenarios proposed in the EMFF project should use the questionnaire data to assess the impacts on the fishing industry of different management measures.
- Repeating aspects of the questionnaire after four years would identify structural changes and perceptions that have occurred in the Welsh fishing fleet.
- Repeating the economic analysis of the performance of the fleet would provide a robust indicator of the effectiveness of management and investment

Scallop dredging impact on epifauna and and infauna

- Conduct at least one more survey in Cardigan Bay SAC to monitor recovery following dredging in April 2014 to strengthen management advice regarding the environmental sustainability of the fishery.
- Develop models to simulate different management scenarios and their likely impact on the future of the fishery and the stock based on the findings of this large scale study.
- Investigate density-dependent fertilisation success, and scallop egg size and quality to understand the need for closed areas as brood stock.
- Develop genetic markers to identify scallop larvae in the water column to validate models of connectivity.
- Assess the impact of alternative scallop dredge designs on the seabed to improve environmental performance

Sea bass population biology

- Trace element analysis in the scales of adult and young bass. This will allow an isotopic "finger print" of bass from different areas to be better defined.
- Analysis of the isotopic composition of oxygen in the otoliths of bass to explore migration and movement in bass to understand population sub-structure.
- Analysis of otolith growth patterns in bass to identify bass spawning grounds. Genetic analysis of samples of 0 group bass and adult spawning bass will be also performed to find possible genetic correlations between adults and larvae.
- Provide a five-year time series of bass population data by the end of the EMFF project.

Status of elasmobranch population biology

- Conduct scientific sampling surveys across Welsh waters. to describe the composition of the demersal elasmobranch community in Welsh coastal waters and the spatial variation in species richness.
- Elucidate patterns in habitat use by different elasmobranch species.
- Instigate a fishing vessel sampling at sea campaign using remote camera technology.

Population biology of European sprat and other small pelagic fish (industry requested project)

- From July 2015 till March 2016 a monthly acoustic survey will be conducted on-board a commercial fishing vessel along the Welsh coast.

- The survey will include pre-designed transects perpendicular to the coast in North, Mid and South Wales.
- Acoustic data will be combined with drop net sampling along the same transects.
- The planned work will allow the abundance of the main small pelagic species to be estimated.

Scallop stock assessment

- Continue surveying the Welsh scallop stocks to obtain fisheries independent data
- Start the collection of more fisheries dependent data. This can be achieved by re-implementing a revised version of the red bag scheme.
- Gonad samples are being collected and stored for future analysis. Under EMFF we would like to carry out histological analysis of these samples to assess fecundity.
- We would like to carry out egg quality analysis on our stored samples to gain insight into the reproductive fitness of scallops as they age.
- Gonad samples are being collected and stored for future analysis. Under EMFF we would like to carry out histological analysis of these samples to assess reproductive output and how this affects recruitment.

Connectivity of scallop populations in the Irish Sea

- Conduct plankton surveys: this will give us invaluable information on diurnal movements of the larvae
- Develop a genetic marker to be able to distinguish scallop larvae from other bivalves.
- Use the larval dispersal model to test out management scenarios.

Scallop population genetics

- To look more closely at smaller scale genetic differentiation around Wales through the development of Restriction Site Associated (RAD) or RNAseq markers
- This information could be valuable in stock management decisions as large levels of local retention will mean that recovery from overfishing in one area will not be aided with larvae spillover from other areas but will be reliant on the local broodstock.
- This project would benefit from collaboration with Aberystwyth University who have the facilities to develop and sequence RAD markers, with Bangor University providing access to samples due to extensive sea time and scallop surveys.
- The current archived samples can be used to study effective population size and inbreeding using the linkage disequilibrium method. This method is able to use mixed age groups not separated temporally, but it does need large sample sizes, which we are currently collecting and archiving.

Crustacean on-board camera development

- Software development tasks: Development of automatic recognition of crabs and lobsters form the video to allow automated extraction of stills images from the footage. This will cut the processing time in half. The second phase of software development would include the recognition of crabs and lobsters to provide automatic summary data on catch per unit effort

(i.e. per pot). The third phase of software development would be to develop automated measuring of size.

- Hardware development tasks: GPS to overlay onto the video. Larger storage to allow downloading less frequently. Hardwired to the boats 12V system to avoid fishers having to charge the units. Single on/off switch on the outside of the unit.

Baseline lobster fisheries data

- Continued on-board observer data to collect catch and environmental data will allow us to model seasonal and annual variability.
- Deploy semi-permanent moorings for bottom and surface temperature monitoring and key locations (Bardsey, Pwllheli, Aberdovery, Newquay in addition to the current monitoring stations).
- Enhanced temperature loggers to place on fishers pot to collect temperature profiles as pots are being deployed and hauled.

Lobster reproductive genetics

- Sampling of lobsters from additional sites around Wales.
- Additional sampling in multiple years would allow the analysis of the temporal stability of these paternity relationships.

Lobster fecundity and egg quality

- Study lobster fecundity in autumn when the eggs are newly extruded
- Assess fecundity with size and the size frequency of berried females compared with samples from the same location the following spring/summer.
- If smaller females lose their egg mass over the winter then they shouldn't be considered with the same weight when calculating size at maturity. It would also indicate that future size at maturity studies should occur during the spring/summer rather than year round or in the autumn.
- Complete analysis of cement glands from a range of sites around the Welsh coast

Potting bycatch

- Identify the levels of discards associated with whelk, prawn, and sea bass fishing.
- Investigate the survivability of the most commonly discarded bycatch species (including the effects of riddling on whelks and prawns).
- Investigating whether gear modifications could be an option for decreasing bycatch.

Brown crab population biology

- Continued collection of data on size, sex and reproductive condition of crabs using on-board cameras.
- Identify migration routes for crabs through an incentivised tagging programme:
  - T-bar tagging in north, mid and south Wales
  - If comprehensive landings data is available full population demographics can be estimated for Welsh populations

  - This will also provide adult growth data for Welsh populations of crab
- Identify brooding grounds for gravid female crabs:
  - Some anecdotal evidence suggests scallop vessels operating in some areas during the spring are catching significant numbers of berried hens. There are likely ideal marine habitats that serve as brooding grounds for *Cancer pagurus.*
  - Scallop dredge survey from the Prince Madog to gather pot independent data.
  - Together with habitat mapping and video surveys to model and ground truth crab brooding grounds.

Prawn population biology

- Continue the existing sampling programme, as under EMFF, as well as collecting additional data:
- Identify migration and recruitment patterns
    - Monthly monitoring of stocks in winter
    - Weekly monitoring of recruitment through summer
- Investigate the link between rainfall and recruitment success
- Population estimates
    - A depletion experiment with local fishers to estimate stock size and assess gear efficiency

Overall progress and future work

The 'Sustainable use of fisheries resources in Welsh waters' project has greatly advanced our knowledge of Welsh fisheries. We now have methodologies for sampling the main shellfish fisheries in Wales through a combination of fishery-dependent and fishery-independent methods. Continued sampling of these fisheries will ensure that Welsh fisheries will have adequate data to meet the requirements of MSFD and the CFP. Large scale studies have been completed that will elucidate on the impacts of scallop dredging and provide a database of fisher knowledge in Wales.

It is hoped that the worked started under EFF will continue under EMFF funding to build on the current progress and to develop further the necessary long time-series of data necessary to meet the requirements of MSFD and CFP directives**.** The main aims of this work would be to ensure that data collection continues to provide a time-series for Wales' main fisheries to allow stock assessments to be undertaken. Identifying the connectivity between the waters adjacent to Wales will also be a primary focus.

Contents

1 Introduction

1.1 EFF project background

The Sustainable Use of Fisheries Resources in Welsh Waters (SUFRWW) European Fisheries Fund (EFF) project began in October 2012 and will be completed in May 2015. This report outlines progress in the project as of August 2014 and provides an overview of future work that we have identified as important. Subject to consultation, this work will form part of a bid for funding under the European Maritime and Fisheries Fund (EMFF).

The SUFRWW project was divided into five work packages. These covered a broad range of fisheries data needs:

- Work package 1 – Fisher knowledge
- Work package 2 – Habitats and fishing impacts
- Work Package 3 – Exploited populations
- Work package 4 – Connectivity
- Work package 5 – Management recommendations

Each work package (WP) was then divided into multiple work streams. WP 1 consisted of two industry questionnaires; one focusing on economics and the other covering fishing patterns and exploited populations. WP 2 dealt with habitat mapping and assessing the impacts of scallop dredging on benthic habitats. WP 3 examined populations of exploited species in Wales including sea bass, brown crabs, lobsters, prawns, whelks and scallops. WP 4 focussed on understanding connectivity between scallop, crab, lobster and bass stocks. The identification of discrete populations, and therefore appropriate management units, is essential to achieve sustainable fisheries exploitation. WP 5 draws together information gained from the other four work packages to provide an evaluation of different management strategies that can be used by fisheries and environmental managers. This work package is dependent on the results from the rest of the project and will therefore be delivered in 2015.

