Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries

Work Package 2 & 3 Final Report

Monitoring Fishery Catch to Assist Scientific Stock Assessments in Scottish Inshore Fisheries – a Pilot Study

Project code: SFS002SIF

and

Identifying Catch Composition to Improve Scottish Inshore Fisheries Management using Technology to Enable Self-Reporting – a Pilot Study

Project code: SFS003SIF

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Executive summary

This report summarises the findings and presents the results from the two European Fisheries Fund (EFF) funded projects, Monitoring Fishery Catch to Assist Scientific Stock Assessments in Scottish Inshore Fisheries – a Pilot Study; and Identifying Catch Composition to Improve Scottish Inshore Fisheries Management using Technology to Enable Self-Reporting – a Pilot Study.

The main objectives of the two projects were:-

- Install an appropriate Electronic Monitoring (EM) system aboard the selected participating vessels and use EM to verify self-reported catches.
- Train fishermen in self-sampling techniques and design and provide appropriate data recording sheets.
- Undertake sea trials to provide additional training in self-sampling, to collect control data, and to field test technical innovations using radio frequency identification (RFID) tags, data storage tags, Bluetooth callipers and automated discard chutes.
- Collect data using EM technology and self-reporting to help address the issue of data deficient stocks.
- Undertake video review (10% of valid fishing trips) of collected data and carry out analysis on all sensor data.
- Provide catch estimates through video review and undertake comparisons between self–reported and video review catch estimates for verification purposes.

A total of 11 fishing vessels, distributed geographically between Leverburgh and the Isle of Whithorn, participated in the trials; 9 creel vessels, 1 scallop dredger and a *Nephrops* trawler. All vessels were fitted with Electronic Monitoring systems complete with 3 digital video cameras per vessel. After some initial issues relating to radio frequency (RF) interference were addressed, the systems performed very well for the duration of the trials.

The participating vessels undertook a total of 703 fishing trips as part of the project of which 568 provided data of sufficient quality to evaluate the success of self-sampling and data collection by EM technology.

85% of all fishing trips provided valid self-sampling data, whilst 96% of fishing trips produced valid data from the EM technology. Of the valid trips, full analysis and video review was carried out on 12% of the trips. Sensor data collected was reviewed at 100%, providing an excellent dataset on distribution of effort at string or haul level.

Fine-scale effort parameters (number of creels and creel soak time) can be difficult to ascertain from a ‘standard’ EM installation. Development of an integrated RFID system allowed these data to be collected automatically with little or no detriment to catch-handling procedures on-board. Integrating these data with catch data (determined through video analysis or self-reported data) provide CPUE data with fine scale spatial accuracy. A stand-alone data storage tag was also trialled which produced an accurate record of soak time at string level, with the added benefit of temperature at depth data.

Two separate sub-projects were trialled to address data deficiencies with fine scale biological data collection. Utilising Bluetooth callipers, fishers were able to collect length

frequency data on retained target species (brown crab, lobster and velvet swimming crab) effectively and efficiently without any additional time burden as the sampling was conducted whilst steaming back to port. To ensure that the catch was sampled randomly, one keep pot with mixed sizes and sexes was selected for measuring. Approximately 60 individuals could be measured in 5 minutes. This mode of data collection could not only address some of the current data deficiencies but also offer significant cost savings to conventional methods of collecting shellfish length/sex data.

A second trial using a simulated discard chute fitted with 3 additional cameras provided footage that allowed for accurate collection of discard data. This included both number by species, with accurate determination of sex for both brown crab and velvet swimming crab and length estimations on a sub-sample of animals passing down the chute. Further refinement and development of this concept should improve its capabilities in length estimation across all species and sex determination of lobsters specifically.

Review of video data allowed 76% of the retained catch of brown crabs (by count) to be sexed, but only 32% of the discarded component of the catch. EM video review was less successful at sexing velvet crabs with only 25% sexed, and it was not possible to identify the sex of lobsters using video review. Sex ratios estimated by video review are similar to those estimated by the skipper, but more rigorous on-board protocols need to be considered before these data could be used in assessments.

These trials have shown that most, if not all areas where data deficiencies exist can potentially be supplemented with self-reported and/or data derived from EM technology. We would recommend establishing a working-group made up of fishers, researchers/scientists and managers to develop sampling schemes with realistic standardised self-sampling protocols and sampling scheme designs. We would further recommend an expanded trial over a number of years whereby a time series can be established. As these new protocols are introduced into the fishery we conclude that whilst EM can provide valuable data in itself, it is the most effective tool available at present to monitor and validate self-reported data. Further trials of innovative technology and those explored in this project, such as the Bluetooth callipers, the RFID tags and the automated discard chute, should continue to help provide additional stock assessment data.

1. Introduction

1.1 Background to "Evidence Gathering in Support of Sustainable Inshore Fisheries"

A network of Inshore Fisheries Groups (IFGs) covering the entire Scottish coastline was developed under the Marine Scotland Inshore Fisheries Strategy 2012. Fisheries management plans were brought forward by the IFGs on the basis of the local fishing industry within each of the areas identifying the constraints on establishing and maintaining sustainable fisheries. One feature common to all the management plans was the perceived lack of evidence upon which to base management measures. In addition it was recognised that the inshore fishing industry was faced with a range of resource use issues and that there was a requirement for activities to be economically viable in conjunction with environmental sustainability.

The project "Evidence gathering in Support of Sustainable Inshore Fisheries" is a series of complementary Work Packages (WPs) focussed on Scottish inshore fisheries funded by the European Fisheries Fund (EFF). The project has the overall objective of securing sustainable management of Scottish inshore fisheries and supporting the dependent coastal communities. The various Work Packages are intended to be a series of pilot projects aimed at filling evidence gaps and trialling new technology, and will be evaluated in the context of longer term support for effective future management of the Scottish inshore fisheries and development of the industry. The Work Packages are project managed by the Marine Alliance for Science and Technology Scotland (MASTS), and regional facilitators were appointed to assist with the engagement between contractors and the industry.

The seven Work Packages funded under the programme were as follows:

WP1. Establishing the location of fishing activities within Scottish inshore areas

WP2. Monitoring fishery catch to assist scientific stock assessments in Scottish inshore fisheries

WP3. Identifying catch composition to improve Scottish inshore fisheries management using technology to enable self-reporting

WP4. Pilot study to define the footprint and activities of Scottish inshore fisheries by identifying target fisheries, habitats and associated fish stocks

WP5. Improving market intelligence and fishery production co-ordination in Scottish inshore fisheries

WP6. Integrating stock management considerations with market opportunities in Scottish inshore fisheries

WP8. Establishing a dedicated information resource base for Scottish inshore fisheries.

(Note that there were no successful tenders for WP7 - Maintaining landings quality through improved working practices)

Seascope Fisheries Research Limited were contracted to carry out the following two work packages with their respective purpose and objectives:

WP2. Monitoring fishery catch to assist scientific stock assessments in Scottish inshore fisheries (Project SFS002SIF)

Project Context and Purpose:

Historically stock assessment data are collected using sea going observers, research cruises, and monitoring of landings. The west of Scotland inshore fleet consists primarily of a large number of small <10m vessels that mainly target shellfish. Placing observers on these small vessels can be difficult due to space, can present significant safety issues, and it can be extremely expensive to obtain a sampling level high enough to represent a good sub-sample of the different fleets using observer coverage alone. Research vessels are generally large and concentrate on finfish stocks offshore or on their sampling grid, which will not cover local stocks and inshore areas. Landings data do not represent the total catch or total fishing mortality on a stock, due to discarding at sea. It is also difficult and expensive to get a representative sample of landings due to the large number of small fishing ports on the west coast.

Self-sampling by the fishermen at sea will allow large quantities of catch data and additional biological data to be gathered, which could be used to improve stock assessments. Self-sampling will also include discard data and therefore provide total mortality values (when coupled with survival rates) rather than just landed quantities, which can then be used to estimate potential recruitment to the stock. Biological data related to size composition, the ratio between sexes and the proportions of female shellfish that are berried, can be used to identify year class cohorts, and in conjunction with growth rates, can be used to estimate exploitation rate and to assess how the stock would respond to different management measures.

Through implementation of a validated self-sampling regime, it is expected that self-reported data could supplement stock assessment data from conventional sources, and thus improve stock assessments. In addition stock assessments can be improved by ensuring that fishermen are aware of the importance of their contribution to the knowledge base and that they are actively involved in the interpretation of stock assessments.

It is recommended that this project uses the same vessels involved in SFS003SIF as these will be fitted with EM technology and CCTV that can be used to verify the self-reported records.

Objectives:

1. Identify the fisheries where stock data needs to be improved. Then identify, through the assistance of Facilitators and local fishing groups, a list of vessels willing to participate in self-reporting trials and able to accommodate observers to collect control data. Work with Facilitators to contract suitable vessels to conduct the trials.
2. Provide an initial training course that shows crews how to carry out self-sampling techniques and explains the importance of how these data are collected and how they could be used to improve current stock assessments. An overview of how stock assessments are currently carried out for the local stocks will also be included in the training course. Design and supply literature/training materials describing required

sampling techniques. Design and supply data recording sheets to facilitate self-reporting.

3. Undertake sea trips with contracted vessels to further demonstrate sampling techniques, to collect control data and to provide first hand assistance to crews on sampling techniques. This will also allow the observers to witness the issues and conditions faced by these fleets and improve the understanding of these stocks and fisheries. This may be undertaken in project SFS003SIF to avoid duplication of effort and charter fees.
4. Input all data on to an Access database; undertake analysis and carry out QA on the data collected.
5. Conduct the second training course to demonstrate how the data collected by the fishermen can be used to improve stock assessments and how having these data can improve the overall knowledge base. Undertake stock assessment exercise with data.
6. Submit a final report that provides details of the pilot project, a contact list of vessels willing to participate in ongoing trials and their training status. The report will also provide recommendations for future approaches to self-reporting for stock assessment purposes.

WP3. Identifying catch composition to improve Scottish inshore fisheries management using technology to enable self-reporting (Project SFS003SIF)

Project Context and Purpose:

The collection of accurate self-reported data by fishermen could help to resolve data deficiencies in stocks, thus increasing accuracy and confidence in stock assessments. However, self-reported data need to be verified to ensure that the catch data are suitable for scientific use. Electronic and video technology (EM technology) provides a cost effective means of verification of these self-reported records and can provide an effective mechanism by which smaller vessels (which can often present significant health and safety risks to observers) can be utilised as data collection platforms. Previous and current UK trials utilising EM technology (e.g. catch quota trials) have predominantly focused on larger trawl vessels operating in the North Sea and English Channel, targeting mixed demersal fish species, but over 90% of the UK fleet are <10m vessels, which in many ports can account for the majority of landings. As such, these vessels, and the fisheries they prosecute should be subject to monitoring to support both fisheries scientists and policy makers in managing the stocks effectively. This pilot study will help to inform decision makers on how EM may be utilised to monitor and verify self-reported catches, how reference fleets could potentially be used to provide data where there are large numbers of vessels involved in a fishery, and how to monitor smaller vessel activities and metiers such as potting.

EM also presents a potential opportunity to collect additional biological data (length frequency, weights caught and sex ratio) which could provide valuable stock assessment data in otherwise data deficient fisheries. Discarded shellfish have higher survival rates than most finfish species. ICES advice suggests that Nephrops have a 25% survival rate and lobsters a 90% survival rate. Discard data can therefore be used to estimate recruitment values for a stock.

Objectives:

1. Engage with local Facilitators to identify and contract 10 appropriate vessels. Train vessels crew in self-reporting techniques to provide catch data that identifies retained and discarded components of the catch and to quantify fishing effort. Appropriate vessels will be selected across a range of metiers in proportion to the distribution of gear types / fisheries covered by the fleet.
2. To review current systems and install suitable EM systems to use as a tool to verify self-reported data.
3. Review video footage (at a rate of 10%) and sensor data (at a rate of 100%) of the total fishing effort of the selected vessels to provide shore based observer estimates to compare against the self-reported data.
4. Undertake additional innovative trials within the pilot project to explore the use of additional sensors to quantify effort; to provide length frequency data; to accurately collect weight data on relevant catch components at sea; and to modify on board catch handling processes to potentially allow sex and length measurements to be obtained during video review without significant impact on the vessel and crew.
5. Undertake 40 days at sea across the selected vessels and metiers to provide control data to compare against the self-reported estimates and the shore based video observer estimates. These sea-days will also provide the opportunity to conduct the innovation trials detailed below.
6. Undertake data analysis for the pilot fleet and attempt to raise to whole fleet to provide estimates that could be used for stock assessment purposes, if appropriate.
7. Undertake a QA exercise on 10% of the reviewed video using an external subcontracted partner (Archipelago Marine Research).
8. Produce and submit the final report in conjunction with Shellfish stock assessment scientist (Julian Addison).

There are a number of overlapping objectives for WPs 2 and 3, and the two Work Packages have been carried out simultaneously by the same contractor, Seascope Fisheries Research Limited, and using the same participating vessels, and therefore the contractors believe that a single consolidated report will provide added value in comparison with two separate reports.

1.2 Background to projects SFS002SIF and SFS003SIF

Fisheries management within the UK and other EU member states is increasingly driven by the requirements of the recently reformed Common Fisheries Policy (CFP), and by the Marine Strategy Framework Directive (MSFD), and as such data collection will need to be improved significantly in many fisheries for which currently there is a low level of fisheries and biological monitoring. The CFP requires that stocks are exploited at a level of fishing mortality that would achieve the maximum sustainable yield (MSY). The objective of the MSFD is to achieve Good Environmental Status (GES) by 2020, for which descriptor three states that “populations of commercially exploited fish and shellfish must be within safe biological limits and exhibit an age structure and size distribution indicative of a healthy stock.” Under descriptor three of GES, there is a requirement to provide an estimate of fishing mortality as a primary indicator, an estimate of spawning stock biomass or other biomass indices and an estimate of the proportion of fish larger than the mean size of first sexual maturation and the 95th percentile of the fish length distribution observed in research vessel surveys.

Significant progress has been made already in meeting the requirements of the reformed CFP and the MSFD for large-scale industrial fisheries for which there is good information on the large vessels which participate in the fishery, for which there are good data available from both fishery-dependent and fishery-independent sources, and for which governments invest considerable resources in ensuring that fisheries management measures are based on robust stock assessments carried out on an international basis. For many small-scale inshore fisheries subject to national legislation, the level of information available is often much lower and for these data-limited fisheries, meeting the requirements of the CFP and MSFD provides major challenges. Inshore fisheries such as those in Scotland are characterised by large numbers of small vessels with many different landing places often in remote geographical areas. The nature of these fisheries is such that often the only available fisheries data are landings declarations. VMS is not mandatory on these small vessels, often there is little or no reliable information on fishing effort, port sampling of landings size composition is at a low level, and the remoteness of the fishery and the small size of the vessels often preclude carrying scientific observers.

These data limited inshore fisheries are therefore highly suited to self-sampling by fishing vessels' crew. Self-sampling schemes can have major benefits in improving the process of data collection and stock assessment. The fishing process generates a large amount of information which is often not collected and used by fisheries scientists, and so the collection of high quality data by fishermen which can be used by fisheries scientists to produce appropriate scientific advice would result in an improved platform for fisheries management. There is an increasing need for effective, industry-science collaborative research alongside the conventional scientific programmes, and these two avenues of research and data collection need to work effectively alongside each other if they are to be successful. Such collaboration will have the added benefit of promoting better relationships between fishermen and scientists. Perhaps most importantly, at a time of restricted budgets for scientific programmes, self-sampling provides a cost-effective method of collecting additional fishery data.

In addition to traditional methods of self-sampling through log books, and other methods of recording of fisheries information by vessel crews, newly-developed electronic monitoring (EM) technology provides innovative methods of remotely collecting scientific information on fishing activities. EM technology allows validation of self-sampling data which is essential because there is a commonly-held belief that such data may either be biased or at the very least not collected as rigorously as data collected in scientific observer programmes (Kraan et al., 2013).

Previous experience of self-sampling schemes (e.g. Anon, 2010; Bell et al., 2014) shows that such schemes will only be successful if there is continuous good communication between fishermen and fisheries scientists and managers to ensure that initial enthusiasm for self-sampling does not wane over time. In addition fishermen who are involved in self-sampling programmes and collaborative research need to see the results of their efforts being used. This will maintain fishermen's interest in the programme, and ensure that the credibility of the programme is sustained in the eyes of the participants. Furthermore fishermen need to be actively involved in the scientific process leading to the provision of scientific advice through participating in the interpretation of stock assessments and how that impacts on fishery management decisions.

In developing self-sampling programmes for the Scottish inshore fishery, it is important to clarify what gaps in information need to be filled to improve stock assessments, whether the fishing industry would be willing to help in collecting that information, and whether the quality of such industry-collected information would be sufficient to use in stock assessments. It is also important to know how EM technology can contribute to collecting such information with only minimal disruption to the fishing process. Finally, but perhaps most importantly, an assessment is required of how such self-sampling schemes will dovetail with standard data collection programmes, and whether any such pilot schemes will continue to work on a long term basis.

The focus in these two projects is on the Scottish inshore creel fisheries for edible crab, velvet crab, and lobster. These fisheries are characterised by large numbers of small vessels with many different landing places often in the more remote geographical areas of the coastline, and for which there is limited information on fishing effort and fishing position and creel fisheries are generally not covered by observer sampling programmes. Self-sampling programmes and EM technology could provide innovative solutions to the collection of fisheries data in these data-deficient fisheries. In addition to the creel fisheries named, the project also tests the methodology on a Nephrops trawler, an inshore scallop dredge vessel and on the creel vessels when they are targeting Nephrops.

1.3 Self-sampling by fishers

The traditional methods of collecting data for stock assessment purposes include self-reported catch data such as log books and landings declarations, biological sampling at fish markets, at-sea catch sampling programmes and stock assessment surveys. However it is generally accepted that in the past there may have been issues with the accuracy of some of the landings data and that at-sea observer programmes may not always provide unbiased data, as well as being considered an expensive means of gathering data. Biological sampling on markets provides excellent data for the landed portion of the catch including the gathering of samples and otoliths, but does not take into account the fish or shellfish that are discarded at sea and never make it to market, e.g. small undersize marketable species, low value high-graded species, protected species or non-marketable species.

In the UK, regular at sea catch sampling has been undertaken under the European Commission’s Data Collection Framework (DCF) since 2002. An example of the levels of sampling that are undertaken is shown in Table 1.1 for 2012. A total of 574 sea trips were undertaken by observers which represented 0.4% of the UK total fleet’s fishing activity. The highest level of sampling was by the Northern Irish who sampled 1.9% of the total fishing trips, with England and Scotland each sampling 0.3% of their fishing fleet’s sea trips. Whether or not these levels of sampling provide adequate coverage is open to debate and statistical scrutiny but what is clear is that very little sampling effort is undertaken on vessels targeting the creel (pot) fisheries associated with this project. In Northern Ireland, 4 sampling trips were conducted on shellfish potters and no trips undertaken by England or Scotland. Given that these figures are from the DCF programme which is concerned primarily with monitoring discards, it is not unreasonable that sampling rates are low in the creel fisheries because the assumption is that creels are very species specific and that any discards caught and released have very high survival rates. The sampling levels for scallop dredge vessels would appear to be higher at 1.7% (26 out of 1552 trips in England and Northern Ireland) but this does not include the sampling for Scotland as no data were available in the DCF summary table.

Table 1.1 DCF at-sea sampling levels and fleet activity in 2012, for the UK by country.

Member State	Region	Sampling Frame Fishing Activity	Total No. of trips by fleet during year	No. sampled trips at sea	% No. fleet trips sampled
Scotland	North Sea and Eastern Arctic	Trawlers, netters, liners	58398	152	0.3%
		Scotland Total	**58398**	**152**	**0.3%**
England	North Sea and Eastern Arctic	Trawlers, netters, liners	66105	214	0.3%
England	North Sea and Eastern Arctic	Mollusc dredgers	775	18	2.3%
		England Total	**66880**	**232**	**0.3%**
Northern Ireland	North Atlantic	Trawlers, netters, liners	8218	178	2.2%
Northern Ireland	North Atlantic	Mollusc dredgers	777	8	1.0%
Northern Ireland	North Atlantic	Shellfish pot & trap vessels	1081	4	0.4%
		Northern Ireland Total	**10076**	**190**	**1.9%**
		Overall UK[1] Total	**135354**	**574**	**0.4%**

[1] No DCF sampling information was presented for Wales or the Islands. Adapted from 2012 DCF information. Prior to devolved administration, sampling of the Welsh fleet was undertaken by Cefas as a combined English and Welsh fleet (between 2002 and 2009).

At-sea observers collect very detailed biological data such as length, sex, and maturity. They can also collect tissue samples and otoliths/scales for aging purposes. However the inshore shellfish vessels are mainly small (<12m length) and may not be able to accommodate an observer and on the west coast of Scotland they are located in remote ports and on the islands, so that the logistics and costs of sending an observer to sea are prohibitive. In addition, one of the main concerns with observer programmes is staff safety. Before being allowed to go to sea observers must be fully equipped with safety equipment and PPE (Personal Protective Equipment) and given full training in safety procedures. All of these components of an at-sea observer programme require updating regularly, again adding additional costs. If vessels are single handed (i.e. there is only one fisherman aboard the vessel who acts as both skipper and crew) then some institutes, e.g. Marine Scotland Science and Cefas, have a safety policy of not allowing a single observer to sail with the vessel. Instead 2 observers must be sent which could overcrowd the vessel and also double the observer costs for that sea trip.

An alternative approach to the traditional data sources of biological sampling on markets, observer sampling programmes and fishery-independent stock surveys would be to have fishermen collect data about their catches and fishing effort and supply it to the fisheries scientists and managers. Such self-sampling by fishermen removes the need for observers to go to sea, thus reducing the safety risk, logistical and travel costs, and staffing/safety costs. If a sampling programme can be designed that allows fishermen to collect data on a "little and often" basis instead of sending observers, it will greatly improve the seasonal spread of the data collection and reduce the daily burden on the fisherman, not to mention reducing the cost of the data collection process. A full season or year of information can be gathered cheaply, rather than one or two at-sea observer "snapshots" of the fishery. It should also be remembered that having an observer on board the vessel may also influence the behaviour of the crew or even where the vessel decides to fish on that day e.g. to avoid or demonstrate large catches of undersize fish.

The fishermen are in a perfect situation to provide scientists with data on their retained catches, the discarded catch and their own fishing effort. They could also provide additional information on protected species interactions, lost fishing gear, weather conditions, local knowledge on fish distribution patterns and even environmental conditions and influences.

However, one of the main criticisms of self-sampling projects is that the fisherman may not record the data correctly, either by accident or intent, and that they may not provide unbiased data because they have a vested interest in the outcomes. Having the collected data verified by an independent body using EM allows data collection accuracy and crew performance to be assessed and removes the vested interest element. It also allows additional data to be gathered automatically through sensors and GPS, without relying on self-reporting e.g. position and track of the vessel during a sea trip, the exact fishing location, the number of fishing events and the duration of fishing effort. Removing the need for written data supplied by the vessel's crew helps reduce potential bias, as well as potential errors caused by transcribing of paper records.

The concept of self-sampling has been the subject of many recent projects as fisheries managers and scientists seek alternative methods to collect fisheries data (Armstrong *et al*., 2008). Four projects which have particular relevance to the Scottish inshore fisheries studied in this project are described below.

EU LOT1 project

In 2007 the European Commission Directorate-General for the Fisheries and Maritime Affairs funded a series of projects under the title "Joint data collection between the fishing sector and the scientific community in Western Waters" commonly known as the EU LOT1 project (Anon, 2010). The background documentation to the funding of these LOT1 projects provides an excellent rationale for the importance of developing self-sampling projects –

"There is much information generated by the industry that is not collected and systematically used by scientists. A data collection scheme involving fishermen who are able to collect quality field data and scientists who can produce appropriate scientific advice would result in an improved platform for fisheries management while promoting mutual respect and understanding among the 2 groups. The main aim of the study is to expand the scope for improved quality of data to support policy decisions and further strengthen the current state of cooperation between fisheries scientists and the fishing industry by implementing joint data collection programmes. These can provide cost-effective and additional fishery data

and the fishing industry can be actively involved in the scientific process leading to the provision of scientific advice."

The LOT1 projects variously addressed three tasks:

1) Design and implementation of pilot programmes to obtain supplementary information from the fishing industry on the practical fishing operations and the decisions made about the fisheries;

2) Design and implementation of self-sampling programmes to be implemented on board commercial vessels

3) Pilot projects to involve stakeholders in the use of the type of data described under tasks 1 and 2 for stock assessment and management evaluation.

Four separate pilot projects were carried out under the LOT1 programme:

- Brown crab (*Cancer pagurus*) fishery
- Development of a fishery information report for demersal fisheries in the Celtic Sea and western Channel
- Study with electronic logbook in the Basque trawling fishery
- Portuguese artisanal deep-water longline fishery.

The results of the first project on the brown crab fishery had obvious implications for this project. The project comprised of vessels from France, England, Scotland and Ireland and considered how to fill gaps in information related to fishing effort, catch rates, fishing mortality and biological data. The project met with limited success for a variety of reasons and the limitations of the various methods for collecting information (log books, e-log books, private diaries, VMS, GPS, questionnaires, self-sampling and scientist sampling of catches) are summarised in Table 1.2.

Table 1.2 Comparison of resolution, capacity to involve fishermen, costs and limitations in the approach, to collection of catch, effort and biological data in crab fisheries. (Source: Anon, 2010)

Data	Use of data	Spatial resolution	Temporal resolution	Involvement of fishermen	Cost of data acquisition	Cost of data management	Limits
EU log & other mandatory logbook reporting	Distribution of landings	ICES rectangle >10m LOA, sub-rectangle inshore	Daily >10m LOA, monthly or other frequency <10m	Mandatory >10m LOA, mandatory in some cases <10m	Low	Low	>10m LOA poor effort data, low resolution; <10m poor temporal and spatial resolution
Voluntary log	Landings, effort and catch rate index	Variable, per operation or day averaged	Per operation or daily	Take up is low, incentives and management context needed to encourage collective action	Low	Medium	Large reference fleet required as variability in performance between inshore vessels is usually very high
Voluntary E-log	Geographically referenced landings, effort and catch rate indicators	Per operation	Per operation	Take up is dependent on the technology, feedback important, has benefits for the vessel	High	Low	Large reference fleet required as variability in performance between inshore vessels is usually very high
Private diaries	Geographically referenced landings, effort and catch rate index	Per operation	Per operation	Management context and feedback important, assurance and confidentiality needed	Low	High	Large reference fleet required as variability in performance between inshore vessels is usually very high
VMS	Fishing position and effort index	Depends on vessel speed	2 Hour ping rate	Mandatory >15m LOA	Medium	High	Needs to be combined with catch data (Logbooks) for catch rate indicators
GPS	Fishing position (high resolution)	Potentially very high	Can be set	Positive response in this project. Feedback important	Medium	High	Needs to be combined with catch data (Logbooks) for catch rate indicators
Questionnaire	Historic trends, drivers of effort, understanding data, management issues	By fishing area	Annual or multi-annual	Positive response in this project. Usually eager to identify and describe issues	Low	Low	Qualitative or at best semi-quantitative time series. Useful in management context
Self sampling of catch	Biological indicators, analytical assessment	Per fishing operation sampled	Sample per month	Time and resource constraints, training, incentive	Low	High	May be difficult to achieve sufficient sampling rate or area coverage
Scientist sampling of catch	Biological indicators, analytical assessment	Per fishing operation sampled	Sample per month	Deck space, working conditions may be an issue	High	High	Only very low sampling rate is feasible

The project on the brown crab fishery in Western Waters provided important conclusions for any future project trialling self-sampling systems and collaborations between fishermen and scientists:

- a clear management context is required for self-sampling and self-reporting
- the assessment framework or set of indicators needs to be established and agreed with stakeholders prior to self-sampling
- if a strong reliance is to be placed on self-sampling and self-reporting frequent communication between fishermen and scientists is required (the scientists must become teachers and facilitators)
- strong feedback mechanisms to "self-samplers" is required
- Integration of fishers in to the assessment process is then the next logical step.

Bangor study

Hold *et al.* (2015) used on-board camera systems on four vessels to collect data from the trap fisheries for brown crab (*Cancer pagurus*) and lobster (*Homarus gammarus*) fisheries in Wales. The camera systems were set up such that both vessel crew and researchers could pass the catch under the camera across a defined area incorporating a reference scale so that individuals of landed, discarded, bycatch and bait species could be identified. Brown crabs were presented ventral side up to allow determination of sex, and lobsters were presented dorsal side up to allow determination of size (carapace length). Crabs and lobsters were measured and sexed by observers and then compared with size and sex as estimated from video images.

Identification of sex in crabs by visual inspection of the images from the video was 100% accurate for the full size range of the 700 crabs sampled. Male lobsters of all sizes were correctly identified as males for all size ranges encountered, whereas females were 100% correctly assigned for lobsters over 86 mm carapace length, but the accuracy of identification declined to around 50% for female lobsters at 70mm carapace length. This result is not surprising in that the sexual dimorphism observed in lobsters occurs only after sexual maturity in the lobsters. In smaller lobsters sex determination occurs through examination of the pleopods which cannot be achieved using video images.

The predicted size of crabs and lobsters based on the video images was shown to be very similar to the real measurements. The mean difference between the predicted and real crab measurements was -0.853 mm with a standard error of 0.378 mm, suggesting that the model tends to underestimate the real carapace width slightly, whereas the mean difference between predicted and real lobster measurements was 0.085 mm with a standard error of 0.208 mm. The study concluded that the error attributable to using video data rather than manual measurement was small enough to ensure that it was possible to detect growth increments in these species.

Cefas scallop red bag scheme

Scallops are the most valuable fishery in England, but collecting data at the appropriate scale to carry out stock assessments has proved challenging because previous studies within the English Channel have shown that growth rates of individuals are highly variable over relatively short distances. To supplement conventional biological sampling of scallops, Cefas initiated the red bag scheme in 2011 whereby vessel skippers were requested to put all scallops from two or three dredges that were above the minimum size into a special red bag prior to delivery to the scallop processors as normal. The processor would then shuck the scallops and return the flat scallop shell to the red bag for later collection by Cefas scientists.

The scheme identified 7 separate sampling areas based on the fisheries and potential variations in scallop biology: North Sea (ICES area IV), Eastern Channel (ICES area VIId), Lyme Bay (East VIIe to Start Point, from coastline down to 49^{o} 30^{oo}N), VIIe west of Start Point from coastline down to 49^{o} 30^{oo}N, Offshore (anything south of 49^{o} 30^{oo}N in VIIe and VIIh), Celtic Sea (VIIg and VIIf) and Irish Sea (VIIa). Sampling targets were set at 6 samples per area per quarter in order to provide sufficient information to undertake regional stock assessments. These samples provided information on length frequency of the catch (numbers at size), and then a sub-sample was aged using the growth rings on the flat shells, which provides an age-length key permitting an estimation of the age structure of the whole sample.

Approximately 1500 red bags have been distributed by Cefas with 60 vessels expressing an interest in participating in the scheme. By June 2014, Cefas had received 150 samples, generating more than 23,000 shells which have been measured of which over 3,600 have undergone age reading. However the samples have not originated equally across all areas, and clearly some fishermen have been particularly diligent in providing samples, whereas others have displayed less enthusiasm for returning the red bag after the initial interest waned. Unfortunately sampling targets were rarely reached and although data from the scheme permitted a preliminary investigation into the potential exploitation rates experienced by two of the stock areas (Inshore Cornwall and Lyme Bay), there were insufficient samples to attempt any form of stock assessment in the other areas (Bell et al., 2014).

The low level of samples provided in many areas was disappointing considering the significant amount of effort input by Cefas staff to encourage vessels to contribute samples on a regular basis. In addition to the low level of sampling, there were also problems with poor recording of information on the sample, round shells rather than flat shells landed, lost or discarded samples and samples collected from outside the scheme’s boundaries.

GAP2 project

The GAP2 project was a major Europe-wide project funded by the European Commission’s FP7 Capacities programme. The project’s purpose was to demonstrate the role and value of stakeholder driven science within the context of fisheries governance. The aim was to bring scientists, fishermen and policy makers together including through a series of case studies centred upon fishers and scientists working together. Two of the case studies were particularly relevant to this project – Fishermen and scientists working together on self-sampling projects to obtain better information on discards in the Dutch flatfish fisheries, and Investigating brown crab behaviour in the UK fishery using fishers’ and scientists’ knowledge. The crab project involved scientists working with fishers to develop methods that can be used by fishers themselves to evaluate and manage the crab fishery that they exploit.

A year was spent making trips on board crab boats to gather data on the temporal and spatial distribution of catches, information on fishers' ecological knowledge was collected through interviews, and scientists ran seminars to explain the basics of fish stock estimation and to gather input from fishers on how an individual based fishery model should be structured. The project was intended to integrate fisher's knowledge about crab distribution and biology with previously gathered scientific information and the project team are trying to develop an app where fishers can collect their own catch and discard data to inform management. A key success of the project was the raising of awareness in some of the fishers of the main problems associated with running a fishery sustainably, and the clear communication of results throughout the project gave fishers greater faith in working with scientists.

In addition the GAP2 project convened two scallop workshops on management of the scallop fishery in the English Channel which attracted a wide range of stakeholders from both the UK and France. Amongst the many outcomes, the workshops concluded that a 'science and data working group' should be established with the aim of designing regional protocols for data collection on both sides of the Channel, and that for co-management of the scallop resource to be successful, all segments of the fleet should be represented and viewed as integral to data collection methods and in developing ideas for future management of the stock.

1.4 Electronic Monitoring Systems

Electronic monitoring systems used on commercial fishing vessels for fisheries management usually combine several sensors and a means to record the position, time and speed of a vessel, as well as CCTV cameras to record the fishermen's activities. A GPS receiver allows the position of a vessel to be determined and because this information is captured every 10 seconds it also allows speed to be calculated between the two points. Sensors can include hydraulic pressure sensors to determine when the hydraulic system is being used and the "strain" that the hydraulic system is being put under; a winch rotation sensor can determine when the winches are operational, which can also be combined with the hydraulic sensor information (if it is a hydraulic operated winch rather than compressed air); a user interface (e.g. keyboard and display screen); CCTV cameras to record video of activities (Figure 1.1); and a means to store this information e.g. on a removable hard drive, for later review and assessment. Other sensors can also be added depending on the type of vessel and aims of the project but in general those already mentioned will allow the EM system to determine the activity of a vessel, as well as when and where that activity has occurred. It will also allow the master of the vessel to input comments and interact with the system (e.g. carry out functionality checks), and it will record video images of that activity for verification and other purposes. If a satellite communication device is also added to the system, the GPS and sensor data can be sent to shore for near live monitoring, as well as to "health-check" the performance of the system. However, video data files are large, so gathered data are currently stored on a removable hard drive which is swapped over at suitable intervals, rather than sent via the satellite option. The imagery can then be used to obtain information on catch handling, discarding practises and catch composition, gather scientific data, verify self-reported information, or to monitor for compliance with regulations. Figure 1.2 shows cameras being installed on the masts of vessels.

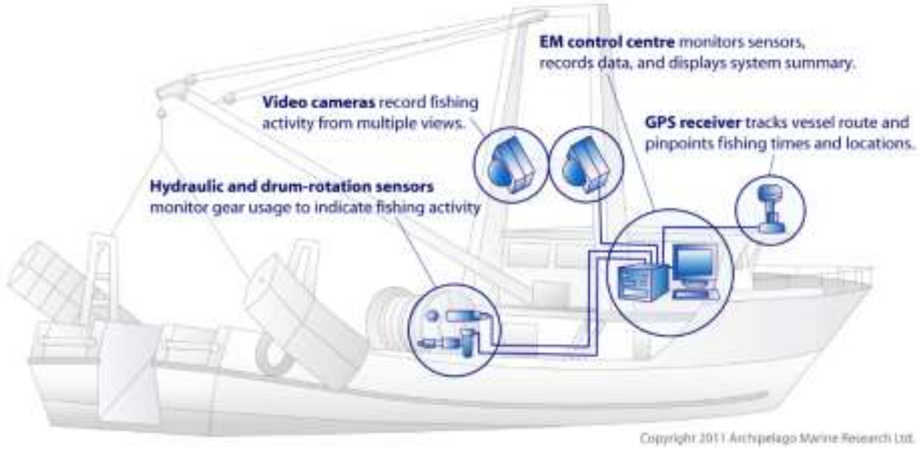


Figure 1.1 Diagram of a remote electronic monitoring system (REM) installed upon a fishing vessel (Courtesy of Archipelago Marine Research Ltd.).

Figure 1.2 Cameras installed on fishing vessels

Figure 1.3 An Archipelago Marine Research EM Record v4.5 control box and a hydraulic sensor.

Several suppliers of EM systems were approached at the beginning of this project and their systems were evaluated for suitability to be used on small inshore vessels and for this project. All systems were deemed fit for purpose on initial investigation and it was thought that perhaps a mix of system providers would be the best way to assess suitability. However due to a delayed start in the project it was felt unfair to assess these systems in such a constrained time frame. The systems would only be fully installed and operational on all the selected vessels for 5 months (January to May 2015, although some would be installed and producing useable data in November/December 2014) and this would not have allowed durability and reliability to be properly assessed. It was also felt that the additional burden of learning several new systems and their associated software in such a short time frame would be too onerous on the project team and would detract from the primary aims of using an EM system to verify self-sampling of catches. It could also potentially further delay the start of data gathering as suppliers needed adequate time frames to build the required systems. It was therefore decided that the project would use the Archipelago Marine Research (AMR) EM system because the team were already familiar with installation and maintenance of the v4.2 and v4.5 systems (Figure 1.3) and in the analysis processes using the EMI Pro software, and also systems were readily available. At the time of equipment purchase AMR were just beginning production of their new v5.0 system (Figure 1.4), therefore a mix of v4.5 and v5.0 systems were purchased and installed on the 11 selected vessels. The main differences between the v4.5 and v5.0 systems are versatility and construction. The v4.5’s design and construction restrict mounting options first and foremost. The v5 enclosure is a more robust machine that can be mounted in any orientation. The v5 also has an integral 48v power supply which can power the PoE (power over Ethernet) switch directly. With the v4.5 this required another external power supply. The other benefit that makes the v5 more versatile is that it can be powered by 12vDC, 24vDC or 230vAC supplies. The v4.5 is restricted to 12vDC and 230vAC power supplies only.

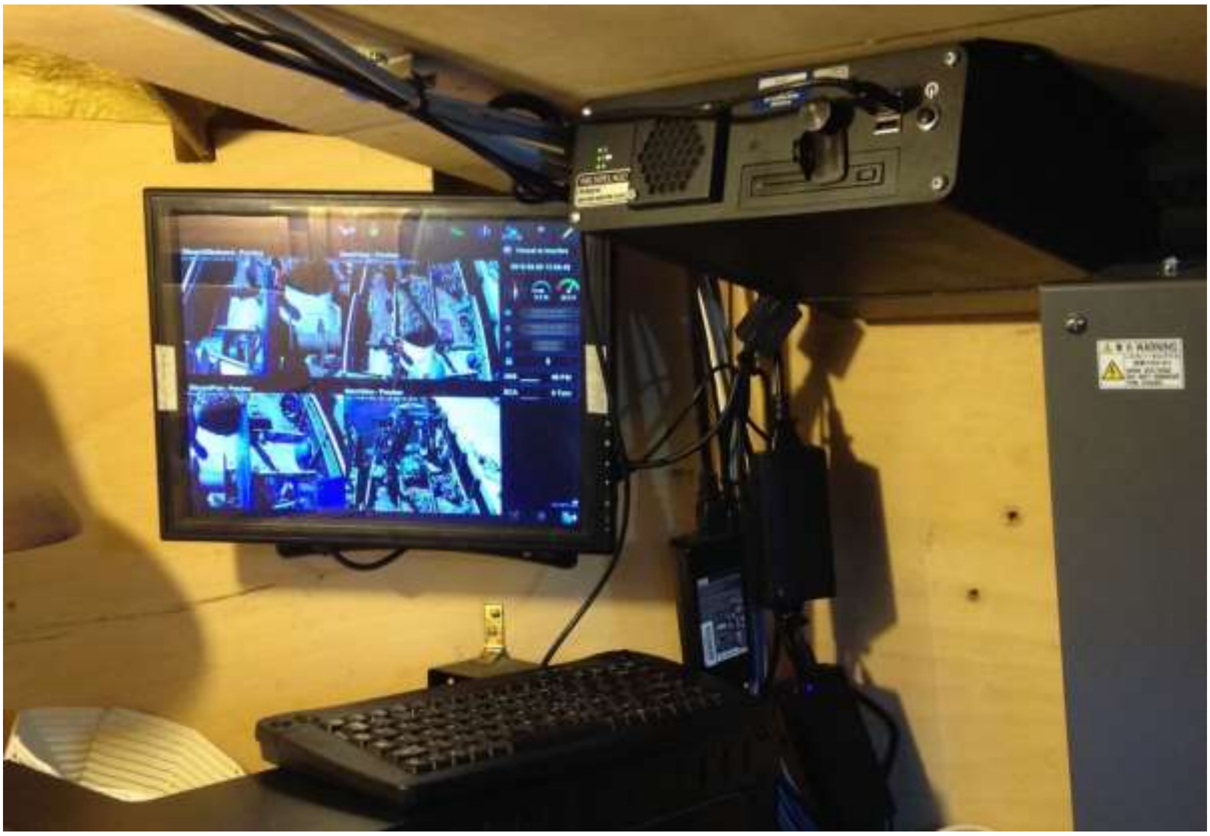


Figure 1.4 A v5 electronic monitoring system installed on a small vessel (photo courtesy of Archipelago Marine Research Ltd.)

For over 10 years EM has been used to monitor fisheries around the world. The technology was predominantly developed in North America and used to ensure compliance with regulations that required vessels to land all of their catch. This is similar to the position facing the European fishing industry under the Landing Obligation (Council Regulation (EC) No 1380/2013). Using EM to monitor 100% retention of catch is thought to be "less complicated and more easily accomplished through the use of technology e.g. a camera system" (Zollett et al, 2011). In 2013, eight countries were operationally using EM to monitor catches and 33 pilot trials had been carried out (Mangi et al., 2013). Some of these include;

- **British Columbia** – In the hook and line groundfish fishery, the fishermen are required to self-report catch data and vessels are monitored using REM systems with cameras. Independent third parties are used to review 10% of the video collected for compliance with regulations and if the vessel is found to be misreporting or discarding then further video is reviewed at the expense of the vessel. In 2013, the entire fleet of approximately 200 vessels, 1200 sea trips and 10000 days at sea were fully monitored. Full reviews are provided in Stebbins (2009) and McElderry et al. (2003).

- **Alaska –** EM has been successfully used in monitoring compliance in Alaskan fisheries for several years. These include the Alaskan pollock fishery, Rockfish, and Pacific cod freezer longline fishery in the Bering Sea. EM has also been used to estimate the quantities discarded and in some fisheries it has been concluded that using video monitoring is sufficiently accurate and precise for management's needs when compared to estimates obtained from the current observer sampling methods (Bonney and McGauley, 2008). In the west coast trawl hake fishery EM has also been trialled to ensure compliance with a discard ban (Loefflad, et al., 2014).

- **New Zealand –** Trials have been conducted in New Zealand to collect fishery and protected species data from set net vessels and trawlers. These studies concluded that EM systems can operate reliably on inshore set net and trawl vessels and could be used to effectively monitor dolphin encounters in both fisheries. The set net imagery could also be used to identify the majority of fish catch to species or species group (McElderry et al., 2007; McElderry et al., 2011). They also estimated that using EM was approximately 40% of the cost of using at sea fishery observers during its comparative trials. In July 2015 the New Zealand government also announced a tender process for operational monitoring of 20 vessels in the snapper trawl fishery.

- **Australia –** Trials have been undertaken on gill net fisheries, in particular to assess the performance of EM systems against at sea observers (Evans and Moloney, 2011) and it was concluded that 100% species identification was possible and that using EM was cheaper than using at-sea observers. Also in March 2015 it was announced that EM would be installed to monitor all vessels participating in the Australian Gillnet Hook and Trap (GHAT) and the Eastern and Western Tuna and Billfish fisheries (ETBF and WTBF), to provide greater insights into Australia's fishing operations, effective management and fishery sustainability (AFMA, 2015).

- **United Kingdom –** England and Scotland have carried out trials using EM systems with cameras since 2009. These have mainly focussed on the offshore otter trawl fisheries that target mixed gadoid species but have also included pelagic trawl fisheries (freezer and RSW), North Sea gillnet cod fishery, sole and plaice in the English Channel beam trawl fishery, Celtic Sea haddock in the otter trawl fishery, and under 10m vessel trials in the Irish Sea otter trawl fisheries (Roberts et al., 2015; Roberts et al., 2014; Course, 2012). The landing obligation for pelagic species was introduced on 1st January 2015 and some vessels are now being monitored for compliance using EM systems. Scotland have also investigated using the cameras to capture scientific data that can be used in stock assessments and to gather data on discard rates and fish length (Needle et al., 2015).

- **Denmark –** In 2008, Denmark was the first European country to undertake large scale trials using EM systems to monitor demersal trawl fisheries (Ulrich et al., 2015) and in 2010 these became coordinated with the UK and Germany in the cod catch quota trials. The 2011 trials in Denmark were conducted on 20 vessels and covered over 1100 fishing trips, 9800 fishing operations and over 80,000 hours at sea. It was found that the systems were successful in monitoring catches and that data loss was minimal (0.2% video data loss due to power failures on board the vessel) with the highest risk of data loss occurring during the mailing of completed hard drives (Dalskov et al., 2012). In addition to trawl vessel trials the Danish have also undertaken projects to monitor and quantify the incidental bycatch of cetaceans in Danish gill net fisheries. It was found that results obtained using EM with CCTV were more reliable than results provided by fishermen because on occasions the cetaceans would drop out of the net before coming aboard the vessel. It was also concluded that it was approximately 6.7 times cheaper to use EM than it was to use observers (Kindt-Larsen et al., 2012).

1.5 Current Scottish stock assessments

Creel fisheries

The main focus of this project is on the creel fisheries of the West coast of Scotland with 9 of the 11 participating vessels being creel fishing vessels, primarily targeting brown crabs, velvet crabs and lobsters, with one vessel also targeting Nephrops with creels (see section 2.1 below).

Fisheries data from these vessels are collected primarily through two methods – log books / ‘Fish 1’ forms and market sampling of landings. In addition, there are occasional observer sampling trips on inshore creels, but resources dictate that such trips are not a priority.

Records of landings and fishing effort on EU log books are mandatory for larger (>10m) vessels to complete, but for the majority of the vessels in the inshore fishery that are under 10m, landings must be declared on the ‘Fish 1’ forms which are equivalent to a weekly log sheet (see Figure 1.5). Fish 1 forms must be completed and returned on a weekly basis and landings for all species by weight must be declared. There is a field on these forms for “creel numbers”, but (as with its predecessor Shell 1 form) the recording of the number of creels fished and their soak time is not mandatory and so the data from Fish 1 forms provide no estimate of overall fishing effort. Some fishermen do record creel numbers on the Fish 1 forms, although as always with creel fisheries, it is not always clear whether these records of creel numbers relate to the number of creels hauled or the number of creels in the water at any one time. These data on creel numbers do not appear to be entered into the central national database FIN, presumably because they are difficult to interpret and validate, and in consequence it is not possible to calculate landings per unit effort (LPUE) (which is conventionally used as an index of stock abundance) for the whole fleet. Marine Scotland Science (MSS) have identified 12 sampling areas for which landings data from all vessels are aggregated. Landings data for brown crab for 2012 show that there is an important creel fishery on the west coast of Scotland (Figure 1.6).

MSS also undertake market sampling of landings at the quayside which provides length frequency distribution of landings. Tables 1.3 to 1.5 show the sampling levels for brown crab, velvet crab and lobsters undertaken by MSS over the period 2009 to 2012, showing that there is a relatively low level of sampling on the west coast areas in comparison with other areas.

The length frequency distribution data collected from the market sampling programme provides the input to the main stock assessment method used in Scotland’s creel fisheries. Age determination of crustacean species is not possible on a routine basis and so the application of conventional age-based assessment methods is problematical. Length cohort analysis (LCA) (Jones, 1974) uses length frequency data in conjunction with growth data to provide estimates of fishing mortality in relation to Fmax (the fishing mortality rate which maximises yield-per-recruit and which acts as a proxy for Fmsy, the fishing mortality level at MSY) and to assess how yield and biomass-per-recruit will respond to changes in fishing mortality due to changes in management measures. MSS undertakes LCA on a regional basis for males and females separately. LCA provides an indication of the state of the stock in relation to growth overfishing, but the method assumes that the population is in equilibrium, and so does not provide any information on actual short term stock dynamics or on recruitment overfishing. In addition to the low level of length frequency distribution sampling on the west coast, little is known about variations in growth rate between fishing areas.