1.2 Future knowledge needs

In recent years the European Union has adopted a range of measures that mandate the provision of data that provide insights into population status across a much wider range of species than are monitored at present. The Marine Strategy Framework Directive (MSFD) was adopted in 2008 with the aim of achieving Good Environmental Status (GES) in the marine waters of the European Union by 2020. The primary objective of the MSFD is to ensure that marine biodiversity is maintained (EU Directive 2008/56/EC). Simultaneously, the reformed Common Fisheries Policy (CFP) requires that an ecosystem-based approach to fisheries management is adopted such that marine biological resources are exploited sustainably and that the marine environment is protected to allow the achievement of GES by 2020 (Regulation (EU) No 1380/2013).

The introduction of the MSFD and the reform of the CFP will require EU member states to commence collection or improve the collection of data for species which previously required little or no formal reporting of catches or catch composition. Reporting requirements of the CFP are moving towards ensuring that stocks are exploited at a level of fishing mortality (F_{MSY}) that would achieve the maximum sustainable yield (MSY) (Comm 2006). In addition, the MSFD aims to "*...contribute to coherence between different policies and foster the integration of environmental concerns into other policies, such as the Common Fisheries Policy (CFP)... ".*

Future knowledge needs are likely to be driven by these changes in fisheries and environmental legislation. In our application for EMFF funding we will directly address these needs. This will be achieved by building on the outcomes of our present project, through the identification of knowledge gaps, and through continued consultation with stakeholders. In the following sections we outline progress in the SUFRWW project and propose areas of research for June 2015 and beyond.

2 Work Package 1: Fishing industry questionnaires

2.1 Fishers' knowledge: An assessment of the spatial distribution of fishing activity and historical patterns of activity in relation to target species

What have we achieved? • Developed GIS-based questionnaire software. • Conducted 61 questionnaires with fishers across Wales; 29 in North Wales, 11 in Mid Wales, and 21 in South Wales. • Compiled a database of fishers' knowledge.
What does this mean for managers and fishers? • Engaging with all stakeholders is a key element of the ecosystem approach to fisheries management, a key aim of the Marine Strategy Framework Directive. This information will help reach these objectives. • Managers will gain insight into the broad distribution of fishing effort, especially for under 10m vessels (for which there is currently no vessel tracking system), as well as the structure of the Welsh fishing fleet and changes observed by fishers with respect to target species. • Managers will have economical and biological information on target species that could inform future sampling and inform the outcomes of management measures. • This project will provide fishers with a portfolio of independent evidence that can be used in the marine spatial planning process
Current and future knowledge needs • Agreement with the industry as to the resolution for any maps produced. • A clear idea of how fishers will be given their data at the end of the project. • Continue to expand the proportion of the industry sampled, particularly in South and Mid Wales. • A repeat of the questionnaire in four years to assess changes over time.

Aims and achievements

The three main aims proposed for the Fishers' Knowledge Questionnaire work package were to 1) map current fishing effort and past fishing grounds, 2) determine the reasons why fishers target particular grounds, and 3) assess the historical changes in target species behaviour, abundance and size.

The first aim was proposed to enable the SUFRWW project to focus sampling within areas of known and important fishing grounds and to highlight potential conflicts with conservation and between sectors. The second aim was proposed to identify the main drivers underlying fishing behaviour which can be used to predict fishing fleet behaviour with respect to changes of external factors, such as management decisions or fuel prices. Finally, the third aim was proposed due to the absence of

historical datasets for most Welsh fisheries. The information obtained with this questionnaire will allow a baseline can be constructed against which future scenarios can be compared.

Currently, 61 questionnaires have been completed across Wales, amounting to 14% of the active Welsh fishing fleet. The aim is to interview around 20% of the Welsh fleet. The remainder of the interviews will be focused in the sectors and geographical areas where fewer questionnaires have been conducted to date.

Work proposed under EMFF

In order to continue using the questionnaire, it will need to be upgraded to be compatible with version 10 of ArcGIS. The questionnaires that have been completed before the end of the EFF project will be analysed and written into a report; however, new fishers that are met and interested in the EMFF project can be interviewed and their information added to the existing records and the analysis updated. Furthermore, the information from the questionnaire will be extremely valuable for the EMFF project to focus sampling effort and identify areas of concern for the industry that the project could address. Any management scenarios proposed in the EMFF project should use the questionnaire data to assess the impacts on the fishing industry. Repeating aspects of the questionnaire after four years will identify changes that have occurred in the Welsh fishing fleet.

3. Work Package 2: Habitat mapping and fishing impacts

3.1 Scallop dredging impact on epifauna and infauna

What have we achieved? • We have mapped out the habitats in an experimental area in the Cardigan Bay SAC (with videos and side scan) and produced a report • We have conducted a large scale fishing intensity experiment • The experiment consisted of 3 surveys: one pre and one post impact and one recovery survey. • During those surveys we collected beam trawl samples, grab samples and videos, as well as multibeam and sidescan sonar data. • We conducted a recovery survey in September. • A preliminary report will be completed in 2014 and the final report by ay 2015. • We have assessed the impact of scallop dredging on the main Welsh scallop grounds. We have defined thresholds relating fishing effort to changes in epifauna and infauna. • We have estimated the catchability of scallop dredgers
What does this mean for managers and fishers? • In light of the findings of our large scale experiment, managers and fishers can now discuss management scenarios in the context of an ecosystem approach to fisheries. • Rotational spatial closures are of interest to fishers. The potential effectiveness of this management system in Cardigan Bay SAC can be evaluated based on our findings. • Further information obtained from this experiment, such as catchability, will be important for stock assessment; models testing management scenarios; or predicting fleet behaviour.
Current and future knowledge needs • The recovery of the boxes fished during the experiment need to be monitored for a longer period of time (at least once more in spring/summer 2015) as the first recovery survey occurred only 4 months after impact (recovery has been shown to take many years in places) • The outputs need to be used to test out management scenarios in future simulations. • We need to obtain more accurate oceanographic data for Cardigan Bay and the rest of Wales to be able to disentangle the effects of fishing from the effects of natural disturbance.

Aims and achievements

Aim: Assessing quantitatively the effect of dredging on scallop habitats

Achievement:

- Conducted a habitat survey in the Cardigan Bay SAC (west of the open area)
- Conducted 3 surveys to assess the direct impact of fishing on infauna and epifauna as well as impact on substratum
- Analysed all the videos and beam trawl data (infaunal sample processing is underway)
- Analysed part of the pre and post survey multibeam and side scan data
- Report on all the findings and provide advice by May 2015
- Identify areas where further science is needed

Work proposed under EMFF

- Re-survey the experimental area of Cardigan Bay SAC to monitor recovery

We need to conduct at least one more recovery survey using the same methodology as in earlier surveys: one in spring/summer 2015 and one in summer 2016 would be ideal. This work would include beam trawling, camera surveys, grab sampling, sidescan sonar and multibeam echosounders surveys.

During the current project we were able to draw on expertise within the School of Ocean Sciences to undertake processing of acoustic data free of charge. However, this is not likely to be possible in the future. Therefore, under EMFF we would contract an expert to process the side scan and multibeam data in future surveys of Cardigan Bay.

We need to develop models to simulate different management scenarios and their likely impact on the future of the fishery and the stock based on the findings of this large scale study. We now have most of the basic information needed to develop such models which could be very Informative for fishers and managers. This information includes scallop population dynamics and distribution, a larval dispersal model and quantitative assessment of fishing impacts on associated fauna and habitats and their recovery.

One thing which is missing and which is vital to inform such a model is information on scallop spawning and recruitment. How much do they spawn, how far apart do they have to be at the maximum to be successful, what percentage of larvae settles and how many recruit to the fishery?

One method of investigating density-dependent fertilisation success would be to place bags of appropriate mesh size with eggs in the water, releasing sperm upstream and downstream at different distances). This would be similar to a study on sea urchin spawning undertaken by Levitan (1991). There are several key areas for study:

- Density dependent scallop fertilisation success
- Age/size dependent egg size and quality of scallops
- Development of genetic markers to ID scallop larvae in the water column
- Using the genetic markers to find out where and when the scallop larvae occur
- Improving existing connectivity model
- Implications of the findings for management (e.g. MPAs – do we want high densities, old scallops? if so where do we want them?)

In addition to this, we still need to find out if scallops move and if so how much. To do so we should undertake a tagging programme in Cardigan Bay. This would involve releasing scallops across the open and closed areas of Cardigan Bay and recording how many are caught in the open area.