ALL SPECIES 10M AND UNDER WEEKLY LANDING DECLARATION FORM

Marine Scotland Compliance
Sector Office
Scorrybreac
Portree
Isle of Skye IV51 9DH
email: FO.Portree@scotland.gsi.gov.uk

PLN
Vessel Name

Port of Landing
Owner/Master
Signed

Species	Fishing Area	ICES/NAFO AREA	ICES	Freshness	Size	State	Presentation	Weight (Kg)	Gear	Buyer(s)

Week Commencing (Sun)
Week Ending (Sat)
Creel Numbers

No of Arrivals in week
Vehicle Reg of transporter

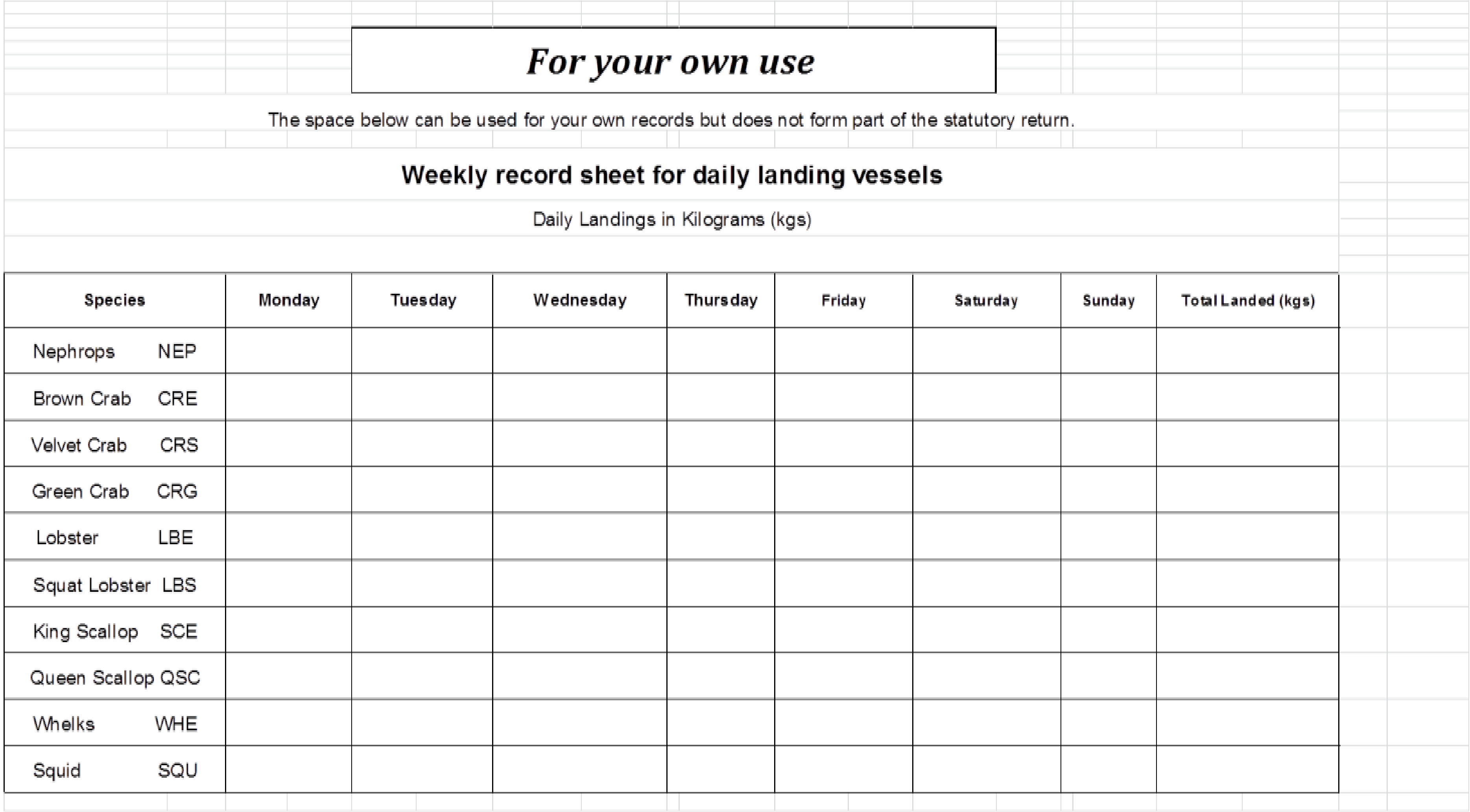
Important Notes

1. Vessel owners must complete a form FISH1 (landing declaration for vessel to which this licence relates, 10 metres and under in overall length) in respect of all landings of all species and submit it to the Fishery Office at which the vessel is administered within 48 hours of the conclusion of the fishing week - a fishing week runs from 0001 hours Sunday to 2359 hours Saturday.

2. Landings of all quota species made by the vessel during the calendar year are subject to monthly catch limits set by Fisheries Departments.

3. Landings made by the vessel will not be taken into account in the event of any future decision to introduce quota management arrangements based on landings by that vessel.

Data Protection Act
All data provided by means of this form, will be handled and processed in accordance with the Data Protection Act 1998. It may be disclosed to other Fisheries Departments in the UK, their Agencies and authorised agents and to other Government Departments. It may also be published or disclosed in an anonymous and aggregated form to these organisations, bodies or persons for other organisations, bodies or persons for other purposes, including economical and scientific research.



For your own use

The space below can be used for your own records but does not form part of the statutory return.

Weekly record sheet for daily landing vessels

Daily Landings in Kilograms (kgs)

Species	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total Landed (kgs)
Nephrops NEP								
Brown Crab CRE								
Velvet Crab CRS								
Green Crab CRG								
Lobster LBE								
Squat Lobster LBS								
King Scallop SCE								
Queen Scallop QSC								
Whelks WHE								
Squid SQU								

Figure 1.5 Fish 1 form – weekly landings declaration form

Table 1.3 MSS Market sampling statistics, number animals measured, number of sampling trips and percentage of landings sampled for brown crab by assessment unit, 2009-2012. (Source: A. McLay, MSS)

	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Animals measured	2009	110	3870	2084	0	903	2582	1321	1104	3781	513	2384	0
	2010	0	3259	3301	0	0	9306	3938	745	1997	1039	5847	159
	2011	42	2573	4437	0	0	6518	4545	1935	1171	1236	1554	0
	2012	245	7134	6370	0	1259	11432	747	3461	2695	1048	10673	193
Sampling trips	2009	2	25	12	0	2	18	1	9	28	4	3	0
	2010	0	27	8	0	0	78	2	11	25	6	14	1
	2011	1	27	10	0	0	47	3	16	22	6	3	0
	2012	4	35	19	0	3	70	1	15	33	3	17	2
Percentage of landings sampled (%)	2009	0.9	0.9	0.8	0	1.1	0.8	0.8	1.2	1.8	0.2	1.4	0
	2010	0	1.1	0.5	0	0	3.1	1.8	1.5	1.5	0.3	7.2	0.2
	2011	0.5	1.0	0.8	0	0	2.0	2.6	2.3	1.1	0.3	1.6	0
	2012	1.9	1.1	1.5	0	1.6	3.0	0.8	1.7	1.6	0.2	9.9	0.3

Table 1.4 MSS Market sampling statistics, number animals measured, number of sampling trips and percentage of landings sampled for velvet crab by assessment unit, 2009-2012. (Source: A. McLay, MSS)

	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Animals measured	2009	1331	1297	1120	0	0	3812	0	0	121	1271	0	0
	2010	353	1791	911	0	0	6265	285	3233	147	0	0	0
	2011	2159	631	1687	0	0	9925	0	3972	0	132	0	0
	2012	2532	4008	2788	0	0	7560	0	4152	307	819	0	0
Sampling trips	2009	5	6	6	0	0	18	0	0	1	7	0	0
	2010	3	14	6	0	0	23	1	6	1	0	0	0
	2011	9	7	12	0	0	41	0	10	0	1	0	0
	2012	10	18	15	0	0	30	0	11	2	4	0	0
Percentage of landings sampled (%)	2009	2.4	0.2	0.5	0	0	0.6	0	0	0.1	0.3	0	0
	2010	1.3	0.6	0.4	0	0	0.8	1.7	0.5	0.1	0	0	0
	2011	3.9	0.3	1.1	0	0	1.6	0	0.9	0	0.1	0	0
	2012	4.9	0.7	1.4	0	0	1.4	0	0.9	0.1	0.3	0	0

Table 1.5 MSS Market sampling statistics, number animals measured, number of sampling trips and percentage of landings sampled for lobster by assessment unit, 2009-2012. (Source: A. McLay, MSS)

	Year	Clyde	East Coast	Hebrides	Mallaig	North Coast	Orkney	Papa Bank	Shetland	South East	South Minch	Sule	Ullapool
Animals measured	2009	302	476	763	0	0	552	0	0	779	297	0	0
	2010	92	374	1833	0	0	1605	346	1019	916	151	43	0
	2011	229	602	403	0	0	1187	256	2098	904	550	101	0
	2012	269	1085	557	0	36	2078	208	707	1172	307	0	0
Sampling trips	2009	4	12	11	0	0	16	0	0	17	3	0	0
	2010	4	12	18	0	0	25	2	8	19	2	1	0
	2011	4	13	7	0	0	18	4	17	15	4	1	0
	2012	6	16	3	0	1	33	1	15	21	5	0	0
Percentage of landings sampled (%)	2009	1.4	0.3	0.6	0	0	0.5	0	0	0.5	0.1	0	0
	2010	1.1	0.4	1.0	0	0	0.8	1.7	0.9	0.6	0.1	1.1	0
	2011	1.4	0.3	0.5	0	0	0.6	4.4	2.3	0.4	0.2	1.5	0
	2012	2.1	0.4	0.2	0	0.6	1.3	1.1	1.8	0.6	0.3	0	0

An example output of LCA for the brown crab in South Minch shows that fishing mortality is currently above Fmax (used as a proxy for Fmsy) for both males and females (Figure 1.7a) and a summary of LCA results over recent years showed that fishing mortality for all areas of the west coast for brown crab (except for male crabs in Hebrides in 2009-2012) was close to or above Fmax and that assuming a direct relationship between fishing mortality and fishing effort, a reduction in fishing effort would be likely to increase both yield and biomass per recruit (Marine Scotland Science, 2015). LCA suggests that fishing mortality for velvet crabs on the west coast is also close to or above Fmax, and that the velvet crab stock would also benefit from a reduction in fishing effort. There was insufficient data to undertake assessments for lobsters in all west coast areas, but in those areas for which data were available, fishing mortality for one or both sexes was estimated to be at or above Fmax. (Mesquita et al., 2011; Marine Science Scotland, 2015).

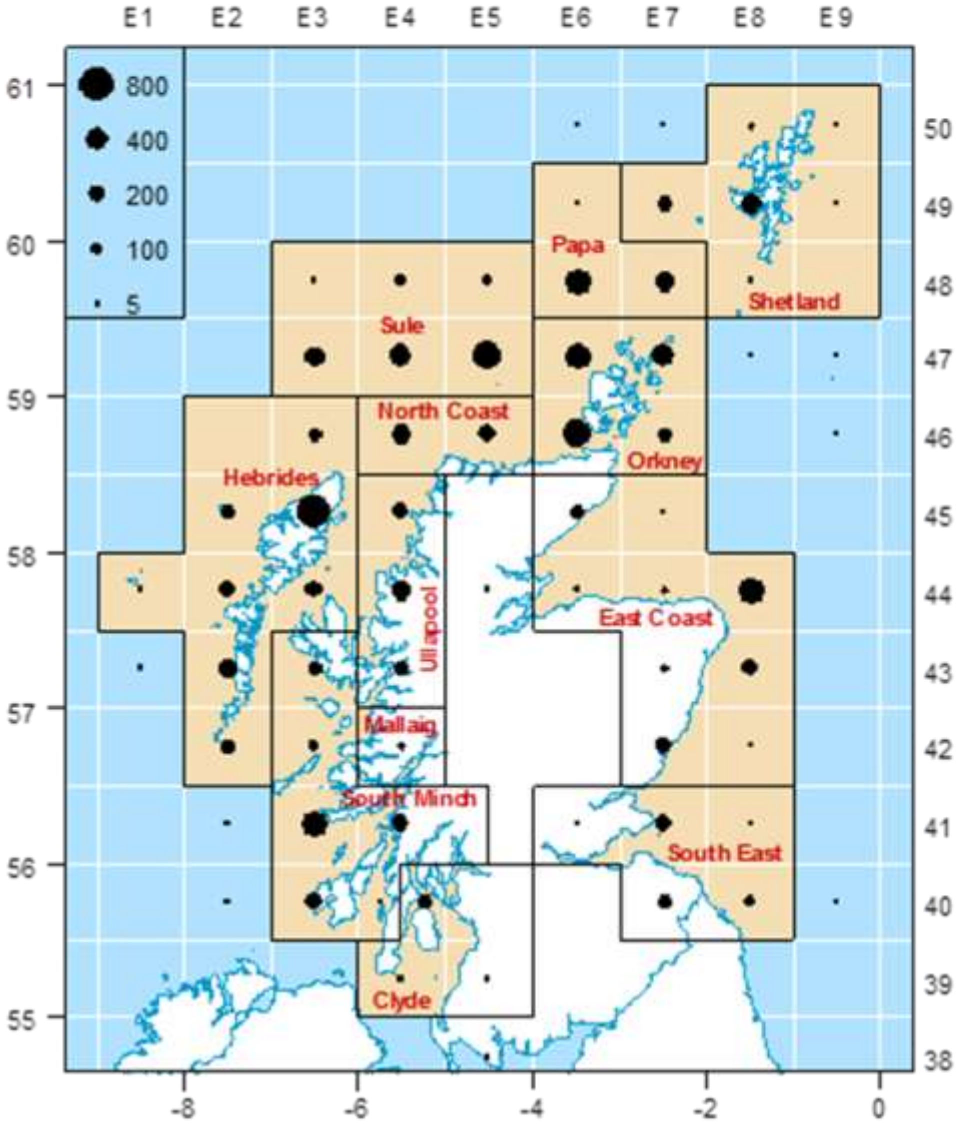
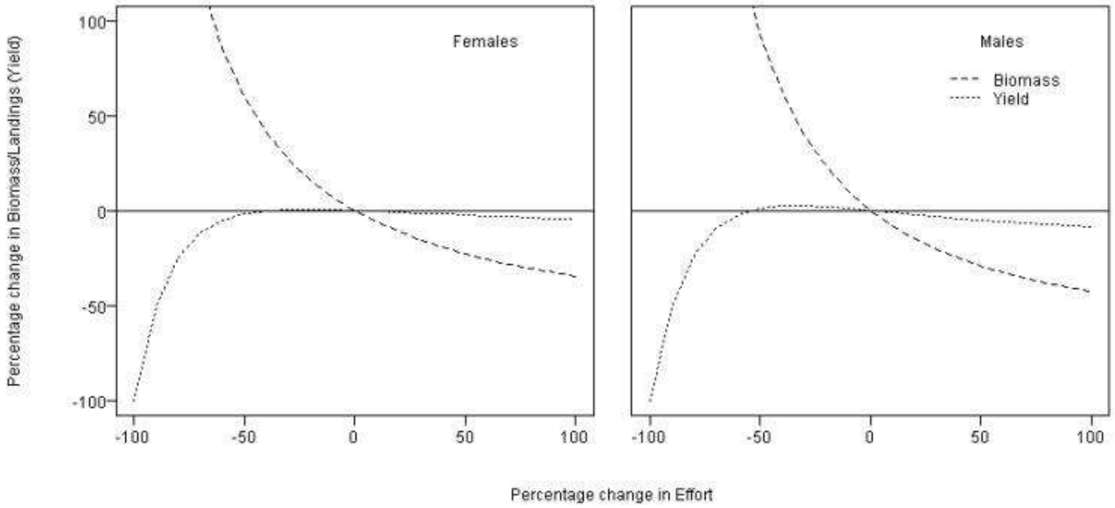
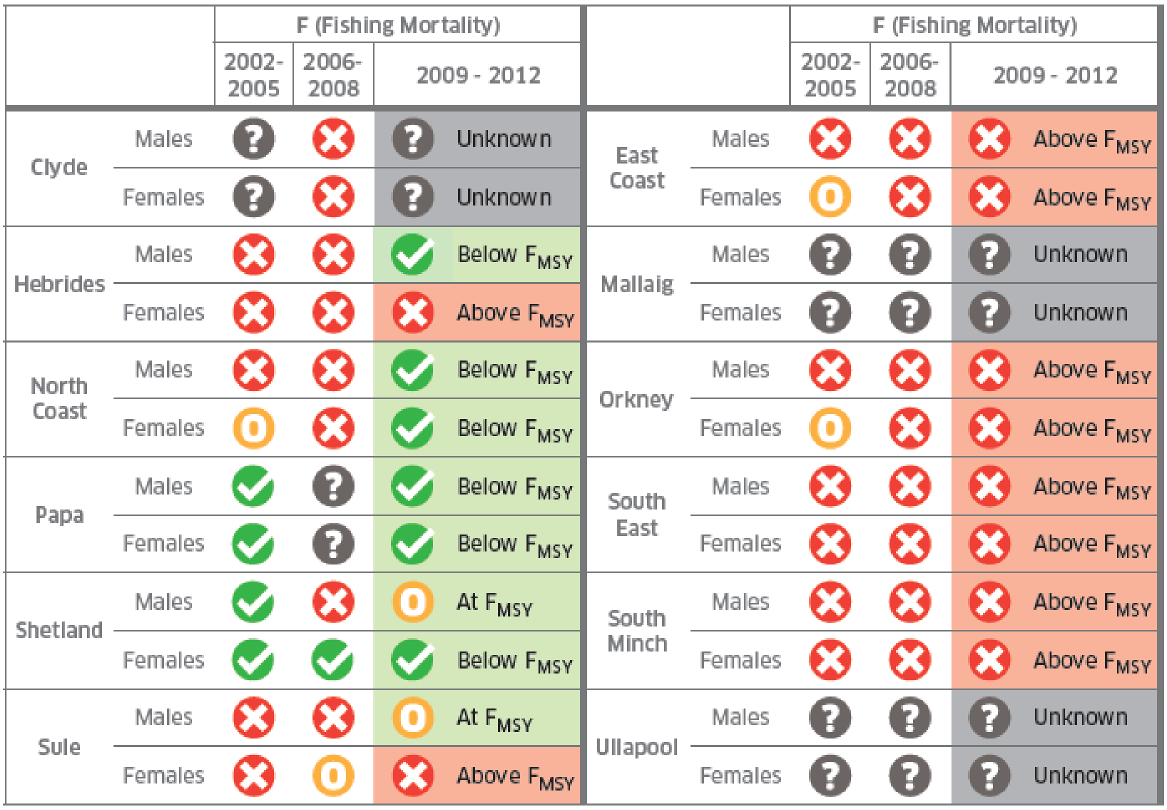


Figure 1.6 Assessment areas for the creel fisheries and the distribution of landings by area in 2012 for brown (Cancer pagurus). (Source: A. McLay, MSS)





		F (Fishing Mortality)					F (Fishing Mortality)		
		2002-2005	2006-2008	2009 - 2012			2002-2005	2006-2008	2009 - 2012
Clyde	Males	?	✗	? Unknown	East Coast	Males	✗	✗	✗ Above F_{MSY}
	Females	?	✗	? Unknown		Females	O	✗	✗ Above F_{MSY}
Hebrides	Males	✗	✗	✓ Below F_{MSY}	Mallaig	Males	?	?	? Unknown
	Females	✗	✗	✗ Above F_{MSY}		Females	?	?	? Unknown
North Coast	Males	✗	✗	✓ Below F_{MSY}	Orkney	Males	✗	✗	✗ Above F_{MSY}
	Females	O	✗	✓ Below F_{MSY}		Females	O	✗	✗ Above F_{MSY}
Papa	Males	✓	?	✓ Below F_{MSY}	South East	Males	✗	✗	✗ Above F_{MSY}
	Females	✓	?	✓ Below F_{MSY}		Females	✗	✗	✗ Above F_{MSY}
Shetland	Males	✓	✗	O At F_{MSY}	South Minch	Males	✗	✗	✗ Above F_{MSY}
	Females	✓	✓	✓ Below F_{MSY}		Females	✗	✗	✗ Above F_{MSY}
Sule	Males	✗	✗	O At F_{MSY}	Ullapool	Males	?	?	? Unknown
	Females	✗	O	✗ Above F_{MSY}		Females	?	?	? Unknown

Figure 1.7 (a) Output of length cohort analysis (LCA) for female and male brown crabs in South Minch and (b) the relationship between current F (fishing mortality)and Fmsy proxy for 2002-2005, 2006-2008 and 2009-2012 (Marine Scotland Science, 2015).

The creel fisheries for brown crab, velvet crab and lobster in the Scottish inshore fishery are can be considered data-deficient. There is some information on fishing effort from individual vessel data from a period when some fishermen were paid to complete logsheets and data from other ad hoc or contract studies data, but no continuous time series of LPUE data from which trends in stock abundance can be inferred (A. McLay, MSS, pers. comm.). In comparison, in the Shetland Islands creel fisheries, licensed vessels must complete log sheets which include the number of creels from which a 15 year time series has been generated (Figures 1.8 and 1.9) and which is used to provide an index of the stock biomass in relation to pre-defined reference points and subsequent harvest control rules if the index drops below those reference points. LPUE data such as those collected in Shetland can also be standardised using General Additive Modelling (GAM) techniques to take into account explanatory variables such as year, month, area or vessel size.

In addition to the lack of good information on fishing effort, the length frequency distribution data are collected at the landing ports and so do not include any information on the catch of crabs and lobsters which are returned to the sea because they are under the commercial minimum size or for other reasons such as being soft-shelled, missing claws, berried (egg-bearing) or otherwise of no commercial value. As noted above, there are occasional observer trips on these vessels, but such trips are not considered a priority in comparison with other fisheries where discard sampling is critical. There is scope therefore for developing innovative methods for collecting data on fishing effort in terms of creels hauled and their soak time and size frequency distribution of the total catch including discards.

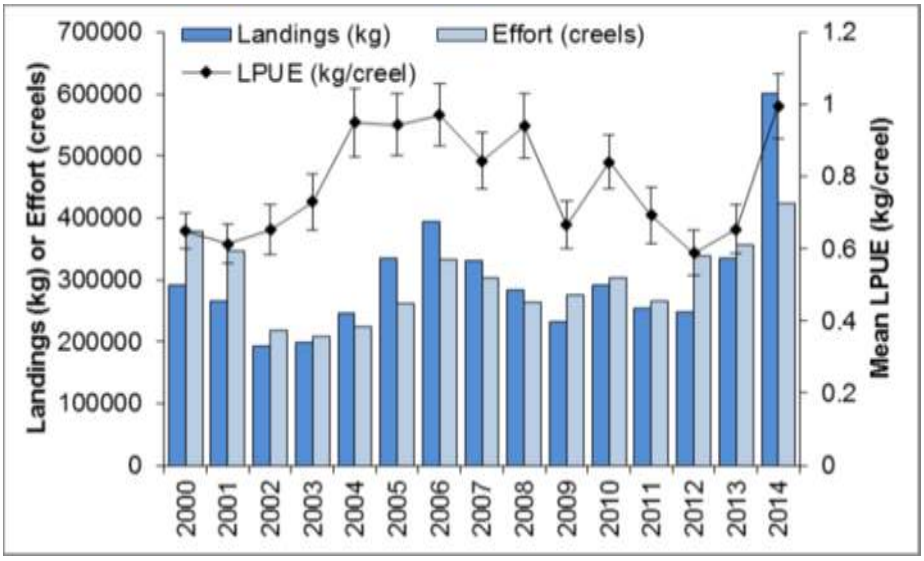


Figure 1.8 Trends in landings, fishing effort and LPUE for the Shetland Islands brown crab (Cancer pagurus) fishery. (Source, B. Mouat, NAFC, Shetland)

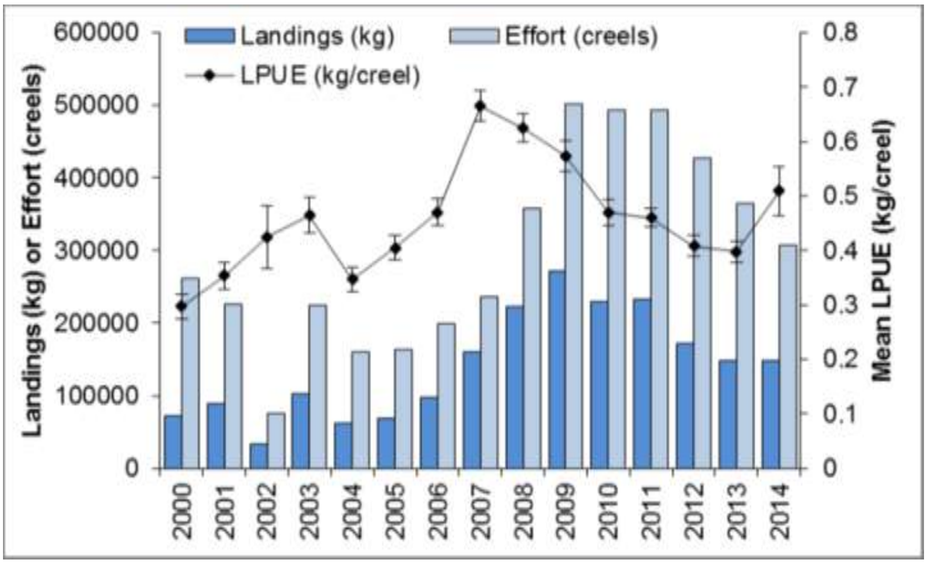


Figure 1.9 Trends in landings, fishing effort and LPUE for the Shetland Islands velvet crab fishery.(Source, B. Mouat, NAFC, Shetland)

Nephrops fishery

In contrast to the fisheries for crabs and lobsters, the fisheries for Nephrops, which are quota managed, could not be considered to be data-deficient. Landings of Nephrops in 2012 were just under 22,000 tonnes with a first sale value of £82 million making Nephrops the most valuable fishery in Scotland (Marine Scotland Science, 2014). Previously stock assessments of Nephrops used standard size-based assessment models based on stock surveys and landings per unit effort. However there were major uncertainties underlying these standard fisheries models because Nephrops live in burrows, and so are only vulnerable to trawls when they emerge from their burrow. Nephrops exhibit distinct diurnal patterns in emergence behaviour leaving their burrows primarily around sunset and sunrise at intermediate light intensity levels. Nephrops also show seasonal variability in emergence behaviour and egg-bearing females rarely leave their burrows at all. As a result Nephrops catches are dominated by males in the winter months with a more balanced sex ratio in summer fisheries.

As conventional fisheries data may provide a poor indicator of stock status, a fishery-independent method of estimating Nephrops stock abundance has been developed using underwater TV surveys of Nephrops burrow complexes. As the method counts burrows and not adult Nephrops, this approach is not reliant on Nephrops emerging from their burrows and so can be undertaken at any time. The method was pioneered in Scotland in the early 1990s and involves towing a TV camera mounted on a dredge over Nephrops grounds as defined by patches of muddy sediment and counting the number of Nephrops burrow complexes within a known area. All Nephrops burrow openings identified in view of the camera are allocated to a burrow complex, and the numbers of burrow complexes that cross a defined line on the TV screen are counted. Assuming a 1:1 rate of occupancy, the average population density can be estimated which is then raised to the known area of suitable sediment to give a measure of population size. However, population density will be overestimated if the counts include all burrow complexes that extend beyond the edges of the field of view (the edge effect). Regular surveys have been conducted for many of the main *Nephrops* fisheries around Britain and Ireland (ICES, 2010) providing long-term abundance indices. There are a number of inherent uncertainties in the methodology, including recognition of burrows created by Nephrops rather than other burrowing animals, burrow occupancy, burrow and animal size, variation between counters, “edge effects”, survey design (randomised fixed grid or random stratified sampling) and the level of sampling effort required to obtain a precise measure of burrow density. These uncertainties in the methodology have been investigated in depth through a series of ICES workshops and Study Groups (e.g. ICES, 2007: 2008; 2010; 2012) and peer reviewed publications (e.g. Campbell et al., 2009; Morello et al., 2007), and standard TV survey methodology is now agreed under the auspices of the ICES Study Group on Nephrops Surveys (SGNEPS).

The TV survey provides an estimate of stock biomass. Data on total catches defined as landings including dead and surviving discards, along with an assumption of a discard survival rate of 25% (Wileman et al., 1999) permits a calculation of total removals from the fishery. The ratio of total removals to stock biomass provides an estimate of observed harvest ratio.

In terms of managing the Nephrops stock within a MSY framework, the ICES WGNSSK selected preliminary stock-specific Fmsy proxies according to the perception of stock resilience, factors affecting recruitment, population density, knowledge of biological parameters, and the nature of the fishery including the relative exploitation of the sexes and the historical harvest rate vs. stock status. For the South Minch stock, F35%SPR, which represents the fishing mortality rate that corresponds to 35% of the unfished spawning stock biomass per recruit, was considered to be the best proxy for Fmsy.

Having developed a decision-making framework for selecting stock-specific Fmsy proxies, the next stage is to calculate values for those proxies for the stock using data from the fishery on size at length in a cohort analysis approach using either an age structured model or a length structured model. As the exploitation rates in many stocks vary significantly between the sexes because of differences in emergence patterns, the Fmsy proxies were determined for males, females and combined sexes. The use of a yield-per-recruit cohort model then allows the calculation of harvest ratios which are equivalent to the various potential proxies for Fmsy. The cohort model predicts the population size of animals >17mm CL at the Fmsy proxy, which is compared with projected landings to provide a "target" harvest rate. The projected landings are the projected catch at size using the Fmsy proxy value of F and applying the appropriate selectivity dependent on mesh size used in the fishery.

The model assumes that 25% of discards survive and are not therefore counted as "removals", i.e. the same assumption is used in the calculation of harvest ratio as that calculated from observed landings and biomass estimates from the TV survey.
The calculated harvest ratio reference point can then be used in conjunction with the biomass estimate from the TV surveys in two ways. Firstly, comparison of the observed harvest ratio with the harvest ratio reference point allows an evaluation of stock status against a defined reference point. Secondly, the harvest ratio reference point can be used with the stock biomass estimate to set a TAC for the fishery next year. In addition to defining a target fishing mortality, the fishery is managed to ensure that stock biomass levels do not fall below MSY Btrigger defined as the lowest observed TV survey estimate of stock biomass in the time series. Based on the TV survey for 2013 and the landings data, the current observed harvest ratio in the South Minch is 15 .8% which is significantly above the target harvest ratio of 12.3%. ICES advice therefore is to set the TAC in line with a harvest ratio of 12.3% based on stock biomass estimates from the TV survey. Time trends in stock biomass from the TV surveys suggest that stock biomass is well above MSY Btrigger in 2013, and that the harvest rate has in recent years been fluctuating around the harvest rate of 12.3% equivalent to the Fmsy proxy (Figure 1.10).

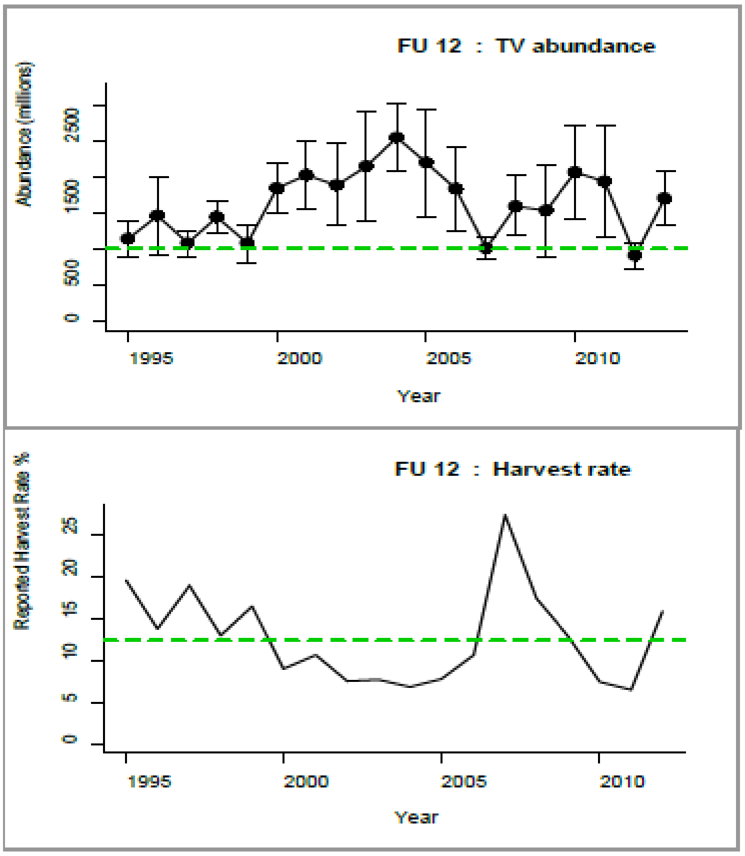


Figure 1.10 Nephrops in South Minch. Underwater TV survey abundance estimate in millions with 95% confidence levels, and harvest rate. Green dashed lines represent MSY Btrigger and Fmsy harvest ratios. (Source: ICES Advice 2013, Book 5)

[Author's note: the most recent assessment which will form ICES 2015 advice is that stock biomass remains well above MSY Btrigger and that the current harvest rate is now below Fmsy harvest rate.]

As the stock assessment for Nephrops is based upon the fishery-independent TV survey estimate of stock abundance, there is less need to develop alternative methods of collecting data in this fishery. Whilst many vessels in the South Minch fishery are larger vessels, there are a number of smaller vessels fishing inshore using creels rather than trawls, for which observer sampling does not take place regularly. In view of different growth rates exhibited by Nephrops between areas within a stock, increased sampling of creel-caught Nephrops would provide useful information.

Scallop fishery

Landings of scallops in 2011 were 7,800 tonnes with a first sale value of £16 million making scallops the second most valuable shellfish fishery in Scotland after Nephrops (Marine Scotland Science, 2014). Stock assessment of scallops in Scotland uses an aged-structured method entitled Time Series Analysis. The method uses three sources of data: reported landings data, catch at age data from the MSS annual scallop dredge surveys, and age and size frequency data collected as part of the MSS market sampling programme conducted at landing sites around the Scottish coast. The TSA assessment model provides annual estimates (with confidence intervals) of yield, fishing mortality, spawning stock biomass and recruitment. Two stock assessment areas are designated on the west coast of Scotland, West of Kintyre and North West (Figure 1.11).

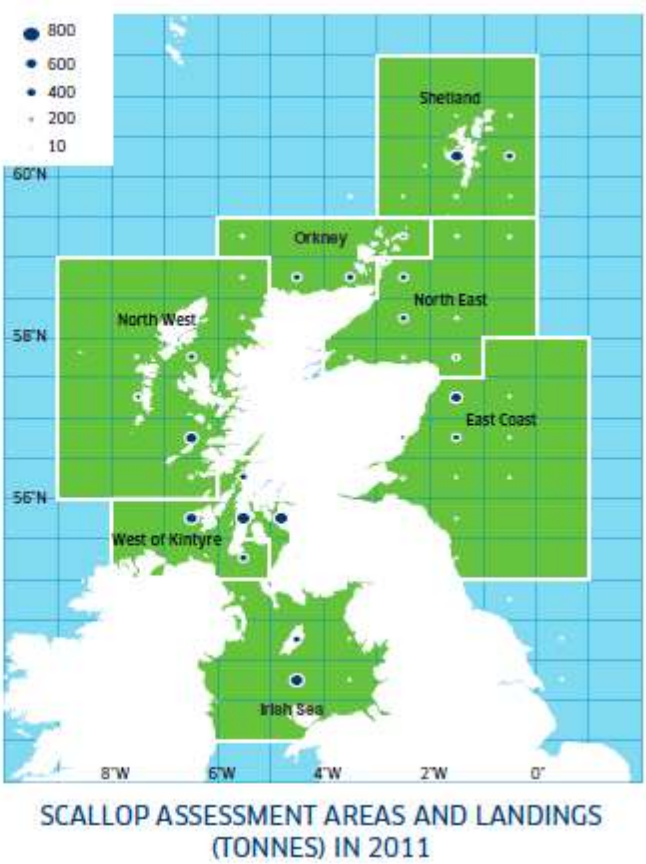
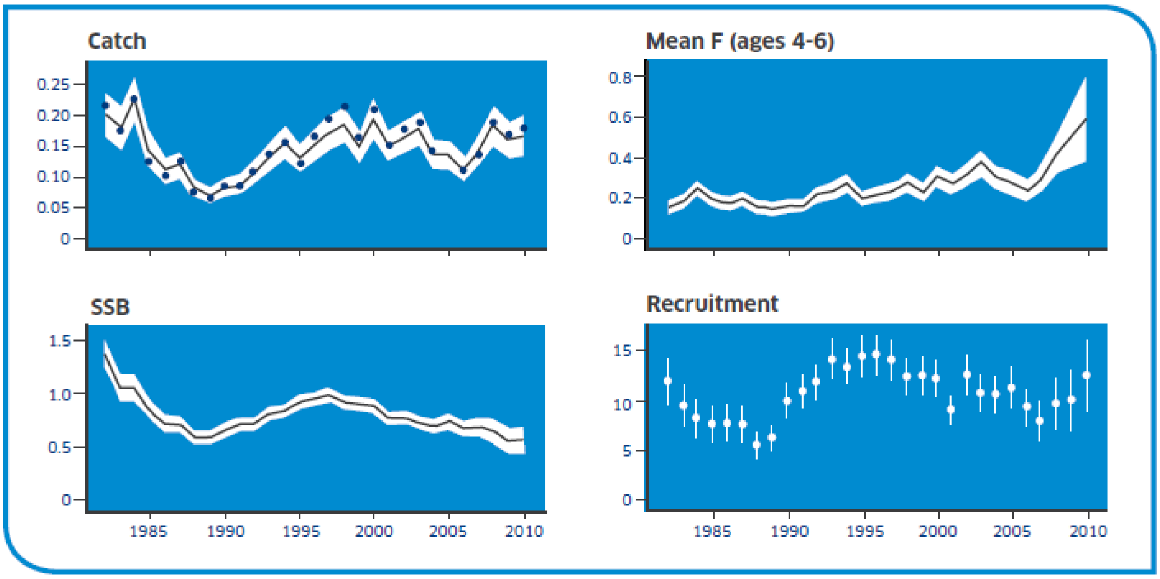


Figure 1.11 Designated stock assessment areas for scallops in Scotland. (Source: Marine Scotland Science, 2014)

The assessment for West of Kintyre shows that with only moderate recruitment and high catches in recent years, the spawning stock biomass (SSB) has declined significantly in recent years and reached its lowest point in the time series in 2010, and fishing mortality has increased significantly (Figure 1.12) (Marine Scotland Science, 2014). Management advice therefore for the West of Kintyre stock is that fishing mortality should be reduced.

The assessment for the North West shows recruitment has declined in recent years following a period of high recruitment in the mid- to late nineties and consequently stock biomass and catches have declined significantly (Figure 1.13) and there has been a subsequent reduction in fishing mortality (Marine Scotland Science, 2014). Management advice for this area is that there should be no increase in fishing mortality as stock biomass levels remain low.



WEST OF KINTYRE STOCK SUMMARY SHOWING CATCH AND SSB OF SCALLOP MUSCLE (000 T), RECRUITMENT AT AGE THREE (MILLIONS) AND ANNUAL FISHING MORTALITY AVERAGED OVER AGES FOUR TO SIX.

Figure 1.12 Stock assessment output for scallops for the West of Kintyre stock Source: Marine Scotland Science, 2014)

NORTH WEST STOCK SUMMARY SHOWING CATCH AND SSB OF SCALLOP MUSCLE (000 T), RECRUITMENT AT AGE THREE (MILLIONS) AND ANNUAL FISHING MORTALITY AVERAGED OVER AGES FOUR TO SIX.

Figure 1.13 Stock assessment output for scallops for the North West stock Source: Marine Scotland Science, 2014)

For scallops, there is good information on landings, length frequency distribution and a fishery-independent stock survey which provides information on bycatch species as well as the target species, although the survey does not cover all areas fished for scallops. There is however scope to trial innovative methods for recording scallop fishing effort, length frequency distributions of the total catch and bycatch species without costly observer programmes or stock surveys.

1.6 Aims of the projects

The key elements of the two projects are the trialling of a self-sampling programme in the Scottish inshore fisheries and the use of EM technology to gather fisheries data remotely and to validate self-sampling. A series of sub-projects will also be carried out trialling RFID tags, motion-compensated scales, electronic Bluetooth callipers and cameras on the chute to collect length data. The emphasis throughout the projects is to engage fishermen in the process of data collection and its use in stock assessment and during the project two training days will be held with project participants to encourage “buy-in” to the project.

2. Methodology

2.1 Vessel Selection Process

These projects (WP2/WP3) were always intended to be a feasibility study into whether or not EM systems could monitor small vessels, verify self-reported data and provide additional data that could be used in stock assessments. The original remit was:

- to carry out the research in the geographical area between Oban in the south and Cape Wrath in the north;
- to use vessels less than 10m;
- use vessels that target data deficient shellfish species (i.e. brown crab, velvet crab, lobster, scallops).

Originally this was to be a trial using 10 vessels. To ensure that there was open and fair competition to participate, a vessel recruitment scheme was carried out by Sea Fish Industry Authority. An advertisement was placed in the Fishing News (deadline 19th September 2014) requesting vessel owners to apply to be considered for inclusion in the project. In total 27 vessels expressed an interest in participating. However most of these vessels were outside the geographical area, a number targeted only Nephrops when creeling and there were also a number of Nephrops trawlers that applied (*Nephrops norvegicus* is NOT a data deficient stock on the west coast of Scotland). Therefore the issue was discussed with project managers and the original vessel and sampling area specifications were revised so that vessels from anywhere on the west coast of Scotland (including the Solway Firth) could now be considered. These criteria for selection were relaxed to allow the concept of using EM to be fully trialled in different areas and to make the use of EM highly visible. In addition the length of vessel was revised from <10m to <12m because these vessels still fished the inshore waters; and the gear used was also relaxed to allow Marine Scotland an opportunity to test the EM equipment on a wider range of fishing gears (e.g. Nephrops trawlers and scallop dredgers). However preference was to be given to those vessels that best fitted into the original criteria. The number of project participants was also extended to 11 vessels to allow a scallop dredger to be included. Systems were also trialled on small single handed creel vessels.

When vessels applied to be on the scheme they provided a brief overview of their seasonal fishing activity and their main target species, along with their main operating port. This information was be used to assign a “score” to each vessel, to ensure that all vessels were treated fairly. In addition the coastline was “split” into 3 study areas to allow an even distribution of participants throughout the west coast, but with preference being the original Oban to Cape Wrath range. These 3 areas were:

- Area 1 – Central (Tiree/Barra);
- Area 2 – Northern (Leverburgh/Uig/Skye/Mallaig);
- Area 3 – Southern (Islay/Kintyre/Clyde);
- Plus an additional sub-area, the Solway Firth.

Vessels were scored on the weighted criteria shown in Table 2.1. Target species was given the highest weighting priority, followed by area and time spent targeting this species. The sum of all the scores was used to rank the vessels. The 3 highest scoring vessels in each area, plus a vessel in the Solway Firth and a scallop dredger would be selected. The exception to this being Area 2 where 2 creel vessels and a Nephrops trawler were to be selected to allow Marine Scotland to explore the use of EM in this metier. This scoring process resulted in the 11 vessels shown in Table 2.2 being selected. Their distribution pattern on the west coast of Scotland is shown in Figure 2.1.

Table 2.1 Scoring criteria and weighting process used to select project vessels.

CRITERIA	1. Within study area?	2. Target Priority Species (main target)	3. Time targeting priority species fishery (factor)	4. Species x Targeted time	5. Relevant Gear Type	6. Bonus fraction point
SCORING GUIDANCE	4= Yes 2 =just outside 0 = Not within or close to area	4 = mainly lobsters/crabs, 3 = scallops, 2 = velvets or creel Nephrops, 1= trawl Nephrops, 0 = Other	Fraction of a year e.g. 6 months per year = 0.5	Result of Criteria 2 x Criteria 3	2 = Creel, 1 = dredge or creel and secondary gear, 0 = Trawl	Range between 0 and 1in 0.25 units and only used where scores were tied. Based on information provided in the application and through follow up telephone discussions
Importance Weighting	2	3	1	2	1	1

Table 2.2 List of vessels selected for the project along with their declared main target species and location.

Vessel Name	Activity	Location
Annie T	Creel – Brown Crab, Velvet, Nephrops	Barra
Kestrel	Creel – Brown Crab, Velvet	Tiree
Atlantis	Creel – Brown Crab, Velvet	Tiree
Shuna	Creel – Brown Crab, Velvet, Nephrops	Kyle of Lochalsh
Valhalla	Creel – Brown Crab, Velvet, Nephrops	Leverburgh
Protera	Trawl - Nephrops	Mallaig
Jacamara	Creel – Brown Crab, Velvet	Islay
Obsession	Creel – Brown Crab, Velvet	Islay
Solstice	Dredge - Scallop	Islay
Kyra	Creel – Brown Crab, Velvet	West Tarbert
Bright Horizon	Creel - Lobster	Isle of Whithorn

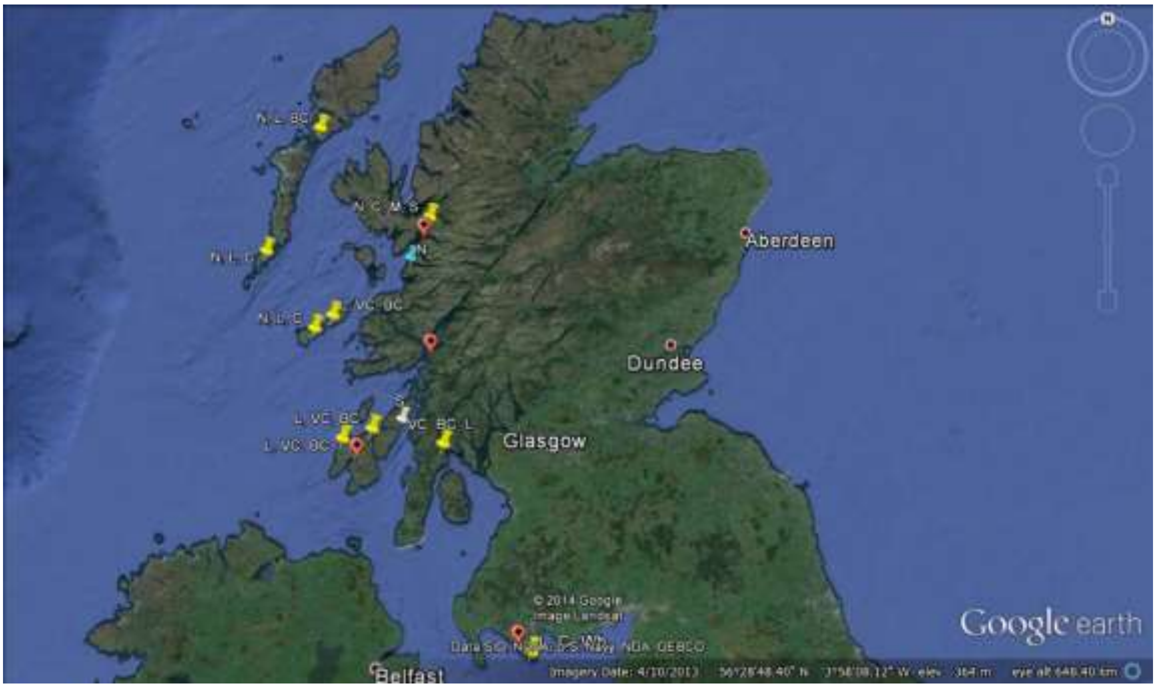


Figure 2.1 Geographical spread and main gear type of vessel. Yellow is Creel, Blue is Trawl and White is Dredge. Map courtesy of Ali McKnight.

2.2 Installation of EM equipment

Installation of equipment began in late October 2014 following receipt of the first consignment of equipment (v4.5 systems) from Archipelago Marine Research Limited. These systems have an expected lifespan of 5 years if regular services are undertaken. All equipment was bench tested prior to deployment in the field to ensure all components were operable. Initially a provisional installation schedule (allowing 2 days/vessel) was drawn up based on vessel/skipper availability and geographical location (see Table 2.3).

Skippers were contacted by phone or email prior to travelling to confirm vessels power supplies available in order to ensure all required equipment could be taken to the vessel to complete the installations.

Upon arrival at a vessel, skippers were consulted on the following points;

- Available power supplies
- Space in wheelhouse and elsewhere for mounting equipment
- Existing and potential new cable routes
- Catch handling procedures for optimal camera placement

In general, all vessels were fitted with 3 cameras. These cameras were located on existing vessel super structure with the view to achieving 3 main streams of video imagery (Figure 2.2).

Firstly an overview camera through which analysts should be able to see most, if not all of the vessels' deck, allowing for views of gear deployment and retrieval along with views of retained catch as stored in keep pots, boxes etc. The remaining 2 cameras would be located to optimise views of catch sorting area(s) with one focussed on collecting suitable imagery for assessment of retained catch whilst the other would be utilised to assess the discarded portion of the catch.

Figure 2.2 Three camera views. L-R, deck overview, discard view and sorting/retained catch view.

Table 2.3 Vessel installation schedule along with start of valid data collection dates.

AMR consignment	Vessel	Location	Installation date	System commissioned	Start EM data collection
1	Annie T	Barra	21-22 Oct	22 Oct	17 Dec
1	Kestrel	Tiree	24-25 Oct	26 Oct	15 Nov
1	Atlantis	Tiree	26-27 Oct	24 Nov	25 Nov
1	Shuna	Kyle of Lochalsh	30 Oct	30 Oct	27 Nov
1	Protera	Mallaig	1-2 Nov	2 Nov	9 Nov
2	Jacamar	Islay	11-12 Nov	12 Nov	19 January*
1	Obsession	Islay	12-13 Nov	13 Nov	15 Nov
2	Solstice	Islay	14-15 Nov	15 Nov	16 Nov
2	Kyra	West Loch	17-19 Nov	19 Nov	20 Nov
2	Bright Horizon	Isle of Whithorn	21-22 Nov	22 Nov	23 Nov
2	Valhalla	Leverburgh	3-4 December	4 Dec	13 Feb*

* Denotes vessels which experienced interference with VHF signal when system running. These two vessels were advised to leave systems switched off until such a time as an effective remedy could be applied, hence late start to data collection.

Once appropriate locations for equipment were agreed, installation commenced by installing cabling between agreed control centre location to;

- camera location(s) (3 per vessel),
- PoE (power over Ethernet) network switch
- Independent GPS
- Hydraulic sensor
- Drum rotation sensor (where fitted-trawl and scallop dredge vessels only)
- Screen and keyboard (user interface).

All EM systems fitted during this study utilised IP digital cameras and connections between cameras and PoE switch, and PoE switch and control centres were made with screened, gel-filled cat5E cables, fitted with screened EZRJ45 connectors. Where connection to the vessels power supply for control centres and (in the case of v4.5 control centres) PoE switches involved more than simply plugging in to an existing 230v 3 pin outlet, skippers were requested to seek a competent qualified person to make these connections. Similarly, hydraulic sensors were run to an appropriate location for connection either by the skipper themselves or a suitably qualified person. Due the remote location of some of the vessels on this trial, some vessels did not manage to have the necessary hydraulic connections made due to lack of local expertise or access to appropriate hydraulic couplings and fittings.

Once all cabling and connections were made and fixed in place, systems were powered up and tested. Any obvious changes required to cameras location and focus, along with configuration of recording parameters etc. were made at this time. Once systems were deemed operable skippers were briefed in the systems operating platform, the functionality of the user interface and how to monitor system performance, along with how to exchange hard-drives. Skippers also agreed to a "duty of care" arrangement, where they agreed to keep cameras clean, equipment safe and dry where necessary (e.g. the control box), and to inform the project managers as soon as an issue was detected with the performance of the EM equipment or when advice was needed.

As noted in Table 2.3, two vessels that were installed with EM equipment reported significant interference on their VHF radios when EM systems were operational. These vessels were advised to switch systems off immediately and the equipment providers were consulted on the issue. A number of solutions were tested including ferrite clamps and inline RF inhibitors. The level of interference experienced appeared to be related to both the number of cameras fitted and their proximity to the VHF aerials. An interim solution for the two vessels in question was to reduce the number of cameras from 3 to 2 and to fit additional ferrite clamps to cat5E cables connecting cameras to both the PoE switch and the control centre. Whilst this allowed data collection to resume the compromise of reducing the number of cameras meant that accurate catch analysis was compromised. Subsequent visits to these vessels allowed for the installation of another camera on each (with fitting of additional ferrite clamps) in locations well away from VHF aerials to improve the available camera views.

When the VHF issue was identified all vessels participating in the scheme were contacted and asked to report if they were experiencing similar issues. Only one response was received that indicated that the EM system was causing interference with FM radio reception. Whilst efforts were made to rectify this (including segregation of cables and fitting of additional ferrite clamps) the interference with FM radio reception persisted. Upon completion of the data collection period a further two vessels notified Seascope to say that they had also encountered interference with FM radio reception. They had initially assumed that the interference was related to their own equipment (radios and aerials) and only realised that the interference was related to the EM systems when systems were either turned off or uninstalled and normal reception resumed.

Equipment suppliers (AMR) are currently reviewing and testing different IP cameras to minimise and/or eliminate RF (radio frequency) interference.

Other issues around installation and commissioning of equipment included non-functioning or intermittent power supplies (inverters) that were pre-existing on vessels. Whilst quay-side testing was often successful it was noted that when systems (or parts of systems eg. PoE switches) were connected to AC supplies these systems would often encounter breaks in power supplied. Where this occurred the power supplies were changed from AC (via inverters) to direct connection to the vessels 12 or 24VDC supplies, which greatly improved system performance.

All EM systems came supplied with an independent screen for displaying EM output and the user interface in the wheelhouse. On four of the participant vessels, skippers felt installation of an additional screen was not possible due to potentially impaired vision or total lack of physical space within the confines of the wheelhouse. On two of these vessels an existing screen was utilised to display EM output. This is often less than ideal however as the screen may be used for other purposes (plotter/ TV etc.) which means that EM output (and any potential alerts e.g. “hard drive nearly full”, or “cameras dirty/not recording”) can be over-looked.

On the other two vessels, one was fitted with a small 9 inch screen and the other had an independent screen fitted in the accommodation area. Again, neither of these solutions were ideal as the small screen resolution made it hard to read displayed text (e.g. the display detailing remaining hard drive capacity) and image resolution was low which didn’t necessarily allow the skipper to detect such things as dirty camera domes, during a function test. On the vessel where the screen was fitted in the accommodation area the skipper wouldn’t always be aware of issues with the equipment because the accommodation area was seldom used.

Another issue that came to light, most notably on the two vessels which only had 2 cameras operating for a period of time, was that initial installations are made based on the catch handling described by the skipper at the time of installation. As the project progressed however, and vessels switched target species it became apparent that a 2 or even 3 camera set-up optimised to one fishery may not necessarily provide adequate deck and camera coverage when vessels catch handling procedures change with a change in target species. This however could be addressed with the installation of an extra camera(s).

A summary of equipment faults is provided below in Table 2.4.

Table 2.4 Equipment faults reported and rectified during course of project.

Fault/problem description	Number of occurrences	Remedy	Subsequent data loss
Camera failure	2	Replace camera	1 vessel lost 1 camera view for approximately 1 week before replacement could be fitted. Second vessel lost 2 days video from 1 camera. On both occasions ingress of water due to insufficient sealing of camera caused the failure.
Screen failure	1	Replace screen	As screen was faulty (due to excessive vibration most likely), which skipper reported, he was unable to monitor how full hard drive was. By the time the screen was replaced the hard drive was filled to capacity* and 2.5 days of video data were lost.
Hard drive wouldn't initialise	2	Check hard-drive mounts and re-secure	Nil, another spare hard drive aboard
Hard drive over-filled	2*	Exchange hard drive	Vessel failed to notice hard drive was full, lost 2.5 days video data until disk replaced.
Rotation sensor failed to trigger video recording	1	Change recording configuration to always record outside of port area.	Scallop dredger was initially configured to have video recording triggered by drum sensor activity. After approx. 2 months of operation reflectors that trigger drum sensor became covered in grease which resulted in no recording trigger when gear deployed. Lost 2.5 days of video from 2 of 3 cameras due to this fault.
Loose connection to PoE switch	1	Connections checked and strain relief (cable ties) re-fitted to control centre external wiring loom.	Loose connection occurred when trying to rectify interference issue. System did not record video data for a period of 5 fishing days.
Vessels AC supply insufficient or intermittent.	3	Change to DC power supply if possible. Where not possible a larger capacity replacement inverter was fitted.	First hard drive from 1 vessel contained multiple time gaps and corrupted video files due to inadequate inverter power supply. Only 1 trip of first 12 deemed valid. Second vessels own inverter failed leading to no cameras recording for 4 fishing trips. On 3rd vessel it became obvious that inverter supply was insufficient during commissioning so switched to DC power supply. No associated data loss.

2.3 Introductory training sessions

As a condition of acceptance on the project, all participating skippers were expected to attend a one-day training course which was designed to facilitate engagement with the project, to demonstrate the use of EM technology alongside self-sampling and to help fishermen to gain an understanding of the nature of stock assessments and how they might participate in the assessment process.

The aims and objectives of the training session were:

- To provide an overview of why and how stock assessments are carried out.
- To provide an explanation of the basis of stock assessment modelling and to provide an introduction to current stock assessment techniques used in Scottish inshore fisheries.
- To provide an understanding of what data are required for stock assessments and how "self-sampling" can play a role.

It was stressed that the objective of the training course was NOT to train fishermen to carry out stock assessments, but primarily to explain the nature of stock assessments and prepare fishermen to participate in the interpretation of stock assessments.

The training session provided an opportunity for participants and project staff to iron out any initial problems that may have occurred following the installation of the technology on board the vessels. Most importantly however the training sessions aimed to achieve "buy-in" of the participants to the project, because experience shows that the success of all such collaborative programmes between the fishing industry and fisheries scientists requires good communication between participating fishermen and project managers and continuous feedback on the project to participants.

In addition to participating skippers, the training course was opened up to skippers and vessel owners who expressed an interest in participating in the project, but had not been selected, and was also advertised to other interested individuals through the local Inshore Fisheries Groups. Despite the wide advertising, only one additional skipper outside the project requested to attend the training course. (In the event, that one individual did not attend on the day.)

Three courses were held during the week of Monday 24 November 2014 at venues as close as possible to participants' home ports, and were timed to coincide with ferry times for those fishermen who had to travel by ferry to the venue.

Location	Date	Time	Attendees
Tiree – An Talla Community Hall, Crossapool	24 November	10.00 – 13.45	Project participants Ross MacLennan (Atlantis) Trainers Grant Course Julian Addison Guy Pasco Project facilitator Ali McKnight
Skye – Skeabost Country House Hotel, Dunvegan	25 November	14.30 – 18.00	Project participants Bruce Langlands (Shuna) Don MacLennan (Valhalla) Allan Cameron (Protera) Trainers Grant Course Julian Addison Project facilitator Kyla Orr
Islay – Gaelic (Columba) Centre, Bowmore	27 November	10.30 – 14.30	Project participants Kevin Campbell (Solstice) Trainers Grant Course Julian Addison Guy Pasco Project facilitator Ali McKnight

Despite the training sessions being organised at local venues as close to the fishing vessels' home ports as possible, and positive responses to the invitation from almost all project participants, the attendance rate at the training sessions was disappointing with the exception of Skye, with only 50% of participating fishermen attending a training session. Feedback from those who did not attend (despite an initial positive response) was that the weather and seas conditions were very good all week and those fishermen chose to go fishing rather than attend the training session. Nevertheless the training sessions were well received by participants who seemed fully engaged with the project and the training material was widely discussed at all meetings. The project team made regular visits to see all participants throughout the project to ensure continued engagement in the project, so the lack of attendance did not seriously impact on the success of the project.

Figure 2.3 Project manager Grant Course (second from left) and participating skippers at the Training Course on Skye (photo: Kyla Orr).

Figure 2.4 Presentation of the stock assessments at the Skye Training Course (photo: Kyla Orr)

The key features of the Training Course are summarised below:

Projects within “Evidence Gathering in Support of Sustainable inshore Fisheries”. This project contains two work packages of a much wider series of seven projects focussed on Scottish inshore fisheries funded by the European Fisheries Fund (EFF), of which the overall objective is to secure sustainable management of Scottish inshore fisheries and support the dependent coastal communities. One feature common to all Inshore Fisheries Group management plans was the perceived lack of evidence upon which to base management measures, and so a series of pilot projects have been funded to fill evidence gaps and trial new technology.

What are stock assessments and why do we need them? Stock assessments are a formal method for assessing the status of the stock often against pre-defined reference points (targets). They provide evidence for whether current management measures are adequate, provide advice on sustainable fishing, and may allow an evaluation of the relative benefits of different management regimes. Stock assessments can be relatively simple analyses of trends in data (stock indicators) but may require complex mathematical or computer models. Whilst many stock assessments use complex mathematical models, the emphasis throughout the Training Course was that stock assessment is not ‘rocket science’, and fishermen and other stakeholders can play an important role in the interpretation of stock status in relation to fisheries management based on the stock assessments.

Stock assessments involve scientific monitoring and research to support fisheries management, and there is therefore a need to understand the biology of the species (growth, life history etc.). For the purposes of stock assessment, a ‘stock’ can be the population of cockles in a small estuary or the population of cod in the North Sea. To assess whether current management measures are adequate, some measure of the status of the stocks is required.

Stock indicators. Traditionally four stock indicators are evaluated to determine stock status:

1. Spawning stock biomass (essentially stock size) – the weight of mature fish/shellfish in the population.
2. Fishing mortality – i.e. the rate of fishing or exploitation rate. What proportion of the stock are caught each year.
3. Recruitment – how many young fish or shellfish are coming into the fishery each year?
4. Landings – total tonnes of fish landed each year. (If the weight of discarded fish or shellfish is also known, then this is a bonus.)

Pre-defined reference points and Maximum Sustainable Yield (MSY). Reference points are target levels to aim for, or threshold levels to avoid. Within the international community, the agreement is that all fish stocks should be managed at Maximum Sustainable Yield (MSY). Within Northern Europe, fisheries stock assessment is coordinated by the International Council for the Exploration of the Sea (ICES), and stocks are managed by the European Commission based on ICES advice, which uses a MSY framework. MSY is the highest possible yield (catch) that can be maintained indefinitely (assuming environmental conditions remain constant). This occurs at an intermediate level of fishing mortality (exploitation rate). High fishing rates produce high catches in the short term, but not in the long term.

MSY or the stock size at MSY (Bmsy) and the fishing mortality at MSY (Fmsy) are calculated by using information on growth rate, mortality rate and the relationship between stock size and future recruitment. In practice, it is often very difficult to calculate MSY because the relationship between stock size and recruitment is unknown. In that case, alternative measures to Bmsy and Fmsy are used. The participants were shown some examples of stock assessment outputs including trends in stock indicators for mackerel based on Marine Scotland Science assessments, ICES advice in 2011 for West of Scotland haddock and ICES advice in 2013 for North Sea and Skagerrak shrimp.

Estimates of key stock indicators or their proxies. Ideally stock assessment would be based on direct observation of key stock indicators. However in the sea that is not always possible. On land when undertaking forestry management, for example, it is relatively straightforward to count the total number of trees, count the number of new young trees, record the number of trees removed and hence calculate the harvest rate. In the sea this is usually not possible. For inter-tidal mollusc stocks, it is possible to make a direct count of the population and manage the harvest accordingly. For many stocks however, stock biomass must be estimated from fishery-independent stock surveys, or inferred from catch-at-age or catch-at-size data using mathematical models. However for many species such as lobsters and crabs, no estimate of stock size is available, and so an index of stock size (relative abundance) such as catch per unit effort (e.g. catch of crabs per 100 creels hauled) is used. Similarly if no estimate of stock biomass is available, then the fishing mortality rate or exploitation rate will have to be estimated from the size or age distribution of the stock.

Example outputs from stock assessments. Participants were shown two examples of stock assessment outputs – one for which the stock assessment is based on evaluating trends in a series of stock indicators (Newfoundland snow crab trap fishery) and one for which a Bayesian stock production model was used to estimate stock status against pre-defined reference points (Barents Sea shrimp trawl fishery). Participants were invited to interpret these stock assessments and to consider how uncertainty was taken into account in the two assessments. For the snow crab fishery, assessment of stock status was based on multiple stock indicators rather than a single indicator reflecting inherent uncertainty in all the stock indicators, whereas for the shrimp fishery uncertainty is tackled in a statistical way providing probabilities of the stock being below its target reference point or fishing mortality being above its target reference point for a range of catch options.

Why do we need complex computer models to answer relatively simple questions? An example was provided of how mathematical models may be necessary to answer apparently simple questions. For example, how do we evaluate the benefits of increasing the minimum landing size of lobster to 90 mm carapace length? Common sense tells us that if we return an 88 mm lobster to the sea, by next year it will have moulted and will weigh much more, and we know that larger females may also produce more eggs. However to fully quantify the benefits, we need to know the probability of moulting, the moult increment, the annual mortality rate, the probability of capture next year (fishing rate), any variations in this information for males and females and the maturity and fecundity of female lobsters in relation to size. The calculation of the likely benefit is therefore quite complicated and computer models allow us to make many such calculations very quickly. Furthermore the models will allow a comparison between the benefits of different management measures. More generally these models allow you to manage the fishery to avoid growth overfishing (catching fish/shellfish at too small a size) and recruitment overfishing (catching too many fish/shellfish so that recruitment to the next generation is threatened).

Data used in stock assessments and their sources. To undertake stock assessments, ideally we need the following data:

Landings and fishing effort (e.g. no. of creels hauled) data – collected through landings declarations, quayside monitoring, log books

Stock size – collected by direct counts, or proxies e.g. catch or landings per unit effort from commercial fisheries, research vessel surveys

Recruitment – collected by research surveys, age/size/sex compositions and nos. berried from quayside monitoring, discard monitoring by observers or self-sampling

Exploitation rate/ Fishing mortality – collected through age/size/sex compositions by observers or quayside monitoring or self-sampling

Biological data (e.g. growth, maturity/fecundity) – collected through biological samples, tagging returns etc.

In addition, stock assessment is improved if we also have information on fishing position / area fished from log books, VMS or AIS data, information on movements from tagging studies which is important for stock definition, and for creel fisheries we need to know soak time and bait type. We also need to record weather patterns such as water temperature, wind, swell etc., as all these environmental factors may influence catch rates.

Much of this information is not available for the Scottish inshore fisheries. For example, for the creel fisheries, the recording of fishing effort information on the FISH 1 form is not mandatory, size distribution data are patchy, there is little data on discarding of sub-legal or other non-commercial animals and there is only old growth and growth parameter data which needs updating. Hence the need for this project.

Self-sampling. As can be seen from the above list of data requirements, collection of data can be time-consuming and expensive, so there are great benefits if data can be collected by the vessel's crew or automatically using Electronic Monitoring (EM) equipment. The benefits of self-sampling are that a reasonable amount of accurate, unbiased and representative data could be collected, that there is the possibility of remote downloading of data, and that innovative technology may allow a wide range of data to be collected and then analysed later, all without the need for a high-cost observer programme. The disadvantages of self-sampling are there is no dedicated observer to take measurements and fishing will always be the priority for vessel crew, trained scientists are not being used so there may be problems with, for example, identification of bycatch species or sampling bias, and the initial enthusiasm of vessels and individuals to participate in a self-sampling scheme may disappear resulting in incomplete or biased data being collected. EM technology has been used successfully in beam trawl, otter trawl and under 10m vessel fisheries in the UK, and also longline fisheries in Hawaii and the Gulf of Mexico, in inshore trawl fisheries in New Zealand and in billfish and tuna fisheries in Australia.

Scottish stock assessments. A summary of the most recently available stock assessments for the creel fisheries for lobster, brown crab and velvet crab, the Nephrops (prawn) fishery and the scallop dredge fisheries were presented. The participants were invited to provide their views on the perceived status of these stocks.

Progress on project to date. In addition to the introduction on stock assessment and how fishermen might participate in the interpretations of stock assessments, the participants were appraised of progress to date on the project. The inception of the project, how the target vessels, fisheries and geographical areas were chosen, and the selection process for the participating vessels were described. A full list of participants and their geographical locations was provided. The components of the equipment, how they all work together and the installation process were described. Most importantly, participants were shown examples of the first sets of data to come out of the project; this generated much discussion amongst the participants and did more than anything to facilitate engagement of the participants in the project.

2.4 Self-sampling methodology

One of the main aims of this project was to enable fisherman to self-sample their catches to gather information that could potentially be used by stock assessment scientists, to help address the issue of data deficient stocks. Therefore we first needed to identify the stocks that were considered data deficient and then identify the type of data that needed to be collected to help Marine Scotland scientists with their assessment processes.

As stated earlier these stocks were identified as brown crab, velvet crab, lobster and scallops. Identifying the species allowed the correct main gear types to be targeted i.e. creel fisheries and scallop dredge fisheries. Once these were identified the issues of which data needed to be collected by the fishermen could be addressed. This was done through discussions with Marine Scotland. In addition to these fisheries creel caught Nephrops and a Nephrops trawl were included in this study as additional areas of interest, even though Nephrops is not a data deficient stock in this area.

The collection of the following data types were identified as necessary to help improve stock assessment data and were potentially able to be self-sampled:-

- Retained quantities
- Discarded quantities
- A calculated discard rate
- Sex ratios
- Fishing effort data
- Length data

How these data types were collected depended on the gear type, vessel layout, on-board catch handling procedures and time it would take to collect the information. To decide exactly what information was collected it was necessary to consider whether it was reasonable to ask the fishermen to spend time collecting certain types of information as well as carry out their normal fishing activities. We needed to consider how the data would be collected to ensure the data were useable in stock assessments and we needed to consider the design of the self-reporting forms, to allow the necessary data to be recorded simply and easily across all vessels.

It was also necessary to consider the long term collection of data. It was not enough to just ask fishers to collect data that would satisfy this short term project but also to consider what fishermen could be realistically asked to collect on a long term and widespread basis. It was essential that self-sampling of the catch did not place an unrealistic burden on the fishermen. Fishermen routinely record information on catches and effort for their own records so it was more a question of formalising this process, recording the data and filling in the gaps where fishermen don't normally gather information e.g. discard rates and sex ratios. Also because this was a project about self-sampling, it was important not to be too prescriptive about which methods of sampling should be used. All vessels handle catches and operate the fishing gear in different ways and it is therefore important that the sampling methods used are developed by the crew to best fit their own personal operating circumstances.

Retained Quantities – In stock assessments the numbers and weights of retained catch are necessary. Currently the fishermen report a weekly total weight landed using the FISH1 form (Figure 1.5). It was therefore originally thought that the fishermen could collect the numbers of retained fish/shellfish per pot on at least one string per day. However this was not practicable because of the large quantities caught, the large number of pots fished (often in excess of 500 per day) and the speed at which pots are processed. Therefore the fisherman were asked to report daily total weights retained by species and where possible provide a count for a subsample of a specified weight, and number of pots or strings hauled. At the same time they could sex this retained catch to allow a sex ratio for retained catch to be calculated. This would allow a number by sex per kg retained to be calculated which when raised by the total weight for the day, would allow trip totals to be calculated.

Discarded quantities – When finfish are discarded they are often, damaged, dead or dying and therefore can become an additional mortality on the stock. When undersize shellfish are discarded it is thought the majority of these can survive and therefore if the returned shellfish can be quantified it can give an indication of recruitment and health of the stock. If the shellfish were discarded because they were damaged, soft, or diseased then survival rates may be less and the data would be a mortality rather than a recruitment value. The fishermen were asked to provide daily estimates of the quantities discarded (in weights or numbers or both) of the data deficient stocks. Alternatively if time was restricted, then the fishermen could provide an estimate based on a percentage, although numbers or weights were preferred.

Discard rate – Having weights or numbers of both retained and discarded for each species by trip, allowed a discard rate per trip to be calculated. Where only a percentage estimate was provided by the vessel, then this had to be used.

Sex ratios – The numbers retained by sex could be gathered by the fisherman during the nicking, banding or “keep-potting” process or by taking a subsample of a known quantity and counting the numbers of male, female and berried in the sample. Fishermen were also asked to provide a sex ratio for the discarded catch by quantity or estimated percentage.

Fishing effort – this information is extremely important in stock assessments but currently for creeling vessels it is not required to report it. The only information that is available is days at sea and total number of vessels. It was therefore decided that vessels should report the number of strings and pots being fished as well as a soak time for the strings lifted on that day. Towed gears would report the number of tows fished and the tow duration. The recording of daily fishing effort would allow catch per effort data to be calculated.

Length data – it was decided that it was not feasible to ask fishermen to undertake self-sampling of lengths of shellfish caught. This would have required considerable time and effort because fishermen would have had to take a reasonably sized unbiased subsample, use callipers to measure the individuals and then record all of the information on to a log sheet. In turn these paper records would need to be entered on to databases at a later stage. Length data would therefore be gathered during the training and control data gathering observer trips. In addition one of the sub-projects would investigate the use of some new technology, Bluetooth enabled callipers, and how these could be used to help facilitate fishermen collecting their own length data in an efficient way in the future.

2.5 Data Logsheets and Database Design

Skipper's Logsheets

To ensure that all of the above data could be collected in a comparable way, suitable logsheets and data storage needed to be designed and developed. Having three different gear types needed to be accommodated as did five different target species. The at-sea logsheets needed to be able to capture discarded and retained quantities, sex data, and effort data. Examples of the logsheets for each gear are shown in Annex 1.

The two towed gears, Nephrops trawl and scallop dredge, could be treated in a similar way and the two logsheets were very similar (Annex 1: Figures A1 and A2, respectively), although the scallop dredge logsheet has a reverse side that allowed the skipper to record a count and weight of scallops from a subsample taken per tow (Annex 1: Figure A3). The creeling vessels were different and the initial design tried to take into account the Fish1 form design (Figure 1.5) and data requirements. Initially it was also thought that the data could possibly be collected and recorded on a string by string basis but this was unrealistic due to the constant workload faced by the fishermen at sea and even between strings e.g. nicking crab claws and packing retained catch into keep pots. Therefore the final sheet design (Annex 1: Figure A4) was on a trip basis because of the amount of additional data that was now to be recorded.

Video Analyst Recording Sheet

Two different types of recording sheet were designed for the video review process, one for vessels using creels and one for vessels that were trawling (Annex 1: Figures A5 and A6, respectively). It was necessary to design these sheets to ensure that video analysts all collected the same data parameters when reviewing the video, to ensure that data from different vessels could be compared. The creel data recording sheet was designed at a pot by pot level to allow quality assurance to be carried out in the results. Observers at sea could collect data at that level by counting the number of crabs caught in a pot and these values could then be compared to the video analyst's values. It also allowed the results between two different video analysts to be compared and any differences to be easily identified and reviewed again.

Database Design

To store the data collected during this project a Microsoft Access database was constructed. This had to allow the data from the different sources (skipper, video review, and observer sea trip information) to be stored, analysed and compared against each other. In addition it had to be able to link to the Annotations Database produced by the AMR EMI Pro software because this database contained all the information regarding position and fishing effort automatically recorded by the GPS and EM sensors. Although this work stream required a considerable amount of effort and time invested by the project team, it is essential in allowing the self-sampled data and the reviewed video data, to be properly analysed and integrated with the automatically produced GPS and sensor data.

Training of Participants

To ensure that the participating fishermen were fully aware of why this research project was being carried out and how their contribution would be collected and used, an initial training day was set up (see section 2.3). Training of participants occurred on a continuous basis during installation of the EM equipment and during regular communications with participating skippers. It was reiterated that this was a pilot trial and that although the data collected would be evaluated for its potential use in stock assessments, the data would not be used in any real stock assessments at this stage.

How the data were to be collected was also discussed with all participants but no single sampling strategy was insisted upon. For this project to succeed in producing useable data on a long term basis without undue burden on the fishermen, it was felt that the fishermen needed to develop sampling procedures that they felt could be sustained over the long term. Every vessel is different and at the beginning of this project it was felt inappropriate to be dictating sampling strategies without having experienced the at-sea procedures and sampling opportunities of each vessel. Instead the concepts of random and representative sampling were presented and a list of the type of data that they needed to collect.

In addition to the shore based training, at-sea observers would also accompany the participants on two sea trips during the project to observe their catch handling practises, highlight potential sampling opportunities, and collect length data and control data for comparing against video review data.

2.6 At-Sea Observer Trips

The focus of this project is to determine whether it is feasible for fishermen to collect self-sampled fisheries data that can help improve the stock assessments on data deficient stocks. In addition the project is also testing the efficacy of EM to verify this self-reporting, provide additional effort data through sensors and act as an alternative source for gathering catch data for stock assessment purposes. To determine whether this can be done an element of “ground-truthing” is required. Therefore the project would conduct at-sea observer trips to collect “control” data. In addition, the observer trips would also be carried out to provide hands-on self-sampling training and to test the innovations described in the sub-projects.

A total of 42 observer seadays were scheduled to take place during this project; 2 days on each of the 11 participating vessels for training and control data purposes (22 days) spread throughout the project; and 5 days each on the 4 subproject vessels (20 days) scheduled for June/July 2015.

Whilst at sea on the control data/training trips, the observer would observe the crew's catch handling processes and their subsampling techniques. If there were some immediate improvements to the protocol for sampling the catches that could be suggested, then the observer was to demonstrate these to the crew. In addition the observer was to gather their own catch estimates, so that these could be compared against the estimates made by the video reviewer and the estimates made by the crew. On some trips length samples would also be collected so that they could be used in any stock assessment exercises.

2.7 Archipelago Marine Research (AMR) EM Systems

Two versions of the AMR EM systems were purchased, the v4.5 and the v5.0 (Figures 1.3 and 1.4, respectively). Both versions had the same sensors and hardware available for attachment. These were:

- A GPS receiver – to provide position and speed data
- A hydraulic pressure sensor – to determine when the hydraulic system was being used, thus indicating when the winches or haulers were being operated.
- A winch rotation sensor – these were only installed on the towed gear vessels. No secure and safe fixing point was available on the creel vessels' line haulers.
- A video display screen – to allow the skipper to view the camera imagery and complete system function tests.
- A keyboard – to allow the skipper to interact with the system to enable function tests to be carried out and record any comments.
- A POE switch – to relay the collected data back to the control box and to power the digital CCTV cameras.
- CCTV cameras – digital cameras for recording fishermen's activities. The number of cameras installed on a vessel ranged between 2 and 4 depending on size and set up of the vessel, available superstructure for attachment and catch handling processes used by the crew.
- The control box – this was either a v4.5 or v5 and it contained all software associated with the system and also a removable hard drive that was used to store the data and allow it to be easily transferred to Seascope analysts.

Collecting the data with these sensors allowed the exact number and timing of every sea trip that the vessel undertook to be recorded. The exact location of every string or tow that was shot or hauled could also be recorded, and on towed gears we could get an exact towing duration. Obtaining soak time on creel strings was more problematic because the gear deployment position may be very close to other strings making it difficult to identify exactly which string was being hauled, or the gear may have drifted with tides and poor weather, or the shooting of the gear may have happened when a different hard drive was in the control box making it extremely time consuming to identify the string. This issue was anticipated in the project proposal and a sub project to help obtain exact soak time in a more automated way was undertaken (see RFID Tag Sub-project section).

The hard drives used to store the data were Western Digital 1TB SATA removable hard drives. One hard drive was inserted into the control box during the system installation process and a further 2 hard drives were provided to the skipper as spares. When a hard drive was nearly full of data (usually after 3-4 weeks) the skipper would swap the full hard drive for an empty hard drive and the full hard drive would be posted to Seascope using recorded delivery, or collected in person by Seascope staff. As a hard drive arrived with Seascope, a replacement would be mailed back to the skipper. Each hard drive received would be backed up on to a stand-alone server before any analysis took place. This ensured that there were always two copies of the original data set in case one set of data should become corrupted or lost somehow.

All hard drives would have their sensor data fully annotated to identify all trips and strings (tows) fished, as well as trips which were not actual fishing trips e.g. angling trips, shooting of gear only, hauling of keep pots on market day. This was done either manually by looking at the sensor data or automatically using an expression that allowed speed and pressure parameters to indicate where strings had been shot or hauled, but with manual checking afterwards to ensure accurate identification. In addition the video for each string would be opened to identify the type of creel being used on that string and which species was being targeted. This was necessary for raising any catches as it would be inaccurate to use the fishing effort associated with targeting lobsters to raise up velvet crab data. The lobster trap may of course have a small bycatch of velvets but care must be taken in the evaluation of catch-effort information for a species which is not being targeted.

The cost of an EM system can be in the region of £6000. However when planning an EM project there are additional costs that also need to be considered. These include;

- Installation of EM equipment (2-4 man days/vessel)
- Maintenance and troubleshooting of equipment (2 days/vessel/year)
- Management and transport of hard drives (approx. 1-2 man days per vessel per year)
- Video review and sensor data analysis (at 10% of fishing effort review rate, estimated at 1.5 days for every day fished in creel fisheries).
- Travel and subsistence (a vessel may need to be visited for 4-8 man days per year, including installation)

If systems are to be swapped between vessels there will also be additional de-install and re-install costs, as well as additional consumable costs e.g. cabling, cable ties, tools etc. All of the above costs were taken into consideration when planning this project.

2.8 Video Review

To undertake the video review, 10% of all valid trips fished would be analysed. The trips to be reviewed would be selected using a random number sequence generator found on

Random.org (https://www.random.org/sequences/). During the review process the analyst would collect the following information for the data deficient stocks.

- Numbers and estimated or calculated weight of discards
- Numbers and estimated or calculated weight of retained
- A sex ratio for the discarded brown and velvet crabs
- A sex ratio for the retained brown and velvet crabs
- A sex ratio for lobsters (if possible)
- Any incidental catches of unusual or protected species
- Count of bycatch finfish and their fate (retained or discarded)
- Count of strings and pots hauled
- Time taken by the analyst to review the video
- Anything else of interest

These data would be compared against skipper and observer data

All estimates for our stocks of interest would be entered into the Seascope designed database. Any points of interest, catches of rare/protected species and catches of finfish would be entered on to the AMR EMI Pro software to allow the incident to be linked to exact time and location of capture on the annotations database.

The counts obtained during the review process could be converted to weight using the conversion factors shown in Table 2.5. This was thought to be a more consistent way to estimate weight than using by eye estimates based on basket, box or keep pot volume. From previous experience with EM, Seascope were aware of the difficulties of obtaining weight estimates and therefore a sub-project using portable motion-compensating scales was included in the proposal (see section on Sub-projects). The Length Weight relationships used were obtained from Dobby *et al*.(2012) and Mesquita *et al*. (2011). It is acknowledged that this is not the “true” weight caught because with shellfish, discards often occur above the minimum landing size and of course discarded individuals can be a lot smaller than the reference length used. However it was felt that this would at least attempt to keep any errors made consistent between video analysts.

Table 2.5 Lengths used to calculate weight estimates from counts of retained and discarded shellfish species.

Species	Minimum Landing Size (mm)	Discard Reference Length (mm)	Retained Reference Length (mm)	Average Discard Weight (kg)	Average Retained Weight (kg)
Lobster	87	80	90	0.31	0.465
Brown Crab	140	130	160	0.35	0.65
Velvet Crab	65	60	70	0.07	0.11
Scallop	100	90	110	0.14	0.235

2.9 Quality Control

Although the staff at Seascope are amongst the most experienced in Europe in undertaking electronic monitoring trials and analysing the collected video, it is important that an element of quality control is undertaken to ensure that best practises are being followed. To allow this, Seascope sent 10% of all trips where the video was analysed to AMR, so that comparisons between Seascope's and AMR's estimates could be made. It was anticipated that high levels of agreement would indicate that the initial analysis had been carried out to a satisfactory standard. However it should also be remembered that this project is one of the first to trial using EM on shellfish creeling vessels so that finding someone suitably qualified and more experienced than Seascope, to undertake quality assurance video review was difficult.

2.10 Data Comparisons

Undertaking the video review would allow comparisons to be made between the skipper's self-sampled estimates and the video analyst's estimates. On reviewed trips where an at-sea observer was also on board, further comparisons can be made between the observer's "control" data and the skipper's and video analyst's estimates to determine the more accurate method of data collection. The following comparisons were made and in addition, where the observer was also aboard then these data would also be compared:-

- Trips – number of fishing trips declared by skipper during project period: number detected by EM sensors.
- Strings/Tows – number per trip declared by skipper: number per trip detected by EM sensors.
- Tow Duration – Towed gears only. Total time towing per trip declared by skipper: total time towing detected by EM sensors and video review analyst.
- Number of pots – Total number of pots per trip hauled on an analysed trip, declared by skipper: counted by video review analyst.
- Quantity target species retained – weight or count of retained main target species declared by skipper: weight or count of retained main target species estimated through video review.
- Quantity target species discarded – weight or count of discarded main target species declared by skipper: weight or count of discarded main target species estimated through video review.
- Sex ratio – quantity (or ratio) of different sexes retained/discarded and declared by the skipper: quantity (or ratio) of different sexes retained/discarded estimated by the video review analyst.

2.11 Participant feedback and final dissemination of results

Following the completion of the project and analysis of the results, a second training session for the participants was held at Inverness on 8th October 2015. The training session provided feedback to participants on the results of the various elements of the projects, and provided an opportunity for participants to feedback their views of the success of the project and to make the project partners aware of any problems that occurred during the project. The training session also summarised how the data collected during the project could be used in stock assessments if the methods trialled in this pilot project were implemented on a continuing basis for these fisheries.

3. Results

3.1 Activity and Effort

The majority of the vessels were fully installed with EM by the end of November 2014 and began collecting EM sensor data, video footage and self-reporting catch and effort data from this installation date. Two vessels had VHF/FM radio interference issues after initial installation in November 2014 and this delayed their full start on the project until January 2015, due to the potential safety implications. All EM systems and data collection ceased on 31st May 2015, except for those vessels involved in the sub-projects or who voluntarily continued to collect more data. Vessels have been anonymised for the remainder of the report, where possible, but with only two towed vessels participating, using different gears and targeting different target species, it is difficult to give complete anonymity. This was necessary because some of the data generated by the project could be considered commercially sensitive.

Table 3.1 shows the number of Valid and Invalid trips that were undertaken by each participant during the sampling period. A Valid trip was any normal fishing trip where a sufficient amount of self-reported data was collected to allow comparisons between those data and the video analysts, and where the EM system was fully operational during fishing operations. An extra category of trip called “Additional” is also shown and these were the trips undertaken after 31st May 2015. These have remained in the dataset as they could be analysed in future if required. However to allow a complete dataset for comparison between vessels 31st May 2015 was set as the cut-off date.

In total the participating vessels undertook 750 sea trips of which 568 were considered Valid and useable for this project. The total number of trips (750 trips) includes any occurrence of the vessel leaving port. So those trips where the vessel was only shooting gear or hauling keep pots on landing day, are also included in this total number (but are considered as invalid as they are not normal fishing trips). Being able to account for all trips irrespective of purpose is important from a compliance point of view as it allows all vessel movements to be accounted for, as well as allowing days fishing to be quantified. All data comparisons in this section will only be conducted on the 568 valid trips, unless otherwise stated.

Table 3.1 Total number of trips undertaken by each participating vessel and classed as Valid, Invalid or Additional (post-31st May 2015).

Vessel Name	Valid	Invalid	Additional	Total
CREEL 4	52	6	0	58
CREEL 1	58	37	3	98
CREEL 5	42	17	0	59
CREEL 2	49	15	0	64
CREEL 6	77	12	0	89
CREEL 3	61	33	2	96
CREEL 7	75	3	0	78
TOWED 1	39	6	0	45
CREEL 9	17	8	0	25
TOWED 2	82	9	0	91
CREEL 8	16	26	5	47
Total	568	172	10	750

Trips were classed as Invalid for several reasons. Table 3.2 shows these aggregated into general classifications for each vessel. Each general heading contains several different reasons why trips were not considered for video review. For example, within the category “non-fishing trip” there are trips where the vessel left port to haul keep pots on landing day, or recover damaged and lost pots, to take out divers, moving gear around the port, tried to get to sea but the weather was too rough, or the vessel was only shooting gear on that day. These “non-fishing trips” should not be used when assessing the effectiveness of the EM system or the self-reporting practises of fishermen. They are shown purely to illustrate that the vessels often sail for reasons other than to commercially fish, and it is important that these activities can be identified when considering effort control regimes or enforcement monitoring solutions.

“Insufficient paperwork” was used to identify any trip where there was not enough information on catch and effort supplied by the fishermen, to allow comparisons between data self-reported and data gathered during video review

“No paperwork” was used for trips where there was a complete absence of a self-reporting logsheet.

Included within the “EM system related” category is any trip where no video was recorded or where video was missing at critical times, e.g. during the catch processing stages. However this also includes trips where the crew failed to keep cameras clean enough to view the catch, or where power failures aboard the vessel corrupted video files irretrievably. In other words this is not necessarily a complete malfunction of the system but could be a single component (e.g. a crucial camera failure) or an issue related to the vessel (e.g. power failure).

One vessel also conducted trips targeting whelks and these trips were excluded from analysis.

Table 3.2 Number of trips by each vessel that were not analysed and the main reason why.

VESSEL NAME	EM SYSTEM RELATED	INSUFFICIENT PAPERWORK	NO PAPERWORK	NON-FISHING TRIP	WHELK POT TRIP	TOTAL
CREEL 4		1	5			6
CREEL 1	4	3	18	12		37
CREEL 5		1	2	8	6	17
CREEL 2		5	4	6		15
CREEL 6		10	1	1		12
CREEL 3	12		21			33
CREEL 7			3			3
TOWED 1	1	1	4			6
CREEL 9	4			4		8
TOWED 2		2	7			9
CREEL 8	9		17			26
TOTAL	30	23	82	31	6	172

Of the 172 trips where no analysis was possible, 135 trips were fishing trips that should have been analysed if the issue (paperwork or EM system related) had not arisen. This means that the total number of fishing trips undertaken by the participating vessels was 568 valid trips plus 135 invalid trips, a total of 703 trips.

Therefore, 19% of the fishing trips were unusable, of which 30 of these (4% overall) were related to the EM system performance and 105 (15% overall) were due to the self-sampling undertaken by the crew being incomplete or missing.

3.2 Valid Trips Fishing Effort

Each participating vessel was asked to supply data on the number of strings, number of creels and an estimated soak time fished on each fishing trip undertaken. Where the number of creels or soak time (or both) were missing from the self-reported data, the trip was still classed as Valid. But when number of strings and creels was missing, then the trip was classified as “insufficient paperwork supplied” and deemed invalid. The fishing effort self-reported is shown in Table 3.3.

Table 3.3 Total number of trips, string or tows self-reported by the participating vessels.

Vessel	Number of Trips	Number of Strings or Tows	Total Number of Creels	Average Creels per String (or tows/day)
CREEL 4	52	447	24239	54
CREEL 1	58	579 (+16)	22480	39
CREEL 5	42	471	13600	29
CREEL 2	49	579 (+47)	16033	28
CREEL 6	77	888 (+79)	28039	32
CREEL 3	61	1340	33525	25
CREEL 7	75	642	19421	30
TOWED 1	39	84	NA	2.2
CREEL 9	17	46	909	20
TOWED 2	82	687	NA	8
CREEL 8	16	231	19770	86
Total	**559 (+9)[1]**	**5994 (+142)** **5223 (creel only)**	**178711**	**34**

[1] In addition to the values shown in this table are 9 trips, totalling 142 strings, where a count of creels was not provided. These strings are show in () for the relevant vessels.

It can be seen that of the 568 valid and fully reported trips fished, 438 were conducted by creel vessels. They fished a total of 5223 strings and over 180,000 individual creels were deployed. This gives an average of 34 creels per string overall. If this value was used to estimate the number of creels fished on the additional unreported 142 strings (9 trips) then a further 4828 creels were also fished.

Vessel “Towed 1” fished an average of 8 tows per trip over 82 sea trips, the highest number of trips by any of the participating vessels. Towed 2 was sold in March 2015 and therefore left the project, however 39 valid trips were still reported with an average of 2.2 tows per day.

Soak time was less easy to self-report or assess. Strings were often left to soak from as little as 24 hrs, to in excess of 2 months, if poor weather had stopped vessels getting to some of their gear. This meant on some days there was a wide mix of soak times that could have been reported. Assigning these soak times to a specific string was not possible and the number of strings soaking at each of these durations could not be identified. When more than one soak time was reported for a specific day then an average was taken and entered into the database. However this information has not been presented as it cannot be fully attributed or assessed.

3.3 Catches Self-Reported

Self-sampling Practises

Skippers of participating vessels were asked to report the quantities of catch that were retained and discarded on each fishing trip. The main target species was to be reported but in addition fishermen were asked to quantify the other project specific species, where possible. Catch was to be reported in weight (kg) and as a count if possible. Where catches were large, weight estimates only were expected. Table 3.4 shows the number of retained and discarded catch components that were reported.

Table 3.4 Reported catches for retained and discarded components.

Catch Segment	Total Number of Reports	Weight Only	Count Only	Both
Retained	982	845	22	115
Discarded	968	582	195	191
Total	1950	1420	219	304

The retained catch weight was reported on all trips with the exception of 22 records where the skipper had provided a count only. To allow a full dataset of weights to be illustrated these counts were converted into weights using the conversion factors in the Video Review section of the Methodology. Counts were not provided on 845 of the 982 retained catch weights reported. This was expected and was due to the impracticalities of counting large quantities of crabs at sea and during normal working practises. Of the 137 catch records where both weight and number were provided (this includes the calculated weights from the 22 count-only records) for the retained catch, 106 records were lobsters and 31 records were a mixture of brown crab, velvet crab, scallops, Nephrops and crawfish. A further 187 retained catch records were reported for lobster with the majority of catches reported (109 records) being less than 10kg and the maximum weight being 90kg. This would suggest that Lobster may be a species where the retained number and weight could be realistically requested on a long term project.

A total of 968 discard records were reported of which 582 were weight only, 195 were counts only and 191 were both weight and count. Lobster was the species with the highest count-only of 82 reports with the remainder made up of finfish species. Brown crab and velvet crab were reported as counts-only on 6 and 10 occasions respectively. However when the discard data was examined to determine which species were reported for both weight and count, brown crab had the highest number of reports with 83, scallops had 76 reports, while velvet crab had 15 reports, lobster 11 and Nephrops 2 reports. This would suggest that perhaps lobster, scallops and brown crab could all be counted and weighed. However it should be noted that on only 3 occasions out of 352 records, did a count of brown crab occur when there was a weight above 50kg. It is not until the total discard weight for brown crab drops below 20kg that count and weights are recorded regularly (78 times out of 101 instances). In contrast between 20-40kg weights, counts were only made on 5 out of 19 occurrences. This may indicate that a 20kg subsample could be a useable weight in future self-sampling programmes.

Catch Components Self-reported

Table 3.5 shows the weights reported by each vessel for the retained catch over the period for each vessel. It shows that 6 of the creel vessels targeted brown crab, 1 creel vessel targeted predominantly Nephrops (Creel 8), 1 towed gear targeted Nephrops (Towed 1), 1 towed gear vessel targeted scallops (Towed 2), and 1 creel vessel targeted lobster (Creel 5). Vessel Creel 9 was a smaller part-time vessel and reported very low catches across all our main species. All 6 of the creel vessels that reported larger catches of brown crab also reported catches of velvet crab. Vessel Creel 3 had the largest catches of velvet crab at 12,405kg. This was 3 times the size of this vessel's brown crab catch which would indicate that this vessel mainly targets velvet crab (at this time of year), rather than brown crab. For vessel Creel 4, velvet crab catches were considerably lower than for the other vessels and therefore it is likely that velvet crab was a bycatch of the brown crab fishery rather than a seasonally targeted fishery.

Table 3.5 Retained catches (kg) self-reported for the main project specific species.

VESSEL	Brown Crab	Lobster	Nephrops	Scallop	Velvet Crab
CREEL 1	9030	348	-	-	2692
CREEL 2	6543	514	12	-	2873
CREEL 3	3885	331	-	-	12405
CREEL 4	4650	446	3837	-	430
CREEL 5	-	1806	-	-	-
CREEL 6	4672	542	-	-	7783
CREEL 7	21950	1179	-	-	4429
CREEL 8	50	44	2572	-	-
CREEL 9	-	-	18	-	-
TOWED 1	-	-	6423	-	-
TOWED 2	2	-	-	39775	-

The reporting of the discarded catch was less uniform than for the retained catch, in that some vessels opted for weight only, some opted for count only and others reported both (compared to retained where weight was nearly always reported). For example, vessel Creel 5 counted all lobsters discarded rather than providing an estimated weight and also reported all retained lobsters by count and weight. Therefore a discard rate by count could be obtained for this vessel, but not weight, unless a nominal weight was attributed to each discard lobster e.g. 0.31 kg equates to a lobster with an 85mm carapace based on published Length/Weight relationships.

Therefore to obtain total weights discarded to allow comparisons with the retained weight estimates and to estimate discard rates, it is necessary to convert the data where only counts were provided, into weights using the L/W relationships adopted for this project. This is also necessary because vessels were not always consistent between trips in how the discard data were reported. There was a suspicion that discard data were not always self-reported for every trip and this suspicion was supported by observer trips where it was noted that skippers recorded retained catch but not the discarded catch. However this may have been due to confusion over the role of the observer whilst at sea.