3.2 Gear modification: Scallop skid dredges

What have we achieved? • We have conducted preliminary research on using skids on dredges to limit impact on the seabed • We have found that the catchability of the dredges was not affected by the use of the skids • There was inconclusive findings on the fuel consumption with or without skids
What does this mean for managers and fishers? • Fishers and managers in Wales could agree to make skids mandatory to fish in Welsh waters which would limit the impact on the ecosystem and thus preserve the sustainability of the fishery and discourage some fishers to enter the fishery
Current and future knowledge needs • We need to find out if the skids do indeed limit the impact of scallop dredges on the seabed

Aims and achievements

Aim: Testing out gear modification to limit the environmental footprint of fishing

Achievement:

- Conducted some preliminary trials and have got some preliminary results showing no difference in the catch of scallops >MLS between dredges fitted with skids and those fitted with no skids

Work proposed under EMFF

We need to conduct further research to see if the skids are really more sustainable regarding the effects of scallop dredging on the associated species and habitats. A protocol to undertake these tests needs to be develop and funds sought to evaluate the wider ecological effects of the different gear designs.

4. Work Package 3: Data collection to quantify the distribution, abundance, biomass and age structure of target species in Welsh waters

4.1 European sea bass (*Dicentrarchus labrax*) population biology

What have we achieved?

- Developed a monthly sampling programme involving 12 fishers and 7 fish processors. Data on length, weight, sex, maturity stage, capture location and fishing gear have been collected for a total of c. 2000 bass from 33 areas around Wales.
- Gillnets and line (rod and line and longline) are the main gears used by inshore fishers to target bass. The catch at age matrices per fishing gear have been developed and differences between line and gillnet have been detected.
- Sex ratio (males/males+females) has been based on a sample size of 780 bass. There is a significant difference in the sex ratio between north (0.28 ± 0.27SD) and south Wales (0.57 ± 0.43SD) for fish caught with line, such that female fish are more prevalent in the north.
- The spawning period of bass for the season 2013-2014 has been identified (January-May) with the maximum GSI occurring in March. Preliminary results also indicate that there is a decrease in the size at maturity of bass females to 40 cm.
- A recruitment index of 0 group bass (abundances of 0 group bass) has been developed for 2013 and 2014.
- We characterized the carbon and nitrogen stable isotope signatures for the last season of growth measured from the scales of adult bass caught from different locations around Wales. Differences in the isotopic signal between North, Mid and South Wales have been detected.

What does this mean for managers and fishers?

- A decrease in the size at maturity for bass females to 40 cm represents an indicator of the possible overexploitation of the stock. This finding stresses the urgent need for effective management measures. One of those measures could be the increase of the MLS to 40 cm.
- An increase of the MLS to 40 cm will have a different impact on fishers depending on the gear used. It would possibly generate higher economic loss to rod and line fishers than to gill netters.
- The identification of the spawning period is useful for planning temporal fishing closures, as the protection of the spawning stock during the reproduction period can be a management target.
- The female-skewed sex ratio identified in north Wales is useful information if the protection of mature females through spatial closures is a management target.
- The recruitment index is essential to monitor the state of the stock and future recruitment to the fishery.
- The isotopic analysis improves the knowledge on bass movements and stock boundaries and could provide a management tool for tracking movement patterns.

Current and future knowledge needs

- The current sampling programme has established a robust monitoring programme; however, this will need to be maintained to build an adequate time series of data for the purposes of stock assessment.
- Although we have gained some insights into the bass movements through the analysis of carbon and nitrogen stable isotopes in fish scales, a better definition of possible movement patterns and connectivity between areas is needed. This could be achieved by analysing both the stable isotopic and trace element (microchemistry) signatures in the scales and otoliths.

- We have developed a recruitment index but more information is now needed on the origin of the recruits and thus on the location of the spawning grounds

Aims and achievements

To date Wales has been overlooked in comparison to other UK areas for data collection on various stocks, including bass. Our challenge has been to put in place scientific monitoring, in close cooperation with fishers and fish processors, to give the Welsh Government improved insight into the state of the bass stock in Wales and how best to manage it. The most important aspect of our research was to know how many bass are caught, in which area, and by what method. To this end we have involved 12 fishers and 7 fish processors around Wales to collect information on fishing areas, size of the bass caught and fishing gears used. A total of about 2000 bass were sampled from 33 areas around Wales.

Understanding the age structure of the bass population around Wales has been the second essential aspect of our research. Catch at age matrices per fishing gear have been developed and differences between line and gillnet (the main gears used by inshore fishers to target bass) have been detected.

A third essential aim of this project was to estimate the proportion of males and females that are caught by area and season, the maturity stage and the size at maturity. Sex ratio (males/males+females) was based on a total of 780 bass that were dissected to determine their sex and maturity. There was a significant difference in the sex ratio between North (0.28 ± 0.27SD) and South Wales (0.57 ± 0.43SD) for fish caught with hook and line. The spawning period of bass for the season 2013-2014 was identified (January-May), with the maximum GSI occurring in March. Preliminary results also indicate that there has been a decrease in the size at maturity of bass females from 42 cm to 40 cm based on a comparison of current data and historical data from the 1980s (Pawson & Pickett 1996).

We have developed an annual bass recruitment index around Wales. The knowledge of the abundance of the post-larvae bass (0-group bass) in nursery areas is essential to understand the state of the stock and the future recruitment to the fishery. During summer 2013 we sampled with a seine net in 10 different estuarine areas around Wales. Zero-group bass were detected in small quantities only in south Wales and in the Aberdovey estuary, indicating that 2013 was a poor recruitment year.

The last aspect of our research has been to characterize the carbon and nitrogen isotope signatures measured from the scales of adult bass caught from different locations around Wales. Preliminary results indicate spatial differences in the isotopic signal between North, Mid and South Wales. The isotopic analysis improves the knowledge on bass movements and represents a novel tool to determine the origin of the bass caught from spawning aggregations. What the isotopic signatures show is the fish are regionally resident, however until we are able to sample spawning aggregations it will be difficult to determine the level of mixing during the spawning period.

Work proposed under EMFF

The current sampling programme has established a robust monitoring programme that needs to be maintained to build an adequate time series of data for the purposes of stock assessment. It is hoped that under the EMFF project the data collection programme started with the EFF project will be

maintained with a particular emphasis on the analysis of stable isotopes and trace elements to determine more accurate movement patterns of adult and young bass. Preliminary results on the isotopic composition of scales of adult bass indicate that there is a difference in the isotopic signal between North, Mid and South Wales. These analyses have been based on two elements (nitrogen and carbon isotopes) and small sample sizes. However, 76% of discrimination between regional groups has been achieved. This analysis could be improved by increasing sample sizes and the percentage group assignment can probably be increased by including trace elements (e.g. Strontium and Barium) in the analysis in order to better define/discriminate between regional groups. The inclusion of otoliths as well as scales will provide the potential for otolith isotope analysis that will track more accurately changes in water temperature that is related to fish movement patterns. A greater focus would be placed on locating spawning grounds. Work would therefore encompass four main areas:

1. Trace element analysis (e.g. Strontium and Barium) in the scales of adult and young bass already analysed for the ^{15}N and ^{13}C isotopic composition and in the new scales collected under the EMFF project inside and outside Wales. This will improve the separation between groups and thus will allow the "finger print" of each area to be better defined.
2. Analysis of the isotopic composition of oxygen in the otoliths of the bass collected during the EFF project and of bass that will be collected during the EMFF project, including samples from outside Wales. In fact otolith oxygen isotopes provide an extremely powerful tool to explore migration and movement in fishes, particularly across temperature and salinity gradients. Moreover, the results obtained with the analysis of otoliths will be compared with those obtained from the scales' analysis to assess the consistency in the pattern and thus to validate both methodologies.
3. Analysis of otolith growth patterns in the post larvae bass. The distance between specific otolith increments will indicate the age, in days, of the 0 group individuals. This information, combined with a particle tracking model on larval dispersal, will give insights on the location of bass spawning grounds. Genetic analysis of samples of 0 group bass and adult spawning bass will be also performed to find possible genetic correlations between adults and larvae.
4. The potential of using scale shape and growth patterns (which will be dependent on food productivity and temperature and so should show regional variation) as another potential tool to try to identify the region of origin of each fish.

By the end of the EMFF project a five-year time series of bass data will be provided and a better picture of the bass movements and the stock boundaries will presented.

4.2 Thornback ray (*Raja clavata*) population biology

What have we achieved?

- Preliminary data collected during the 2013 sampling survey (October 2013) in North Wales revealed a predominance of thornback ray (*Raja clavata*) around Conwy and Red Wharf Bay. A larger pan-Wales survey did not occur due to lack of permission from Welsh Government to sample fish communities.
- Sex ratio, size at maturity, growth curve and other life history parameters are currently under analysis.