In total only 195 reported discard catches out of a total of 968 were provided as counts only, of which 82 were lobsters, 6 were brown crab, 10 were velvet crabs, and 103 were various finfish species. Therefore these brown crab, lobster, and velvet crab counts-only were converted to weights. Table 3.6 shows the weights reported for discards and the converted weights based on counts.

Table 3.6 The weights of discarded catch self-reported by the skippers.

VESSEL	Brown Crab	Lobster	Nephrops	Scallop	Velvet Crab
CREEL 1	7097	23	-	-	716
CREEL 2	12500	148	7	-	439
CREEL 3	15020	239	-	-	9350
CREEL 4	3740	68	5	-	413
CREEL 5	-	3914	-	-	-
CREEL 6	3857	105	40	-	1791
CREEL 7	35020	330	-	-	-
CREEL 8	-	-	266	-	-
CREEL 9	11	-	0.06	-	1
TOWED 1	31	5	13	7	-
TOWED 2	874	-	-	1636	-

*This includes 82 records where lobster counts were converted to weight (Count = 12877, weight = 3992kg), 10 velvet crab records weight (Count = 37, weight = 2.59kg), and 6 brown crab records weight (Count = 26, weight = 9.1kg).

Nearly all creel vessels, except for two, reported large volumes of discarded brown crab; the highest being Creel 7 with over 35 tonnes and the lowest being Creel 9 with 11kg (although catches from Creel 9 were all extremely low). Vessel Creel 5 had the highest levels of discard lobsters with 3914kg, the majority of which are based on converting count only data. This vessel targets lobsters almost exclusively, with a seasonal summer fishery of whelks, so this level of discards is not unexpected. The highest quantity of discarded velvet crab was reported by vessel Creel 3, with 9350kg. Creel 3 also had the second highest brown catch discard weight reported. Vessel Towed 2 (scallop dredge vessel) had 1636kg of discarded scallops and Towed 1 (Nephrops trawler) had 13kg of Nephrops discards reported. Figure 3.1 shows the catches self-reported by each vessel. The percentage discard rates have not been calculated as it was felt that these may be misleading if not all data were reported accurately on each sea trip. This highlights the need to have self-reported data verified and EM technology allows this process to occur.

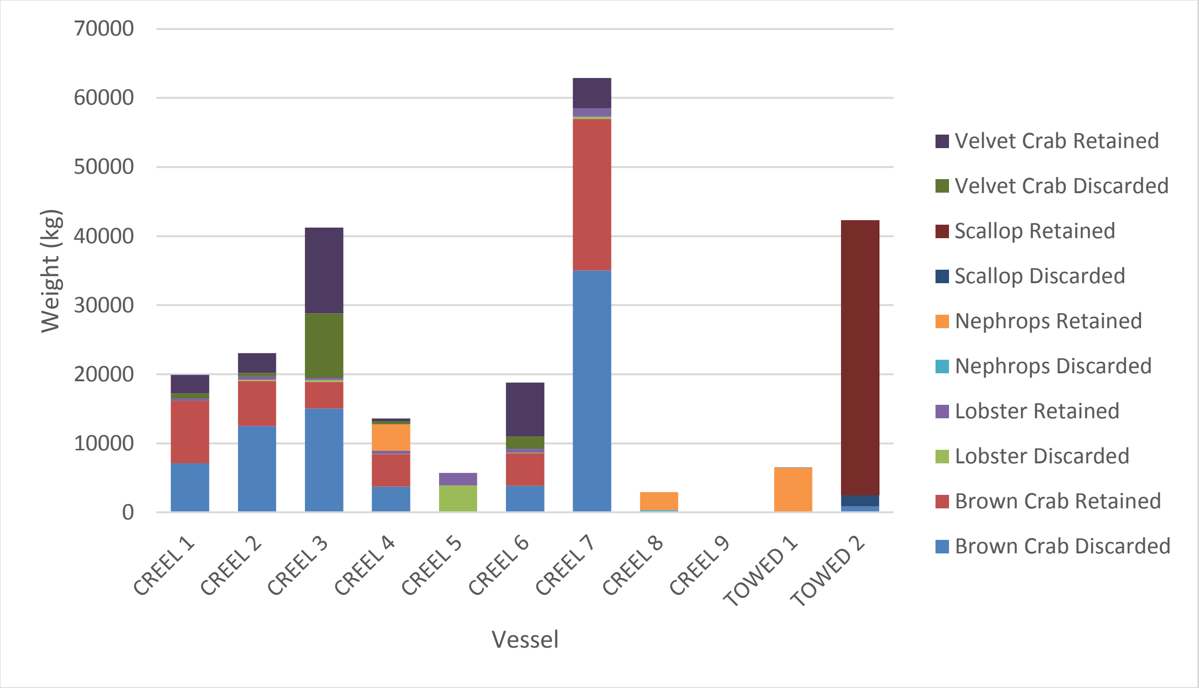


Figure 3.1 Catches self-reported by each participating vessel, for the main target species and data deficient species associated with this project.

3.4 Observer Sampling

A total of 36 sea trips were undertaken by observers. Some of these trips were dedicated to training crews in self-sampling techniques whilst others concentrated on collecting data that could be used as control data for assessing the video analyst's estimates. In addition sea trips were conducted to gather data related to the sub-project aims. Table 3.7 shows the number of observer trips carried out on each participating vessel. The target was to undertake 2 observer trips for training/control data purposes, followed by 5 days on each sub-project vessel.

Table 3.7 Number of observer trips completed during the project.

Vessel	Number of Observer Trips	Target Met	Comment
CREEL 1	7	Y	7 trips (2 + 5 trips) target
CREEL 2	2	Y	2 trips target
CREEL 3	7	Y	7 trips (2 + 5 trips) target
CREEL 4	2	Y	2 trips target
CREEL 5	2	N	7 trips (2 + 5 trips) target. 1 control day and 1 chute day completed. Weather and switch to Whelks reduced opportunities
CREEL 6	7	Y	7 trips (2 + 5 trips) target
CREEL 7	2	Y	2 trips target
CREEL 8	2	Y	2 trips target
CREEL 9	2	Y	2 trips target
TOWED 1	1	N	2 trips target. Vessel left scheme before 2nd trip could be completed
TOWED 2	2	Y	2 trips target
Total	36	86%	42 trips target

Although the target of 42 sea trips was not met, 36 sea trips (86%) were completed during this project. Targets were met for 8 out of the 9 creeling vessels and for one of the two towed gear vessels. There were mitigating circumstances associated with not meeting the targets on the two remaining vessels. The towed gear vessel (Towed 1) left the project before the 2nd sea trip could be undertaken and with little notice given, therefore only one trip could be completed. Attempts to complete the sea trips on Creel 5 at the start of the year were hampered by poor weather conditions, however as this vessel was participating in two subprojects later in the year (the chute trial and DST trial) it was anticipated that sea trips could be completed at this time. Unfortunately the vessel switched to targeting whelks for the majority of the time with only a 2-3 day window during the periods of high spring tides available to sample lobster/crab creels. If these periods coincided with poor weather or other seagoing commitments then the opportunity to go to sea was lost.

Observer Collected Data

The type of data collected by an observer at sea depended on the purpose of the sea trip. If it was primarily to undertake a sub-project then it was essential that the correct data to evaluate the innovation was collected. During training trips the onus was on the observers to provide hands-on guidance and support to the fishermen, so it was acceptable to reduce the observer's own sampling levels to provide suitable advice and to evaluate the best way for a fisherman to self-sample his catch. The control data trips were aimed at collecting data that could evaluate the video analysts' estimates. The observer trips were not dedicated to collecting data that could be used in routine stock assessments or for assessing the skipper's self-reported catches, although of course some data collected were similar to that which would be collected for those purposes.

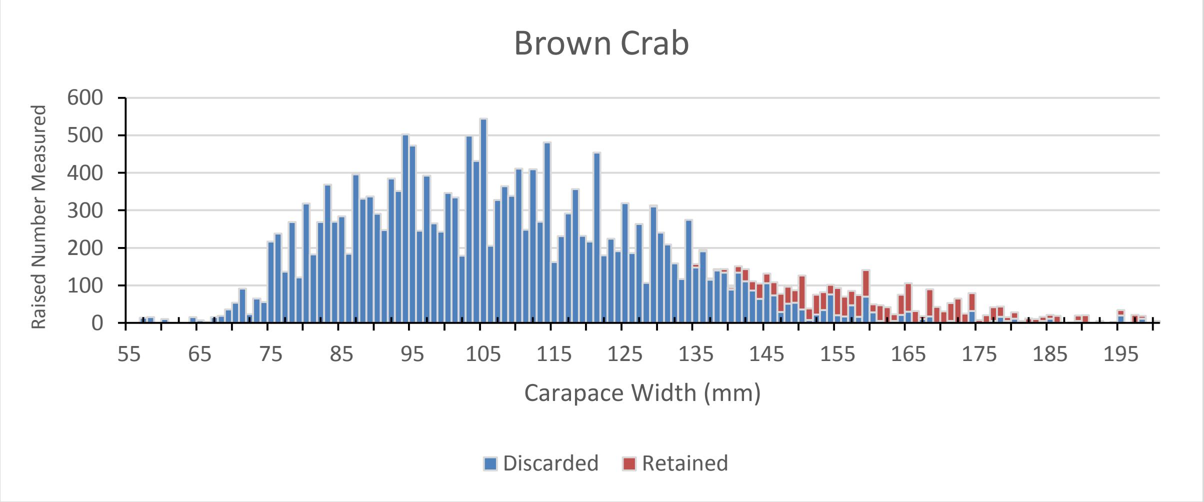
During the observer trips data were collected on weights retained for the main species (by string or trip); counts by creel of retained or discarded species to allow creel by creel comparisons with video analysts; length frequency data on some retained and discarded species; sex ratios; counts of creels and strings fished by the vessel; and incidental bycatches of rare species or finfish (on creel vessels and scallop dredge) (Table 3.8).

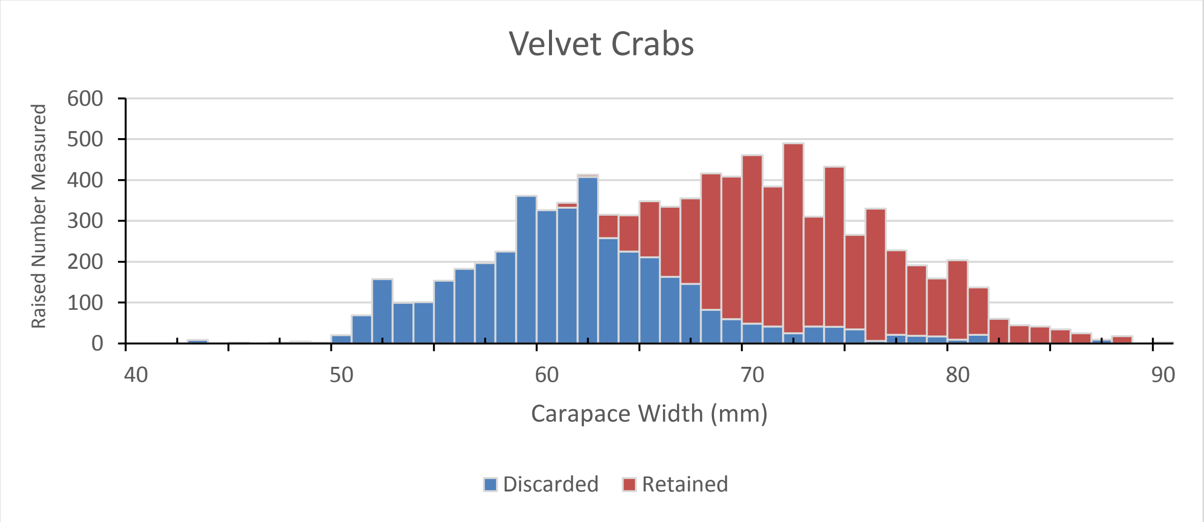
Table 3.8 Information collected by at-sea observers during the course of the project.

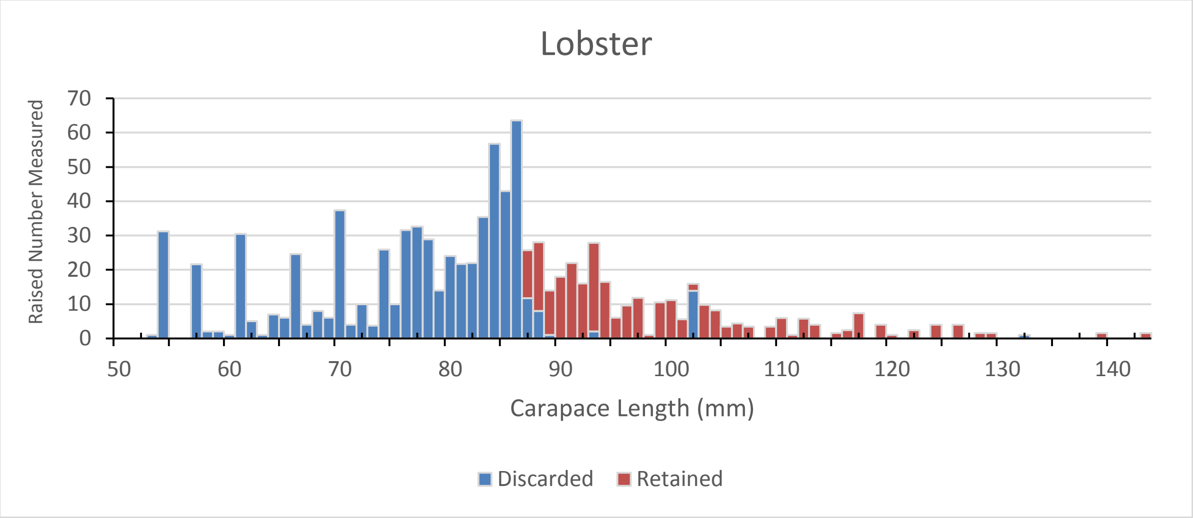
Data Type	Quantity	Trips	Comments
Length Measurements	6405	23	These are the individual measurements taken from subsamples.
Weight Estimates Discarded	153	20	Doesn't include the two chute trial only trips
Weight Estimates Retained	64	20	Doesn't include the two chute trial only trips
Pot by Pot Counts	763	2	Carried out to evaluate the EM video analysts estimates
Additional Length Measurements (Chute Trial Only)	1003	5	2 trips were conducted after the 31st May.
Sex Ratio Data	6504	26 (21 other + 5 chute)	All length data was sexed except for 2 velvet crabs and all 902 scallop measurements.

Length Frequency data

Where possible the observers collected length frequency data. This was usually taken from a subsample of the total catch or from a specified number of creels sampled and fished, but on some trips it was possible to measure all individuals caught for some species. The numbers at length measured were raised to the trip or string level using the calculated raising factors. These were combined with the other trips to give a length frequency distribution for each species (Figure 3.2). Obviously from a biological interest point of view the geographical spread of these data is wide and ideally these length frequency distributions should be shown for each trip to allow any trends in sex distribution to be identified. However it was thought useful to present them as an aggregated west coast stock, for illustrative purposes only. In addition the length data were also sexed and could also be presented in this way to highlight areas where different sexes congregate and to calculate sex ratios.







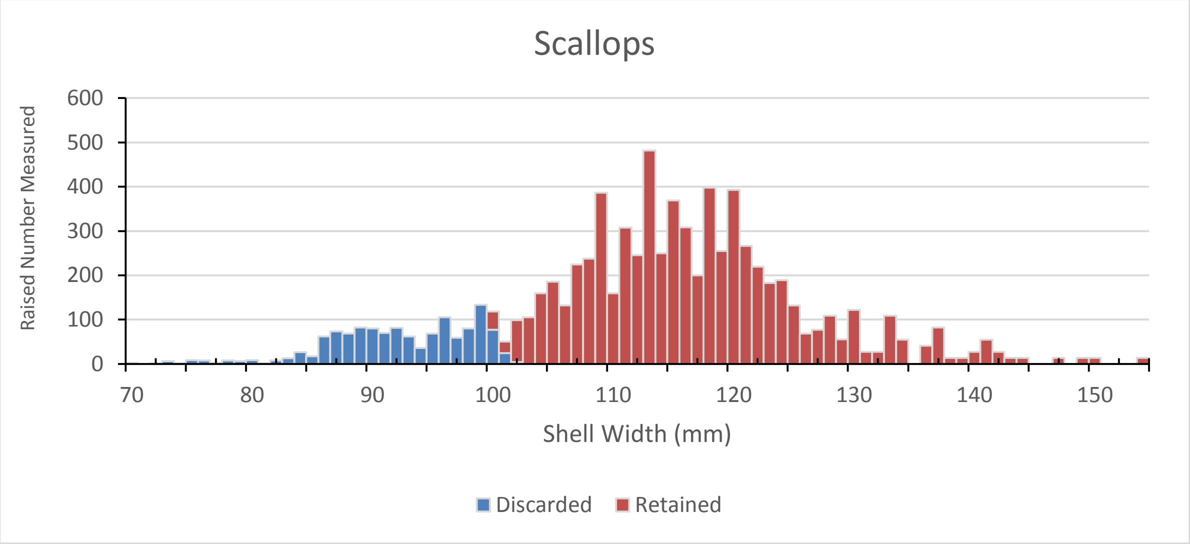


Figure 3.2 Length frequency distributions (stacked column charts) of brown crabs, velvet crabs, lobsters and scallops as estimated from observer sampling.

3.5 Electronic Monitoring

The main aim of this project was to test the use of EM equipment in verifying fisher self-sampled data and in providing its own independent data set. To do this the EM system must provide automatic data that can be compared to the self-reported data and it must record video which a video analyst can review and make their own estimates that can be compared against the skipper's estimates.

If EM was shown to provide the verification tool required, then it would allow large scale self-sampling projects to be established with EM providing the evidence that the data collected are predominantly accurate. Alternatively EM could be used to provide these data instead of the fishers.

As stated earlier a total of 568 valid sea trips were undertaken by the fleet of which 10% were to be reviewed using EM. Table 3.9 shows the number of trips per vessel undertaken and the percentage reviewed using EM. A total of 68 trips were reviewed, approximately 12% of valid fishing trips. A total of 703 fishing trips (valid + invalid trips) were undertaken by the participating vessels, therefore a total of 9.7% of all fishing trips were reviewed.

Table 3.9 Number of valid trips undertaken by each participating vessel, and the percentage of these valid trips that were reviewed using EM

Vessel	Number of Valid Trips	Number of Trips Reviewed	Percentage Reviewed
CREEL 1	58	6	10
CREEL 2	49	5	10
CREEL 3	61	7	11
CREEL 4	52	7	13
CREEL 5	42	6	14
CREEL 6	77	8	10
CREEL 7	75	8	11
CREEL 8	16	2	13
CREEL 9	17	7	41
TOWED 1	39	4	10
TOWED 2	82	8	10
Total	568	68	12

All vessels were sampled to at least 10% of valid trips and one vessel had 41% of valid trips reviewed (Table 3.9). However this was a part time vessel which only shot 2-4 strings of 20 pots per trip and therefore undertaking this additional review took very little extra time and was thought worthwhile in case catches began to increase for this vessel.

Fishing Effort

Each vessel was asked to record their fishing effort on each trip. As previously explained if too much of the fishing effort was not reported then the trip became an invalid trip and would not be considered for review. On receipt of the hard drive from a vessel the video analyst reviews all of the sensor data and uses it to identify each time a vessel leaves port and each time it shoots and hauls. Figure 3.3 shows how an EM sensor file (emi file) is displayed on opening a hard drive and prior to any analysis by the video reviewer. The sensor data and speed are shown in the line graphs with the green line graph representing speed (based on time and location data generated by the GPS) and the red line graph being the hydraulic pressure sensor data. If a winch rotation sensor had been installed this would show as a blue line graph. The GPS data are only shown in a map format below the line graphs. The data provided in the box graph section of this display is information generated by the software to automatically indicate where some user-defined criterion has determined when and where the trips and hauls occur. Figure 3.4 shows these same data after the video analyst has used the GPS and sensor data (and box graph data) to identify the sea trips and fishing activity. These are normally copied from the box graph automatically and then manually checked by the analyst to ensure that no false readings or misidentification of fishing activity have copied across. When the vessel leaves port the speed and location are used to identify the start of the trip. The skipper then sails to the fishing grounds, usually at higher speeds (see green line on the line graph), until he reaches his first string of creels for hauling. During hauling the speed drops considerably and the hydraulic sensor records an increase in pressure. When the last creel on a string has been hauled the vessel sails to his next string and the process and sensor data are repeated. Once all strings have been hauled and re-shot, the vessel returns to port. This process can be seen in Figure 3.5 where the analyst has scrolled in to the data and selected one day only for illustrative purposes.

A similar screen view is shown in Figure 3.6, however this is for a towed gear vessel which was fitted with a winch rotation sensor (blue line on line graph). This sensor detects any winch activity and can therefore be used to identify shoot and haul positions. It can be clearly seen that the vessel undertook 2 tows during its day trip at sea and the GPS allows the position and duration of these tows to be plotted and calculated. The vertical red video position line is shown and when the video viewer is opened it allows the video analyst to know exactly when and where the video was recorded.

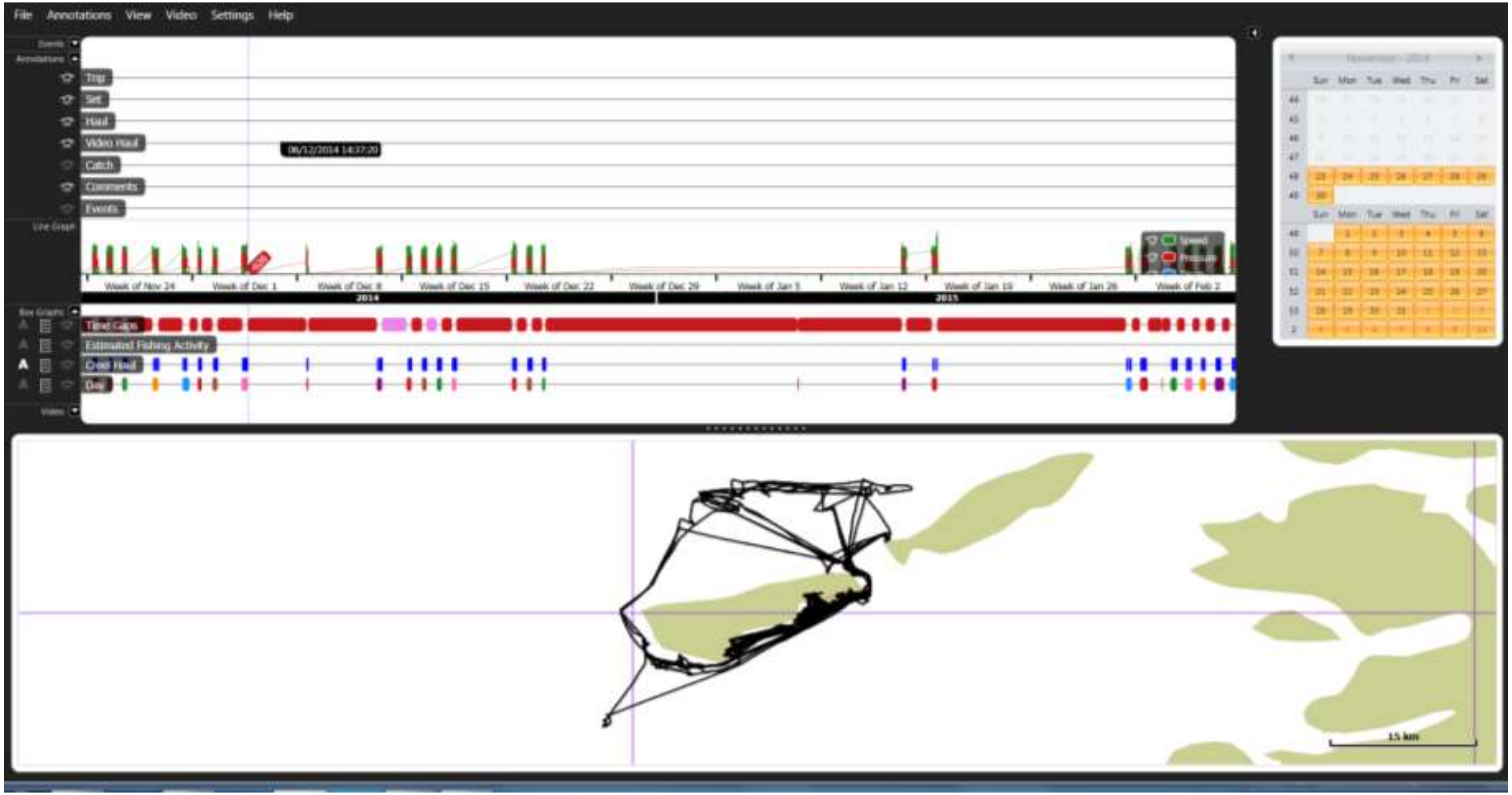


Figure 3.3 An EMI Pro sensor file for a full hard drive, prior to any annotating by the analyst.

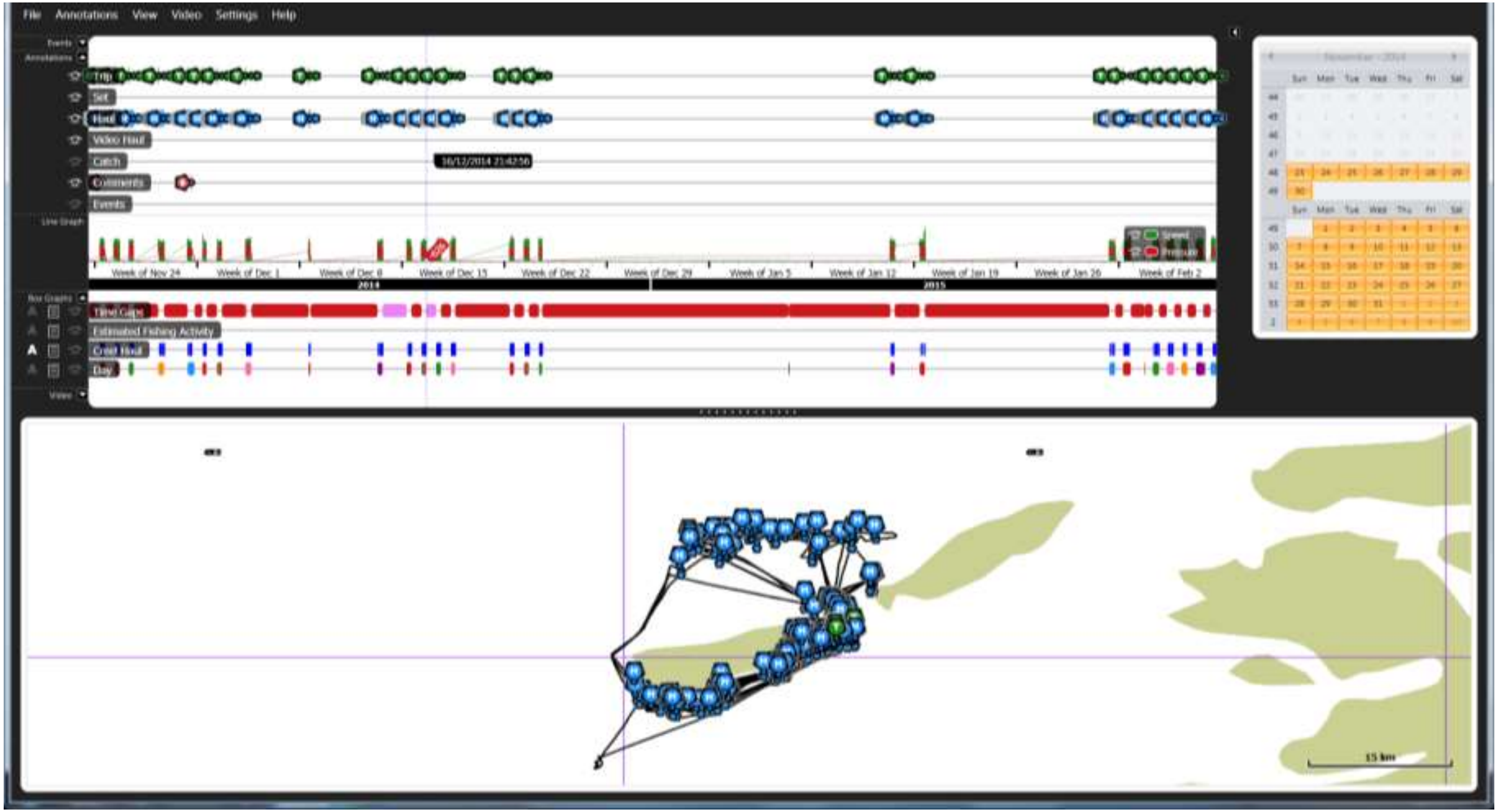


Figure 3.4 The same annotation file after the analyst has used the software to identify the trips (green) and strings (blue) fished. The positions of each string also appear on the map below the sensor line graph data.

Figure 3.5 A completed annotation file for the same data set but with only 1 trip selected for display. Note the speed and hydraulic pressure readings on the line graph which are used to identify string hauling position.

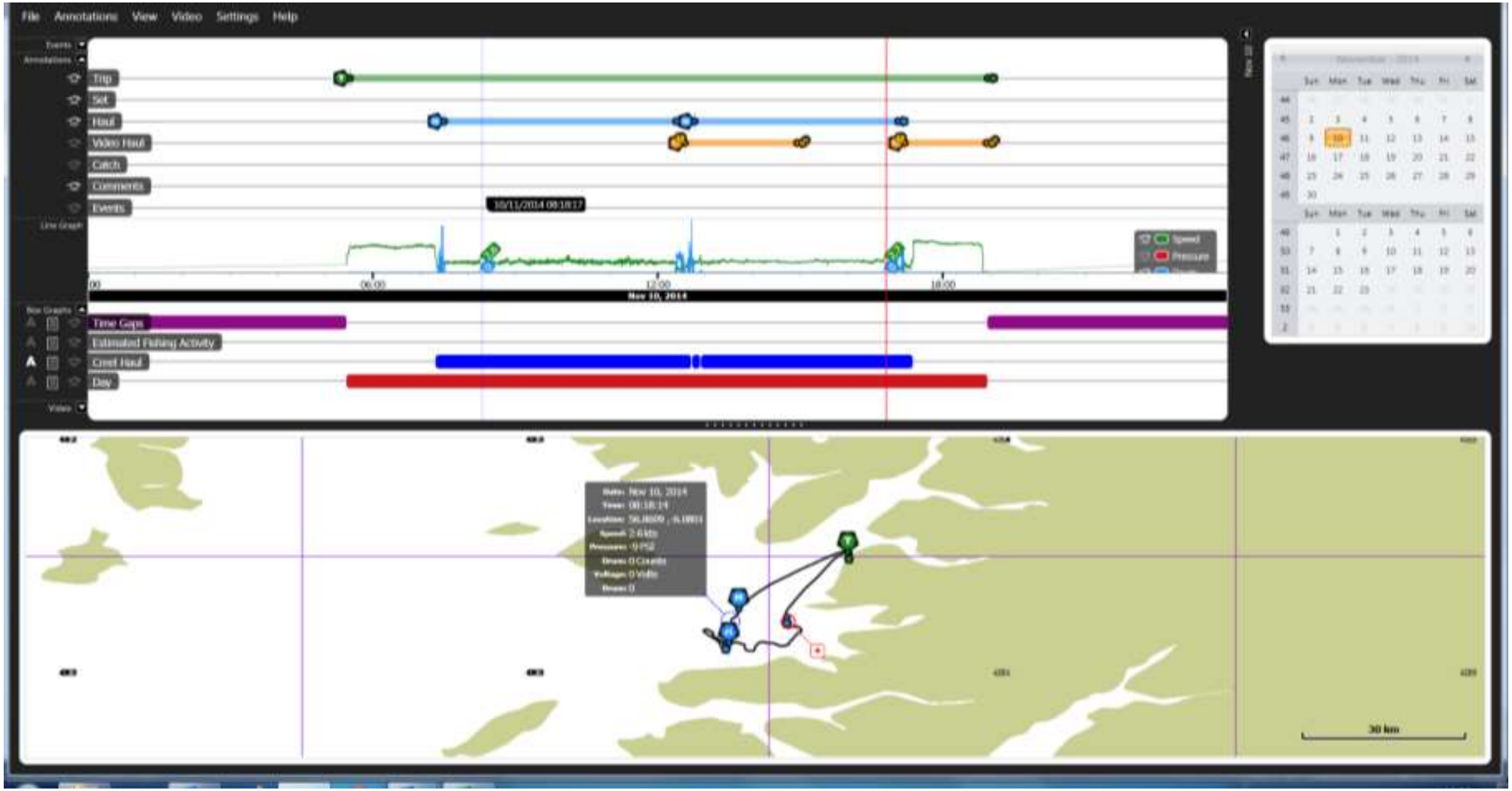


Figure 3.6 A completed annotation file for one trip on a towed gear vessel. Note the blue line graph reading showing winch rotation activity. Also shown is the actual footage reviewed by the video analyst (orange).

This process was completed for 100% of all hard drives received from the fishermen and allows the position of every string or tow to be plotted on a chart (Figure 3.5 from annotations). Non-fishing trips can also be easily identified during this process as no winch or hydraulic pressure sensor usually occurs and therefore no hauls are annotated. In addition the video analyst viewed the video associated with all trips to determine which species was being targeted by every string/tow undertaken and double checked that no fishing has occurred on suspected non-fishing trips. These are then labelled on the annotations file accordingly. The fishing effort identified using EM can also be used to verify the fisherman's self-reported fishing effort.

For our participating fleet all hauls and tows fished are shown in Figure 3.7, split into different gear types to show where fishing vessels targeted specific species. A close up of the Islay/Jura area shows clearly where each string has been hauled and shows areas where concentrations of fishing effort by gear type occurs, as well as areas where only occasional fishing effort occurs (Figure 3.8). These results can also be linked to date to identify seasonal fishing patterns and the effort used in these fisheries, or can be linked to the reported catches for these trips to show an abundance distribution.

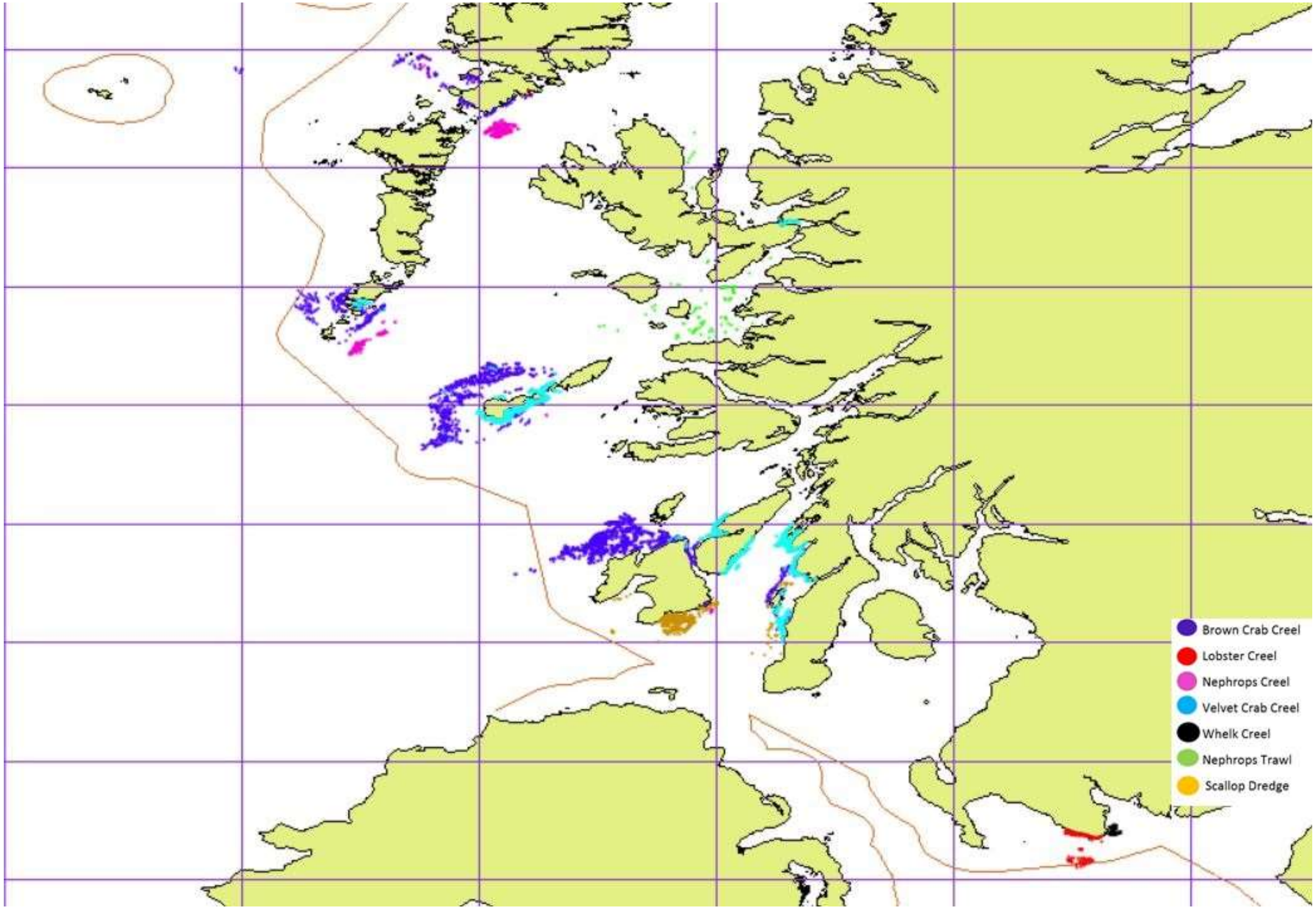


Figure 3.7 Map showing where all strings and tows occurred during this project. GPS positional data were linked to the video analysts gear type annotations to identify where the different gear types operated.

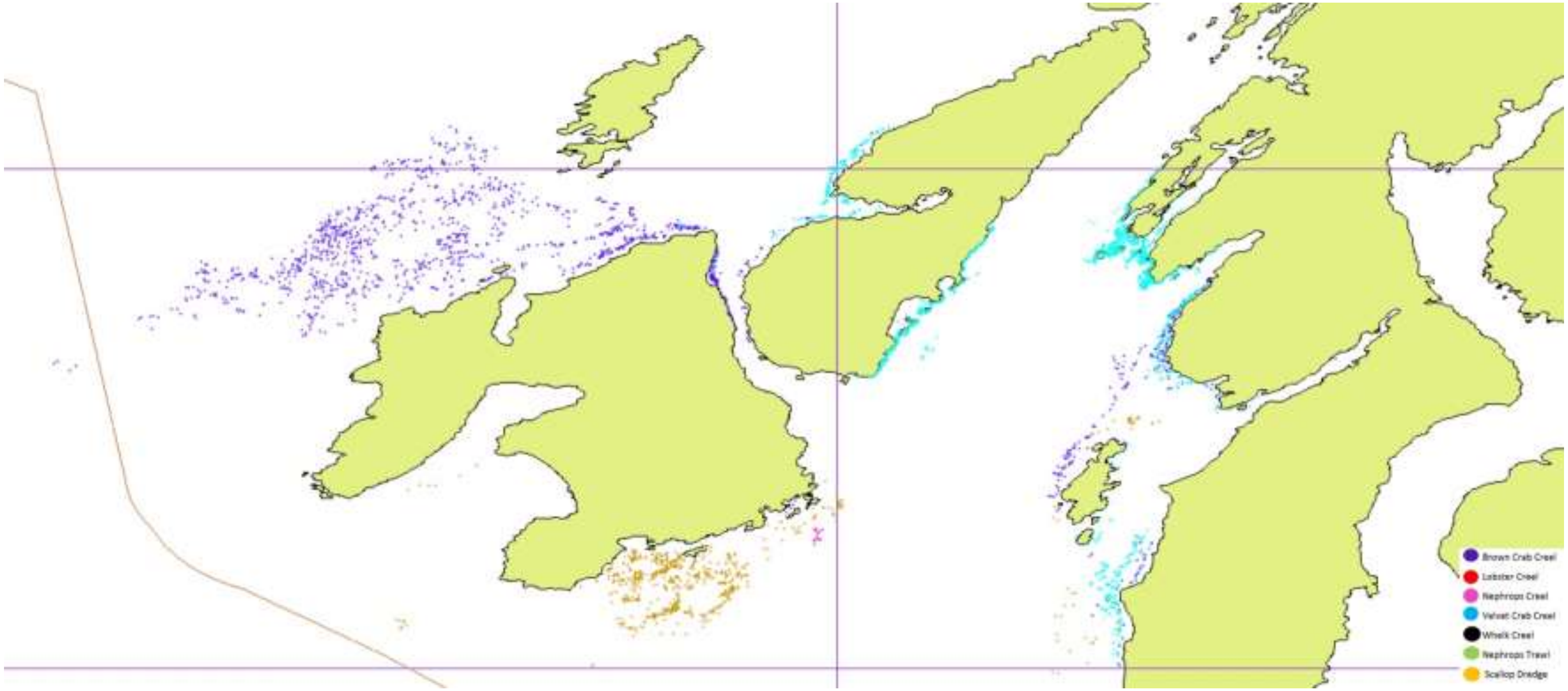


Figure 3.8 A finer resolution map of the Islay area allows exact fishing location by each gear type to be identified.

The number of creels shot and the soak time for every string fished could not be easily detected by the EM system, without extensive additional video review. Therefore an RFID tag trial was undertaken to investigate if this technology could be linked to the AMR EM system and whether this could provide these additional fishing effort data (see the RFID and DST sections in the Sub-projects chapter).   However during the video review process, the video analyst is able to count the strings and creels fished by the vessel on the reviewed trips (68 trips).

Figures 3.9 and 3.10 show the comparison between the fishing effort declared and the fishing effort observed during video review of the selected 10% of trips, for the number of strings/tows and the number of creels, respectively.

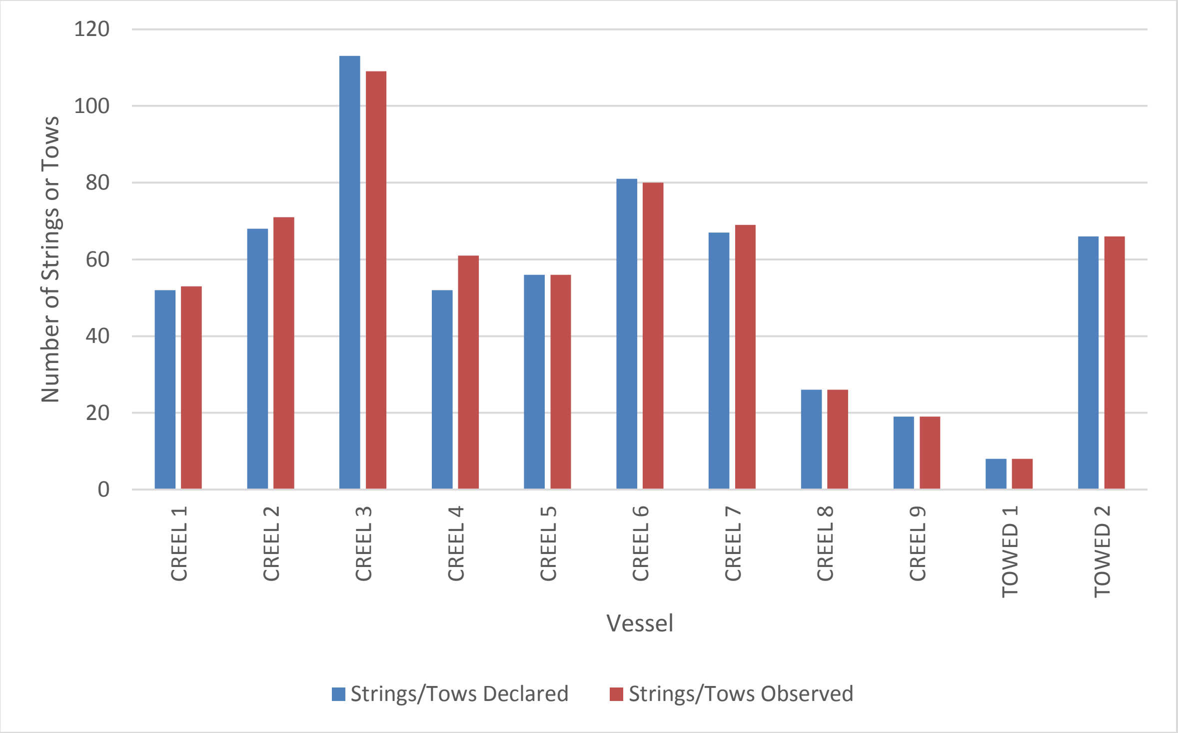


Figure 3.9 Comparison between the number of strings self-reported and the number observed during video review.

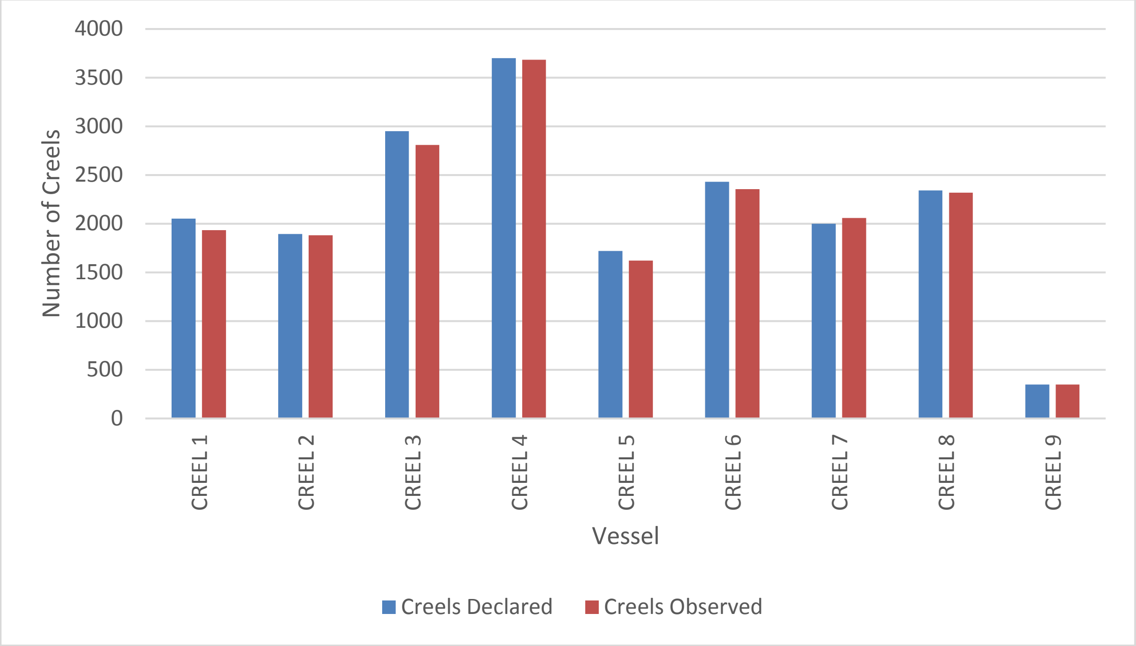


Figure 3.10 Comparison between the number of creels self-reported and the number observed during video review.

In general the number of strings observed during video review matched with those declared by the skipper. The towed gear vessels matched exactly. Two creel vessels marginally over-reported the number of strings fished, 4 creel vessels under-reported and 3 creel vessels matched the number of strings observed. The largest difference over-reported was 4 strings (Creel 3) and the largest difference under reported was 9 strings (Creel 4). In total the fishermen declared 608 strings for these 68 reviewed trips whilst the 618 strings were observed in the video review.

In contrast, the fishermen declared that they fished a total of 19,433 creels on these 68 trips, whereas the video analysts only observed 19,002 creels, a difference of 431 less creels. Only 1 vessel over-reported the number of creels fished (59 creels by vessel Creel 7) and this vessel also over-reported the number of strings fished by 2. All other vessels under-reported the number of creels fished.

During discussions with the fishermen it became clearer why there is a tendency to over report the number of creels. The fishermen think of strings as a set number of creels e.g. a 30 creel string. But when they occasionally lose a creel from a string, they still think of it as a 30 creel string, because they usually replace the lost pot when they shoot away again. So technically they shot 30 creels last trip and shot 30 creels this trip, but the catch for that day only came from 29 successfully hauled creels. Occasionally the fishermen don’t carry enough spare creels to replace lost ones immediately and the string is shot away again with a reduced number of creels. Therefore when the fishermen self-report the number of creels fished at the end of the day it is easy to see why there can be confusion. They fished 30 creels but the catch only came from 29 creels, so it is unclear which fishing effort should be reported.