What does this mean for managers and fishers?
• The knowledge of the state of the stock of thornback ray is essential for management of fisheries targeting rays or that land rays as bycatch.
Current and future knowledge needs
• More information is needed about the state of the ray stocks and the composition of the elasmobranch community in Welsh coastal waters to provide evidence to underpin management.

Aims and achievements

We started the characterization of the thornback ray stock in North Wales and by the end of the EFF project the comparison of the life history parameters with previous studies on the area will be made. MSc projects studied the population biology of thornback rays in North Wales in the late 1960s and early 2000s providing some information on changes in population size/age structure and population dynamics over the last 50 years.

Work proposed under EMFF

A 10 day sampling survey around Wales with the RV Prince Madog is planned under the EMFF project. The design of this survey will be informed by fisher knowledge of ray grounds (and the International Beam Trawl Survey data) to improve the precision of estimates of stock abundance. On this cruise we will describe the composition of the demersal elasmobranch community in Welsh coastal waters and the spatial variation in species richness. We will therefore evaluate whether there is a North-South/East-West gradient in the richness of the elasmobranch assemblages as well as the presence of hotspots characterized by high species density and diversity. Data collected will also be compared with previous studies (http://ecosystemdata.ices.dk/) to assess possible temporal variations in these assemblages. This survey could also integrate evaluation of other fish species and could be extended to more efficiently incorporate the scallop survey.

Special attention will be paid to skates and rays in the survey, in particular thornback ray (*Raja clavata*), blonde ray (*Raja brachyura*), small-eyed ray (*Raja microocellata*) and spotted ray (*Raja montagui*). For all these species, life history parameters such as the asymptotic length (L_∞) and the length at first maturity (L_{50}) will be estimated as well as the rate of total instantaneous mortality Z (y^{-1}) for males and females. These parameters will be also compared with those estimated from samples in Colwyn Bay in 1967 (Lesser, 1967) and Caernarfon Bay in 2003 for thornback ray (Whittamore & McCarthy, 2005); in Carmarthen Bay in 1974/76 for thornback, small-eyed and spotted rays (Ryland & Ajayi, 1984); and in the Irish Sea in general in 1997/98 for all four species (Gallagher et al., 2004). These comparisons will be essential to assess the state of the Welsh stocks, as a possible decline in current L_∞ and L_{50} compared to previous published studies could indicate potential compensatory effects in these life history parameters in response to over-exploitation (Jennings & Kaiser, 1998).

Sampling would be carried out during summer 2016 in Welsh coastal waters using otter trawl gear (76 mm mesh) towed at 2-3 knots. Four sampling zones per area (North, Mid and South Wales) have been identified on the basis of the density values of rays derived from IBTS (http://ecosystemdata.ices.dk/), two over the depth range 10-30m and two covering the range 40-60m. Two replicates by depth range will be conducted in each zone, for a total of 8 stations by area and 24 stations in total.

For each tow, the species composition of the catch will be assessed. Each individual from each elasmobranch species caught will be measured, weighed and classified by sex (for the species presenting sexual dimorphism). For each tow, a maximum of 14 individuals (7 males and 7 females) for each ray species studied (*Raja clavata*, *Raja brachyura, Raja microocellata*, *Raja montagui*) will be retained across the size classes present in the sample to guarantee a minimum of 100 individuals (50 males and 50 females) per area (North, Mid and South Wales) per species. This sample size is considered the minimum required to estimate with confidence the selected life history parameters (L_∞, L_{50} and Z) according to Whittamore & McCarthy (2005). However, it is likely that the four species will only be found together in the same sampling areas in South Wales, according to the current data on species distribution (http://ecosystemdata.ices.dk/).

Data from the fishing survey will be also be compared and integrated with data obtained from fishers and fish processors in South Wales, which represents the main fishing area for rays in the region. By the end of the EMFF project we would have a picture of elasmobranch richness in Welsh coastal waters, its spatial variation in species richness, the state of the rays' stocks and the level of their exploitation.

4.3 Population biology of European sprat (*Sprattus sprattus*) and other small pelagic fish

Background

The sprat population around Wales is not assessed by ICES and is considered to be poorly understood (ICES, 2014). Currently no studies have been conducted to address the question of stock structure along the Welsh coast. Lack of information is also related to other small pelagic species as herring (*Clupea harengus*) and sardines (*Sardina pilchardus*). In Wales fisheries targeting small pelagic fish are not well developed. However, historic information suggests the presence of a past fishery targeting small pelagic fish in South Wales (Gray, 1995).

The aim of the project is to assess the abundance of the sprat, herring and sardine populations along the Welsh coast by means of acoustic data collection.

Work proposed under EMFF

From July 2015 till March 2016 a monthly survey will be conducted on-board a commercial fishing vessel along the Welsh coast. The survey will include pre-designed transects perpendicular to the coast in North, Mid and South Wales. A local fishing vessel experienced in pelagic fishery will be chartered for the study and an echo-sounder, previously calibrated, will be used to record acoustic data over the transects. The acoustic data will be cleaned and processed after the survey using specific processing software to be able to extract clupeid species from the raw data.

Acoustic data will be combined with sampling along the same transects. A drop net will be used to catch representative samples of fish inside the shoals identified with the echo-sounder. The catches will be used to establish the catch species composition, length frequency, age and maturity

information. The use of the drop net will allow a relatively small amount of fish to be caught avoiding the large amount of discards that will result with the use of a commercial ring net.

The planned work will allow the abundance of the main small pelagic species to be estimated as it will be conducted during the month when the three main species are present.

References

Grey, 1995. The coastal fisheries of England and Wales, Part III: A review of their status 1992-1994. Fish. Res. Tech. Rep., MAFF Direct. Fish. Res., Lowestoft, (100): 99pp

ICES. 2014. Report of the Benchmark Workshop on Sprat Stocks (WKSPRAT), 11–15 February 2013, Copenhagen, Denmark. ICES CM 2013/ACOM:48. 220 pp

4.4 Scallops

4.4.1 Scallop stock assessment

What have we achieved?

- We have conducted three comparable surveys and compared the outputs of different sampling methods (i.e. stills camera, video and dredge)
- We have started a spatially explicit time series of abundance indices of scallops
- We have determined the population dynamics parameters of scallops around Wales and estimated densities in fished and unfished areas
- We found that abundances in the closed area of the SAC were much higher than in the open area and that there was a difference in age structure too (with larger and older scallops in the closed area)
- We also found in 2013 that the scallops seemed to spawn at different times between Cardigan Bay, the Llyn Peninsula and north of Anglesey
- We have obtained VMS and logbook data from the MMO and have mapped out where the most valuable catches came from in Welsh waters since 2000 (with limitations)

What does this mean for managers and fishers?

- We have provided managers and fishers with information which will be essential to estimate MSY in the future as this requires a time series of abundance indices and some population dynamics parameters such as growth, mortality and maturity
- We have provided fisheries independent data and fisheries dependent data, again with the objective of defining MSY.
- Based on these data, fishers and managers can start discussing management strategies and these strategies can be tested with models.

Current and future knowledge needs

- The current sampling programme has established a robust monitoring programme and, combined with logbook and VMS data, forms the basis for a well-informed management programme. However, this will need to be maintained (expanded) to build an adequate time series of data for the purposes of stock assessment.
- Our surveys have covered the main fishing grounds and therefore we have reliable estimates of scallop densities on those grounds. However, there are still gaps in our knowledge of the scallop stock extent, particularly within 1nm and 3nm off the coast.
- Greater emphasis is needed on understanding the connectivity of the scallop stocks around Wales. This implies research on spawning time and locations and larval behaviour.

- The scallop stock assessment has to be put in context of a wider ecosystem approach to ensure sustainable management.

Aims and achievements

Aim: Collecting fishery independent scallop stock data

Achievement:

- Collected population dynamics data (age, length, growth, maturity, mortality)
- Collected distribution and density data
- Compared changes over 3 years on 3 different fishing grounds
- Obtained fishery dependent information
- First attempts at a formal stock assessment completed.

Work proposed under EMFF

We need to keep surveying the Welsh scallop stocks to obtain fisheries independent data, especially in areas where the scallop industry does not have access (so where no fishery-dependent data exist). This can be achieved by keeping the research surveys going either with the RV Prince Madog or with fishing vessels and by taking dredge samples and/or video samples. We will need to extend our inshore survey – probably using drop down cameras or towed cameras from small fishing vessels where static gear prevents dredging.

We need to start collecting more fisheries dependent data. This can be achieved by re-implementing a revised version of the red bag scheme. This method of sampling was not successful in its original form due to an inadequate number of scientific personnel to manage the scheme. An alternative would be to undertake more observer coverage at sea or port sampling. Further work needs to be done regarding spawning and larval behaviour (this is discussed in Section 4.4.2).

4.4.2 Reproduction in king scallops

What have we achieved?

- Developed a weekly sampling programme involving three fishers at two locations in Wales and are compiling data on scallop weights (gonad, soft tissue, muscle) and age as well as gonad maturity stages.
- Collected tissue samples of scallops from the North of Anglesey to examine the genetic connectivity of scallops between age classes.
- Collected gonad samples from mature scallops at different ages to store for future analysis of egg quality and fecundity. Gonad samples have been stored in Davidson's solution with the aim of carrying out histological analysis.

What does this mean for managers and fishers?

- Gathering information on spawning times for populations of scallops will allow better management of the stocks. When paired with environmental and larval behavioural data in computer models it will allow us to build a picture of settlement patterns and connectivity between stocks.
- The above data can also be linked with the genetic data that we are collecting to further understand the structure of the stocks so we will have better information for management decisions. For example, whether all the stocks connected and should be managed as one unit or as separate stocks?

Current and future knowledge needs

- The current sampling programme has established a robust protocol; however, it is limited to North Wales. We would like to increase the sampling effort and collect samples from across Wales so we can determine the timing of king scallop spawning.
- Although we have gained some insights into the environmental drivers that affect scallop spawning it would provide a much more robust data set if we could collect detailed oceanographic data to link with spawning events.

Aims and achievements

The aim was to gather data on the spawning times of king scallops in Welsh waters. We aimed to determine whether scallops had a single spawning event or multiple spawning events and whether this varied by region. Furthermore, we aimed to develop a protocol to assess the fecundity and egg quality of scallops across their age range. So far we have established a protocol for the collection of scallops and the initial stages of laboratory analysis. We now need to expand the study to include more regions, particularly Cardigan Bay, and to continue with the laboratory protocol for fecundity at age.

Work proposed under EMFF

Gonad samples are being collected and stored for future analysis. Under EMFF we would like to carry out histological analysis of these samples to assess fecundity. This is the most accurate method as maturity of the oocytes can be assessed, providing a better estimate of fecundity. Furthermore, we would like to carry out egg quality analysis on our stored samples to gain insight into the reproductive fitness of scallops as they age. This information is a missing gap in our current knowledge, and would provide useful evidence for management decisions regarding landing sizes.

4.5 Crustacean on-board camera development

What have we achieved?

- Built a prototype video camera system which was trialled on six different fishing boats.
- Scientific observers measured over 3000 crabs and lobsters whilst simultaneously capturing them on the video system.
- Extracted these images of the measured crabs and lobsters from video footage and measured their size in Image J software.
- Statistical analysis of the relationship between the real measured size and the size estimated from the video footage.

• Analysis of the error associated with using video instead of on-board observers for sex identification and size. • Comparison of size frequency estimates from on-board observers and the video footage.
What does this mean for managers and fishers? • Port sampling, whilst easier and more cost effective than on-board observers, does not provide any data on animals under the minimum landing size. • On-board observers are costly both in terms of time and effort. In addition, it is not usually possible to have observers on-board throughout the year; therefore, data is often only a snapshot during the year. Consequently, having more efficient data collection systems in place will be vital to obtaining the data necessary to inform effective fisheries management. • This study is a proof of concept for the use of video capture of fisheries data for the crustacean pot fishing sector and could represent a considerable increase in data collection capability at a lower cost than would be possible with on-board observers.
Current and future knowledge needs • This study has shown that video capture is an effective means of collecting fisheries data without sacrificing data accuracy. • Future work needs to focus on the development of the software component as extraction of images from the video can be time costly. • In addition, the prototype video box needs to be refined to make it as robust and user-friendly as possible.

Aims and achievements

This project aimed to test the possibility of using video equipment to collect fisheries data for crabs and lobsters. Such technological advances will improve data collection in several ways:

1. Increase the geographical coverage of data collection.
2. Increase the frequency of data collection.
3. Decrease the cost of data collection.
4. Provide a fully documented fishery.

All of these aims can be met without sacrificing data accuracy. This study investigated the accuracy of video data collection as a proof of concept.

Usability

The camera unit was tested by six fishermen and footage was collected with minimal interference to their normal working routine. Each crab or lobster is passed under the camera's field of view and only needs to be held in place for less than a second for good quality images to be recorded. None of the fishermen involved reported that the unit interfered with their fishing.

Accuracy of data

A major focus of this study was to analyse the accuracy of the size and sex data collected from the video footage compared to the error associated with traditional in situ measurements. To achieve this, an on-board observer took in situ measurements of sex and size and then the animals were passed under the camera. Over 3000 measurements were taken. 75% of the data set was used to analyse the relationship between in situ measurements and those taken from the video. The remaining 25% of the data set was then used to test this relationship and estimate the error of the video measurements.

The sex of crabs was 100% correctly identified from video footage by observing the shape of the abdominal flap. In lobsters the sex was determined by calculating the ratio of the carapace length to the abdomen width, as the abdomen is wider in females. The sex of lobsters was 100% correctly assigned in lobsters greater than 86 mm in carapace length. Below this size females were assigned as males as the sexual dimorphism of the abdomen width occurs at sexual maturity.

There was no significant difference in the length frequency histograms from in situ measurements and those from the camera for either crabs or lobsters. For a sample of 192 crabs the difference in mean size estimated from the cameras compered to in situ was 0.85 mm (-1.22 to 0.48 mm 95% Confidence Interval) with 45 crabs classified as undersized compared to 48 in situ. For 355 lobsters the difference in mean size estimated from the cameras compered to in situ was 0.08 mm (-0.32 – 0.49 mm 95% Confidence Interval) with 210 lobsters classified as undersized compared to 211 in situ.

Overall, the error associated by using the video methodology to collect size data allows crabs to be categorised into 3 mm size classes and lobsters into 2 mm size classes.

Work proposed under EMFF

Software development:

1. Development of automatic recognition of crabs and lobsters form the video to allow automated extraction of stills images from the footage. This will cut the processing time in half.
2. The second phase of software development would include the recognition of crabs and lobsters to provide automatic summary data on catch per unit effort (i.e. per pot).
3. The third phase of software development would be to develop automated measuring of size.

Hardware development:

The hardware will need to be refined to include the following:

1. GPS to overlay onto the video.
2. Larger storage to allow downloading less frequently.
3. Hardwired to the boats 12V system to avoid fishers having to charge the units.
4. Single on/off switch on the outside of the unit.

4.6 Lobsters

4.6.1 Baseline lobster fisheries data

What have we achieved?

- Monthly (where weather allowed) on-board observer data from 2013 until end of project in May 2015.
- On-board observer data includes CPUE, size frequency, sex ratio, proportion of berried females and by-catch.
- Monthly shore-based length and weight measurements.
- Water temperature data from multiple sites around Wales.

What does this mean for managers and fishers?

- Lobster CPUE can vary depending on the season, weather, water temperature as well as with abundance. It is therefore important to monitor CPUE over time to model the effect that the season, annual water temperatures and weather will have on catches. This allows the natural variation to be mapped which in turn will allow any changes in CPUE due to abundance and fishing effort to be monitored.
- Changes in fishing effort or minimum landing sizes can cause changes in the size frequency of catches. Baseline data is therefore important to enable monitoring of the size frequencies in response to any changes in technical measures or fishing effort.
- Landings data is reported in kg, whereas fisheries data is usually abundance and size. Therefore it is important for stock assessment models, to be able convert landings data into catch number and size data. Lobster weight is likely to change throughout the year due to the moulting process. Therefore the conversion factor for length-weight may vary depending on the month and season. The monthly length weight data will allow accurate conversion of landings data.
- Sex ratio changes may be observed due to preferential harvesting of one sex over another (e.g. due to protection of berried females). Baseline data of sex ratios in catches will therefore allow the monitoring of this biological parameter in response to any technical measures introduced. Changes in sex ratio can have consequences for genetic diversity, reproductive strategies and reproductive output (e.g. sperm limitation).
- The CFP reform will require the limitation of discards. Although this is initially focused on white fish fisheries it could extend to crustacean fisheries in 2018. It is therefore important to document the type of by-catch, the abundance of by-catch and the condition/survival of by-catch to ensure that the crustacean fisheries will not unnecessarily be limited due to any discard concerns. In addition, as much of the pot fishery occurs within SAC's and other protected areas, documenting the low levels of by-catch and the condition/survival of by-catch will be important in addressing the impact of the fishery.

Current and future knowledge needs

- By the end of the current project we will have catch data over 2 years. In order to separate natural annual variability from fisheries induced changes it will be important for this time series to continue for as long as possible.
- Improved and extended water temperature monitoring will be important for modelling the effect of the temperature on seasonal/annual variability in the catch.