Catches on Reviewed Trips

The video analyst randomly selected 10% of the valid fishing trips completed by each vessel and carried out video review to quantify the retained and discarded catch, the fishing effort and the sex ratios for each data deficient stock. Occasionally it was necessary to raise the catch estimates obtained during video review. Some examples of why this occurred included video failure for one string during an observer trip due to power issues; crucial camera view temporarily obscured on one or two strings of creels. On the Nephrops trawl, the large volume of catch sometimes caught meant that subsampling was necessary e.g. the analyst reviewed 4 baskets out of 16 sorted by the crew to give a raising factor of 4 on these discard data. Therefore the data used during these comparisons will be raised to trip where necessary. It should be noted though that a raising factor was only used on 5 of the creel vessel trips and the raising factors ranged from 1.14 to a maximum of 2.98.

During observation of the catch, the video analyst makes estimates of catch weight by eye and count the number of shellfish/finfish caught. The most accurate observation by the video analysts is counts. Therefore analysts were instructed to concentrate on obtaining the most accurate counts possible and these could then be converted to estimated weights using the nominal weights we have assigned to discard and retained individuals (see Table 2.5). The main exception to this is for retained scallops and Nephrops, where the weights were usually obtained by counting the full baskets of retained catch at the end of each haul and multiplying this number with a nominal full basket weight, supplied by the skipper (checked by at sea observers).

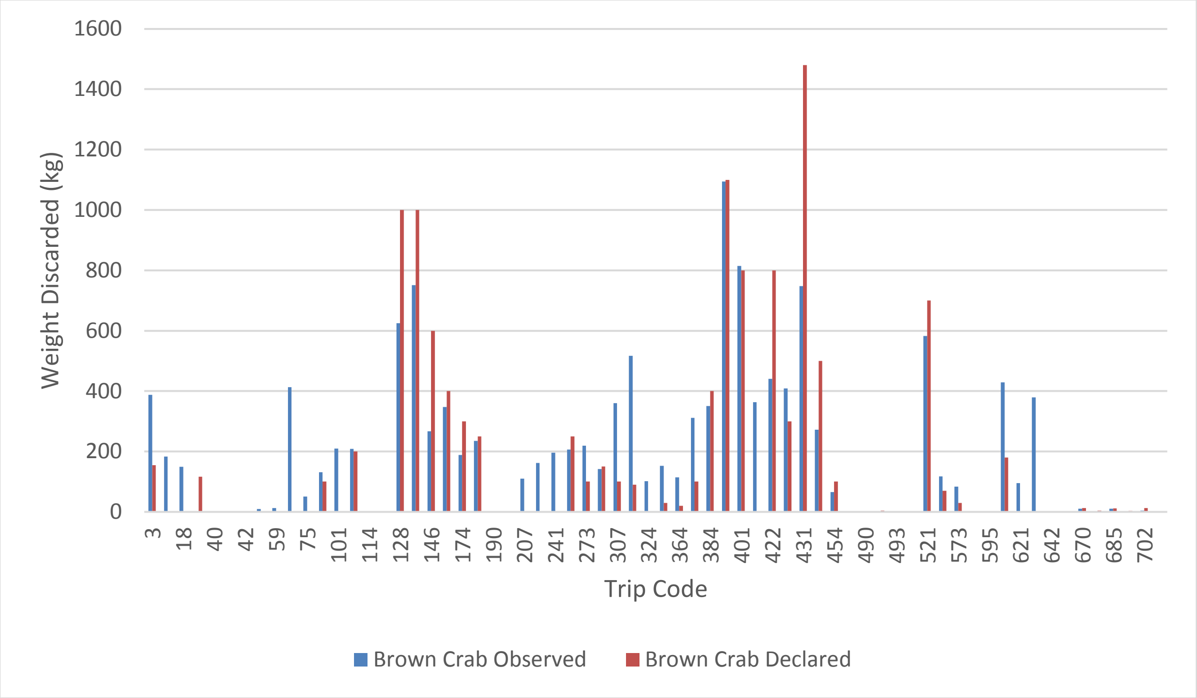
On each trip reviewed, the skipper provided an estimate of the amounts of catch retained and discarded, primarily for the main target species but often for the additional data deficient species as well. The analyst provided the estimates for all species. Undertaking a comparison between the video analyst's estimates and those provided by the skipper, allows the skipper's estimates to be verified. It will also highlight areas where the self-reported data are deficient. Comparisons for the total catches retained and discarded are shown in Figure 3.11 for brown crab, scallop, velvet crab and Nephrops.

The estimates provided by the skippers for brown crab discards were often higher than those estimated by the video analyst. It is extremely difficult for the fishermen to provide this estimate because the catches of brown crab discards are usually high and the fishermen is having to make a retrospective estimate at the end of the day's fishing. Obtaining a weight for the retained is easier because at the end of the day the retained crab are available on board for the skipper to quantify. The retained brown crab are also available to be viewed by the video analyst (albeit as a count converted to weight on most occasions), resulting in weight estimates that are quite similar.

Retained scallop catch weight estimates are also very similar. This is due to the estimation method used being virtually the same for the video analysts and the skipper. Both count the full and part baskets of scallops retained and convert them to weight using 25kg as a nominal full basket weight. Any differences are due to determining whether a basket is 100% or 90% full, or how much is in a part basket (e.g. is the basket a quarter full (6.25kg) or a fifth full (5kg)). The discarded scallops are counted and then converted to a weight. On all occasions the skipper underestimated the weights discarded compare to the video analyst's estimates. During an observer sea trip the discarded part of the catch was weighed after the skipper had made his estimates. It was found that the actual weight was approximately twice what the skipper had estimated, making the video analysts estimates shown in Figure 3.11 the more accurate.

Retained Nephrops caught in the Nephrops trawler are quantified in a similar way as the retained scallops on the scallop dredge vessel, by volume in baskets, where a full basket of live Nephrops is 20kg and a full basket of tailed Nephrops is 25kg. Estimates between the video analysts and the skipper are very similar (Figure 3.11). On creel vessels the different size grades of retained Nephrops are stored in tubes in different crates. Each full crate at different size grade has a number of tubes and a nominal weight associated with it. Therefore the full crates can be counted and a total weight or count estimate can be made. This method is used by both the video analyst and the skipper to quantify retained catch. The discarded Nephrops estimates made by the video analyst and the skipper are less similar. On most trips, no or very few discarded Nephrops are self-reported. However on two of the trips the skipper has reported nearly double the amount viewed by the video analyst. The reasons for the difference in these estimates are not clear.

The retained velvet crab estimates (Figure 3.11) provided by the video analyst appear to be less than those provided by the skipper on most trips. The video analyst usually obtains this retained weight by counting the retained velvet crabs and applying a nominal weight to this count based on a retained velvet crab being 0.11kg each. This weight was based on the weight for a 70mm velvet crab. However the length frequency data collected on observer trips and presented earlier show that most retained velvet crabs caught were 72mm. If this width had been used instead of 70mm then the nominal weight of a retained velvet crab would be approximately 0.19kg each, which in turn would increase the weight estimate of the video analyst. If future projects are undertaken, perhaps the nominal weights used to convert numbers observed by the video analyst to weights can be obtained from the at-sea observer length frequency data. The skipper’s estimates of discarded velvet crabs are quite similar on most trips, except for four, where the skipper has over-estimated the catches compared to the video analyst. On investigation of the data sets it is likely that the estimates made by the skipper were retrospective estimates from memory at the end of the day and that the video analyst’s estimates are more realistic. On one of these four trips an observer was aboard the vessel (Creel 8) and observed the skipper sub-sample the discarded catch. The skipper weighed the discarded velvet crabs collected from 7.5 creels (the skipper stopped collecting velvet discards half way through sorting the 8th creel) and then calculated a raising factor based on the total creels fished on that string, which can then be multiplied by the number of strings (in this case 25). This results in a weight of 200kg being self-reported. However when this calculation was undertaken the skipper stated that the discards came from 5 creels and not the 7.5 creels observed by the observer. When raising factors are adjusted for this error a revised discard estimate of 133kg is calculated. This is still higher than that reported by the video analyst but if the discards were larger in size than the 60mm carapace width used, then the individual weight of a discard (60mm= 0.07kg) will increase and will reduce this difference further.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1400
1200
1000
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400
200
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3
18
40
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59
75
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174
190
207
241
273
307
324
364
384
401
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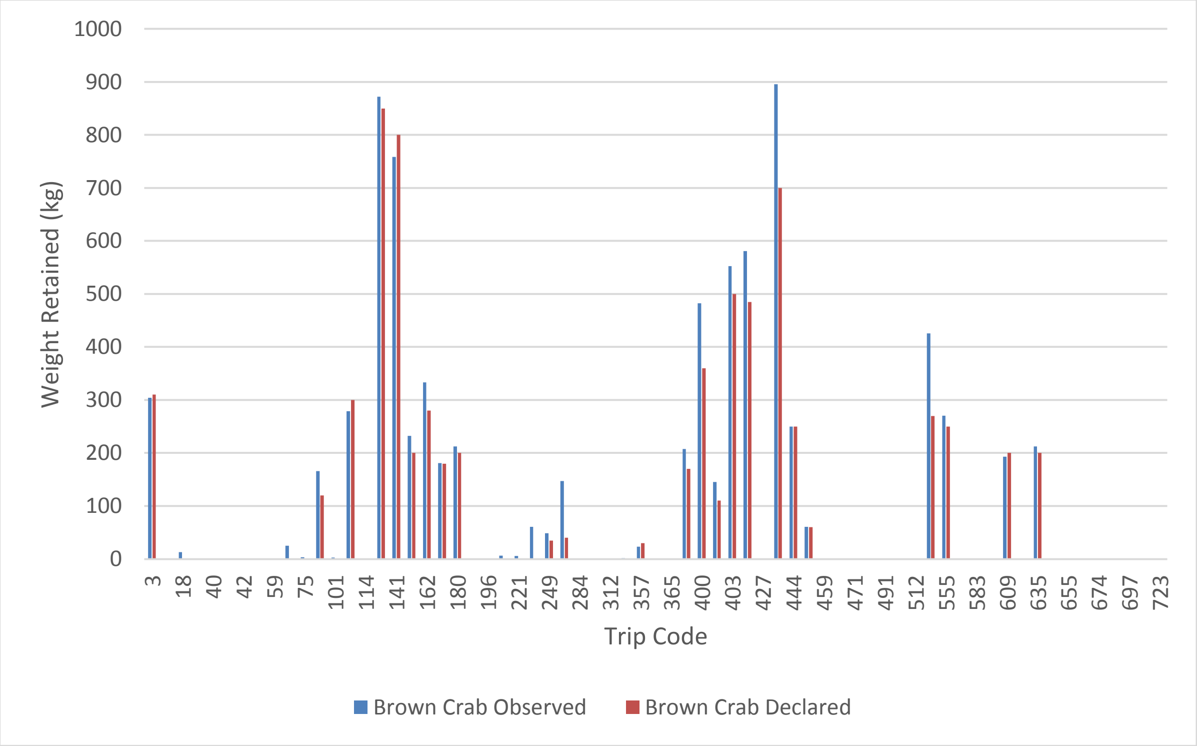
490
493
521
573
595
621
642
670
685
702
Trip Code
Brown Crab Observed
Brown Crab Declared


Weight Retained (kg)
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900
800
700
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500
400
300
200
100
0
3
18
40
42
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114
141
162
180
196
221
249
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365
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403
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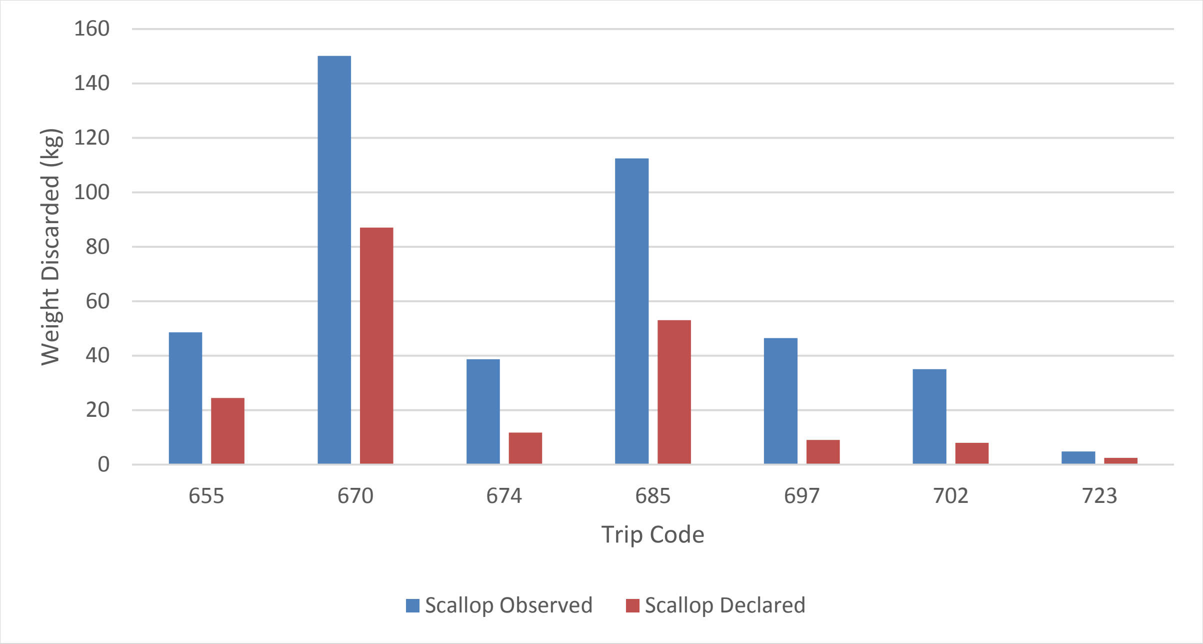
609
635
655
674
697
723
Trip Code
Brown Crab Observed
Brown Crab Declared


Weight Discarded (kg)
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140
120
100
80
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40
20
0
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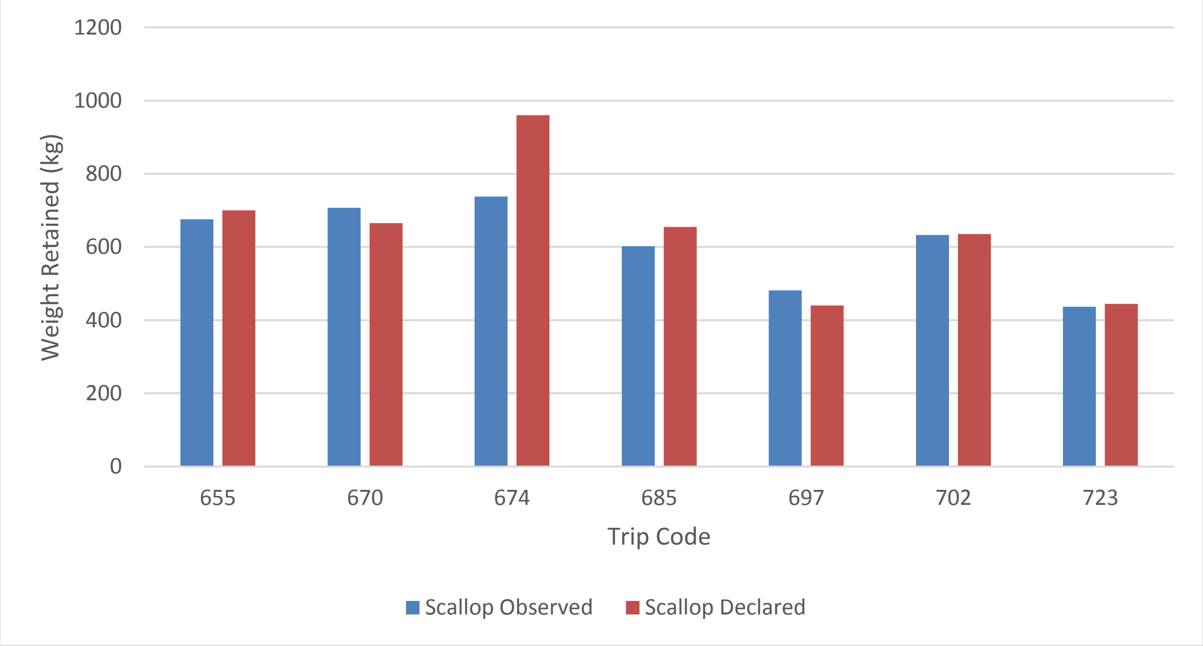
670
674
685
697
702
723
Trip Code
Scallop Observed
Scallop Declared


Weight Retained (kg)
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674
685
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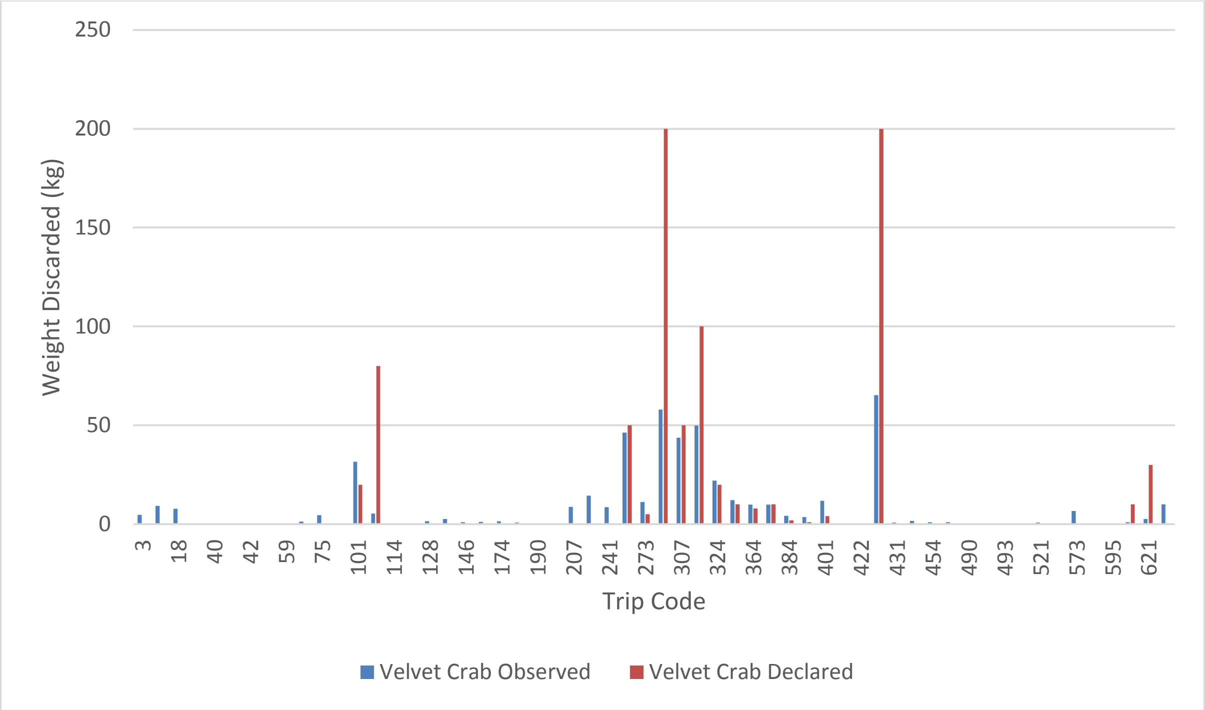
Trip Code
Scallop Observed
Scallop Declared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200
150
100
50
0
Weight Discarded (kg)
3
18
40
42
59
75
101
114
128
146
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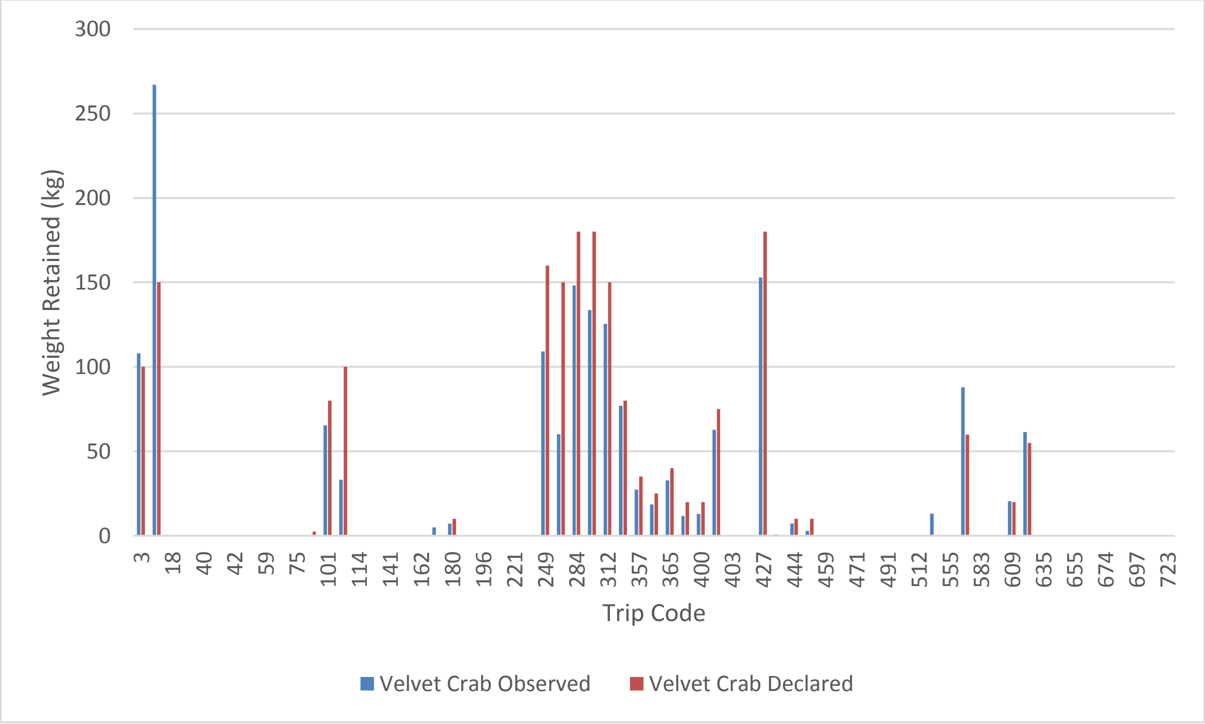
207
241
273
307
324
364
384
401
422
431
454
490
493
521
573
595
621
Trip Code
Velvet Crab Observed
Velvet Crab Declared


300
250
200
150
100
50
0
Weight Retained (kg)
3
18
40
42
59
75
101
114
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180
196
221
249
284
312
357
365
400
403
427
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Trip Code
Velvet Crab Observed
Velvet Crab Declared

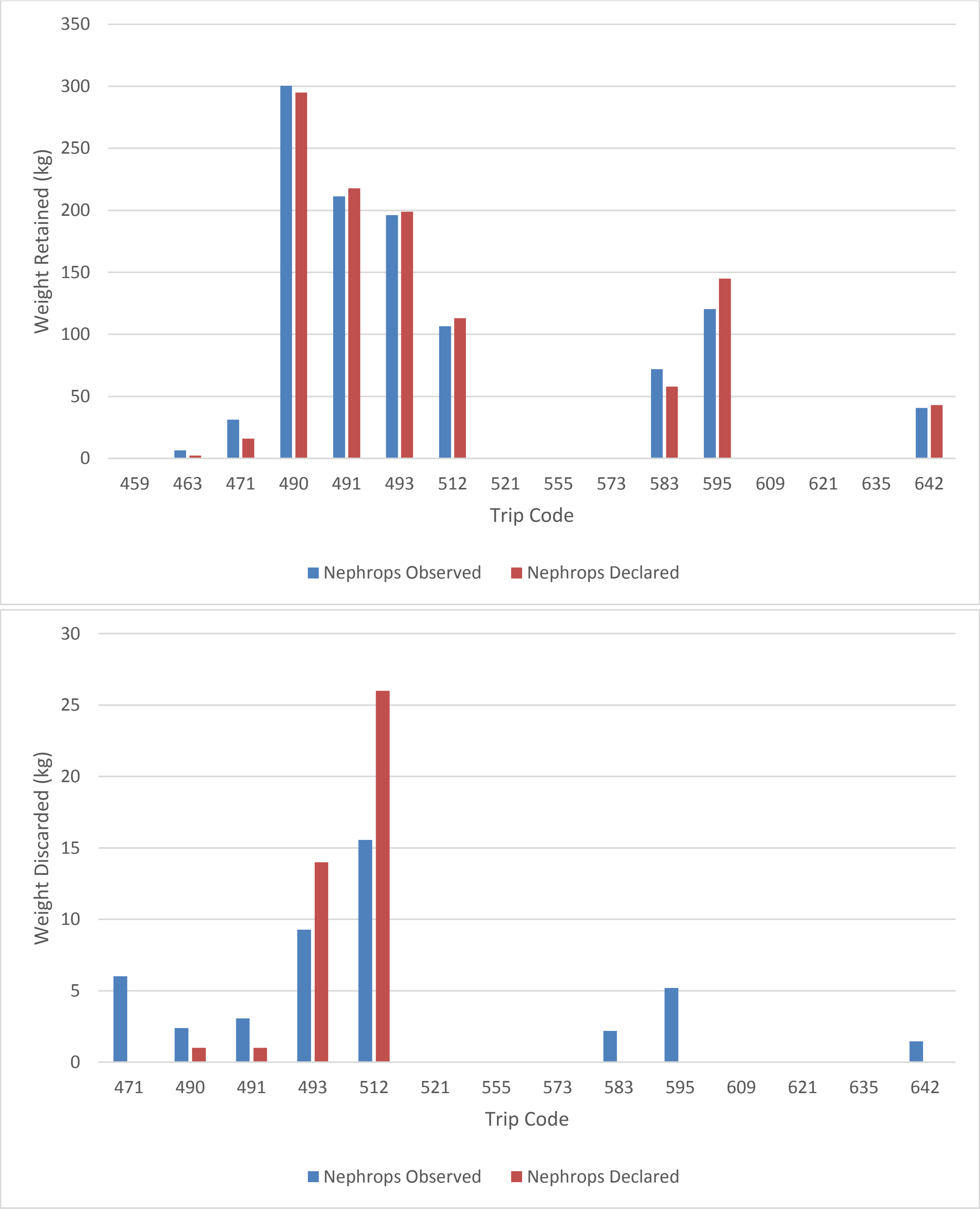


Figure 3.11 Comparisons of weights (kg) self-reported by skippers and the estimates obtained by the video analysts for brown crab, scallops, velvet crabs and Nephrops.

Lobster was not shown by weight because they were mainly reported by count by vessel Creel 5, which specifically targets lobster all year, and the other vessels. Video analysts gathered nearly all their catch estimates by count and then converted the count data to a weight based on nominal conversion factors. Therefore a count comparison for lobster can be made (Figure 3.12). It can be seen that using the counting estimation method for both the retained and discarded catches of lobsters results in some very close estimates. For those trips where declared catch is not given by count, catches were reported as weights only and therefore could not be compared by count with video estimates unless the weights were converted to counts based on a nominal weight per discard or retained individual.

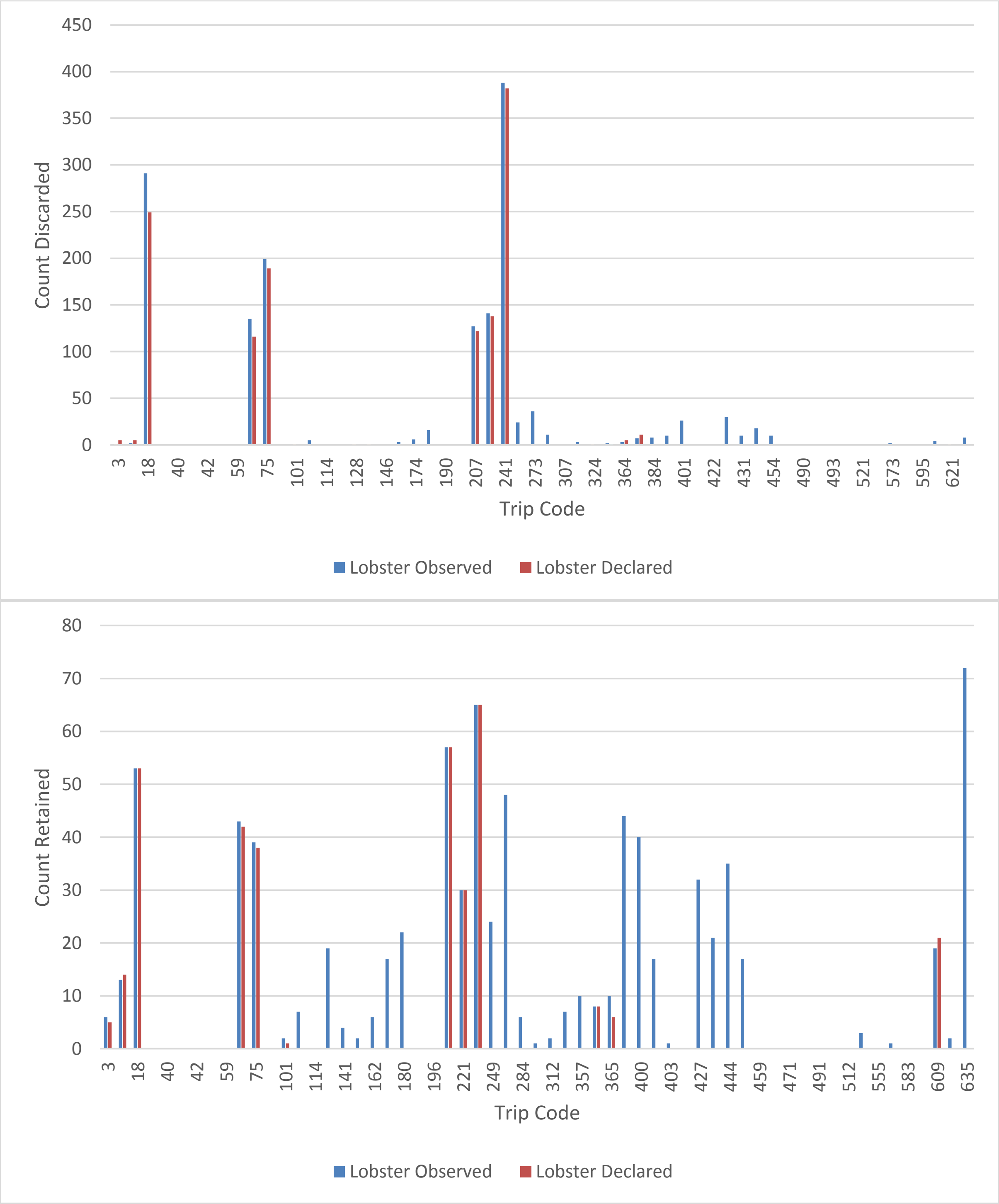


Figure 3.12 Comparison of counts of lobster obtained by the video analyst and self-reported by the skippers.

Video analysts state that they find it easier to collect counts than to estimate weights by eye. However fishermen cannot be expected to collect data in this way for species with high levels of catches. Undertaking sub-sampling of the retained and discarded catches allows the skipper to obtain a count for a known weight or volume (for the retained catch) or a count of effort (string or number of creels). For discards the count usually comes from a subsample of the pots or strings because the fishermen do not retain the whole discard catch on board, unlike the retained marketable catch. These counts can then be raised up to trip level as described earlier. However this can create large raising factors and if the selected creels are not representative of the whole day's fishing, results can be skewed. Video analysts have observed large differences between creels that were hauled on the same string, which suggests that discard estimates made by the skippers may not always be representative of the trip.

Creel By Creel Comparisons

An at-sea observer collected creel by creel counts of retained and discarded catch during two sea trips. In total counts were made for 645 creels over 18 strings. These data were collected to examine if there was variability in the catches from different creels within a string. These data were also used to compare against the video analyst's estimates as a form of quality assurance on the estimates obtained by video review. All species encountered were noted by both the at sea observer and the video analyst but for the purposes of this exercise only brown crab data will be illustrated because it was the most abundant species encountered on these two trips. The comparisons between the video analyst counts and the counts collected by the at-sea observer generated 763 data comparisons because a creel could contain both retained and discarded brown crabs. These are shown in Figure 3.13 for the discarded brown crab and Figure 3.14 for the retained brown crab. Table 3.10 also shows a summary of the data set.

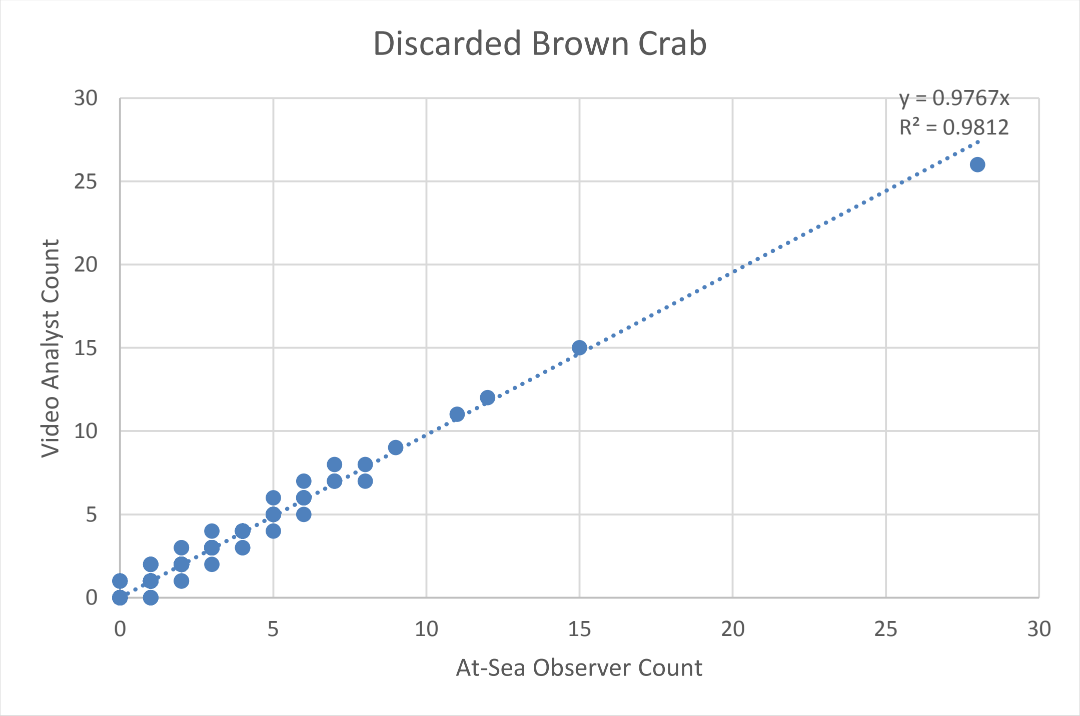


Figure 3.13 Comparing the counts of discarded brown crab obtained at sea by an observer and during video review by a shore based video analyst.

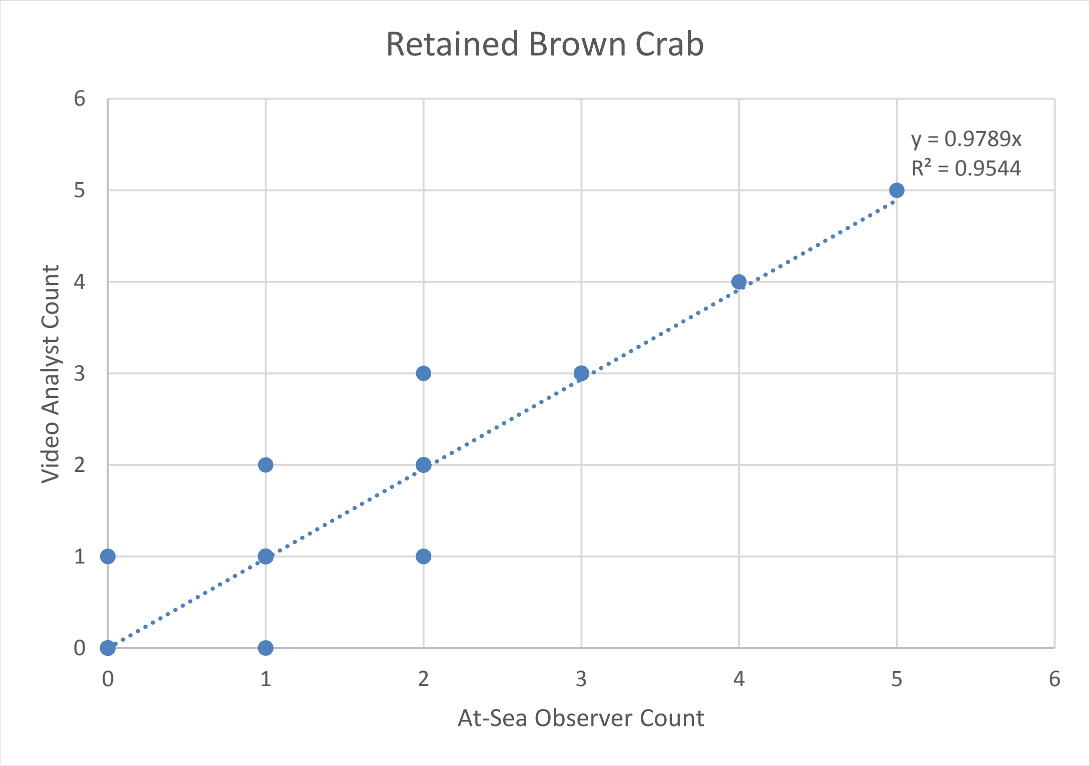


Figure 3.14 Comparing the counts of retained brown crab obtained at sea by an observer and during video review by a shore based video analyst.

Both the observer and the video analysts counted the same number of creels during these two trips which would indicate that the EM system and video reviewer are able to provide an accurate count of creels fished. It was noted on a different observer trip that the observer missed 5 creels that the video reviewer had observed. All missed creels were empty and the observer had forgotten to record the zero value. Video review has the added advantage that it can be replayed if the reviewer should momentarily lose concentration.

The seagoing observer reported that 326 creels contained less than 5 discards although 4 creels did contain over 10 brown crabs with the most being 28 discards in a single creel. The video reviewer also reported that 326 creels had less than 5 brown crabs and that 4 creels contained more than 10 brown crabs. Although in this case the largest number counted was 26 crabs on the same creel the at-sea observer had reported 28 crabs. The video was replayed on several occasions and the same answer was reported, suggesting that in this case the at-sea observer's count was wrong. It should be remembered that the at-sea observer and the video reviewer are counting crabs as they are thrown back into the water and the at-sea observer does not have the benefit of a rewind or slow motion button to help provide the totals. Of the 340 records for discards, 33 were 1 crab different and 1 record was 2 different. The counts were identical on 306 of the creels with discards.

Retained brown crab were reported in 423 of the 645 creels fished. The video analyst counted 299 brown crab being retained whilst the at-sea observer counted 303. The video analyst reported 1 crab more than the at sea observer on 5 creels whilst the at sea observer reported an extra crab on 9 creels. Again it is suggested that the video review counts are correct because during the video review it was noted that the crew occasionally reached into the retained crab container (called a “bongo”) and discarded a crab that was previously retained. This was usually done between the sorting of two creels and whilst the observer was writing up his records for the last creel sorted. As before, the rewind, half speed playback, frame by frame playback, zoom and pause functions of the EMI Pro software allow the video reviewer to examine footage closely and at their own preferred pace. Even if it had been witnessed the observer may have allocated it to the next creel hauled which may in effect double the number of creels with 1-crab difference, the first creel under-estimated and the next creel over-estimated.

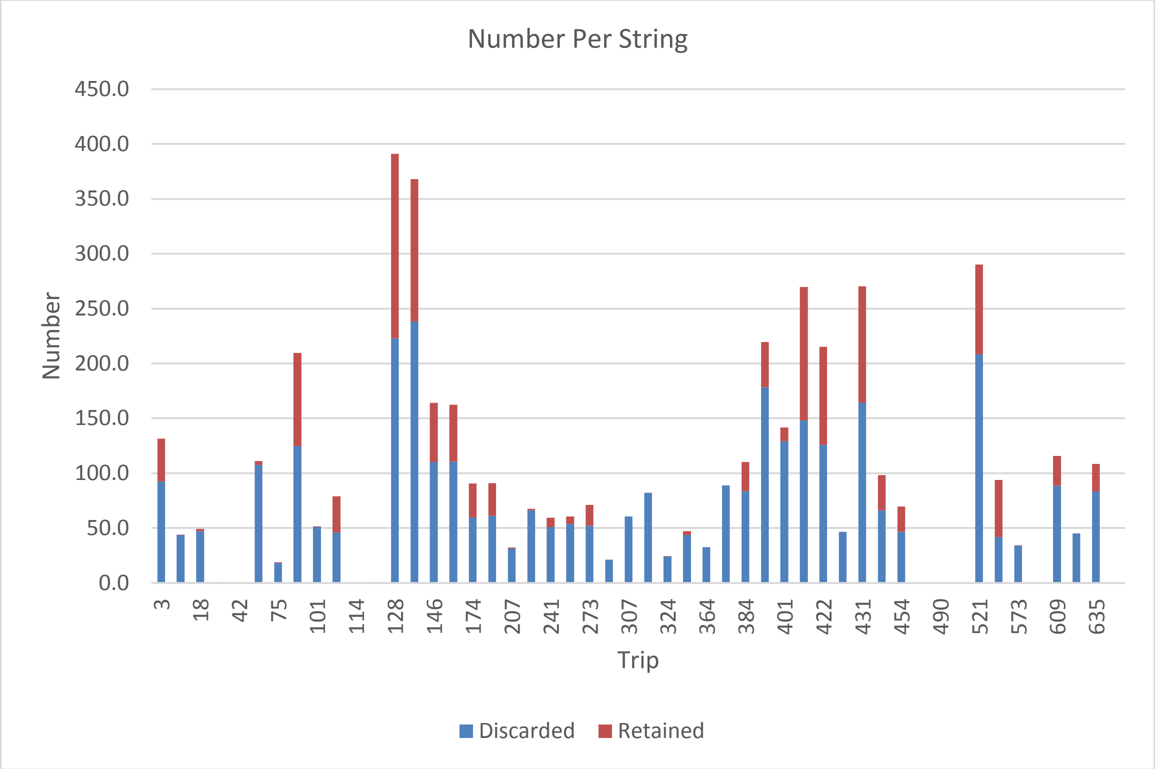
Table 3.10 Summary of the data collected during the pot by pot comparison trial

	Total No. Creels	Total Count - Brown Crab	No. Creels: 1-Crab Difference	No. Creels: 2-Crab Difference
Video Analyst - Retained	423	299	5	0
At-Sea Observer - Retained	423	303	9	0
Video Analyst - Discarded	340	578	17	0
At-Sea Observer - Discarded	340	579	16	1

Of the additional species caught all finfish and lobster counts made by the video analysts and at-sea observer matched exactly. Velvet crab was the only other species caught (although catches were low) and there was a 1 crab difference on 2 creels, with all others matching exactly. To have a 5 crab difference in total numbers out of approximately 880 viewings is approximately a 0.6% difference.

Catch per Unit Effort (CPUE)

The catch data collected by the video analyst and EM system can be used to calculate catch rates, which can be linked to geographical position through the EM system’s GPS. The analyst counts the number of crabs and lobsters being discarded from a string and collects the effort data associated with this vessel, i.e. the number of creels fished, the number of strings fished, and the number of trips the vessel makes per year. Counts can then be converted to a weight using a nominal weight value for retained and discarded individuals. Catch values are based on the raised counts and calculated weights for brown crabs observed by the video analyst. Figure 3.15 shows the total catches per string and per creel (by numbers and weight) for both the discarded and retained brown crab observed during video review. Towed gear were excluded from the exercise as skippers didn’t provide enough data on hours towed to allow any comparisons to be made.


Number Per String
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400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
3
18
42
75
101
114
128
146
174
207
241
273
307
324
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384
401
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431
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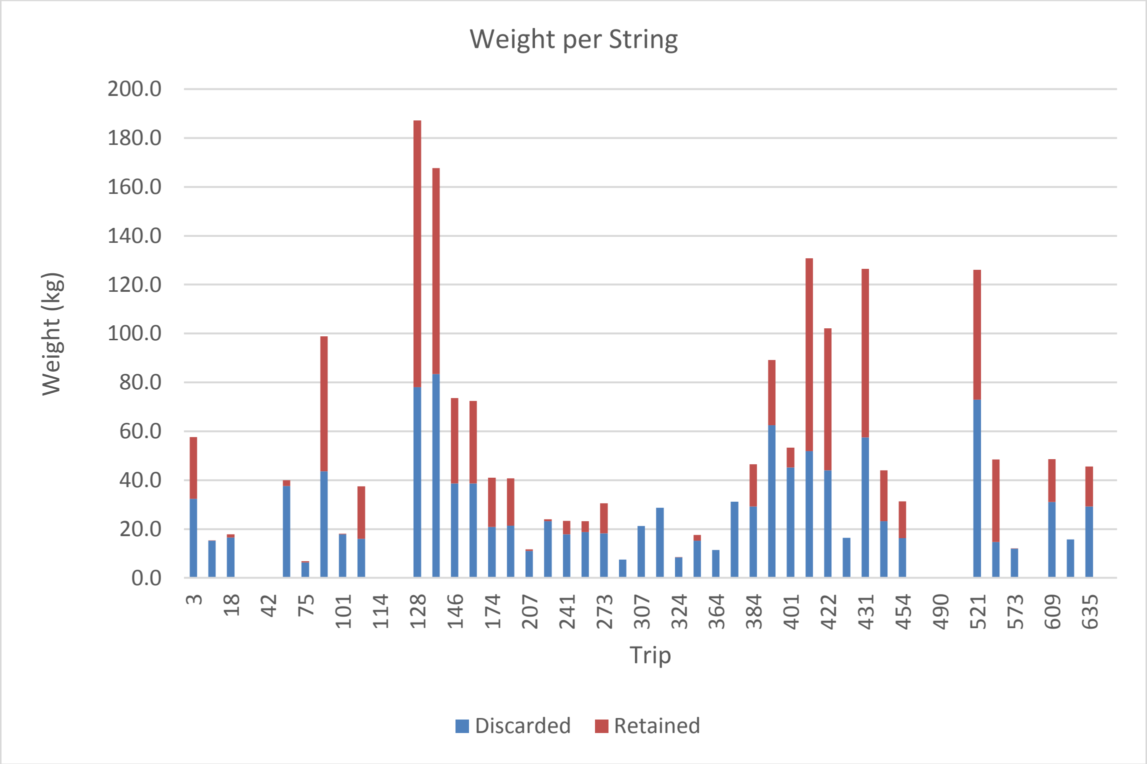
521
573
609
635
Trip
Discarded
Retained


Weight per String
Weight (kg)
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160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
3
18
42
75
101
114
128
146
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Trip
Discarded
Retained

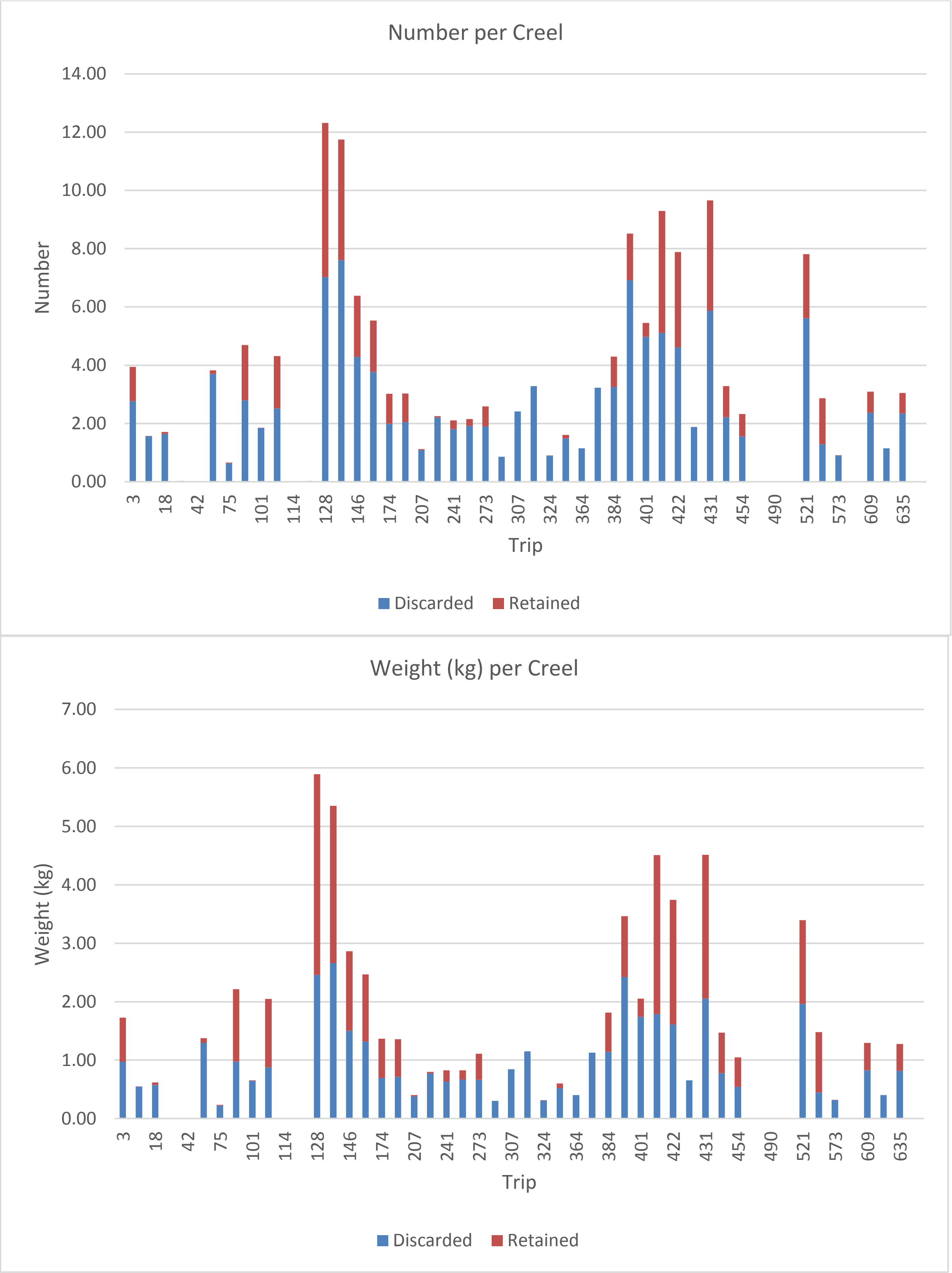


Figure 3.15 Catch per unit effort for brown crab as a number and weight per string and as a number and weight per creel.

These CPUE calculations and charts can also be repeated for the towed gears and for any species observed during the trial. Brown crab was chosen for illustrative purposes because it was an abundant main target species for most vessels.

Soak time may be an effort measurement that is considered useful to managers. At present it cannot be easily collected using the AMR EM system, which is one of the reasons the DST and RFID sub-projects were undertaken. RFID was also undertaken to provide an automatic creel count. Towing time for towed gears is easily extracted from the EM system and could be used to calculate catch rates per hour towed.

If managers are interested in effort restrictions based on numbers of creels being fished then catch rates per creel would be useful especially when a string of creels can contain anything between 10 and 100 creels depending on the fishery and size of the vessel. Catch rates per creel would allow managers to explore how many creels a vessel could fish to ensure that the stock is not over-exploited.

What is certain is that EM and reviewed video can provide high quantities of good quality data for management and scientific purposes.

Sex Ratio Data

Video analysts obtain counts of crabs and lobsters as the fishermen sort the creels. During normal fishing operations the fishermen throws the discards back over the side immediately, straight out of the creel. These “flying” crabs are able to be counted and if their abdomen is visible they can often be sexed at this time. The retained crabs and lobsters are placed in bongos, boxes or tubes (lobsters are often placed in short sections of drainpipe standing upright in a box prior to banding), to await nicking or banding of claws when the fishermen have time. This operation is also reviewed by the video analyst and allows a count of retained individuals as well as an estimated (by-eye) weight or volume. The nicking process and the sorting process both give an opportunity to view the underside of the retained catch and to estimate a sex ratio.

Sex Determination – Most fishermen sex lobsters based on the shape of their abdomen and tail and claws, where females have a wider abdomen and tail and smaller claws than a male. However in smaller lobsters this becomes unreliable because these morphological differences don’t appear until the females are sexually mature (Hold et al, 2015). Therefore to estimate a sex ratio for retained and discarded lobsters, they were sexed by observing the first pair of pleopods between the legs as these differ between males and females. Crabs (brown crab and velvet crab) were sexed based on the shape and size of their abdominal flap (see Figure 3.16 for brown crab).

Figure 3.16 A male (left) and female (female) brown crab being discarded by the fisherman.

It became clear early in the project that determining the sex of every specimen caught using the normal video camera views would not always be possible due to the way the catches were handled. If the underside of a lobster or crab is not visible then it cannot be reliably sexed and even if it is visible it is not always possible to determine the sex of the individual. Therefore the sex of an individual animal was only specified when the video observer was 100% certain that it could be determined accurately. All specimens that could not be sexed were recorded as “unsexed”. All berried females were noted as “berried” providing useful data that could allow biologists to identify any local seasonal breeding patterns and to obtain localised data on maturity-at-size.

Table 3.11 shows the results obtained by the video analysts during review of the 68 selected trips. Over 33,300 brown crabs were observed being discarded and reviewed for sex, of which 32% (10,777) were successfully sexed. The number of retained brown crab observed on these reviewed trips was lower (12,150) but more were able to be sexed (76%) because they were often tilted upwards during the nicking process having been selected for landing. Very few lobster were observed (826) and very few of these could be sexed (16) during normal video review. The video analyst was able to sex 25% of velvet crabs caught, for both retained and discarded, giving a total of 3711 velvet crabs sexed out of a total of 14878 observed.

Table 3.11 Total numbers of lobster, brown crab and velvet crab observed and successfully sexed during video review.

Species	Category	Female	Male	Berried	Unsexed	Total	Percentage Sexed
Brown Crab	Discarded	5551	4954	272	22606	33383	32
Lobster	Discarded	1	0	6	566	573	1
Velvet Crab	Discarded	379	368	81	2474	3302	25
Brown Crab	Retained	5402	3761	108	2879	12150	76
Lobster	Retained	4	5	0	244	253	4
Velvet Crab	Retained	1420	1438	25	8693	11576	25

To calculate the percentage of male and female in the sexed sample it is necessary to add the females and berried females together and remove the unsexed portion of the observed catch. Figure 3.17 shows the percentages of male and female brown crab, velvet crab and lobster retained and discarded. Lobster was not included due to the low numbers that were able to be sexed.

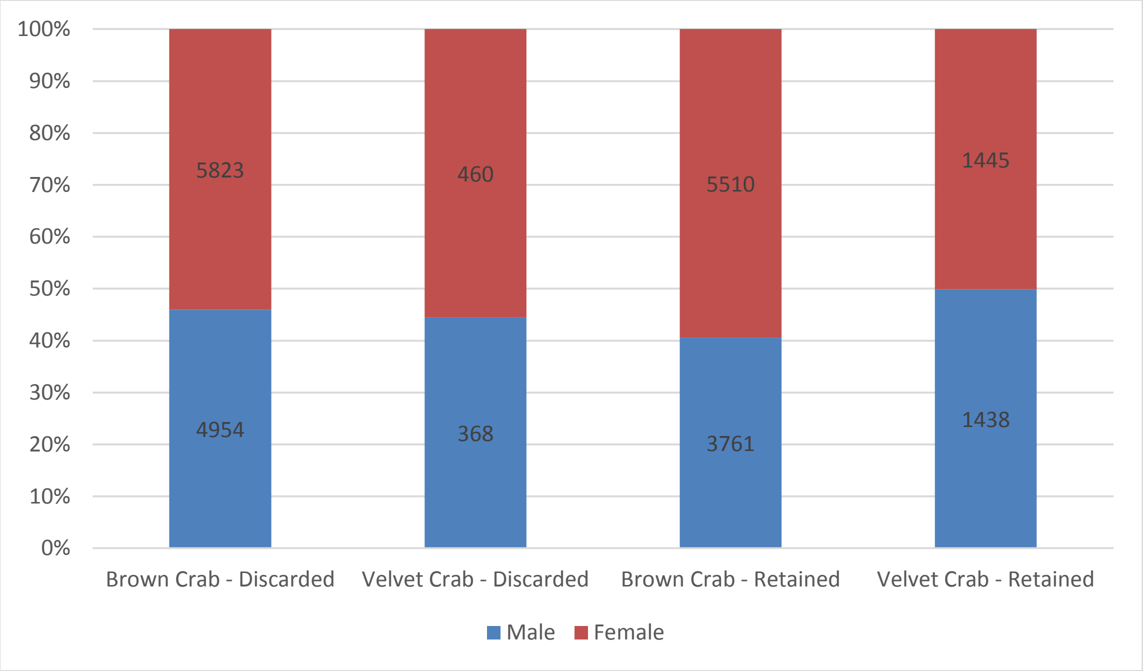


Figure 3.17 Sex ratio and numbers able to be sexed during video review for brown crab and velvet crab.

The retained velvet crabs are almost 50% male and 50% female, whilst the discards are predominantly female (56%). The numbers of velvet crabs sexed during the review process is low although the proportion between sexed and unsexed is the same for both retained and discarded velvet crabs. The discarded brown crab were observed to be mainly female (54%) as were the retained brown crab (59%).

This dataset mainly came from 8 creel vessels (the two towed gears and part time creel vessel supplied little or no sex data) where 10% of their trips were reviewed by a video analyst. In some cases the number sexed was too low to be useful e.g. lobsters and perhaps discarded velvet crabs, but if the EM systems were installed on more vessels that were representative of the fishery then the dataset available to scientists could be large and very useful in determining discard rates and sex ratios. If enough vessels over a wide geographical area could be persuaded to carry EM systems then local population differences in sex ratio and size could be identified.

Table 3.12 shows the percentage of males for brown crab and velvet crab collected by the skipper on all trips where they conducted a count (265 trips), compared against the percentage males calculated from the video analyst's count for trips where the video was reviewed (68 trips). This comparison was undertaken to try and establish the levels of sampling undertaken by each collection method, to arrive at these sex ratios, which may give an indication of which was the more accurate. For example the skippers undertook sex sampling on 265 trips and observed 8,149 brown crabs, so an average sample rate of 31 crabs per trip. The observer sampled by sex on 68 trips and observed 20,048 brown crabs, an average of 295 crabs per trip. This shows that video analysts are able to collect good quality sex data and sample nearly 10 times as many individuals per trip than the skippers which should more lead to more accurate estimates of sex ratio.

Table 3.12 Comparison between the percentage of males counted by the skipper on all trips and the percentage males obtained by the video analyst on the reviewed trips only.

Category	Species	Skipper Count: % Males (Sample Size)	Video Analyst Count: % Males (Sample Size)
Discarded	Brown Crab	52 (5126)	46 (10777)
Retained	Brown Crab	54 (3023)	41 (9271)
Discarded	Velvet Crab	57 (2663)	44 (828)
Retained	Velvet Crab	76 (9145)	50 (2883)

However comparing the skipper's self-reported sex ratio with the video analyst's estimate should only be carried out on the video reviewed trips where the skipper produced a sex ratio using a count (rather than weight or percentage estimate) and where they have both estimated a sex ratio for the same catch component (retained or discarded). This comparison is shown in Table 3.13. It can be seen on most trips the video analyst's sample was either larger than or similar to that of the skipper, with the exception of trips where discarded velvet crabs were sexed. It is more likely that where sampling levels are higher, the sex ratio will be more accurate because it reduces any potential geographical bias based on subsampling only 1 or 2 strings at sea.

Table 3.13 Sex ratio data collected on the reviewed trips by both the video analyst and the skipper for comparative purposes.

			Count Males		Count Females[1]		Percentage Males	
Trip	Species	Category	Skipper	Analyst	Skipper	Analyst	Skipper	Analyst
284	Velvet Crab	RET	121	158	34	53	78	75
307	Velvet Crab	RET	121	79	20	13	86	86
427	Velvet Crab	RET	64	239	89	60	42	80
431	Brown Crab	DIS	29	239	34	430	46	36
431	Brown Crab	RET	29	381	33	702	47	35
521	Brown Crab	DIS	210	114	256	320	45	26
521	Brown Crab	RET	4	82	36	260	10	24
555	Brown Crab	DIS	38	61	32	48	54	56
555	Brown Crab	RET	8	109	17	104	32	51
573	Velvet Crab	DIS	194	1	71	2	73	33
573	Velvet Crab	RET	59	156	12	87	83	64
621	Velvet Crab	DIS	62	1	19	1	77	50
621	Velvet Crab	RET	54	135	12	88	82	61
635	Brown Crab	RET	50	52	24	68	68	43

[1] This includes any berried females.

If sex ratio data are to be collected routinely by skippers then a more uniform method of data collection is required that collects count data, rather than weight data, for both the retained and discarded catch of each species of interest. These can then be compared against all video analyst estimates made on video review verification trips. Alternatively the video analyst’s sex ratio could be used.

During sea trips the at-sea observers collected length data from retained and discarded sub-samples of the catch. As part of this process they would also collect the sex of each crab/lobster measured. This allowed a comparison to be made between the sex data collected by the at-sea observer and the sex data collected by the video analyst (see Table 3.14). Any trips where there were less than 10 specimens caught were excluded from the comparison.

The first thing to note from this comparison is that the at-sea observer data all comes from subsamples of the catches whereas the video analyst attempts to sex all individuals caught. This leads to an additional category called “unsexed” (data not shown) for the video analyst. Despite not being able to sex all crabs viewed the video analyst has been able to sex a higher number of crabs than the at-sea observer on all trips. For example on trip 635 the at-sea observer has sexed a subsample of 39 brown crabs whilst the video analyst has sexed 11 times that amount (429), and on Trip 400 the video analyst successfully sexed over 1100 brown crab compared to 171 by the at-sea observer. The other important point to note is that the video analyst is able to collect data from all strings fished throughout the trip. The at-sea observer has to work around the normal fishing operations and sampling opportunities are governed by the quantity of different data sets they are trying to observe and collect, how fast the crew process a string and how far it is to the next string. The video analyst can watch the same string or creel as often as they wish to collect their data set.

The percentage of males in the catch obtained by the video analyst and observer are often quite different. In Trip 365 the at sea observer sample contained 70% males whilst the video analysts value was 43%. Subsampling of the catch can lead to bias because the catches between strings can be highly variable in both numbers and sexes caught. The creel-by-creel comparison section described earlier clearly illustrated this variability when one creel caught 28 crabs whilst the creels on either side of it in the same string caught less than 5 crabs between them. However on some trips the percentage of males are similar, e.g. Trip 635 discarded brown crab and Trip 427 retained velvet crabs.

Table 3.14 Sex ratio data collected on the reviewed trips by both the video analyst and the at-sea observer for comparative purposes.

			Count Males		Count Females		% Males	
Trip	Species	Category	At-Sea Observer	Video Analyst	At-Sea Observer	Video Analyst	At-Sea Observer	Video Analyst
101	Brown Crab	Discarded	122	117	47	148	72	44
101	Velvet Crab	Discarded	108	66	54	136	67	33
101	Velvet Crab	Retained	92	57	32	205	74	22
180	Brown Crab	Discarded	50	134	54	117	48	53
180	Brown Crab	Retained	42	194	39	133	52	59
365	Brown Crab	Discarded	28	115	12	151	70	43
365	Velvet Crab	Discarded	24	22	53	23	31	49
365	Velvet Crab	Retained	84	23	16	78	84	23
400	Brown Crab	Discarded	86	444	85	731	50	38
400	Brown Crab	Retained	38	170	20	130	66	57
401	Brown Crab	Discarded	160	361	111	285	59	56
401	Brown Crab	Retained	37	74	21	19	64	80
427	Brown Crab	Discarded	34	53	33	19	51	74
427	Velvet Crab	Discarded	36	32	74	61	33	34
427	Velvet Crab	Retained	126	239	42	60	75	80
555	Brown Crab	Discarded	19	61	13	48	59	56
555	Brown Crab	Retained	30	109	19	104	61	51
635	Brown Crab	Discarded	24	245	15	184	62	57
635	Brown Crab	Retained	18	52	13	68	58	43

Which value is correct is difficult to assess. It is likely that because the video analyst is able to collect data throughout the whole trip and from all strings, that their estimate is more representative of the stock, but this assumes that there is no bias in visually sexing crabs. In other words, if it is harder to see a male crab flying through the air during discarding than a female crab then there will be more male crabs in the unsexed category, which would have been allocated to male if the two sexes could be identified equally as easily. This potential bias can only be assessed by carrying out a dedicated trip where all discarded crabs are kept and sexed. But even then this action of retaining the normally discarded crabs affects the way they are seen by the video analyst so it would be important to replicate a normal fishing trip to ensure that the video analyst is reviewing video footage that is representative of normal working procedures.

Lobster sex ratios were unable to be obtained through normal video review due to the difficulties in viewing the pleopods. Therefore it was not possible to verify any sex ratios provided by the skipper. The modified discard chute being explored in the sub project section may offer a more successful option for sexing lobsters.

Quality Assurance Exercise

As part of the project's quality control, 10% of the video reviewed by Seascope was given a second review by an external company. Archipelago Marine Research Ltd. was selected to undertake this process as they are one of the leading companies in the world involved in EM technology and monitoring programmes. It should be noted that this project is thought to be the first where EM systems have been trialled on small inshore creel vessels and scallop dredgers and therefore there was no one available with more experience of EM in these fisheries than Seascope to undertake this exercise. Therefore this QA is not about whether or not Seascope's estimates match those of AMR exactly but more about getting estimates that are similar to provide reassurance that review processes were being properly undertaken.

In addition, it should be noted that AMR is a west coast Canadian company and that their video analysts are highly experienced in Pacific based fisheries and are highly skilled at recognising Pacific species. They do have experience elsewhere in the world but this was the first time they have been involved in reviewing video from Scottish west coast inshore fisheries.

Only the video from the full-time creel vessels was reviewed. The video for the part time vessel was removed as catches were very low.

The results of the comparison can be seen in Table 3.15. The first thing to note is that all crab species had to be aggregated to allow the comparison to be undertaken. This was due to the high quantity of unidentified crab included in the AMR estimates, where the analyst felt unable to determine whether it was a brown crab or velvet crab.

Table 3.15 Comparison between the count data collected by the Seascope and AMR video analysts.

Trip	Total Crabs Seascope	Total Crabs AMR	AMR as a % of Seascope	Total Lobster Seascope	Total Lobster AMR	AMR as a % of Seascope
221	679	642	**95**	171	168	**98**
273	1559	1521	**98**	84	77	**92**
357	895	812	**91**	12	11	**92**
403	1887	1830	**97**	1	1	**100**
444	1269	1063	**84**	53	47	**89**
491	4	4	**100**	0	0	**100**
555	751	715	**95**	0	0	**100**

In all cases the AMR estimates were lower than the Seascope estimates. The lowest levels of agreement were on Trip 444 with crab having an 84% agreement and lobster an 89% agreement. This would suggest that there was some difficulty in viewing this trip that resulted in these lower values. All other comparisons had agreement levels higher than 90% with the closest agreement being 98% on Trips 273 for crab and 98% on Trip 221 for lobster. This excludes the 100% agreements where neither the Seascope or AMR analysts observed any crab and lobster being caught.

Differences may be down to such things as raising factors used or different levels of familiarity with the fisheries leading to some crabs being "missed" by the analyst. What is reassuring is that virtually all levels of agreement are higher than 90% agreement, indicating that video analysis is capable of counting high numbers of animals (e.g. over 1800 crabs on Trip 403) to a high level of accuracy. It was never expected that we would achieve an exact match on any of the trips because there are always different levels of experience between the analysts.

4. Sub-Projects

4.1 RFID Tag Project

Background

With over 1300 vessels (source: 2014 Vessel and Employment tables at www.gov.scot) operating in the Scottish inshore creel sector, establishing a robust means of monitoring fishing effort was deemed an important aspect of improving the quality and quantity of data for the data-deficient stocks. With an electronic monitoring and data-logging platform already aboard the project vessels, a technical solution to monitoring fishing effort was sought that would have minimal impact on crew gear handling procedures and safety. Whilst it is relatively simple and highly accurate to count the number of creels deployed and retrieved by reviewing the video footage, it can be time consuming when vessels are deploying and retrieving up to 1500 creels per day.

Similarly, whilst estimating soak time can be achieved within the data collected on the standard EM platform, the data can often be hard to interpret. For example, if datasets are split over 2 or more hard-drives it can be difficult, time consuming and therefore costly, to extract and verify these data.

For these reasons we looked at developing a relatively cheap and efficient add-on to the AMR EM hardware/software system that would allow these data to be collected and recorded directly onto the existing EM dataset. This was undertaken in conjunction with AMR.

Method

After completing a number of sea-days as part of this project a fairly consistent picture of gear deployment and retrieval was developed. During these sea trips the observer recorded video footage of the shooting and hauling activities, using both the EM system and separate hand-held devices. This video was shared with AMR to assist them in developing a RFID tag system that was both user-friendly and safe for fishermen to use without slowing down the fishing operations.

The system also had to be transferrable and relatively easy to install/uninstall so that it could be utilised on all creel vessels fishing any creel gear (from heavy parlour pots down to lighter-weight Nephrops creels), as well as on vessels that deployed gear both manually over the gunwale, or by self-shooting through a hatch located at the stern or side of the vessel.

With safety in mind we sought a technical solution that would allow both gear retrieval and deployment to be recorded (to determine accurate soak times) whilst acknowledging that gear deployment is the most dangerous aspect of fishing operations due to the inherent dangers of entanglement.

It was decided that using two independent RFID readers and RFID tags fitted on both the dahn buoys and all creels would allow data on gear retrieval and deployment to be gathered. On retrieval the first hauled buoy would be scanned so that the string could be identified.

Then creels would be scanned as they were hauled by running them over the top of an RFID reader located in line with the normal passage made by creels during the sorting process (Figure 4.1). In addition it became clear that the fishermen would require some form of acknowledgement of a successful reading or ‘swipe’ so that they could tell the creel had been registered on the system. Both audible and visual signals were considered, but again, mostly for safety reasons, the audible signal rather than the visual one (e.g. flashing LED) was fitted. This allowed crew to know that the gear had been recorded to the system successfully without the distraction of having to check a visual signal. As each creel was swiped the RFID tag’s unique identification number would flash up on the display screen in the wheelhouse to allow the skipper (if not on deck) to verify that the system was functioning correctly.

In consultation with AMR a prototype system was built to meet the above requirements. At component level the system comprised of;

- 2 Off-the-shelf RFID modules (ID Innovations) encased in an 18cm polyester resin block
- RFID system powered directly from EM on-board 12vDC power supply
- Electronic switch (housed in waterproof housing)
- 2 12vDC automotive buzzers
- Data transmission via RS232 connection and driver on EM control centre.
- 200 RFID tags (Figure 4.2)

Figure 4.1 The AMR designed RFID readers. A close up view of the shooting reader (left) and a view of both readers (right), with the haul reader just visible on the left side of the gunwale.

Figure 4.2 An RFID tag with hole to allow an attachment to the creels using a cable tie.

The system was successfully installed aboard the trial vessel on the 16th May 2015. During the installation process the RFID readers and EM system were thoroughly tested by swiping the tags over the readers and ensuring that the tags registered on the EM system display and that the audible signal (horn) was triggered. A 100% success rate was noted.

Sea trips were undertaken between the 25th and 28th May 2015 by an observer so that the RFID tags could be attached to the creels and buoys. These trips also allowed the observer to train the crews in the use of the new equipment and the procedure of swiping the dahn buoys during the shooting and hauling process and the creels during hauling. The creels were not to be swiped during shooting because it was deemed too dangerous as this would involve the fishermen handling the fishing gear during deployment.

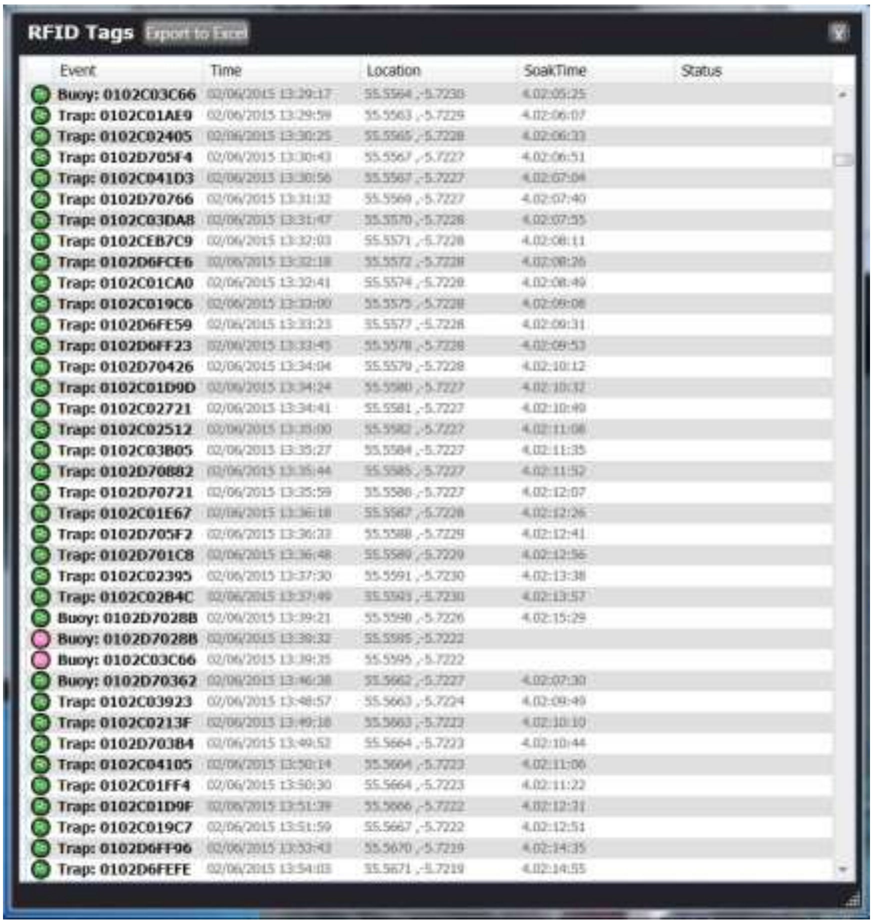
The basic swiping procedure during normal hauling is:

- Haul first dahn buoy and swipe on haul reader
- Haul creels and swipe each one on the haul reader as the catch is sorted
- Swipe final dahn buoy on haul reader
- Just prior to shooting, swipe both dahn buoys on shoot reader
- Deploy gear as normal

Results

A total of four strings each of 25 creels were fitted with RFID tags. They were deployed during the observer sea trips, between the 25th and 28th May. Over the next few weeks the fishermen repeated the swiping procedure for all RFID fleets and the data were recorded directly to the EM system. The trial finished on the 2nd July 2015.

Figure 4.3 shows a sub-sample of the data produced by the AMR EM system when coupled to the RFID tag sensors. When a tag is swiped on the Hauling reader the data is displayed with a green icon. It can be seen that the first record shown in the table of data is a green buoy. This means that the buoy was hauled and swiped on the Hauling reader. This is closely followed by 25 “trap” readings as the creels are hauled and swiped and then the second dahn buoy is hauled and swiped, completing the hauling operation. The two dahn buoys were then taken to the rear of the vessel where they were swiped on the “Shoot” reader (shoot icons shown in pink in figure 4.3) ready for immediate re-deployment. The vessel then continued to the next string and began hauling another dahn buoy and string of creels. Also displayed in the table are the haul positons of every dahn buoy and creel with a soak time. The soak time is calculated from the time the gear is deployed, provided by swiping the dahn buoys on the Shoot reader, through to when the dahns and creels are next swiped on the Haul reader. So in this example creel “Trap: 0102C01AE9” (the first creel on the string) was soaking for 4 days, 2 hours, 6 minutes and 7 seconds, or approximately 98 hours.



Event	Time	Location	SoakTime	Status
🟢 **Buoy: 0102C03C66**	02/06/2015 13:29:17	55.5564 ,-5.7230	4.02:05:25	
🟢 **Trap: 0102C01AE9**	02/06/2015 13:29:59	55.5563 ,-5.7229	4.02:06:07	
🟢 **Trap: 0102C02405**	02/06/2015 13:30:25	55.5565 ,-5.7228	4.02:06:33	
🟢 **Trap: 0102D705F4**	02/06/2015 13:30:43	55.5567 ,-5.7227	4.02:06:51	
🟢 **Trap: 0102C041D3**	02/06/2015 13:30:56	55.5567 ,-5.7227	4.02:07:04	
🟢 **Trap: 0102D70766**	02/06/2015 13:31:32	55.5569 ,-5.7227	4.02:07:40	
🟢 **Trap: 0102C03DA8**	02/06/2015 13:31:47	55.5570 ,-5.7228	4.02:07:55	
🟢 **Trap: 0102CEB7C9**	02/06/2015 13:32:03	55.5571 ,-5.7228	4.02:08:11	
🟢 **Trap: 0102D6FCE6**	02/06/2015 13:32:18	55.5572 ,-5.7228	4.02:08:26	
🟢 **Trap: 0102C01CA0**	02/06/2015 13:32:41	55.5574 ,-5.7228	4.02:08:49	
🟢 **Trap: 0102C019C6**	02/06/2015 13:33:00	55.5575 ,-5.7228	4.02:09:08	
🟢 **Trap: 0102D6FE59**	02/06/2015 13:33:23	55.5577 ,-5.7228	4.02:09:31	
🟢 **Trap: 0102D6FF23**	02/06/2015 13:33:45	55.5578 ,-5.7228	4.02:09:53	
🟢 **Trap: 0102D70426**	02/06/2015 13:34:04	55.5579 ,-5.7228	4.02:10:12	
🟢 **Trap: 0102C01D9D**	02/06/2015 13:34:24	55.5580 ,-5.7227	4.02:10:32	
🟢 **Trap: 0102C02721**	02/06/2015 13:34:41	55.5581 ,-5.7227	4.02:10:49	
🟢 **Trap: 0102C02512**	02/06/2015 13:35:00	55.5582 ,-5.7227	4.02:11:08	
🟢 **Trap: 0102C03B05**	02/06/2015 13:35:27	55.5584 ,-5.7227	4.02:11:35	
🟢 **Trap: 0102D70882**	02/06/2015 13:35:44	55.5585 ,-5.7227	4.02:11:52	
🟢 **Trap: 0102D70721**	02/06/2015 13:35:59	55.5586 ,-5.7227	4.02:12:07	
🟢 **Trap: 0102C01E67**	02/06/2015 13:36:18	55.5587 ,-5.7228	4.02:12:26	
🟢 **Trap: 0102D705F2**	02/06/2015 13:36:33	55.5588 ,-5.7229	4.02:12:41	
🟢 **Trap: 0102D701C8**	02/06/2015 13:36:48	55.5589 ,-5.7229	4.02:12:56	
🟢 **Trap: 0102C02395**	02/06/2015 13:37:30	55.5591 ,-5.7230	4.02:13:38	
🟢 **Trap: 0102C0284C**	02/06/2015 13:37:49	55.5593 ,-5.7230	4.02:13:57	
🟢 **Buoy: 0102D7028B**	02/06/2015 13:39:21	55.5590 ,-5.7226	4.02:15:29	
🔴 **Buoy: 0102D7028B**	02/06/2015 13:38:32	55.5585 ,-5.7222		
🔴 **Buoy: 0102C03C66**	02/06/2015 13:39:35	55.5595 ,-5.7222		
🟢 **Buoy: 0102D70362**	02/06/2015 13:46:38	55.5662 ,-5.7227	4.02:07:30	
🟢 **Trap: 0102C03923**	02/06/2015 13:48:57	55.5663 ,-5.7224	4.02:09:49	
🟢 **Trap: 0102C0213F**	02/06/2015 13:49:18	55.5663 ,-5.7223	4.02:10:10	
🟢 **Trap: 0102D703B4**	02/06/2015 13:49:52	55.5664 ,-5.7223	4.02:10:44	
🟢 **Trap: 0102C04105**	02/06/2015 13:50:14	55.5664 ,-5.7223	4.02:11:06	
🟢 **Trap: 0102C01FF4**	02/06/2015 13:50:30	55.5664 ,-5.7223	4.02:11:22	
🟢 **Trap: 0102C01D9F**	02/06/2015 13:51:39	55.5666 ,-5.7222	4.02:12:31	
🟢 **Trap: 0102C019C7**	02/06/2015 13:51:59	55.5667 ,-5.7222	4.02:12:51	
🟢 **Trap: 0102D6FF96**	02/06/2015 13:53:43	55.5670 ,-5.7219	4.02:14:35	
🟢 **Trap: 0102D6FEFE**	02/06/2015 13:54:03	55.5671 ,-5.7219	4.02:14:55	

Figure 4.3 Data produced by the AMR EM system when coupled to the RFID tag sensors.

The collected data can also be displayed graphically on the EMI Pro software. Figure 4.4 shows the data collected for 2 strings fished on the 2nd June. The top chart shows the data displayed in the normal EMI Pro screen, prior to any annotations for trips or hauls and without RFID tag data displayed. The bottom chart has the RFID tag data added to it which indicates the location and a count of all creels hauled.

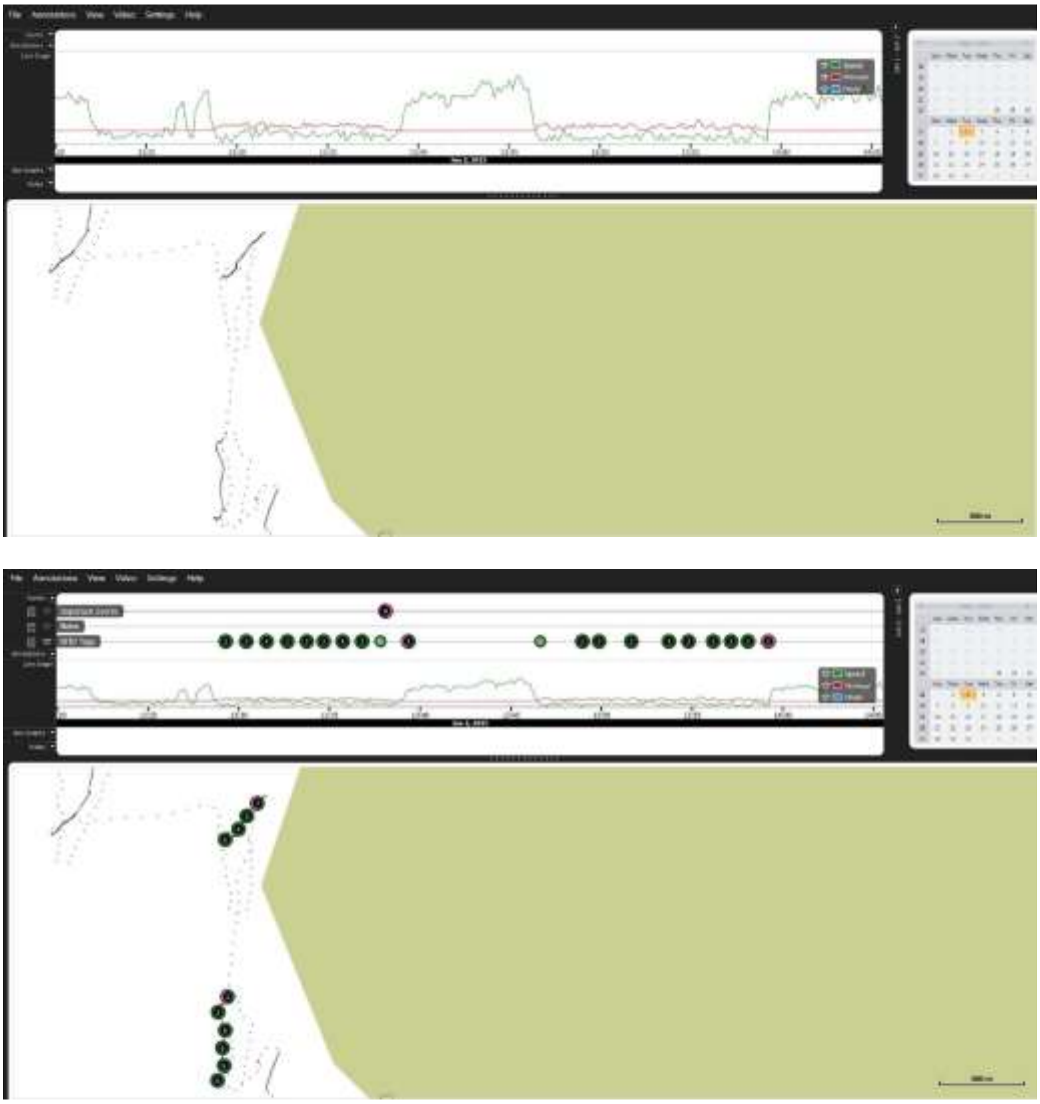


Figure 4.4 Comparison between the EMI Pro chart display with (bottom) and without (top) RFID tag data attached.

When the fishermen first undertook this work there was an issue regarding the swiping of the tags. When the tags were dry they worked perfectly however when the fishermen hauled the first string back he found that multiple attempts were required to obtain a successful swipe and that this was slowing down his creel processing. On investigation it was apparent that the seawater coating that was adhering around the RFID tags and/or reader can detune and shield the RFID reader antenna sufficiently to reduce the reader range by a significant extent. This necessitated moving the reader to a different mounting location on-board of the vessel, away from any vessel structure that could potentially affect the range of the readers. The new position also reduced the distance between reader and tags by mounting it flush with the sorting platform. The initial installation had the haul reader fixed to the under-side of this platform with approximately 70mm of glass reinforced plywood between the reader and the top of the platform. This effect can be explained by the conductivity of seawater, however the extent of range reduction was unexpected and is a valuable result of the trial.

Under dry conditions a reading range of 100-150mm was achievable; this was reduced to 50-80mm under wet saltwater conditions. If future deployments in greater numbers are planned, a follow-up reader design will contain a higher power output stage to compensate for this effect.

In the final stages of the trial, the “shoot” reader and one of the horns became entangled in a rope during shooting and the shoot reader was irreparably damaged. This is not necessarily a system fault, but rather an installation flaw. Readers should have been situated completely away from all moving gear but handy enough to allow easy access by the fishermen. Nevertheless the reader was not a hazard for 4-5 weeks and on an under 10m vessel it is quite difficult to avoid being too close to the gear. A redesign of the shape of the readers could eliminate this issue. There is no reason why the shape and size of the reader is not determined individually and to suit the deck layout of each vessel accommodating the equipment.

The trial showed that an RFID tag system is perfectly able to link to the EM system and provide accurate and automated soak times for every creel and string deployed (assuming they have a tag fitted). However the success of this system relies on two other crucial elements: the reliability and durability of the on-deck RFID equipment; and the performance of the fishermen. The software needs to be able to interpret when a creel or tag is lost and has been replaced; the equipment installed on the deck needs to be durable, compact and have a suitable range for the vessel layout and handling procedures; and the issue of salt water reducing the range needs to be addressed. However if the fishermen does not swipe the tag correctly and according to procedure, then the correct data cannot be collected in the right order and this is likely to make data interpretation less automated and therefore less user friendly.

If EM was to be considered as a routine data gathering tool aboard the inshore fishing vessels then an integrated RFID system is recommended because it can provide accurate trip, string, creel and soak time data automatically linked to position and time. Ideally this can also be linked to video data and verified self-reported catch estimates (or video analyst catch numbers) to obtain catch per unit effort data at location.

4.2 Weighing Catch Components At Sea

Background

Seascope staff have been heavily involved in testing the use of EM systems aboard fishing vessels in the UK and developing operating procedures for video review. Obtaining weights for the different catch components was noted as one of the more difficult pieces of catch information to gather. Estimating weight of catches visually can be problematic as it uses observed estimated volumes and converts them to weights based on known full basket weight estimates. For example, if a full basket of cod is thought to weigh approximately 30kg then a ¾ basket is 22.5kg. However this approximate weight can vary between species and the observer has to estimate how full a basket actually is.

On larger vessels motion-compensated scales are used by fishermen when packing retained fish into fish boxes in the fish holds. They have also been used by research vessels carrying out stock assessment surveys and by observers carrying out research projects on larger fishing vessels.

Therefore it was intended that an investigation into using motion-compensated scales aboard inshore vessels to enable fishermen to self-report accurate weight data would be undertaken. The EM technology would be used to verify activity of the fishermen whilst undertaking the weighing and to verify the weights obtained. If possible the integration of the weighing platform into the EM system would also be investigated.

The aim of this sub-project was to "allow accurate weights of retained and discarded catch to be obtained and to verify self-reported weights".

Method

Two different sets of motion-compensated scales were sourced and trialled and it was felt that the Pols P15 motion compensating scales (Figure 4.5) were the most suited to our needs. These scales were mains powered and could weigh to the nearest 0.1kg. A shore based trial was undertaken and the scales were found to be working correctly and obtaining weights accurately and quickly in accordance with their specifications. This allowed us to progress to sea trials of the system.

The MFV Atlantis was selected from the participating vessels as the most suitable vessel to undertake this subproject because it had a large deck space area to accommodate the scales. Sea trials were undertaken on the 20th and 21st May 2015.

Verification of all weights obtained would be through the use of the CCTV video footage. The video reviewer would watch each weighing process and view the display unit of each weighing system to read the weights and check against those supplied by the fisherman, and to ensure that the scales were not being interfered with e.g. something caught under the weighing platform. They would also check that the fisherman was leaving the catch on the scales long enough for a reading to be obtained.

Figure 4.5 POLS P15 motion compensating weighing scales.

Results and Discussion

Shore-based Trials – During these shore based trials, the scales were tested in the following way.

- 30 weighing repetitions of a 5kg reference weight
- Display visibility was assessed through video review.

The scales weighed the 5kg reference weight to exactly 5kg on all repetitions. This was expected, as these trials were conducted in a dry, windproof and stable environment.

The visibility of the display unit was crucial if verification of any weights taken was to be carried out using CCTV. The shore based trials highlighted that the normal red LED display was very blurry when viewed. However by adding some brown tinted film to the front of the display unit, this glare was removed and the display could be easily read. It was therefore attached to the front of the display units for future sea trials.

Sea-based Trials – Day 1 of this trial was conducted on the MFV Atlantis on the 20th May 2015. The scales were taken to sea and were set up and tested. A power cable was run from the wheelhouse through to the scale location on the deck. The weather conditions on this day were approximately wind force 4-5 with a large SW swell. Unfortunately it soon became apparent that it would be impossible to operate the scales in these circumstances because the motion of the vessel was so rapid and unpredictable that obtaining a weight would be impossible. The skipper was also not willing to risk the chance that the scales would get caught on the ropes during fishing operations and also thought there was a safety risk associated with mains powered scales on a wet and rolling platform. Therefore the trial was abandoned shortly after sailing and instead the sea trip became a routine sampling and control data collection trip.

The following day the trial was repeated but again weather conditions were unfavourable and the same safety concerns still applied. It was therefore decided to abandon this trial until weather conditions were more favourable and perhaps should be undertaken on a vessel that was less lively. However this opportunity never arose because on returning to port it was decided that the safety issues regarding entanglement of scales with ropes and power issues would not be remedied irrespective of weather conditions or vessel used.

Conclusions

The shore based trials showed that the EM cameras were capable of viewing and therefore verifying any weighing processes undertaken and that motion-compensated scales can provide a suitable weighing platform. However these scales need to be compact and battery powered for short term trials. If weighing was required on a long term and daily basis, then they need to be integrated with the vessel's power supply systems and the siting of the scales needs to take into account the vessel's deck layout and fishing operations to avoid safety issues. Perhaps a specifically dedicated project would be able to design an integrated weighing system that links to EM systems, the vessel's power supply and is flexible enough to suit different vessel designs and fishing practises.

4.3 Data Storage Tag (DST) Trial

Initially four sub-projects were to be carried out as part of this project, but because the weighing at sea trial was abandoned due to safety and operational concerns, it was decided to undertake an additional subproject. Sea bottom temperature is an important factor in determining catch rates in creel fisheries. Lobster and crab activity is temperature dependent and during periods of low water temperature crabs and lobsters exhibit little movement and are therefore less likely to enter the creels. This was further supported by the participants who had expressed concerns that the project was running through the winter and spring, which was traditionally their low season when crab and lobster activity was at its minimum.. Therefore it was decided to trial the use of a data storage tag (DST) to determine if useful temperature at depth data could be collected and linked to the AMR software to show temperature at depth at location.

The G5 DST (Figure 4.6) was purchased from Cefas Technology Ltd. It was able to record temperature, pressure, date and time, for over 10 months and at depths up to 100m. These pressure data were converted to depth to provide temperature at depth. More detailed specifications can be found at http://www.cefastechnology.co.uk/products_tags_g5.htm .

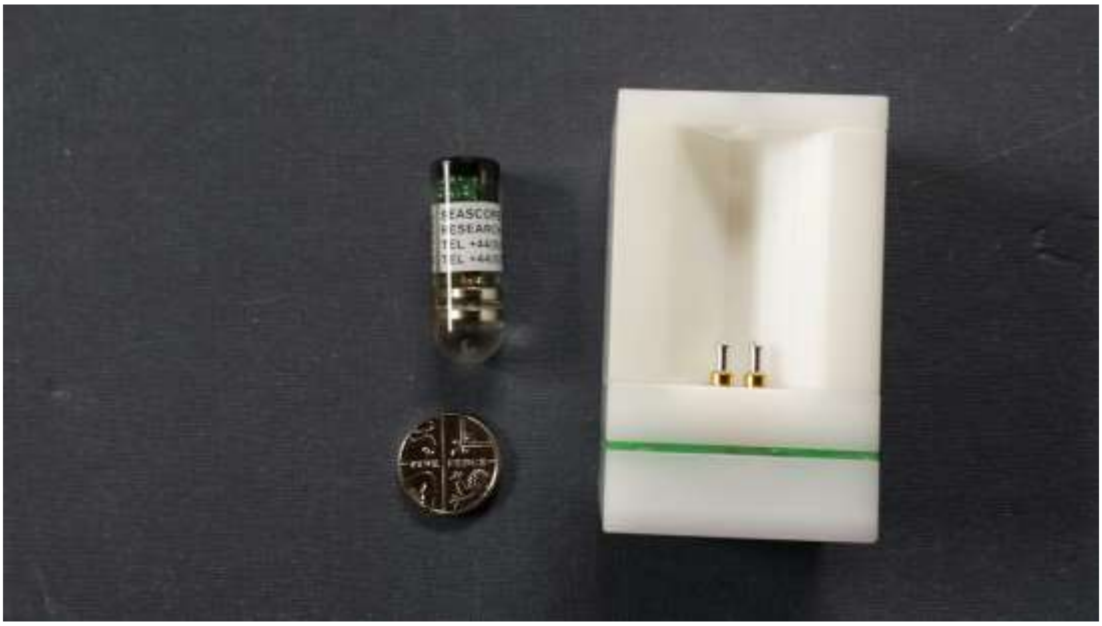


Figure 4.6 A G5 Data Storage Tag manufactured and supplied by Cefas Technology Ltd. Also shown is the data transfer dock and a British 5 pence piece for scale.

The Bright Horizon agreed to trial the DST. On the 19th June, the tag was configured to record data every 5 minutes and was attached to a lobster creel on the 20th June. This creel was taken to sea and attached to a string when it was hauled, and then shot away. The shot date was reported by the skipper as the 22nd June. The inside of a creel was selected as the securest location for the tag because the netting would provide protection from the substrate, rocks and debris, although of course it was always possible that a crab or lobster may damage it, or the creel could be lost.

The DST recorded data between 1400 on the 19th June 2015 and 1755 on the 27th August 2015. During this period 15,600 readings of temperature and 15,600 readings of depth (pressure) were recorded. The outputs from the software included a summary table of the daily maximum and minimum values of temperature and depth (see Table A1 in Annex 1). These data were used to display depth (Figure 4.7) and temperature (Figure 4.8) for this period.

In Figure 4.7 it can be seen that the DST was actually deployed into the water on the 22nd June, confirming the deployment date provided by the skipper. Inspection of the full data set shows on the 22nd June between 1520 and 1525, the depth went from surface (0.34m due to air pressure) to 23.59m, indicating that the creel was shot during this 5 minute window. Figure 4.7 also shows that the depth of the DST was below 3m on a further 6 occasions during this time before being removed from the water permanently on the 13th August. Although a depth of 3m would suggest that the creel was still under the water, it is more likely that this is due to the air pressure or the weight of the netting or other creels lying on the DST. But checking these low depth values against the video collected using EM, it can be seen that the creel with the pressure sensor was hauled and re-shot on all of these occasions. It also allowed the exact location of tag deployment to be determined. Table 4.1 shows the time and date of deployment and recovery, based on pressure values, as well as a calculated submerged duration, to the nearest 5 minutes. All other differences between the maximum and minimum values shown in Figure 4.7 are due to the tidal fluctuations.

On the 12th of August the skipper was contacted and asked to remove the DST at the earliest opportunity so that the data could be downloaded. The temperature data from the 13th August onwards reached in excess of 40ºC and the pressure dropped to nearly 0 bar. This was because the skipper had removed the tag on the 13th August and it was now sat in the vessel's wheelhouse, beside the window. These extreme values compressed the other data shown in Figure 4.8 so these values were removed as it was already established that the tag had been removed.