Aims and achievements

There were two main aims of this project:

1. To derive an abundance index for lobsters around Wales.
2. To collect data on the size and sex composition of catches.

CPUE data do not necessarily reflect the abundance of lobsters.

Work proposed under EMFF

During the EMFF project, continued on-board observer data to collect catch and environmental data will allow us to model seasonal and annual variability.

Additional semi-permanent moorings for bottom and surface temperature monitoring and key locations (Bardsey, Pwllheli, Aberdovey, Newquay in addition to the current monitoring stations).

Improved temperature loggers to place on fishers pots. The current loggers are not able to react quickly enough to temperature changes to log the water depth profile. This data is important not only for deriving abundance indices but also for oceanographic models which can be used to model larval dispersal.

4.6.2 Lobster (*Homarus gammarus*) Reproductive Genetics

What have we achieved? • Genetic samples of female lobsters and their eggs have been collected from 4 sites. • DNA extraction protocols for female tissue and egg batches have been developed. • Microsatellite multiplex PCR protocol developed. • Laboratory work due to be completed by the end of August. • Report due to be completed by December 2014.
What does this mean for managers and fishers? • Exploitation and some management policies can alter population parameters e.g density, sex ratio and size distribution. These changes in the population can then influence the reproductive strategies of the population. This work on paternity and multiple paternity aims to identify changes in reproductive genetics associated with exploitation and management policies. This information should help to inform future management decisions.
Current and future knowledge needs • Results still need to be analysed. • Additional analysis of fisheries data to estimate the fishing effort at each site needs to be completed.

Aims and achievements

Samples of female lobsters and their eggs have been collected from three locations around Wales in addition to of samples from Lundy Island (this provides a control sample where no fishing occurs). We have developed the protocol for extracting DNA from batches of eggs and from lobster tissue has been completed and extraction of DNA from the collected samples is now underway.

We have 12 microsatellite markers that will be used to reconstruct paternity of the brood of eggs. The protocol for the multiplex PCR reaction has been optimised. It is envisaged that all samples will be genotyped using these microsatellites by the end of August 2014 and a report will be finished by the end of the project that will answer the following questions:

1. To what extent do lobsters in Wales show multiple paternity? Work carried out in Norway and Northern Island has suggested that the presence of multiple paternity and the prevalence within a population could be linked to the fishing effort and therefore the population structure and density of the site. This data will add to this growing evidence base and provide data specific to Wales.

2. How many male lobsters contribute to the reproductive output in a population and is this related to the fishing effort and structure of the population? A change from a 50:50 ratio of male to female success in reproduction can significantly increase the rate of loss of genetic diversity from a population.

Work proposed under EMFF

There is scope for adding additional sites from around Wales.

Additional sampling in multiple years would allow the analysis of the temporal stability of these paternity relationships. The EFF project has been undertaken in some extreme weather years and continued sampling would allow the impact of these weather patterns on the results to be investigated.

4.6.3 Lobster fecundity and egg quality

What have we achieved? • Collected egg mass samples from 32 lobsters in North Wales. • Collected egg mass samples from 60 lobsters in Pembrokeshire. • Fecundity counts from north Wales's samples are completed. • Laboratory work for egg size, dry weight and CHN analysis is on-going for north Wales. • Laboratory work for Pembrokeshire samples will commence in September 2014.
What does this mean for managers and fishers? • This work will provide biological data on the importance of female size on the reproductive output. This is important data when setting technical measures such as minimum landing size and when considering protection of large female's or berried females through v-notching, berried ban, seasonal berried ban, maximum landing size etc.
Current and future knowledge needs • This work will provide data on fecundity, egg size and egg quality with female size. • In order to fully understand the potential reproductive output with female size it will be important to understand the reproductive cycle with female size.

Aims and achievements

This work aimed to investigate any relationship between female lobster size and egg number, size, weight and quality. In many species larger females contribute a greater proportion to reproductive output than smaller females. This can lead to technical measures such as maximum landing sizes, refugia to allow individuals to attain larger sizes. In addition these data are useful when considering measures such as prohibition on landing berried females and when considering the most appropriate minimum landing size in terms of functional maturity.

This project has collected 47 samples from north Wales and 60 samples from south Wales to study these relationships. The laboratory work for the north Wales samples should be completed by

September 2014 with a report ready by the end of the year. The laboratory work for the south Wales samples will commence in September 2014 with all work and a final report ready by the end of the project.

Work proposed under EMFF

One hypothesis that was formulated from fishers knowledge was that although small females are physiologically mature enough to produce eggs they are less able to protect them and carry a full brood through the winter; whereas larger females fiercely protect their egg mass. It was intended that lobster fecundity would be studied in the autumn when the eggs are newly extruded and the fecundity with size and the size frequency of berried females would then be compared with samples from the same location the following spring/summer. Sampling was commenced in autumn 2013 but due to record storms there were not enough sea days available for a large enough sample size to be collected. Therefore it is proposed that this study is completed under EMFF. The importance of this work for management is; firstly if smaller females lose their egg mass over the winter then they should not be considered with the same weight when calculating size at maturity. Secondly it would also indicate that future size at maturity studies should occur during the spring/summer rather than year round or in the autumn.

The above study would also allow the temporal stability of fecundity and egg quality to be investigated. It is felt that this is important, not only to investigate natural variability but due to the fierce winter storms the results will be representative of an extreme weather year. It would therefore be preferable to add a third year of summer sampling to this study.

4.6.4 Lobster size at maturity

What have we achieved? • Over 2000 lobsters measured for morphometric relationships. • Over 20 fishing trips sampled to estimate the proportion of berried females. • 50-100 Pleopod samples taken every two weeks from April 2014 – September 2014 for cement gland analysis (archived at present).
What does this mean for managers and fishers? • Size at maturity is a key biological metric in setting minimum landing size. • Size at maturity is a key biological metric in egg per recruit models. • Size at maturity can decrease in response to overfishing and should be monitored every 3 years. Ensuring a robust methodology will allow such monitoring to take place.
Current and future knowledge needs • Size at maturity estimates for the European lobster exist in the literature from Ireland, Scotland and Norway. However they all vary significantly and therefore a local estimate is essential for the robust management of Welsh stocks. • Estimates in the literature use different methodologies; some of which estimate the onset of maturity, size at 50% maturity, physiological maturity or functional maturity. A robust methodology for temporal monitoring needs to be established.

Aims and achievements

In order to determine a suitable MLS for lobster it is important to understand the first age or size at maturity. This will be possible based on the morphometric data collected to date. However, understanding when an animal is functionally mature is a slightly different but perhaps more relevant question. The material collected, if worked up under EMFF, would provide a definitive answer to this question. Further sampling stratified by area would shed light on whether a 'one size fits all' strategy is appropriate for Welsh waters.

Work proposed under EMFF

Process the samples that currently are curated awaiting analysis and produce advice based on these analyses.

4.6.5 Lobster Escape Hatch Study in Cardigan Bay

What have we achieved? • Conducted morphometric measurements on lobsters and brown crabs to determine the appropriate size escape hatches to trial • Installed on-board cameras on four vessels in Cardigan Bay • Designed detailed protocol for fishing experiment • Fishers currently collecting data • Designed camera system mounted above a lobster pot which films what is happening inside • Trialled different designs and cameras and in the finishing stages of confirming final prototype
What does this mean for managers and fishers? • Could provide fishers with a more sustainable and time efficient gear for catching lobster and crab. • This could provide evidence to managers and fishers that escape hatches are beneficial to the fishery and worth investing in. • Provide evidence to managers to inform future consultation on recommendations for regulations to support stock rebuilding
Current and future knowledge needs • Future studies would depend on the results of the current study and camera trials

Aims and achievements

This study was proposed and partially funded by the Cardigan Bay Fisherman's Association (through EFF funds). The work aims to answer the following questions:

1. What size escape hatch optimises the catch of legal sized lobsters and brown crabs?
2. Do escape hatches reduce bycatch?
3. What are the economic consequences of using escape hatches?
4. Are undersized target species using escape hatches?

5. Is cannibalism occurring on undersized target species in pots without escape hatches?

Morphometric measurements of lobsters and brown crabs were collected at sea and in holding facilities to identify the appropriate size escape hatches that will allow escape of lobsters smaller than 87mm carapace length and brown crabs smaller than 130mm carapace width.

Four fishers in Cardigan Bay are currently collecting data for this study and should be finished by the end of summer 2014.

The camera system to record pot activity is still being trialled for the appropriate design and should be in the water collecting data by the end of summer 2014.

Work proposed under EMFF

If all of the proposed work is completed by the end of the EFF project, there will be no need to continue working on lobster escape hatches. As the funds were rewarded to the CBFA in 2011, it is important that the study be concluded and results presented to the fishers of the area.

Once the design for the camera system is complete, it can be used for a variety of applications in the EMFF project. Its most obvious application would be for investigating species interactions in pots *in situ* in more detail, as well as in stocking experiments.

4.7 Potting bycatch

What have we achieved?

- Completed collection of whelk bycatch
- Ongoing collection of lobster, brown crab, and prawn fisheries bycatch

What does this mean for managers and fishers?

- Managers will be provided with valuable bycatch information that can be used when addressing Marine Stewardship Council (MSC) needs as well as an ecosystem approach to fisheries management (EAFM) which is the backbone of the Marine Strategy Framework Directive (MSFD)
- Managers will be provided with an estimation of the level of discards associated with the lobster/brown crab fishery which will be a starting point for research associated with the EU Discard Ban/Landing Obligation.
- Depending on the outcome of this study and how managers use this information, fishers may need to alter fishing practices to fish in a more sustainable way.

Current and future knowledge needs

- Levels of discards for the whelk and prawn potting fisheries need to be assessed
- Future studies will need to address the survivability of bycatch that is discarded
- Bycatch, discards, and survivability of discards associated with bass fishing should be addressed

Aims and achievements

The aim of this study was to provide baseline bycatch data of the potting industry in Wales (lobster, brown crab, prawns, and whelks). The study proposed to identify the bycatch species that are being caught and record their abundance. In the case of lobster and crab potting, the fate of bycatch species was also observed. Information on bycatch is a requirement to meet MSC Principles which provide a good standard to follow for sustainable fisheries.

To date, data collection is completed for whelk potting and analysis has commenced. The data collection is still in progress for lobsters, brown crabs, and prawns.

Work proposed under EMFF

Further work on this topic should identify the levels of discards associated with whelk, prawn, and sea bass fishing, investigate the survivability of the most commonly discarded bycatch species (including the effects of riddling on whelks and prawns), as well as investigating whether gear modifications could be an option for decreasing bycatch.

4.8 Camera system on pots: investigating the inner workings of a lobster pot

What have we achieved? • Designed a camera system mounted above a lobster pot which films what is happening inside the pot. • Trialled different designs and cameras and in the finishing stages of confirming final prototype.
What does this mean for managers and fishers? • This will provide evidence to managers and fishers on whether escape hatches are effective or not. • Provide fishers with insight into what is happening in their pots. For example, cannibalism may occur in lobsters and crabs, or there may be interactions between different species. These interactions may affect the selectivity of the pots and also the incidental mortality associated with pot fisheries.
Current and future knowledge needs • Future work in this area could include investigations into species interactions inside pots and the effect of catch composition on gear efficiency

Aims and achievements

This study aims to provide supporting evidence for two other studies in the SUFRWW project: the Lobster Escape Hatch study and the Potting Bycatch study.

With respect to the lobster escape hatch study this camera system aims to answer the following questions:

1. Are undersized target species using escape hatches?

2. Is cannibalism occurring on undersized target species in pots without escape hatches?

With respect to the bycatch study this camera system aims to answer the following questions:

1. What percentage of individuals entering a pot is actually caught?
2. Do bycatch species affect the catchability of target species?

The camera system is still being trialled for the appropriate design and should be in the water collecting data by the end of summer 2014.

Work proposed under EMFF

Once the design for the camera system is complete it can be used for a variety of applications in the EMFF project. Its most obvious application would be for investigating species interactions in pots *in situ* in more detail.

4.9 Brown crab (*Cancer pagurus*) population biology

What have we achieved?

- Developed a monthly sampling programme involving multiple fishers from north, mid and south Wales and have compiled data on length, sex ratio, moult stage and black spot prevalence
- Collected morphometric data (multiple measurements of body size) and some moult increment data on juvenile and adult crabs to identify inflection points for maturity. This data will be combined with the size at maturity data collected in winter 2014/15
- Identified important habitat variables for juvenile crab populations through a number of masters' projects. These will form a baseline for on-going juvenile population estimates and, in the future, a recruitment index.
- Developed a method of remotely sampling catches via an on-board camera system (see On-board camera section for full details).

What does this mean for managers and fishers?

- Currently the MLS varies throughout the UK; this research will highlight either the need for a unified MLS or justify regional MLS variation.
- The fisheries data can be collated with that held by Welsh government to create a time series to enable a stock assessment of *Cancer pagurus*. Going forward, catch data will be less expensive to collect over broader areas with the use of the camera systems.
- These data contribute towards MSFD and GES targets by providing baseline catch and landings data and juvenile abundance data for a stock assessment.

Current and future knowledge needs

- The current sampling programme has established a robust monitoring programme. However, this will need to be continued to build an adequate time series of data for the purposes of stock assessment.
- While there is good fisher engagement in the current project, work is needed to extend sampling activity into Swansea and Cardiff areas to ensure adequate regional coverage.
- Although we have gained some insights into the environmental drivers that affect crab population biology a number of key questions remain unanswered such as crab migration routes in Welsh waters and habitat use by berried females.

- Greater emphasis is needed on understanding the genetic structure of the population through collaboration with experts at Aberystwyth University (P Shaw)

Aims and achievements

The aim of this study was to obtain baseline data on the brown crab population around Wales.

We have collected data on a several aspects of crab biology:

- Regional length frequency through time
- Regional moult patters through time
- Regional sex ratio through time
- Regional prevalence of black spot disease
- Moult increments of juvenile crab – together with historical adult moult increment data should provide a growth curve
- Identification of important intertidal habitat parameters for juvenile crab
- Size at maturity for populations in UK waters

Work proposed under EMFF

We hope to build on our achievements under EFF to define

- For on-going monitoring data: develop the on-board camera system (refer to On board camera page)
- Continue and expand our fishers' contacts to collect data from the seas east of Solva
- Identify migration routes for crabs: incentivised tagging programme:
    - T-bar tag retention study
    - T-bar tagging in north, mid and south Wales
    - If comprehensive landings data is available full population demographics can be estimated for Welsh populations
    - This will also provide adult growth data for Welsh populations of crab
- Identify brooding grounds for gravid female crabs
    - Some anecdotal evidence suggests scallop vessels operating in some areas during the Spring are collecting significant numbers of berried hens. There are likely ideal marine habitats that serve as brooding grounds for *Cancer pagurus.*
    - Trawl survey from the Prince Madog*
    - Together with habitat mapping and video surveys to model and ground truth crab brooding grounds
    - Camera survey from smaller fishing vessels using the flying array

*Destructive sampling of berried females from this research will provide samples for a full fecundity, maternal investment (CHN analysis) and paternity (molecular) studies.

4.10 Prawn (*Palaemon serratus*) population biology

What have we achieved?

- Developed a monthly sampling programme involving multiple fishers from Anglesey to Fishguard, Wales and have compiled data on regional and seasonal changes in length frequency, sex ratio and catch per unit effort.
- Determined that the size at maturity for prawns
- Recruitment habitats and patterns were recorded and a summer monitoring programme was developed and trialled
- A project was set up in collaboration with Cardigan Bay Fisherman's Association aimed at engaging with local fishers to collect baseline data to monitor stocks as well as assess what data would be needed for the fishery to attain MSC certification

What does this mean for managers and fishers?

- A nationally applied MLS for prawns in Wales would disadvantage fishers that are currently landing all sized prawns.
- High mortality rates of small prawns have been observed through current riddling and release methods so an enforced mesh size to release juvenile prawns on the ground would enhance juvenile survival and avoid on-board sorting
- These data contribute to MSFD and GES targets by providing baseline data on size at maturity and baseline fisheries data.

Current and future knowledge needs

- The current sampling programme has established a robust method of data collection but this will need to be continued to build an adequate time series of data for the purposes of stock assessment.
- While there is good fisher engagement in the current project, work is needed to extend sampling activity to include areas between Cardigan Bay and Anglesey (in particular the Llŷn Peninsula).
- Although we have gained some insights into the environmental drivers that affect prawn population biology a number of key questions remain unanswered including migration patterns.
- Greater emphasis is needed on understanding the genetic structure of the population through collaboration with experts at Aberystwyth University (Dr Joe Ironside).

Aims and achievements

The aim of this study was to develop a method of data collection that can allow continued collection of data on prawns around Wales. The study has met this objective with several specific achievements:

- Regional length frequency distributions through time
- Regional sex ratio data through time
- Functional size at maturity of female prawns

    - Females are larger so males are assumed to mature at a smaller size: by allowing a mesh size to permit immature females to escape we are ensured protection of mature males as well
- Length frequency in commercial catches
- Catch per unit effort
- Bycatch description and estimates of proportions
- Identification of important inshore recruitment / nursery grounds for juvenile *P. serratus*

Work proposed under EMFF

We would like to continue the existing sampling programme under EMFF, as well as collecting additional data.