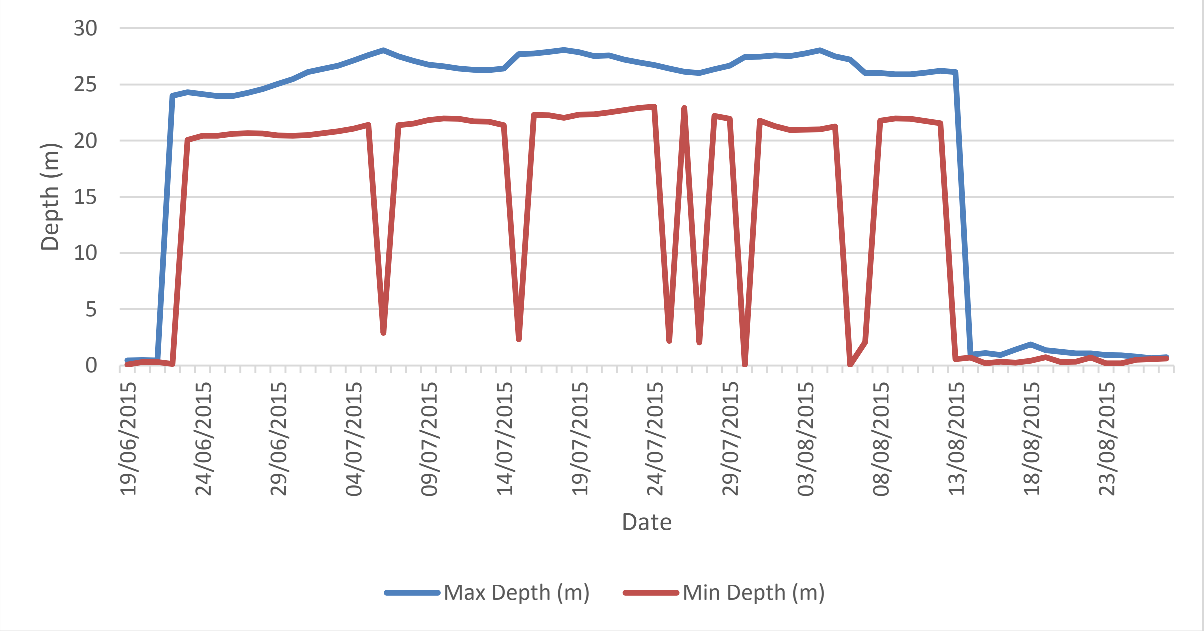


Figure 4.7 Depth profile for the G5 DST deployed from the Bright Horizon

Table 4.1 Time and date of deployment and recovery of DST deployed from the Bright Horizon, and calculated submerged duration

Deployment Number	Date/Time Deployed	Date/Time Recovered	Soak Duration (hrs)
1	22/06/2015 15:25	06/07/2015 06:45	327.33
2	06/07/2015 07:00	15/07/2015 16:55	225.92
3	15/07/2015 17:10	25/07/2015 12:20	235.17
4	25/07/2015 12:40	27/07/2015 13:55	49.25
5	27/07/2015 14:20	30/07/2015 16:20	74
6	30/07/2015 16:35	06/08/2015 16:15	191.67
7	06/08/2015 16:30	07/08/2015 09:50	17.33
8	07/08/2015 10:05	12/08/2015 17:55 to 13/08/2015	Not available*

* DST was programmed to cease recording every 5 minutes at 1800 on 12/8/15 and therefore exact soak time could not be calculated. However maximum and minimum pressures show that the creel was hauled for final time on 13th August 2015.

The temperature range once the DST had been deployed was very narrow between the maximum and minimum values, with the highest differences occurring when the creel was hauled aboard the vessel. However air temperature and water temperature at this time were very similar and the differences between the maximum and minimum values are small, especially when the DST is likely to be wet, in the shade and possibly being wind chilled, when removed from the water for only 10-15 minutes between hauling and re-shooting. The higher maximum temperatures at the start and end of the time series are caused by the tag being transported by car to the vessel at the start and sitting in the wheelhouse at the end. The bottom temperature ranged from 12.203°C on the 23rd June and rose steadily to 15.516°C on the 12th August.

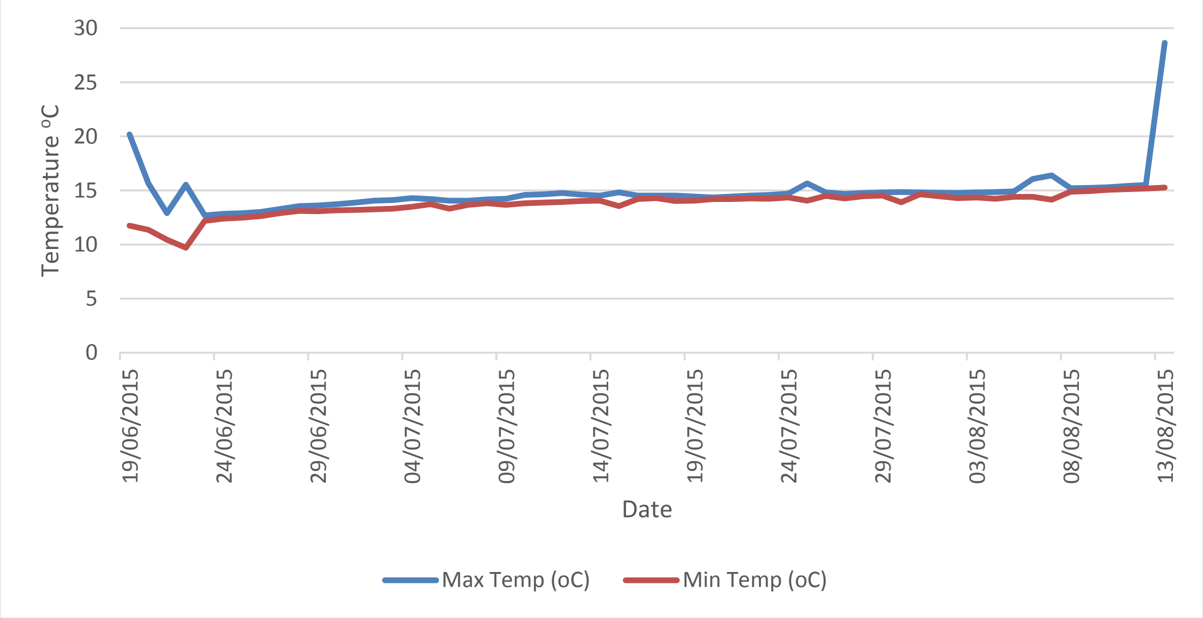


Figure 4.8 Temperature profile for the G5 DST deployed from the Bright Horizon.

Conclusion

The bottom temperature data collected should be useful information for scientists. It can be plotted against catch rates to give indications of when higher catches can be anticipated due to increased activity of crabs and lobsters, or used to compare differences between the timing of annual sea warming processes, which could impact on spawning, larval transport, survivability and therefore stock abundance and distribution.

If all the creel vessels on the west coast of Scotland deployed 2 or 3 DSTs they would produce millions of temperature values all around the coast that could be used by oceanography institutes and meteorological departments, to detect sea current changes and perhaps predict or detect weather pattern fluctuations.

The pressure sensor of the DST was very accurate in detecting when the DST creel was submerged and when it was out of the water. It could record to the nearest 5 minutes the total submergence time. If the DST was configured to record data more frequently then it could even be to the nearest minute, second or fraction of a second. Although of course recording to this resolution would be detrimental to the battery life, available memory and therefore deployment time.

As mentioned in earlier sections, establishing the soak time for each string using the AMR EM system was difficult because of how close the strings were shot together and the process of hard drive swapping. One of the sub-projects was investigating RFID technology to count creels and record soak times directly to the EM system. However the pressure data collected by the DST can also be used to detect when shooting and hauling of gear occurs and can therefore be used to provide soak times. If every string shot had a DST set to record pressure every 5 minutes then all soak times (and count of strings deployed) could be collected relatively easily and cheaply.

4.4 Modified Chute and Virtual callipers to measure and sex discarded crabs and lobsters

Background

Fishermen on creel vessels generally sort the catch direct from the creel, rather than putting the whole catch into a box or hopper and sorting it later, as is usually done in trawling. This meant that the discard catch was potentially unavailable for viewing using CCTV. If fishers were to retain undersize crabs on board to allow some form of self-sampling it could be contrary to fisheries regulations and would potentially require a dispensation before it could occur.

Counts, lengths and sex ratio data are especially difficult to collect because fishermen cannot be expected to measure and sex a crab whilst emptying a creel, or be able to remember exactly how many crabs were discarded on every creel, especially not when the vessels can fish in excess of 500 creels a day. Therefore it was decided to try and design a prototype modified discard chute that would allow the EM system and video cameras to collect data that could help supply this information more readily. The chute was primarily to be designed to collect brown crab data because this is the species with the highest abundance and therefore hardest for the fishermen to sample. Lobster data was thought to be easier to self-sample because of the low numbers usually caught and it was expected that any design capable of collecting brown crab data may also be able to collect velvet crabs data, due to their general shape similarities. It was also hoped that lobster data could be collected, despite the morphological differences between lobsters and crabs.

Method

The initial design for the first chute consisted of a sheet of 10mm clear acrylic sheeting 500mm x 200mm with engraved longitudinal 1 cm increments. This was fixed to a similarly sized aluminium plate with an engraved laminate top, configured in a v shape (Figure 4.9). The aluminium section had a cut-out section which housed a mirror to allow the bottom view camera to not only allow an estimate of off-set (discussed later in section) to be made, but to also determine sex of animals passing over that section of the chute. Initial trials on land indicated accurate length estimates and the ability to sex shellfish on the shoot were possible. The chute was fitted to a wooden frame with 2 x Vivotek FD8134 IP cameras affixed at appropriate viewing angles to maximise the potential of collecting length estimates. One camera was mounted above the chute looking down perpendicular to the laminated sheet with calibration points engraved to determine carapace width. The second was orientated 90 degrees from the top camera and mounted below the chute to determine height above the scale and sex. An example of the views achieved is shown in Figure 4.10.

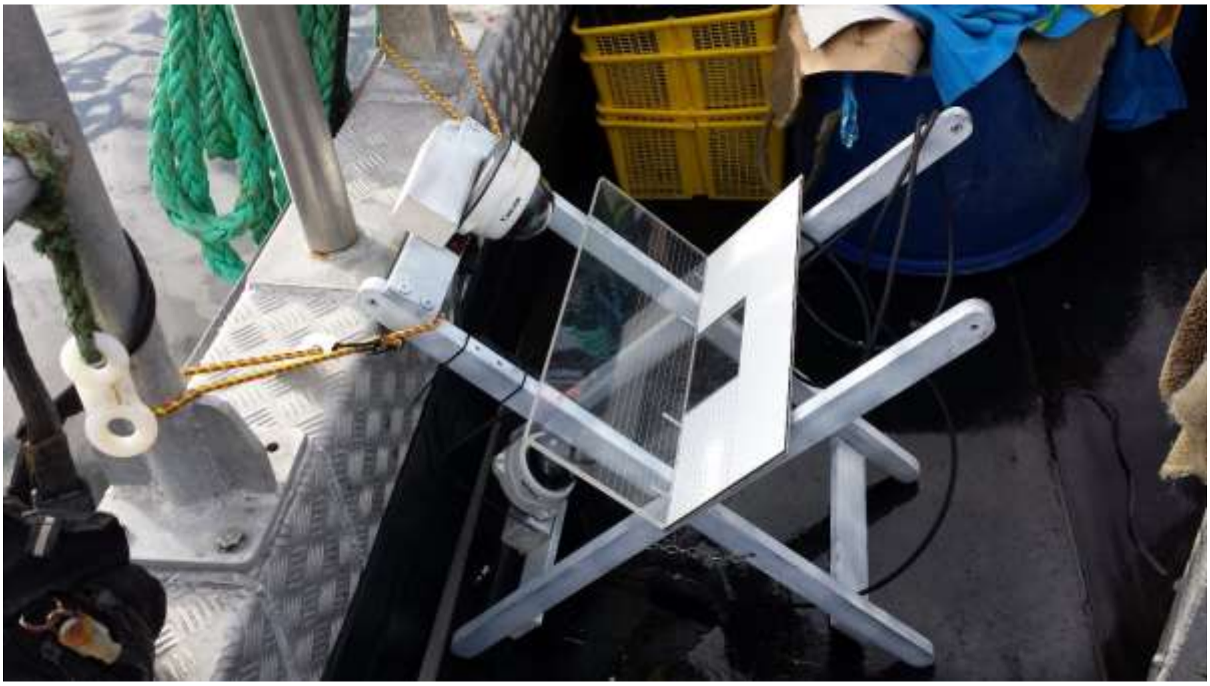
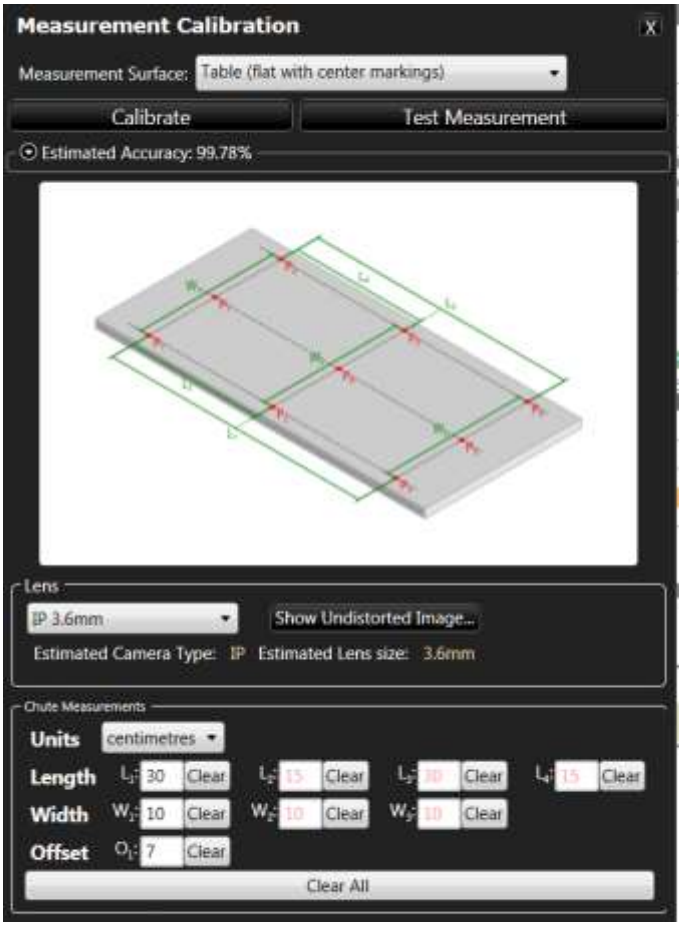


Figure 4.9 Chute 1 in-situ on fishing vessel.

The main focus at this point in time was on whether or not accurate estimates of length could be made using video imagery. With this in mind the camera used for estimating lengths was located fairly close (35cm) from the calibrated surface on which the shellfish would be observed. Testing in an office environment indicated that for lobsters at least, a good clear view (preferably side on) was the best option for the video analyst to be able to pick out the morphological features needed to estimate carapace length (i.e. the eye socket and edge of the carapace).

Figure 4.10 The 2 camera views required to determine carapace length from 1st chute design, Image of lobster against calibrated surface (left) and view of underside (right) to determine sex and off-set (distance above calibrated measuring platform).

The AMR analysis software (EMIPro) used in this project came with an integrated measurement estimation tool. In order to be able use the tool the video images collected require a camera view where animals can be viewed and assessed for length against a calibrated background along with an estimate of how high above the calibrated surface the measurement is collected (offset), as well as the camera lens size specification. Figure 4.11 below illustrates the calibration page within the EMI software.



Measurement Surface: Table (flat with center markings)
Estimated Accuracy: 99.78%
Lens: IP 3.6mm
Estimated Camera Type: IP Estimated Lens size: 3.6mm
Units: centimetres
Length L_1: 30 L_2: 15 L_3: 30 L_4: 15
Width W_1: 10 W_2: 10 W_3: 10
Offset O_1: 7

Figure 10 Length estimation calibration page within the EMI software.

Upon review of some of the initial video data collected with the 1st chute it became apparent that when the camera is located so close to the measurement surface, the offset figure required to calibrate the cameras need to be adjusted for each measurement taken. Similarly, the estimated lengths generated by the AMR software could vary significantly (up to 10mm) with only slight differences in the off-set measurement entered (+/- 5mm).

As such, a 2nd chute was designed (Figure 4.12) which would reduce the effect of the off-set estimation, by having the measurement camera further away (70cm) from the calibrated measuring surface. A section of this chute was also fully enclosed on both sides and top, with a clear acrylic sheet as the base. This was done to reduce the influence of outside light affecting the quality of the imagery for determining sex. This design utilised 3 IP cameras (1 for length estimation, 1 for offset estimation and the 3rd for sex determination). The design also incorporated a hinge at the bottom end of the chute to allow different gradients to be trialled. Examples of the camera views for assessing species, length and sex are shown in Figure 4.13.

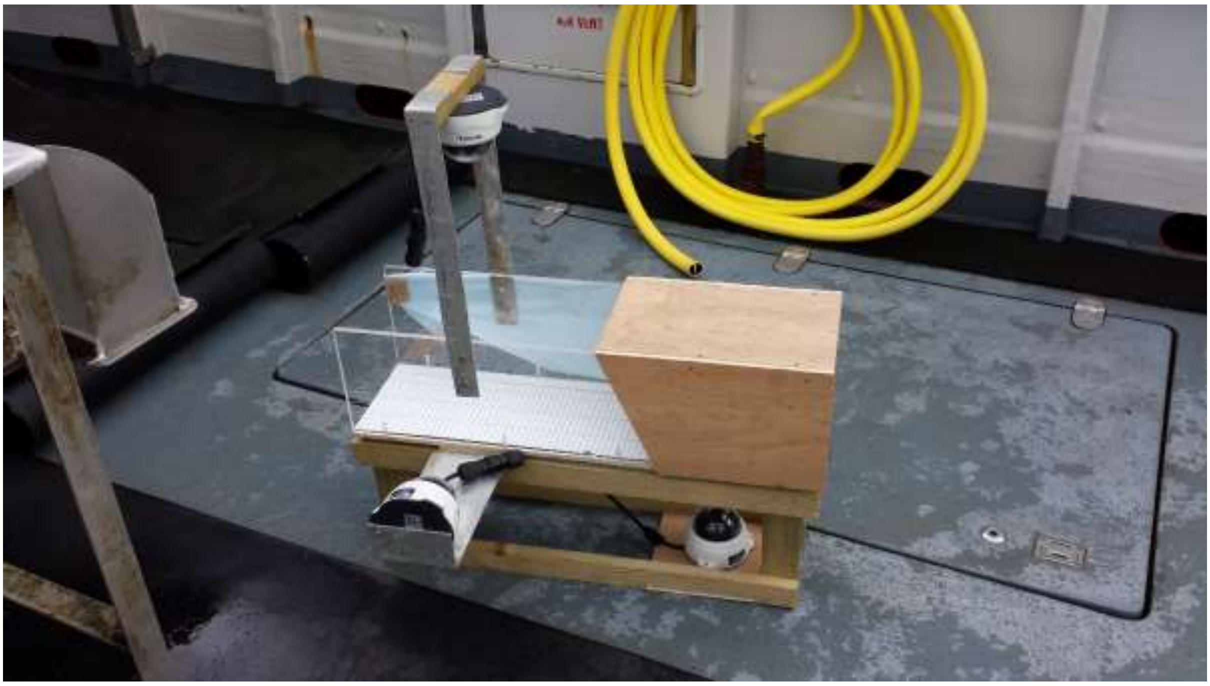


Figure 11 Chute 2 general layout.

Figure 12 Chute 2 camera views showing (from left to right) the measurement camera view, the off-set camera view and the sex determination camera view.

Results

The first prototype, Chute 1, was tested on land in an office environment (using cooked lobsters and crabs) to determine whether the cameras could accurately record footage of the shellfish in a way that allowed the species and sex to be identified and a length measurement to be made using the in-built on-screen calliper tool. At this stage, the design was not about how the shellfish could be automatically delivered to the camera viewing area, but about whether the data could be collected when they were in the field of vision. The cameras were adjusted and calibration measurements fine-tuned until all carapace measurements could be made to within 1 millimetre of the true measurement.

The next stage of testing was to take Chute 1 to sea on a vessel targeting brown crab, to observe how it performed under real conditions. Testing was conducted on the same vessel for 4 days to assess reliability and ruggedness of the chute and the attached cameras, as well as to look at practical issues such as wiring routes, deck space and securing the chute to the vessel. Despite the chute being of a relatively flimsy design at this stage, no issues were encountered with the chute relating to ruggedness or reliability of the camera system. The system worked perfectly for all 4 days.

During the trial, crabs and lobsters were sexed and measured manually using Vernier callipers and then placed on the chute in the correct position in view of the 3 cameras, to allow video data to be collected. The at-sea observer varied the orientation of the shellfish to allow different views to be recorded that could help inform future design modifications regarding how shellfish are presented to the cameras as well as how they react whilst on the chute. During the trial some of the video was reviewed and it was noted that there were issues regarding lighting. Significant glare from the sun was creating a silhouette effect on the crabs and lobsters as well as reflecting off the white deck to shine into downward facing cameras. The light levels were also fluctuating rapidly caused by the motion of the vessel creating rapid changes between completely shaded to fully-illuminated within seconds. To try and resolve this issue and stabilise the light levels, a cover was fabricated that could be lifted to allow the shellfish to be placed on the chute, replaced to allow footage to be recorded and then lifted to allow the shellfish to be removed.

At the end of the trial the chute was removed from the vessel and the hard drive was removed from the EM system, to allow the video to be reviewed ashore. During the review process the video analyst’s objective was to identify the number of individuals placed on the chute, the species and sex of each individual and to obtain a length measurement for each crab or lobster observed.

The second trial was conducted on a different vessel which mainly targeted lobsters. The chute had been redesigned to try and alleviate the light issues encountered during Trial 1. It was also modified to allow the delivery of the crabs and lobsters to the video cameras to be more automated. The new design had a holding area container (large bucket) where the shellfish were placed after being measured, and this was attached to an angled slide with the video cameras attached. The idea was that the shellfish would crawl or slide out of a hole in the container, walk on to the angled slide and slip down past the cameras into a fish box or even through the scuppers (if discards). The angle of the slide could be changed to alter the speed at which the shellfish passed the cameras. Only 1 trip was completed during Trial 2 because the vessel was mainly targeting whelks at this time, poor weather conditions had cancelled several previously planned trips and the project was coming to an end.

Count Comparisons **–** Table 4.2 shows the total number of shellfish observed during video review. The first trial consisted of 4 trips and the second trial consisted of 1 trip. On all 5 trips the brown crab and lobster counts were identical between the video analyst and the at-sea observer. Velvet crabs counts were identical on all but one of the trips, where the at-sea observer reported 11 crabs placed on the chute but the video analyst only counted 9. This demonstrates that even this “homemade” prototype allows the EM system to record video of sufficient quality to allow accurate counts to be made.

Table 4.2 Comparison between number of shellfish placed on the modified discard chute and the number observed on the chute during video review by the shore-based analyst.

	Brown Crab		**Lobster**		**Velvet Crab**	
Trial Trip	Video Analyst	At-Sea Observer	Video Analyst	At-Sea Observer	Video Analyst	At-Sea Observer
1	25	25	89	89	0	0
2	30	30	68	68	1	1
3	41	41	81	81	3	3
4	74	74	80	80	9	11
5	61	61	421	421	21	21

The ability to provide imagery that allowed the sex of the crab or lobster to be determined was also a requirement of the modified discard chute. Table 4.3 shows the number of sexed crabs and lobsters observed by the video analyst and is compared to the at-sea observer’s records.

Sex Identification **–** In Trial Trip 1 there was an exact match between the numbers of male and female brown crab observed, 9 females and 16 males, however lobster was less successful and only 22 out of 99 lobsters caught were able to be sexed by the video analyst using the *pleopod* observation method of sexing. The sexing of lobsters did not improve on the subsequent trial trips and by the fifth trip the video analyst had abandoned trying to sex lobsters due to the time that it was taking to produce poor results. Sexing of the brown crab on the rest of the trips was not as successful as on Trial Trip 1 and there was an increase in the number of unsexed crabs. The least successful brown crab result being on Trial Trip 3 where nearly 50% of brown crabs were unsexed. This low success rate was attributed to the issues regarding light and the produced silhouette effect discussed earlier. Chute 1 was modified on Trial Trip 4 and the results improved to 21% unsexed for brown crab. The video analyst did not attempt to sex the velvet crabs during video review until Trial Trip 5 where the results were extremely encouraging as only 2 velvet crabs could not be sexed (<9% unsexed). Figure 4.14 below shows improved sex determination camera view from chute 2.

Figure 13 Sex determination camera view (brown crab female).

Overall 48 brown crabs could not be sexed out of a total of the 231 placed on the chute, which gave a success rate of 79%. Lobsters were only sexed on approximately 15% of observations (excludes Trial Trip 5 where no sexing was attempted) and although velvet crabs were sexed on approximately 90% of viewings the number of observations was low.

Table 4.3 Sex ratio data collected by the at-sea observer during chute trials and the video analyst during the subsequent video review.

		Brown Crab		**Lobster**		**Velvet Crab**	
Trial Trip	Sex[1]	Video Analyst	At-Sea Observer	Video Analyst	At-Sea Observer	Video Analyst	At-Sea Observer
1	B	-	-	12	22	-	-
1	F	9	9	-	33	-	-
1	M	16	16	10	34	-	-
1	U	-	-	67	-	-	-
2	B	-	-	2	11	-	-
2	F	11	16	-	24	-	-
2	M	12	14	1	33	-	1
2	U	7	-	65	-	1	-
3	B	-	-	2	18	-	-
3	F	10	21	-	24	-	2
3	M	11	20	6	39	-	-
3	U	20	-	73	-	3	1
4	B	-	-	5	8	-	-
4	F	18	26	2	35	-	2
4	M	40	48	10	37	-	9
4	U	16	-	63	-	9	-
5	B	-	-	-	1	-	-
5	F	34	37	-	155	1	1
5	M	22	24	-	264	18	20
5	U	5	-	421	1	2	-

[1] Sex descriptors, B = Berried, F = Female, M = Male and U = Unsexed

Other trials using this technology have had high success rates in sex identification of brown crab and lobster (Holt *et al*, 2015) and the at sea crab handling principles were similar to those used in Chute 1, i.e. shellfish were placed in the optimum viewing position when possible. The design objectives for our Chute 2 design (tested on Trial Trip 5) were focused on self-delivery to the viewing area and processing large numbers of individuals. The theory being that although not all individuals discarded would be able to be sexed and measured, a high number could be processed over a long time frame. For example if a vessel took the chute to sea for a year and only 10% of discards could be processed by the chute, the sampling levels would be huge compared to the current observer programme sampling levels. If 100 vessels were to carry a chute (or even two chutes, one for retained and one for discards) then perhaps the data deficiency issues may be improved upon.

Length measurements – During the trial trips the at-sea observer measured all crabs and lobsters placed on the chutes. During the video review the video analyst also attempted to measure the crabs and lobsters using an on-screen measuring tool (a sort of virtual set of callipers). This tool uses calibration points to assess the width of the animal and “offset” factors to account for the height of the animal, when it passes under the video cameras. A view from the offset camera (with an estimated offset of 5 cm) is shown in Figure 4.15.

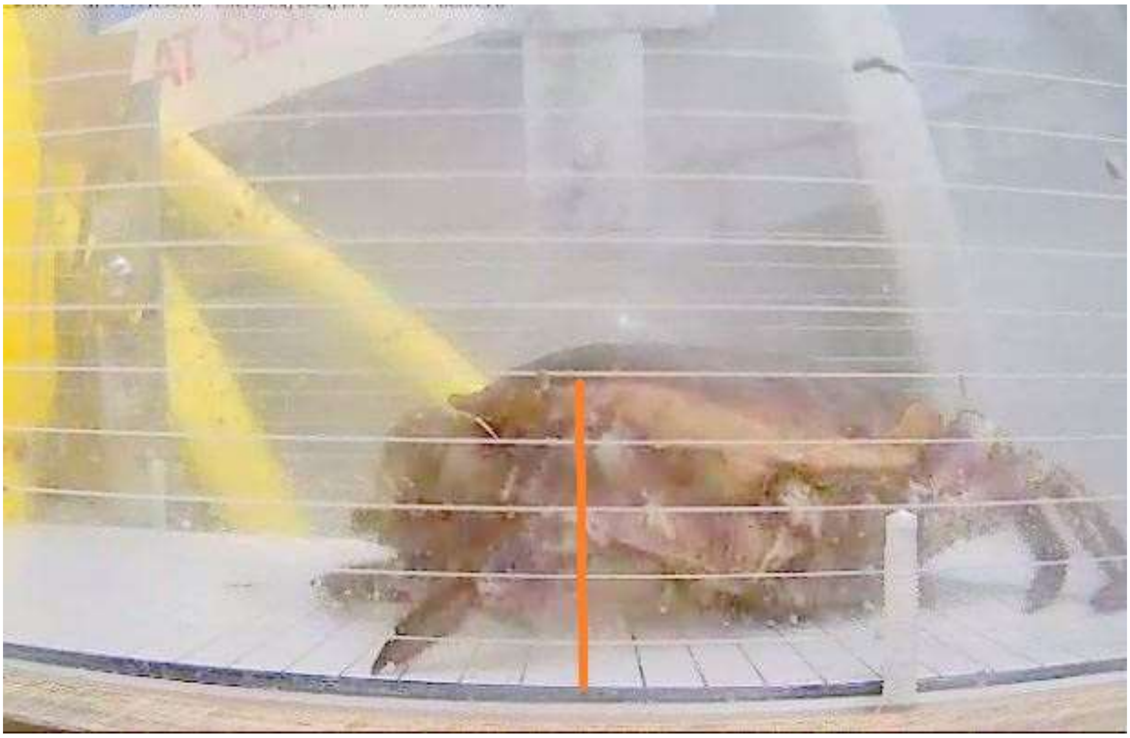


Figure 4.14 Offset camera view with an overlay showing height of carapace above calibrated platform.

With crabs and lobsters being very much alive and active during this process, the cameras needed to be able to provide clear and sharp video imagery that when paused, could allow the eye socket and distal end of the carapace (lobster) and the outer edges of the carapace (brown crab) to be clearly identified (Figure 4.17). Add in the sliding effect generated by the gradient built in to Chute 2, then this becomes a challenging task. Nevertheless in most cases the video analyst was able to obtain a length measurement in over 70% of samples, the exceptions being brown crab on Trip 1 (48%), lobster on Trip 4 (51%), and velvet crab on Trip 3 (67%) (Table 4.4). No data was presented for lobster caught on Trip 5 as length measurements were not attempted.

Figure 4.16 shows a captured still image from video data of a brown crab on the calibrated platform with calibration points P1-P9 overlaid.

Figure 15 Brown crab on chute 2 with calibration points overlaid

Table 4.4 Percentage of the shellfish observed on the modified discard chute by the video analyst, where a length or width measurement could be obtained.

Trial Trip	Brown Crab	Lobster	Velvet Crab
1	48	88	None Caught
2	97	75	100
3	73	70	67
4	70	51	100*
5	70	NA	76

* Although the at-sea observer recorded 11 length measurements for velvet crabs on this trip, the video analyst only observed 9 of these but attempted to measure all 9, hence the 100% value presented.

To determine the accuracy of the on screen measurement tool, each crab or lobster measured at sea needed to be compared against itself when measured on the screen. To do this each animal was given an order number at sea when it was measured to allow a comparison at individual level to be made. The results of these comparisons are shown in Figure 4.18. The last trip (Trial Trip 5) was not conducted in the same way because the crabs and lobsters were thrown into the container attached to the chute and allowed to climb or slide down past the cameras randomly in whatever order they exited the bucket. This was to present a more realistic picture to the video analyst of what may happen if something like this chute was introduced to the fleet. Only crabs were measured on this 5th trip and the video analyst was able to match the animals measured ashore to those measure at sea. In a normal situation though this matching would not be necessary as the measuring system used would already be fully tested and calibrated for accuracy.

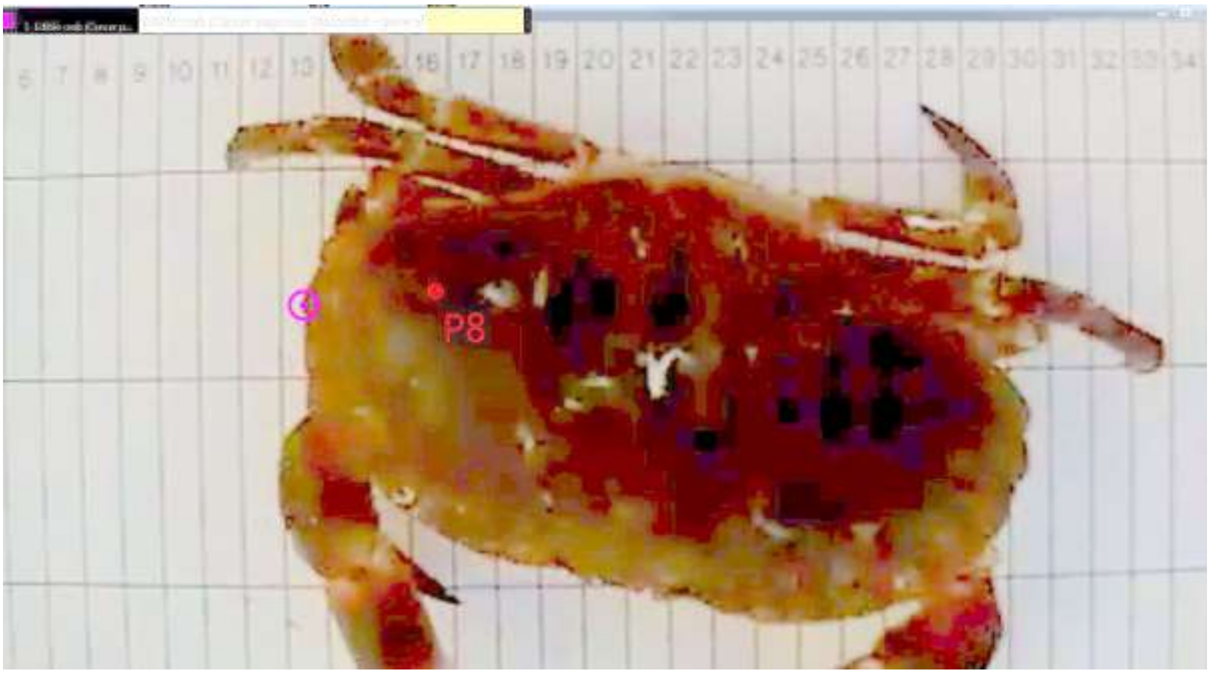
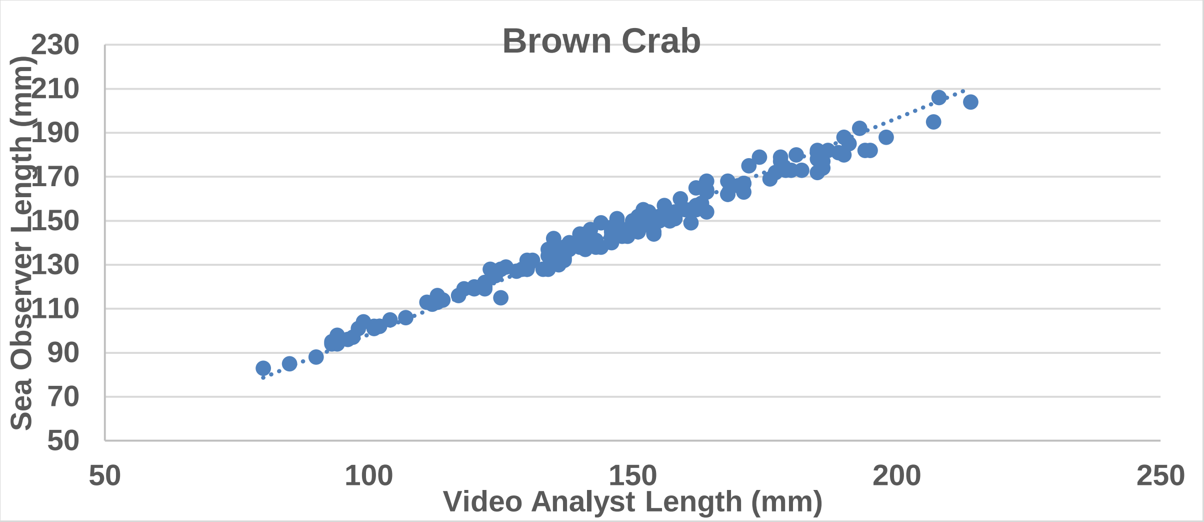
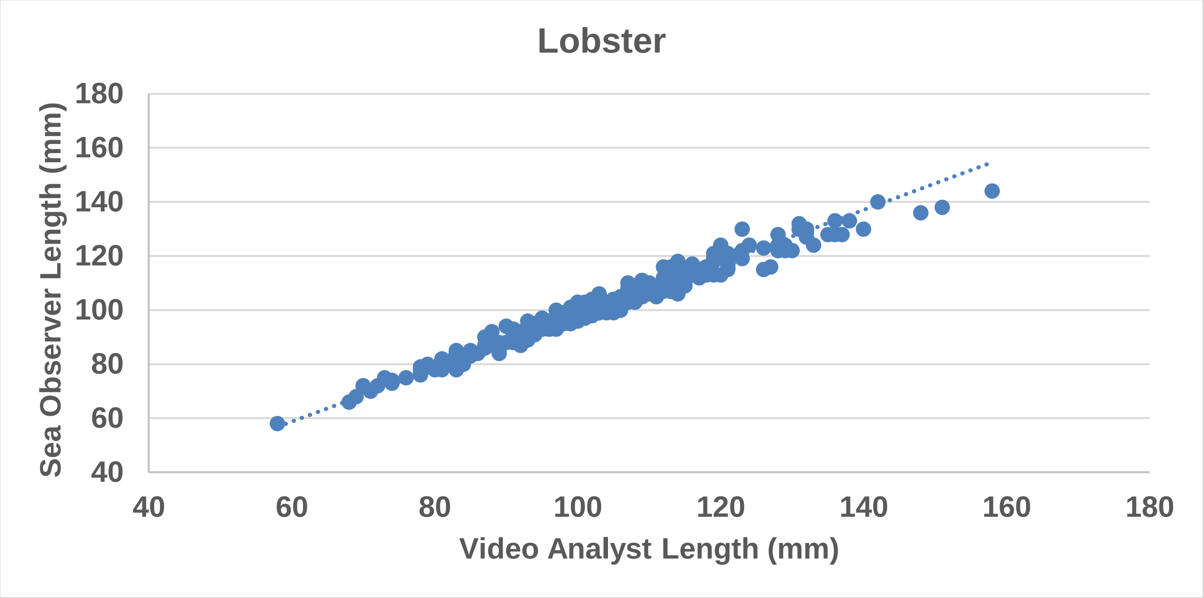


Figure 16 Screenshot showing zoomed image of selection of first of 2 points to determine carapace width on a brown crab. The contrast and colour of the image was also altered and this helped identify the exact edge of the carapace.

The length data collected using the EM length estimation tool can be linked to the other sensor data collected by the EM system e.g. time, location, and pressure readings. This allows the lengths taken to be plotted on the EMIPro software and geographically. This would then allow all length data to be automatically linked to a string, trip or sea area. Figure 4.19 shows an output for length data collected using the EM length estimation tool, which allows the collected length data to be stored automatically without the need for any data inputting and the lengths are linked to species, retained or discarded, time and position. When these data are displayed on the video analysts EM screen the data are plotted as part of the string being hauled and shown in both the line graph data and on the map (Figure 4.20).





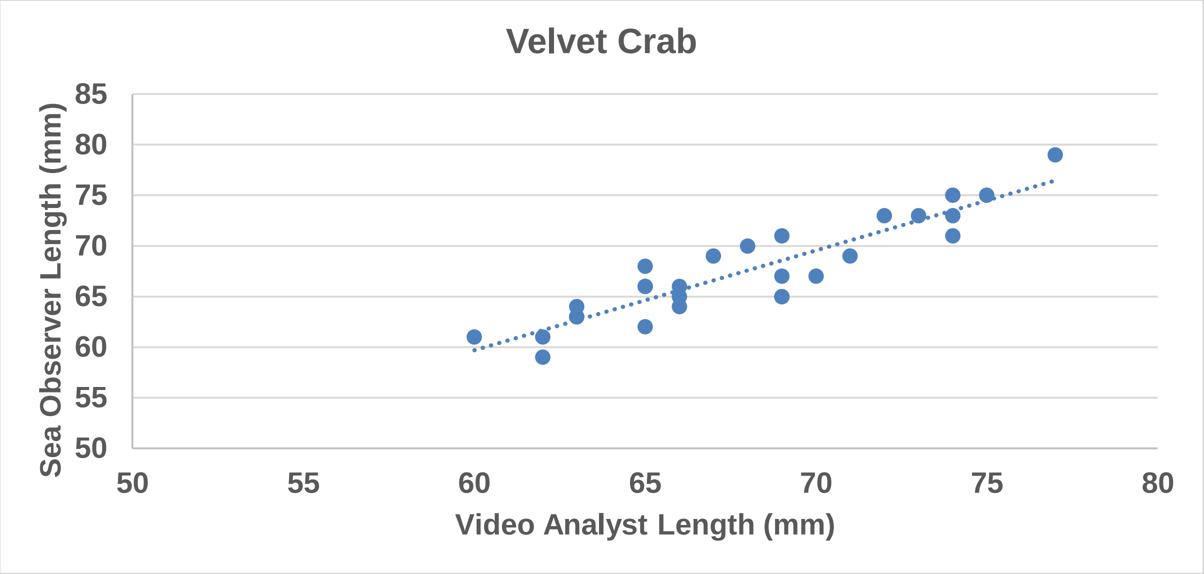
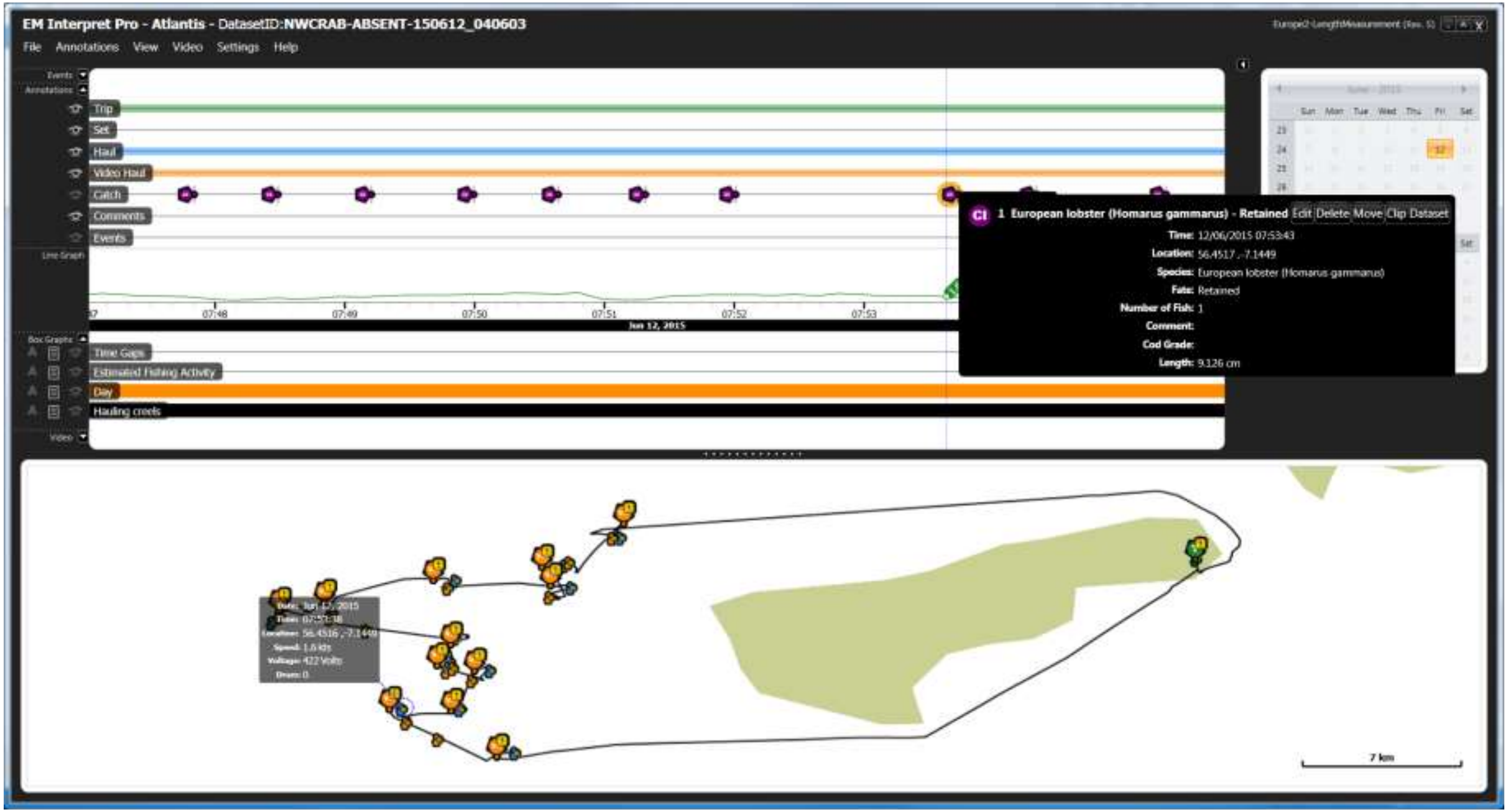


Figure 17 Comparison between the length data collected by the at-sea observer and video analyst for the same individual measured.

Time_D...	Locatio...	Locatio...	PointAc...	Species	Fate	NumbFi...	CatchLe...
12/06/2015 07:...	56.42798	-7.094533	Exact	European lobst...	Retained	1	12.645 cm
12/06/2015 07:...	56.428377	-7.093442	Exact	European lobst...	Retained	1	13.415 cm
12/06/2015 07:...	56.429603	-7.090413	Exact	Edible crab (Ca...	Discarded - gen...	1	14.952 cm
12/06/2015 07:...	56.430133	-7.08948	Exact	Velvet swimcra...	Discarded - gen...	1	6.407 cm
12/06/2015 07:...	56.430133	-7.08948	Exact	Velvet swimcra...	Discarded - gen...	1	6.015 cm
12/06/2015 07:...	56.430223	-7.08938	Exact	Edible crab (Ca...	Discarded - gen...	1	14.809 cm
12/06/2015 07:...	56.429955	-7.089207	Exact	Edible crab (Ca...	Discarded - gen...	1	13.719 cm
12/06/2015 07:...	56.429835	-7.089132	Exact	Edible crab (Ca...	Discarded - gen...	1	cm
12/06/2015 07:...	56.425673	-7.10583	Exact	Edible crab (Ca...	Discarded - gen...	1	12.776 cm
12/06/2015 07:...	56.429587	-7.11374	Exact	Edible crab (Ca...	Discarded - gen...	1	14.678 cm
12/06/2015 07:...	56.431107	-7.116813	Exact	Edible crab (Ca...	Discarded - gen...	1	14.346 cm
12/06/2015 07:...	56.45141	-7.150053	Exact	European lobst...	Discarded - gen...	1	10.196 cm
12/06/2015 07:...	56.451207	-7.148483	Exact	Velvet swimcra...	Discarded - gen...	1	7.62 cm
12/06/2015 07:...	56.451065	-7.14851	Exact	Velvet swimcra...	Discarded - gen...	1	7.845 cm
12/06/2015 07:...	56.450877	-7.148243	Exact	Edible crab (Ca...	Discarded - gen...	1	cm
12/06/2015 07:...	56.45071	-7.147488	Exact	Edible crab (Ca...	Discarded - gen...	1	14.414 cm
12/06/2015 07:...	56.45089	-7.14685	Exact	Edible crab (Ca...	Discarded - gen...	1	cm
12/06/2015 07:...	56.450875	-7.146537	Exact	Edible crab (Ca...	Retained	1	15.759 cm
12/06/2015 07:...	56.451082	-7.14608	Exact	Edible crab (Ca...	Retained	1	16.522 cm
12/06/2015 07:...	56.451688	-7.144913	Exact	European lobst...	Retained	1	9.126 cm
12/06/2015 07:...	56.451885	-7.145088	Exact	European lobst...	Retained	1	cm
12/06/2015 07:...	56.452368	-7.145613	Exact	European lobst...	Retained	1	cm
12/06/2015 07:...	56.452973	-7.145708	Exact	Edible crab (Ca...	Discarded - gen...	1	10.942 cm
12/06/2015 07:...	56.45297	-7.145732	Exact	Edible crab (Ca...	Discarded - gen...	1	10.869 cm
12/06/2015 07:...	56.4528	-7.14614	Exact	Edible crab (Ca...	Discarded - gen...	1	13.23 cm
12/06/2015 07:...	56.452663	-7.146328	Exact	Edible crab (Ca...	Discarded - gen...	1	13.011 cm
12/06/2015 07:...	56.452273	-7.146875	Exact	Velvet swimcra...	Discarded - gen...	1	7.324 cm

Figure 18 A screenshot of the data output from EMIPro showing the position where the animal measured was caught, lengths obtained and the animals where a length was not obtainable.