- Continue and expand our fishers contacts
- Identify migration and recruitment patterns
    - Monthly monitoring of stocks in winter
    - Weekly monitoring of recruitment through summer
- Investigate the link between rainfall and recruitment success
- Population estimates
    - A depletion experiment with local fishers to estimate stock size and assess gear efficiency

5. Work Package 4: Connectivity

5.1 Finding out how the stocks are connected in the Irish Sea (using sensitivity analyses to larval behaviour parameters)

What have we achieved? • We have used a pre-existing model of larval dispersal and re-developed it to predict the larval dispersal of scallops • We have shown which areas were self-sustained (sink and source) and which areas were either mostly source or sink • The results will be available in September
What does this mean for managers and fishers? • Managers and fishers can now have a better idea of how to manage the stock: as a whole for all the Welsh waters or as small units around Wales? They can identify which areas are the most important in sustaining their valuable fishery and manage it accordingly.
Current and future knowledge needs • We need to improve our knowledge on larval behaviour and spawning time and locations in Welsh waters.

Aims and achievements

Aim: Modelling larval dispersal to find out which areas in the Irish Sea are connected.

Achievement:

- Developed a larval dispersal model
- Tested out parameters sensitivity and identified which parameters were causing the main discrepancies in the outputs

Work proposed under EMFF

We need to purchase the plankton net which can sample at different depth at the same time and to conduct one or several plankton surveys: this will give us invaluable information on diurnal movements of the larvae

We need to develop a genetic marker first to be able to distinguish scallop larvae from other bivalves.

We can use the larval dispersal model to test out management scenarios.

5.2 Scallop (*Pecten maximus*) population genetics

What have we achieved?

- Two populations of Welsh scallops (Liverpool Bay and Cardigan Bay) were analysed using 14 microsatellite markers and were compared to populations previously studied around Europe to look for genetic stock structure.
- All of the laboratory work has been completed as has the genetic data analysis.
- Initial results show that there is low connectivity between Cardigan Bay and Liverpool Bay and between the Welsh sites and other populations studied in the Irish Sea and further afield.
- We are currently working on developing an oceanographic model coupled with biological traits of scallop larvae to see if these genetic differences between populations can be explained by oceanographic currents.
- In addition we are looking at the effect of the age structure on the catch on the genetic diversity of the samples analysed.

What does this mean for managers and fishers?

- Genetic differentiation of stocks is a useful tool to help managers to identify the geographic scale at which a stock should be managed. Genetic stock structure is usually at a larger scale than demographic stock structure i.e. genetic stock structure represents the largest scale at which a species should be managed with smaller management units possibly more suitable. This study indicates that Cardigan Bay and Liverpool Bay would be best managed as separate stocks.
- Populations that show low levels of connectivity with other areas are more prone to local extinction when there is overharvesting due to the lack of recruitment from neighbouring populations and therefore it is important that a brood stock is maintained within any population with low connectivity to neighbouring populations. This study suggests that a brood stock within Cardigan Bay and Liverpool Bay should be maintained (the ban on inshore dredging may already provide this).
- Isolated populations will also have a lower effective population size than more connected populations as, with higher levels of connectivity, the effective population size is better represented by the size of the metapopulation (group of connected populations). The effective population size affects the genetic diversity of the population, with smaller effective populations being at higher risk of inbreeding and loss of genetic diversity. Genetic diversity is important for the resilience of the stock to stress and environmental change. Maintaining a large broodstock at high densities may help increase the reproductive success of individual scallops and therefore increase the genetic diversity.

Current and future knowledge needs

- The current genetics programme has established a good baseline for looking at large scale connectivity of scallops and shows that populations in Welsh waters appear to be quite isolated from the rest of the Irish sea; however, greater resolution on the structure of populations/patches of scallops within Wales could be achieved with the development of new generation genetic markers that can be more sensitive to local adaptation.
- The present study has carried out a pilot study to investigate genetic structure between cohorts and the presence of sweepstake recruitment. Sweepstake recruitment is the variability of individual's reproductive success from cohort to cohort. With increased variability there is not complete sexual mixing of the whole population with every reproductive output. This decreases the effective population size, with genetic diversity within a cohort being lower than an overall population. In an unexploited population, where there are many sexually active cohorts of varying genetic diversity at any one time, decreases effective population size may not be problematic. However, in an exploited

population, where the number of sexually active cohorts is truncated, it can lead to overall loss of genetic diversity. In addition, exploited stocks can exist at lower densities which can also decrease the reproductive success of an individual. Larger samples per age group will be needed to investigate this reproductive strategy fully and this is work that could be undertaken as part of EMFF using the existing microsatellite protocol.

- Genetic samples can also be used to look at effective population size and inbreeding. Such analyses need much larger sample sizes than general population genetic studies but can be carried out with the current microsatellite protocol.

Aims and achievements

The results show that there is greater isolation of the Cardigan Bay stock and Liverpool bay stock from each other and other populations studied than has been shown previously on similar geographic scales e.g. the Isle of Man (Figure 1).

Work proposed under EMFF

Microsatellite markers are able to pick up broad scale genetic differentiation but often struggle to show local differences in marine species. Therefore, to look more closely at smaller scale genetic differentiation around Wales, development of Restriction Site Associated (RAD) or RNAseq markers, which are more suitable to showing local differences and adaptations could be considered. Due to the significant differentiation seen with microsatellite markers between Liverpool Bay and Cardigan Bay it is likely that RAD markers would be a useful tool in identifying stock structure around Wales. This information could be valuable in stock management decisions as large levels of local retention will mean that recovery from overfishing in one area will not be aided with larvae spillover from other areas but be reliant on the local broodstock. In addition, local adaptations identified with RAD markers can form the basis of local and regional seafood branding. This project would benefit from collaboration with Aberystwyth University who have the facilities to develop and sequence RAD markers, with Bangor University providing access to samples due to extensive sea time and scallop surveys.

A summer scallop sampling programme is currently underway to study fecundity and reproductive timing. We have been able to take genetic samples from these scallops and they have been archived for future use. Additional samples would be needed to achieve broader geographical coverage for the application of the new markers. Therefore continued sampling of scallops of all age groups (not just legal sized) would be needed.

The samples that have been archived so far would be sufficient to investigate differences in genetic composition between cohorts and the extent to which the whole adult population contributes to the next generation: is there random mating or is there sweepstake recruitment? Sweepstake recruitment can act to decrease genetic diversity and can also lead to unstable recruitment spatially and temporally. It is, therefore, an important reproductive strategy to understand for stock management.

The current archived samples can be used to study effective population size and inbreeding using the linkage disequilibrium method. This method is able to use mixed age groups not separated temporally, but it does need large sample sizes, which we are currently collecting and archiving. The study of effective population size is important in isolated populations in particular as smaller populations are

more prone to loss of genetic diversity which can lead to inbreeding. High genetic diversity provides resilience of a population to stress and environmental change.

6. Overview of progress and future developments

The 'Sustainable use of fisheries resources in Welsh waters' project has greatly advanced our knowledge of Welsh fisheries. Just three years ago the majority of Wales' most important fisheries were data poor. Fisheries for crab, lobster, whelk, prawns, scallops and bass lacked basic biological data. In particular, there was no time-series data for any of these fisheries and it these long term data that are needed to undertake stock assessments. We now have methodologies for sampling the main shellfish fisheries in Wales through a combination of fishery-dependent and fishery-independent methods. Repeated sampling of shellfish and bass fisheries will have been completed over two to three years. Continued sampling of these fisheries will ensure that Welsh fisheries will have adequate data to meet the requirements of MSFD and the CFP.

The gathering of fisher knowledge through the industry questionnaire is another important development. This provides a baseline against which changes in Welsh fisheries and the perceptions of Welsh fishers can be measured. This work is complemented by an economic questionnaire which will help to assess the values of Welsh fisheries. The fishing intensity study undertaken in Cardigan Bay SAC will show definitively the impact of scallop dredging in this habitat and how quickly the seabed recovers. The will allow fisheries and environmental managers to assess whether the current management regime is appropriate. The data from this study will also allow us to assess dredge efficiency, which is an important component of stock assessments.

The outputs of Work Package 5 (Management recommendations) will be delivered in 2015. These will draw on all the results of the project to outline possible management scenarios and their implications for Welsh fisheries. Most data collection will be completed by the end of 2014 with data analysis continuing into 2015, with WP delivered before the end of the SUFRWW project on 31st May 2015.

It is hoped that the worked started under EFF will be able to continue under EMFF funding. The main aims of this work would be to ensure that data collection continues to provide a time-series for Wales' main fisheries to allow stock assessments to be undertaken. Identifying the connectivity between will also be a primary focus. Specific research cruises will examine the composition of ray populations around Wales and monitor long-term recovery in Cardigan Bay.