CI 1 European lobster (Homarus gammarus) - Retained

Time: 12/06/2015 07:53:43
Location: 56.4517 , -7.1449
Species: European lobster (Homarus gammarus)
Fate: Retained
Number of Fish: 1
Comment:
Cod Grade:
Length: 9.126 cm

Date: Jun 12, 2015
Time: 07:53:38
Location: 56.4516 , -7.1449
Speed: 1.6 kts
Voltage: 422 Volts
Drums: 0

Figure 19 Screen shot of the length data displayed on the EMIPro software.

Conclusion

In general the modified chute coupled with video review provided the means to collect accurate counts of shellfish discarded as they pass the video cameras. Less easy to collect were length measurements although a success rate of at least 70% was achieved in most cases (excluding lobster on the final trial trip where no attempt was made). Harder to obtain were accurate numbers by sex. Sex could be determined on brown crab on approximately 79% of observations, but lobster data were extremely difficult to obtain due to the need to view the pleopods and the issues created by fluctuating light levels.

The objective of this subproject was not to produce the perfect seagoing design of a modified discard chute, but to be a first-stage practical test of a concept and to test the plausibility that video technology coupled to a portable chute contraption could allow for large scale sampling of discards. From this it was hoped that a decision could be made as to whether this idea could be developed further. The results above clearly show that this device could provide a delivery mechanism that allows discarded crab (and potentially lobster) to be presented in such a way as to allow accurate counts, sex ratios and length measurements to be obtained. It is our recommendation that this concept should be developed further to enable a robust, compact and portable chute to be built, that allows accurate data to be gathered from the EM systems and video review.

4.5 On board electronic callipers to collect length data through self-sampling

Background

The geographical remoteness of the inshore fisheries on the west coast of Scotland is often a limiting factor for obtaining good quality fisheries and biological data. Often the only data available to fisheries managers are in the form of landings declarations, currently made through the Fish1 form (see Figure 1.5).

Deploying experienced biological samplers (sea-going and shore-side) to these locations can be problematic, due to transportation links, weather conditions and a fishing vessel's ability to carry an additional person. These factors will also increase the costs per sample of collecting biological data in these locations compared to a major port, such as Peterhead.

The aim of this sub-project was to trial recent technological advancements that would allow these fisheries data to be collected in a more efficient way. As the focus of these projects was self-sampling, it made sense to trial equipment that fishermen could use remotely and with ease. As length data are essential in stock assessments but one of the hardest sets of data to obtain from remote locations without a dedicated sampling trip, it was decided that this should be the focus of this sub-project.

Method

A brief desk study of equipment likely to be suitable for the project was conducted.

A set of Mitutoyo **ABSOLUTE Digimatic Coolant Proof Calliper 0-300mm / 0-12"** electronic callipers were selected as they had proved reliable in the past and had the capability of measuring large brown crab. These were retro-fitted with Teflon blocks on the measuring nibs to aid collecting length data on brown crab, where the curvature of the carapace can often make carapace width measurements difficult with standard callipers.

Whilst there are a number of Bluetooth attachments available for electronic callipers, our internet search revealed only 1 adapter that facilitated the transmission of length data by sex. For this reason the Mitutoyo callipers were coupled (via the callipers SPC data out connection) with a Scielex Bluetooth adapter capable of transmitting length measurements to a Bluetooth enabled device (smart phone or tablet) by sex. In realty the callipers don't actually have a "sex" button, but have 2 "send" buttons, one blue and one red. The software allows the user to assign values or identifiers to the two different buttons. So in this instance we assigned male to the blue button and female to the red button. But if sex was not a requirement one could easily measure two different species or discarded and retained catch from one species, just by reassigning the two "send" buttons with the desired identifier.

The callipers came complete with software that allows users to define the method of data transmission (HID-Human Interface Device or Serial pipe mode). HID was selected for this project as it allowed data to be transmitted direct to spreadsheet on a mobile computer device. For this trial the data were transmitted to a Bluetooth enabled Blackberry playbook tablet within a waterproof satchel enclosure. When operational the callipers vibrate (haptic feedback) to confirm that a measurement has been recorded and transmitted. Figure 4.21 shows the callipers fitted with the Bluetooth adapter in both front and rear aspects.

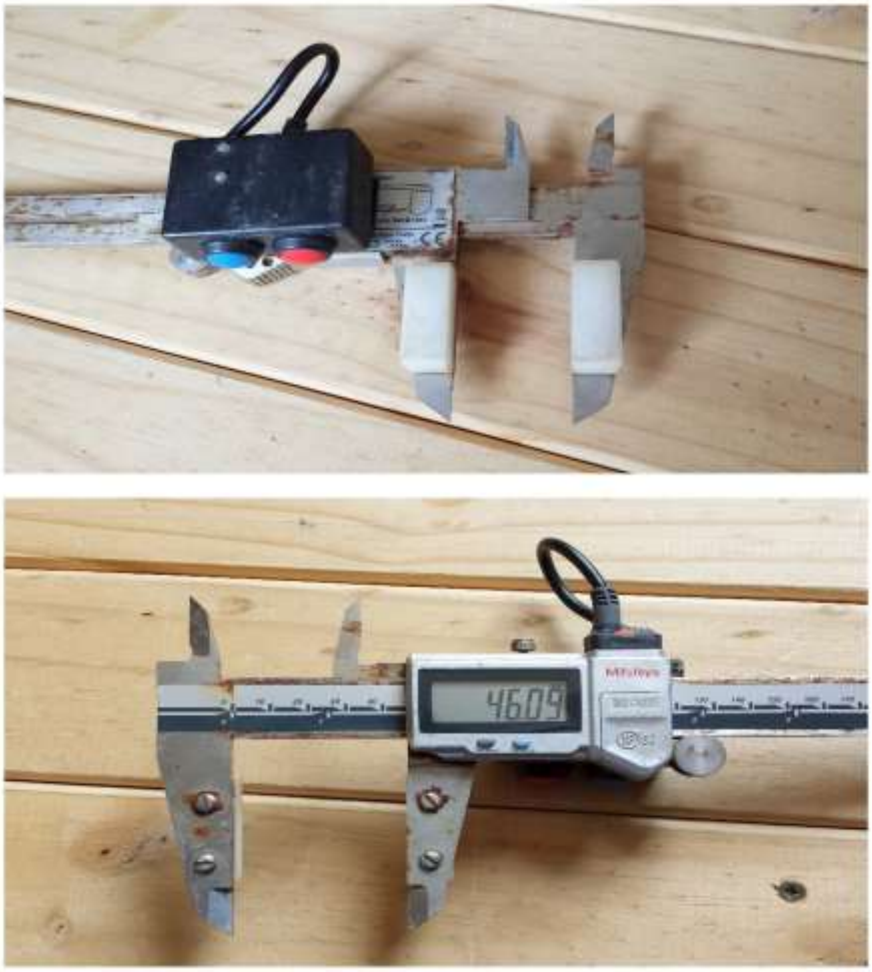


Figure 20 Top - Rear view of calliper/ adapter arrangement showing Teflon blocks and 2 buttons for male and female selection. Bottom - Front view showing digital output on calliper screen and lead connecting calliper unit to Bluetooth adapter

Results

Prior to deploying the equipment in the field it was tested on land to check for functionality and reliability. Early trials on land indicated that the device was occasionally transmitting the same data twice, i.e. creating duplicate records. The manufacturer was consulted on this issue and over the course of the following week the device was tested both on land and at sea and the firmware changes suggested were applied to minimise the amount of duplicate entries.

The callipers were first trialled at sea by Seascope observers to establish how user-friendly the device was and to identify an appropriate sampling regime that would work for fishers. The first day's sea trials were cut short when the battery on the tablet went flat before the end of the fishing day. Despite this, the observer collected in the region of 220 sexed length measurements from both retained and discarded portions of the catch across 3 species. Bluetooth connectivity between the tablet and callipers was reliable at distances within 1.5m of each other. With greater separation there was a tendency for the connection to break. This however was not an issue on this trial as it was found that having the tablet located nearby the sampling location allowed the measurer another form of confirmation that measurements were being recorded in the appropriate field on the template. Similar testing by the observer was conducted over a further 6 sea-days and on 2 different vessels. The immediate benefit realised from these callipers from an at-sea observer's perspective was that there was a considerable time saving created by being be able to transfer the data using Bluetooth. Normally the observer would need to record the data on to a measuring board, then transcribe these measurements on to the paper logsheets, and then clean the measuring board ready for use on the next string.

During the first few sea trips there were still occasional duplicate records appearing in the datasets, most likely caused by holding the "send" button down too long. The dataset was sent to the manufacturers who initiated additional firmware updates (carried out by the users) to help remedy the issue.

The self-sampling trial, where the fisher was collecting length by sex data independently, began on 12th June and concluded on 16th July. Over this period the fisher collected biological data on 12 fishing trips. A simple sampling template spreadsheet was developed whereby the skipper simply titled the template by date and then entered the length data into the appropriate column (for each species), followed by details of amount sampled and total amount caught for the day. Data collected on the EM system indicated a total of 17 trips were conducted during this period which would indicate that sampling was not conducted on 5 of the trips. Table 4.5 shows the sampling dates and the number of samples collected on those days. Sampling was not attempted on discarded shellfish due to the potential legal issues associated with retaining undersized catch on board.

Table 4.5 Summary of sexed length frequencies collected by skipper by date.

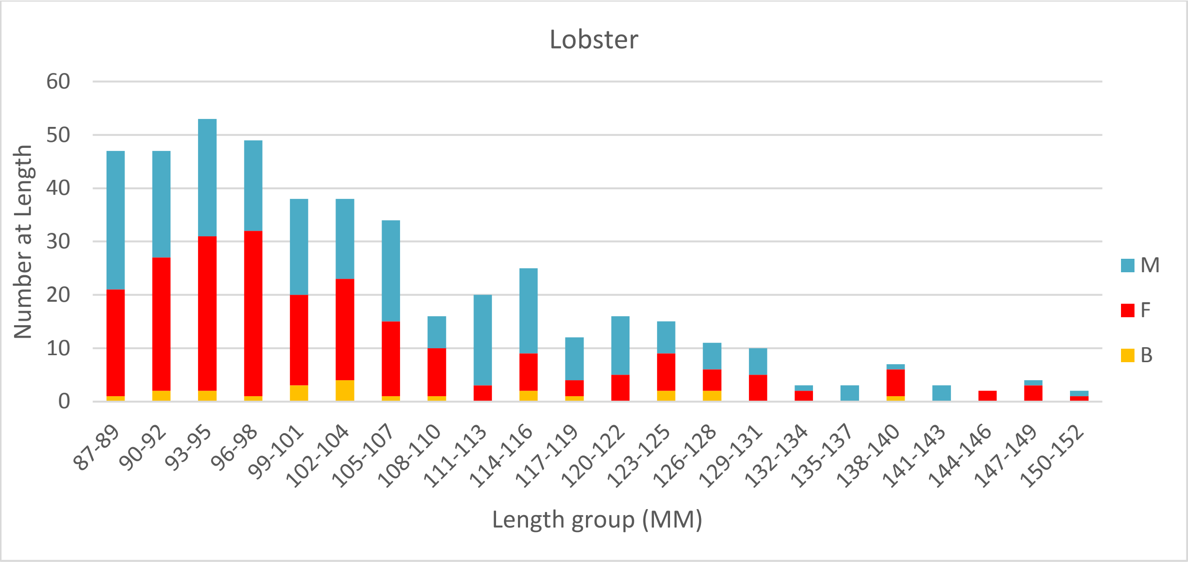
Date	Species	Self-reported number of lengths (uncleaned)	Cleaned number of lengths	Difference count	Video Count
15/06/2015	Brown crab	19	19	0	no view
01/07/2015	Brown crab	66	60	6	no view
07/07/2015	Brown crab	53	52	1	51
09/07/2015	Brown crab	52	52	0	no view
15/07/2015	Brown crab	51	51	0	51
16/07/2015	Brown crab	44	41	3	no view
12/06/2015	Lobster	22	22	0	22
13/06/2015	Lobster	9	9	0	9
14/06/2015	Lobster	25	24	1	23
15/06/2015	Lobster	39	38	1	no view
01/07/2015	Lobster	44	40	4	no view
07/07/2015	Lobster	85	75	10	75
08/07/2015	Lobster	25	24	1	24
09/07/2015	Lobster	31	30	1	30
13/07/2015	Lobster	53	51	2	51
14/07/2015	Lobster	63	50	13	49
15/07/2015	Lobster	48	47	1	48
16/07/2015	Lobster	44	43	1	no view
13/06/2015	Velvet crab	36	36	0	34
14/06/2015	Velvet crab	35	33	2	35
15/06/2015	Velvet crab	36	35	1	35
09/07/2015	Velvet crab	31	30	1	30
14/07/2015	Velvet crab	39	33	6	35
TOTALS		**950**	**895**	**55**	

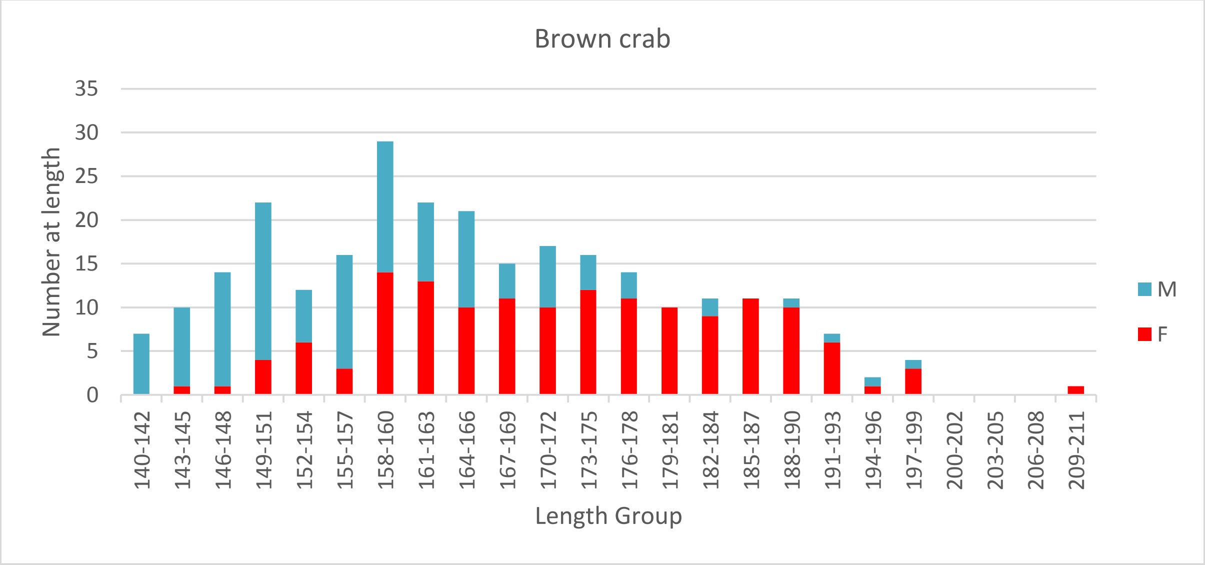
Video data was subsequently reviewed to confirm where possible the quantities measured by species (see Table 4.5) as well as to determine the time taken on deck to collect the sample data (see Table 4.6). It was not possible to obtain this for all samples as occasionally the skipper conducted self-sampling at the rear of the boat or with his back obscuring the sampling from the camera. Therefore Table 4.6 only shows the data for the trips where the sampling could be viewed.

Table 4.6 Length sampling undertaken by date/ species, along with time taken on deck to collect the sample as assessed through video footage of sampling events.

Date	Species	Number of lengths collected	Time to collect samples (Decimal minutes)
07/07/2015	Brown crab	52	6.7
15/07/2015	Brown crab	51	6.8
13/06/2015	Lobster	9	2
14/06/2015	Lobster	24	5.5
07/07/2015	Lobster	75	13
08/07/2015	Lobster	24	5.5
09/07/2015	Lobster	30	4.8
13/07/2015	Lobster	51	9.5
14/07/2015	Lobster	50	5.9
15/07/2015	Lobster	47	9.1
13/06/2015	Velvet crab	36	5.5
14/06/2015	Velvet crab	33	6
15/06/2015	Velvet crab	35	5
09/07/2015	Velvet crab	30	3.3
14/07/2015	Velvet crab	33	4
	Total	895	92.6

The results of the length sampling are shown in Figure 4.22. Data were grouped into length groups of 3mm for brown crab and lobster and remained as 1mm for velvet crab. It can be seen that the larger sizes of brown crab are dominated by females whereas the larger size classes of velvet crab are dominated by males.





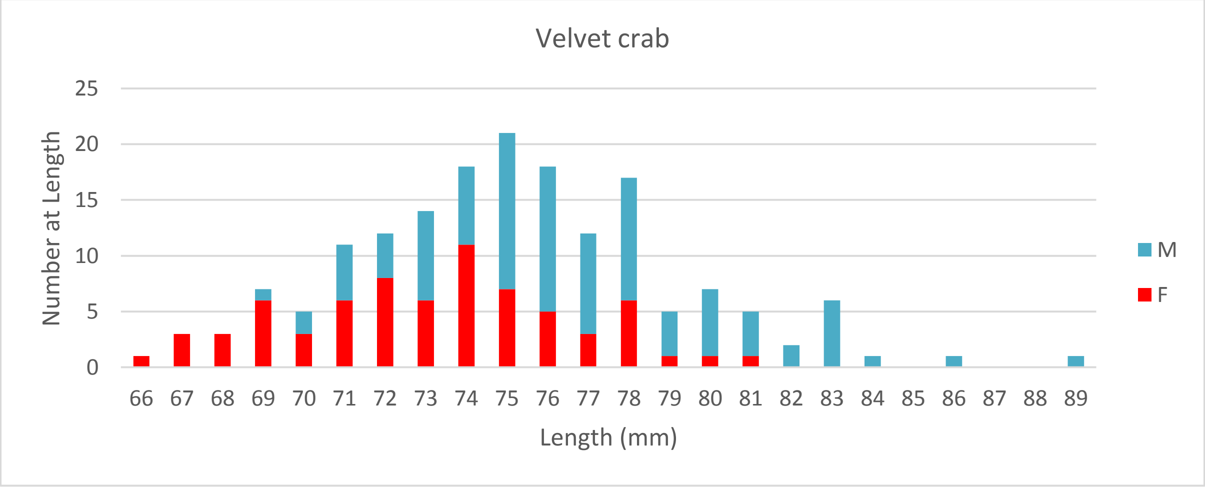


Figure 21 The sexed length data collected by the participating skipper for lobster, brown crab and velvet crab (F = Female, M = Male and B = Berried).

Discussion

The data in Table 3 would suggest that the skipper could collect and transfer to a spreadsheet, approximately 580 length measurements/hour whilst at sea. However it would not be acceptable to ask a fishermen to undertake an hour of length sampling on top of their normal fishing duties. However if a skipper collected 10 minutes of length sampling per day on one or two species then it is likely that several hundred sexed length samples could be collected per species in a week. Care should be taken to ensure that sampling is random and representative. Raise these sampling levels to the year and one vessel can collect thousands of length measurements which are already entered on to a spreadsheet or database ready for use.

As described earlier, an at-sea observer collects length data on to a waterproof board, transcribes it to logsheets, cleans the waterproof board and then still needs to enter the data on to a spreadsheet on return to shore. So even equipping the observers with this tool will present significant savings in staff time to a sampling project.

There are still some minor issues with duplication of records and overall there were potentially up to 55 false records generated during sampling (6%), Thorough checking of the data is required to ensure that “double-hit” data are not included, however given that this was a first trial of these Bluetooth callipers it was regarded as an acceptable error at this stage. More testing and software refinement with the manufacturer is likely to lead to an increase in accuracy.

Conclusion

The trial of these Bluetooth callipers has shown that they are capable of providing large quantities of accurate length data relatively cheaply when provided to the fishermen. Even as little as 10 minutes sampling a day will produce thousands of length measurements over a year for a single vessel. However as with all self-sampling schemes there would still need to be a verification process to ensure that sampling is conducted correctly. Without it some scientists are unlikely to accept the data for assessment purposes. Fishermen may not want to collect these data for free so a small incentive or participation payment may be required, but even with verification, payment, price of callipers and price of a tablet included, this will still be significantly cheaper than sending an observer to sea.

5. Discussion, Implications and Recommendations

5.1 Vessel selection and installation of equipment

The process of selecting suitable vessels took longer than initially expected due to the need to ensure that there was open and fair competition amongst all interested vessels. This required an appropriate tender process to be advertised and completed. To ensure project aims were met and that the process was fair and transparent, a scoring matrix was designed and applicant vessels were scored against the specified criteria, namely target species, time spent targeting data deficient stocks, geographic location and gear type. This ensured that all applications and subsequent decision making processes were robust and assessed equitably.

The large geographical spread of the selected vessels across the west coast of Scotland was extremely useful in understanding local issues and fishing practises. The remoteness of some of the fishing communities helped highlight the difficulties associated with collecting useful quantities of fisheries data and also served to highlight that innovative solutions are necessary if more data are required from these areas.

During the installation process this remoteness was again highlighted. On some islands there is little or no access to skilled marine engineers and spare parts. If a specific tool or accessory was not taken along in the first place e.g. a power invertor or USB extension cable, then it was unlikely that there would be anywhere to source this locally. So being prepared and packing additional spares of all equipment and consumables was essential. This did add additional costs as a full spares inventory needed to be available at all times, as well as equipment/materials that may or may not be of use.

In general the installation process was hugely successful from a logistical point of view. No vessels missed any fishing opportunities because of the installation process. All installations were scheduled around the vessel's availability rather than the installation team's availability. Planning the installation to coincide with ferries, air flights, poor weather to ensure fishermen were available (but not so poor that ferries were stopped) and even undertaking installs throughout the night (to avoid disrupting fishing patterns), helped us to appreciate some of the logistical issues that would be faced in a large scale, routine data gathering programme.

There were several technical issues that were encountered during installation. Power supply was one of the main issues, but in the majority of cases these were remedied by Seascope providing additional power inverters to the vessels to ensure the EM systems had regular power of the correct type.

Local hydraulic engineers were not always available at the time of installation, especially during the late evening and night time installations, so the hydraulic sensor was often left for the skipper to arrange to be fitted at the next available opportunity. As with a lot of inshore vessels, the skippers are often the skipper, owner, crew, electrician and engineer all rolled into one and our skippers were no different. If no specialised local engineers were available then they were happy to undertake these tasks themselves where necessary. This positive and helpful attitude of all participating crews and skippers was greatly appreciated and extended through to the de-installation process as well. However on 4 vessels the hydraulic pressure sensor installation was overlooked by the skipper.

The most frustrating issue encountered during (and just after) the installation process was the interference with the VHF and/or FM stereo radio systems aboard a few of the vessels. The cause of this interference was difficult to pinpoint but was attributable to the EM system. Upon discussions with the manufacturers (AMR) this was rectified by rerouting some of the cabling away from VHF aerials, by adding RF inhibiting ferrite clamps and additional in-line inhibitors. In some vessels it was necessary to move cameras to keep cabling away from other electrical equipment on the vessel. Nevertheless all 11 vessels were operational by early February and were successfully collecting electronic data up until the end of the project. It is understood that this interference issue is being resolved by the manufacturers.

If EM were to be considered as a long term and widespread solution for the Scottish inshore fleet then the installation process would be undertaken slightly differently. Each dedicated installation team would consist of the installation manager who would be a highly experienced seagoing observer and EM video analyst, and an engineer who is qualified in both electrical and hydraulic installation. This would ensure that the installation process is fully completed before the team leave the vessel and that cameras are seeing exactly what is required for video review processes. This would remove the reliance on local resources, which of course may not be available. Obviously if there are several vessels to be installed at the same port and time, then additional labour could be used to help with the less technically skilled tasks and allow the engineer and installation manager to go on each vessel as and when required and oversee the full process. Installation should still be scheduled around the vessel's activities wherever possible as this helps maintain good relationships and ensures skippers are available to assist and provide catch handling information where required.

A larger scale and long term project will also produce efficiency savings as several boats can be installed during the same visit; local services can be sourced, retained and trained for emergency repair situations; and port visits would be able to address several vessels' needs at the same time. Additionally it takes 2-4 man days to complete an install and perhaps half a man day to de-install and there are consumable costs associated with each installation. The EM systems are designed and installed to a standard that allows them to function for 3 - 5 years and a long term project will spread these costs over a longer time period.

5.2 Training sessions

The initial training sessions were scheduled around ferry times and carried out in 3 locations that were thought to allow all skippers an opportunity to attend. The Skye training session was the best attended with all those invited attending. This effort was greatly appreciated by the course organisers. The other two sessions, held on Tiree and Islay, were less well attended. On Tiree we had hoped for both skippers to participate but only one could actually attend (50%) and on Islay only one skipper (and his crew) was able to attend out of the three expected (33%). No non-participating skippers attended any of the courses.

The main issue that affected the attendance levels at these courses was the weather. Unfortunately the courses coincided with the first calm conditions after a prolonged period of rough weather. Therefore all fishermen understandably wanted to be at sea and some could not afford to miss this opportunity. However one skipper could not attend due to personal reasons. The other issue with weather and islands is that if it is too rough then the ferries don’t operate. So it is difficult to find that small window of weather conditions that suits all parties by stopping the fleet sailing but not the ferries.

The issue of attendance was discussed with all skippers and some useful suggestions were put forward to improve attendance for the second session. One skipper suggested that the training be conducted in one location and somewhere where the fisherman would like to attend (Glasgow) and others suggested that it be done in the evening so that fishing would not be missed. This was taken on board and it was felt that the Inshore Fishing Conference in Inverness (9th October 2015) could allow fishermen to attend a useful and interesting event and also be available for the final training workshop the day before. This would also allow fishermen to share their experience with a wider audience first hand.

The content of the initial course was also discussed with those who attended. All found it useful and informative and said that although they were aware of many aspects of fisheries stock assessment, it was beneficial to hear about these in a local fishery context. Participants found it very helpful to understand how data collected through self-sampling programmes could contribute to stock assessments. In addition participants would welcome the opportunity to contribute to the interpretation of stock assessments. In turn such participation would provide a much greater understanding of how conclusions are drawn on stock status, generating increased confidence and engagement with the data collection process. The biggest benefit was felt at the Skye session as there were trawl and creel fishermen in the same room discussing issues of mutual concern, and others where they were polarised, but at least this gave an opportunity to talk face to face.

Although the attendance rate overall for the initial training courses was approximately 50%, this did not unduly hinder the project because each vessel had observers go out on sea trips early in the project. Their role was to observe the catch handling processes and discuss/advise possible sampling practises and to highlight the type of data required. No difference in data quality was discernible between those that attended the initial training course and those that could not. However the training courses allowed those that attended to meet the team and other participating skippers, which helped form a relationship that facilitated good communications.

The second training session was well attended, with 8 participants from project vessels, along with the project facilitators and representatives from Marine Scotland travelling to Inverness to participate. An introductory session from Julian Addison focused on how self-sampling with EM can address particular data deficiencies that can subsequently improve the quality of stock assessments. The emphasis was on how the data collected from this trial project might be used in stock assessments. (As the project did not extend over a full fishing year, it was not appropriate to carry out a stock assessment with the data collected during the project.) This was followed by a session from Grant Course in which the findings of the two projects were presented and discussed amongst all attendees. These sessions were structured informally to allow all/any attendees to engage in the discussion and provide feedback on their experiences.

Below is a list of comments collected from participants offering some of their views on how they felt the project was conducted, what worked and didn’t work from their perspective, along with outcomes and what they would like to see next in terms of continued engagement.

Fishermen's Comments and Perspectives

- Full year coverage required because of seasonal fisheries.
- Full species coverage could be considered.
- All participants stated they would be interested in participating in a longer term project.
- They had more confidence in data collected by themselves and an independent third party than in data collected by compliance or government departments.
- They were less suspicious of motives when a third party company were involved.
- Self-sampling paperwork was good and the amount of data recording required was easily manageable.
- Sub-sampling of discards was achievable but maybe needs a more standardised approach.
- Self-sampling IS extra work for the fishermen. So perhaps a payment should be considered in a long term project.
- Protected species interactions could be self-reported and verified with EM.
- Co-operation with scientists was good in this project because normally they don't listen to fishermen.
- In fishermen's own interest to provide/collect evidence and data.
- EM data provides record of areas fished (more detailed than AIS etc.).
- Great to show positives of fishermen's attitudes and behaviours.
- Negatives (by-catch etc. keep scientists in jobs).
- Potential to quantify how weather effects can determine catches/landings.
- Fishermen in it for the long haul, their livelihoods at risk.
- Fishermen are best placed to provide data.
- Scallop age and measurement data can easily be self-sampled at sea.
- Can characterise fisheries and variations within with fine spatial detail, which is necessary in inshore fisheries.
- Small datasets can be dangerous. Sub-samples can be misleading so a large scale widespread project looking at as much data as possible should be considered.
- Year to year and seasonal variations occur so we need a longer scale project.

Based upon all those skippers and crew in attendance (and comments received from some of those that were unable to attend) there was a strong consensus that fishers themselves, as custodians of the fisheries resource were perhaps best placed to be collecting data to address current deficiencies. All participants welcomed the opportunity to have EM technology on board their vessels as it provided definitive evidence that they were fishing in a responsible manner. Fishers also noted that they would be more comfortable and potentially accepting of future management proposals in a scenario where they had participated in the process of data collection and to an extent the decision making processes associated with that data. They also expressed the view that the use of a third party independent fisheries research company made them more re-assured that there was no ulterior motive for collecting the data and that the performance and attitude of Seascope made them feel comfortable about being a part of the project.

Overall, the level of engagement and enthusiasm from participants in these projects has been hugely encouraging. Utilising this enthusiasm and the training already supplied to these participants (in terms of operation of EM systems, sampling and documenting of catches and understanding how fishers can both contribute data for use in stock assessments and participate in the interpretation of those stock assessments) should be considered an asset and could form the basis for further work in this area. It was similarly encouraging to see both mobile and static sectors working together and constructively. It was also very encouraging that all participants agreed that they would like to continue this type of approach and be involved in a similar project in the future. These fishermen would be very useful in encouraging others to be involved in this type of project and could be regarded as local experts in self-sampling to help advise others in the future.

In addition to this final report, a presentation of the results and recommendations from the project was given at the Inshore Fisheries Conference on 9th October 2015 in Inverness, as well as some general introductory information on the use of technology in fisheries research and some practical demonstrations of some of the equipment used e.g. Bluetooth callipers. These sessions were carried out over two workshops and each was well attended, with approximately 25-30 participants at each. The presence of participating skippers at each workshop and their input throughout the sessions was extremely positive and supportive of the work carried out and provided a perspective that added value for all those in attendance.

On completion of each of the workshop presentations a question and answer session was held. Below is a list of the main questions raised:

- Q. What size of vessel can EM systems operate on?
- A. We worked on vessels down to 7m in length and have installed systems on vessels as large as 110m in the past.
- Q. How reliable is the self-sampled data?
- A. Self-sampled data is reliable when it can be verified as accurate with EM technology.
- Q. What are the costs of these systems?
- A. A system can cost approximately £6,000, installation £2,000 and it can take about 1.5 days to review 1 day of creel fishing data.
- Q. This sounds great, what happens next and who pays?
- A. This would be up to Marine Scotland to decide for any future long term projects. However some participants said that they would be willing to consider paying for an EM system themselves if it helped improve the current data situation.
- Q. How reliable and durable is the equipment?
- A. Most equipment failure was due to minor installation errors and the remoteness of the vessels meant it occasionally took a few days to get to the vessel and remedy the issue, leading to some data loss. However the equipment is designed to have a life span of approximately 5 years and can come with additional warranties from the manufacturers. Only 4% of trips were lost due to equipment failure of which nearly all were linked to an install issue.

In addition to the questions above there was some wider discussion and comments from the floor. Some of these included;

- “I am very positive about the potential of EM systems to gather specific fisheries and stock data. If trying to get length data then the joint self-sampling and EM verification approach could potentially provide great benefits to stock assessments.”
- “Probably not practical to have systems on all vessels but perhaps a reference fleet approach could provide excellent data if representative.”

- "Very impressed with the results of the whole project and that the great buy-in from the fishermen was a credit to the project and industry."
- "It is great that fishermen are being given the opportunity to learn about stock assessments and be a part of the process. It would be good if fishermen could participate in the interpretation of assessments."
- "Very pleased with the outcome of the project and wish I could have kept the equipment on board. Would like to have been able to keep showing the number of juveniles on the grounds, to demonstrate the health of the stock and also to show that we are complying with legislation and fishing responsibly."
- "I can see this technology being very useful to me in my role as a researcher in my country's fisheries."
- "The Bluetooth callipers could be used by all of our observers to speed up data collection and remove data entry costs."

There was also some general discussion about creel limits and how this type of legislation can successfully be policed. There was acknowledgement that EM and RFID tag technology could allow this to occur. There was concern that hobby, unlicensed and part time fishermen are completely un-policed, so why should full time fishermen accept new management measures and legislation when these other fishers are unaffected. Without effective policing new management measures may not be effective.

Overall the workshops were well-attended and the participants were all able to be involved in the discussion and Q&A session. Comments were very positive and supported the idea of EM being developed and used in science and compliance. Some of those that attended also took the time after the workshops to continue the discussions further and expressed their enjoyment of the session.

5.3 Self-sampling

All participating skippers acknowledged that the data available for managing their stocks needed to be improved and that using fishermen to collect these data was a logical choice. Initially there were some reservations because some fishermen did not want to be involved in collecting data on all species and from all creels. There was a concern that the level of self-sampling required would impact on their fishing practises. These initial concerns highlighted the need to develop self-sampling techniques in conjunction with the fishermen and not dictate how data were to be collected. It also became clear that each vessel handles the catches differently and that one technique of data gathering would not necessarily suit all vessels. As long as whichever technique that was adopted could gather the correct data required and didn't introduce bias, then fishermen should work out what sampling levels and procedures suit them and their catch handling processes.

All participants successfully collected data on counts or weights retained and discarded, sex ratios, and fishing effort data, but not always on all trips. There were some initial issues with information not being fully supplied but these were ironed out as the project progressed and observers undertook sea trips (increasing communication). If a set of self-reported paperwork for a trip was missing certain critical comparison data then unfortunately it meant the whole trip could not be used. If paperwork was missing altogether then no comparisons were possible.

For self-sampled data to be used for management purposes the quality needs to be consistent and needs to be linked to the amount of effort fished to collect it. So if the number of strings and creels was missing then the supplied catch data were not usable. (Self-sampled length data could still be of value of course without information on fishing effort.)

In general the fishermen collected data on fishing effort and retained catch to a good and uniform standard. This was not surprising because this is the type of data they routinely collect for themselves on a daily basis. The count of strings was the most accurate whereas the count of creels was based on a perceived number of creels per string (30 creels on every string), whereas in reality there were sometimes creels missing from a string.

Discard data were usually supplied for the main target species but not always for bycatch species. The quality was variable and the collection methods also tended to vary between the vessels. The best examples of discard data collection that we experienced came from two separate vessels fishing for different target species. On one vessel the main target species was lobster and the skipper dedicated all sampling time to recording counts of lobster discarded and retained. This was done at a string level and aggregated to trip and when the video was reviewed by the analysts, similar values were obtained. The other was the skipper of a vessel mainly targeting brown crab who collected discards from a random string during the day and counted the number of creels that they came from. These discards were sexed and counted before being thrown overboard, thus providing numbers at sex for a specified number of creels, which could then be raised to trip level. He also used a similar technique for sexing retained brown crab. As the retained crabs were nicked and placed into a keep pot one crewman would only select females and the other would only select males and they would count how many crabs they had nicked each, thus providing a sexed count per 40kg (average keep pot weight) sampled.

The collection of the sex ratio data was less robust across the participating vessels. Some as detailed above provided accurate counts which was useful but others were only able to provide an estimated percentage of each sex for the discards and retained. This was less useful because in reality it was an educated guess. However it could still be of use and could be applied to the estimated weights or counts declared.

Being able to see the different techniques adopted by the different vessels and having attempted to compare these against the EM collected data, Seascope has been able to see first-hand what can be achieved by self-sampling and what are the best sampling strategies for the different gear types involved. For example, the scallop dredger would place all undersize scallops on the hand rail on each side of the vessel and these could be viewed and counted. They were then shown directly to a camera where again a count could be made, before they were discarded. This also allowed the skipper to get an exact count of what was discarded for the self-sampling paperwork. The retained scallops could be counted as they were thrown into a basket and this provided a retained count per 25kg (nominal weight of a full basket of scallops). What was less easy to see were the discarded brown crab and fin fish species, but if the vessel adopted a similar approach of putting these in a basket and showing them to a camera then verification of his self-declared discards would be possible.

The main issue with self-sampling is longevity of good performance. Our vessels knew this was a limited time span and that eventually they could take a break from providing the extra data and undertaking the extra sampling. If self-sampling was to be a long term solution for providing additional data then it is likely that a small inconvenience payment would be necessary and that the data being requested are not unduly arduous to collect. From our experience we believe that fishermen can self-report good quality data on a long term basis on a trip by trip basis for:

- Strings fished per trip
- Counts on retained lobster
- Weights on retained brown crab
- Weights on retained velvet crab
- Incidental rare species interactions

Discard data, counts on high volume species, creel counts and soak times are likely to be less reliable if self-reported. Below is a feedback comment from one skipper and from discussions with others they generally reflect the views of most of the participating skippers

'It was good to take part in (the projects), quite interesting to look at the catch in a bit more detail than we usually would. Only thing that was a pain after a while was the discards, not so much the estimating weights, just the counting out male and females. The cameras etc. were fine to work with, a few wee problems at the start which was to be expected, but had no problems with it after that. Wouldn't have a problem doing it again in the future'.

There is a need in terms of stock assessments for a larger quantity of high quality data from certain areas / fisheries on the west coast of Scotland. Self-sampling, especially in geographically isolated locations could address many, if not all of the current deficiencies if implemented and verified in the right way. Preferably this should be based on building upon current links and relationships between fishery managers, scientists and the fishers that prosecute that fishery. Data deficiencies and their relative importance to stock assessments should be clearly identified and ranked, and then in consultation with fishers a protocol could be developed that is both realistic, achievable and of benefit to all parties. Through this collaborative process standardised sampling protocols could be developed that would allow for accurate and consistent datasets to be collected by fishers. In terms of verification when using EM technology, the sampling or sub-sampling by counts (whether it be individual animals or keep-pots, bongos etc.) has proved more successful than by weight. As such any subsequent sampling protocols should be developed with this in mind.

If scientists require data to be self-reported then it needs to be on a sustainable and achievable basis. Furthermore it is essential that self-sampling schemes dovetail with standard data collection programmes and that regular feedback is provided to participants. During this project a small feedback report was sent to skippers after analysis was completed on one of their hard drives. There is no point in asking fishermen to self-report data that can be gathered from a different source more easily. All that will happen is the data will become less reliable and will not be trusted by either the scientists or the fishermen themselves. The verification of the data and methods used will be extremely important and it will need to be made independently of fishermen if scientists are to use the data with confidence and credibility.

5.4 EM technology

The EM systems performed very well throughout the project once the initial radio interference issue had been eliminated. In total the participating vessels completed 750 trips of which 30 trips were classed as invalid due to EM related issues. However this number also includes those issues that were attributed to an error during installation. For example if a camera was not resealed correctly and water leaked in then it could cause the system to fail and be switched off until a replacement could be fitted. This is not so much a technical issue but rather human error. No errors could be directly linked to the equipment performance or specifications, other than the radio interference and the manufacturers invested considerable resources into resolving this issue. So once this had been remedied the actual systems performed perfectly and never once “broke down”. This project has demonstrated therefore that EM systems can be safely installed on small inshore vessels in remote geographical locations and consistently provide fisheries scientists and managers with high quality data.

The placement of the cameras was crucial (as with all EM projects) and reliant on good communication with the crew regarding catch handling processes. Some positions needed to be revised during the project to ensure that the best possible views were obtained but all vessels were monitored in a way that allowed catch estimates to be made.

The video analysts found counting crabs as they were flying through the air during the discarding process, surprisingly easy. Good estimates of sex ratio were also able to be made at this time. Where it was harder to get estimates was when the fishermen would shake the contents of a whole creel over the side (for discards) or in to a box (for retained). This was usually when fishing for velvet crabs. The retained counts were also surprisingly easy to collect as there were opportunities to view the crabs during the catch handling process; on extraction from creel in to a bongo or box, during nicking or banding, or during placement in to keep pots. Retained Nephrops were usually counted in “crate” units with the number per crate dependent on the size grade being retained. The retained scallops could be counted being thrown into a basket whilst the discards could be counted being placed on the handrail. As with most EM projects though, converting these counts into weights for comparing to skipper retained weights was less easy and required an assumption of the average size of a retained or discarded individual. This of course would introduce a potential error but was deemed the most appropriate approach because any error created would be consistent.

Data sets were created that allowed full comparison between the data collected by the video analyst and that declared by the fishermen. It was not always clear exactly how the fishermen had arrived at some of their estimates due to the different sampling processes used and the use of a by-eye estimate approach by some skippers for some discards, but the values could still be compared.

The validation of the fishing effort was more straightforward as the EMI Pro software allowed easy identification of the trips and strings (or tows) fished. These did not always match the fishermen’s declared effort but the video footage allowed all disparities to be checked several times to ensure that the video analyst’s counts were correct. This was also the case with the number of creels fished.

To summarise, the EM system allowed the video analyst to obtain excellent count data through video review that could be compared against self-declared catch data. The sensor data provided fishing effort in the form of trips and strings which were linked to position and time and the analyst could provide creel counts for each string reviewed. It provided verification evidence that could be reviewed as often as required at anything between 16 times normal speed to frame by frame footage.

Electronic monitoring has been shown to work on fisheries around the world but this is the first time it has been used to successfully monitor effort and catches aboard small inshore creel and scallop dredge vessels. It can provide a data set that can verify self-sampled information and so could even be considered as an alternative to self-sampling if required. Coupled with an acceptable (to the fishermen) level of self-sampling, it offers a long term reliable solution to gathering data for the data deficient stocks.

If 50-100 inshore vessels on the west coast of Scotland were equipped with EM systems there would be a wealth of information that could be supplied to scientists and managers and at a cost far less than a similar sized observer programme. The systems could also be swapped between different vessels if a reference fleet approach was preferred. The EM system used for this project was not specifically designed to be swapped between different vessels, however it is perfectly capable of being used in this way. There would need to be a proper servicing plan put in place and an element of refurbishment, as well as funding to replace damaged components (e.g. camera seals/units or winch sensors) and consumables (e.g. cabling, cable ties), but this could easily be achieved with proper planning and funding.

5.5 Sub-projects

RFID tags

The RFID project has showed that accurate effort data (number of creels and soak time) can be recorded automatically, reducing the input required from fishers in terms of effort reporting. As a prototype the system performed well, delivering a good dataset that linked directly to time and location by means of the EM data-logger and associated analysis software. Further research and development aimed at reader power (distance at which a tag is readable) and tag construction and apparent durability will further improve the technology to eliminate issues around tags not registering when swiped.

The skipper involved in the trial had the following to say with regards to the equipment and use thereof;

"…they were fine, easy to use……only thing wrong with them was after a while some of them (tags) stopped working. Seemed to be if they got scratched on the tag it would stop them working……..and I could hear the beeping in my sleep………"

These issues could be related to either reader/scanner strength, the 'seawater effect' or as the skipper mentions above, physical damage to the tags themselves. Further trialling of the equipment with different tags, or tags with added protection should minimise these issues for future trials.

Whilst EM systems are able to detect fishing effort to string level without the need for video review, details on pot count were only obtainable on days where video data were fully reviewed or from self-reported estimates. The RFID system automates this process, so not only does it reduce the burden on fishers in terms of self-sampling it can also reduce the burden on any follow-up analysis of video data.

Whether or not all creel gear (buoys and traps) would need to be tagged needs to be considered. An alternative would be to have reference fleets for different gear types tagged at creel level, whilst other strings may only have buoys tagged for soak-time analysis and string count. Application of the technology developed in this trial could support current and potential future effort management regimes by offering a means of both monitoring effort in areas where creel restrictions are in place and assessing effort where there are data deficiencies.

Weighing catch components at sea

The weighing at sea subproject never really had an opportunity to be investigated properly due to concerns with safety, related to power supply and the potential for entanglement, as well as deck space issues due to platform size. However, gathering accurate estimates of weight for retained and discarded catch is still one of the most valuable but one of the hardest values to achieve. If weights could be gathered in a way that is accurate and integrated (or can be linked) with an EM system then scientists would be able to have a count (from the video review) and weight caught, at location and time for an identified quantity of fishing effort (EM sensor data or self-declared). It would complete the data picture.

“Shoe-horning” a currently available motion compensating weighing platform on to different vessels may not be the correct approach and perhaps there is a need to consider alternative and more flexible options. A trade-off between accuracy and flexibility may be required which could allow “low-tech” portable spring loaded scales to be considered if the amount of error due to motion is known or reduced through a redesign in discussions with manufacturers. Alternatively a high-tech and need-specific approach could be taken. For example perhaps a manufacturer could be approached to help develop a Bluetooth-enabled, rechargeable, portable, motion compensated hanging scale, fully integrated with an EM system, with buttons for species and sex, could be developed specifically to meet the needs of this type of project. It all depends on how important weight estimates are to scientists and fishery managers.

Data storage tags

The data storage tag trial (DST) was an additional subproject that Seascope undertook to replace the foreshortened weighing scales subproject. This was a simple experiment to test the deployment of the tag and to review the temperature and depth data that was generated. This project was a success. The tag remained secured to the creel for the duration of the subproject and the expected data set was gathered perfectly.

The temperature data allowed the water temperature at the seabed (within 50cm) to be logged every 5 minutes and over the 6 weeks it could clearly be seen that the bottom temperature rose steadily as the summer progressed. The depth data allowed the temperature data to be linked to depth but as an additional benefit allowed the time the DST and creel were out of the water to be clearly identified. In addition because the DST data were also linked to date and time, it enabled soak time to be calculated. It also allowed the

DST data to be compared to the data gathered by the EM system and this allowed the exact position of hauling to be identified.

A single DST can provide useful data for local biological and environmental purposes, as well as provide fishing effort data for a single creel and string. However if a vessel had a tag on each string then total fishing effort could be calculated for that vessel. If this was then extended to several hundred vessels on the west coast of Scotland then the DSTs could provide a large and important data set for use in oceanography, climatology and for meteorological purposes, as well as all the fishing effort information.

Modified chute and virtual callipers

Initial results from the chute trial/AMR measurement tool have been encouraging. Two chute designs were trialled over the course of the project, on two separate vessels. Each prototype had their own merits as detailed below:

- Chute 1 provided an excellent platform on which individual animal lengths could be estimated for brown crab, velvet crab and lobster. The sexing of animals was difficult with this design, mainly due to the variable light conditions experienced on the open deck.
- Chute 2 provided more versatility in terms of the amount of animals that could be processed without slowing down operations on-board. Due to camera distance from the measuring platform on this prototype however, video imagery of lobsters was not distinct enough to make out the relevant measurement points for accurate assessments of length in this species. However it worked well for brown crabs and velvet crabs.

Further refinements of the Chute 2 design are recommended, focussing on;

- optimum camera distance from calibrated surface for moving animals
- reduction of variable light conditions by enclosing all or part of the chute
- potential refinement of the algorithm used to calculate length
- investigation of rapid stills photography compared to video footage for gathering the best quality imagery
- the use of lasers, image recognition software, or 3D scanners in conjunction with the chute delivery system

The above refinements and investigations could lead to a design that is capable of allowing full accurate counts by species of discarded catch along with accurate sex ratios and sub-samples of accurate length estimates. As the measurement tool is already integrated within the EMI Pro analysis software, this information can be directly linked to the effort data at haul or trip level.

On-board electronic Bluetooth callipers

Initial results from this trial have been very encouraging. By utilising Bluetooth technology the time required to collect fine-scale biological data can be greatly reduced. Along with the time savings evident, the potential for the introduction of transcription errors is removed entirely.

During the course of the sub-project a number of firmware updates were run to eliminate the duplication of records that were apparent. Whilst these were not 100% successful (6% duplicated records estimated), a subsequent discussion with the manufacturers suggest that this level of duplication is not normal and that the adaptor is most likely faulty. A replacement adaptor is expected to have a zero duplication rate.

This technology has the potential to address many of the data-deficiencies as they relate to biological data and the shellfish fisheries on the west coast of Scotland.

Having communicated with the manufacturers of the Bluetooth calliper adapter there is scope that the device could be further developed with the addition of a third button to log berried individuals.

It is feasible that this equipment could be issued to a range of vessels around the coast, or swapped between vessels at pre-defined times to collect biological data across a range of species of interest. Whilst this trial focussed solely on retained catches, due to the legalities associated with retaining under-sized catch on-board, with appropriate derogations this sampling could easily extend to cover sub-sampling of discarded catches also.

5.6 Recommendations for future work

These feasibility projects provide a good starting point for further investigations into using electronic monitoring to verify self-reported data and to help provide independent information for data deficient stocks. It has been shown that both data collection methods can provide useable data and that having both operating simultaneously allows self-sampled data to be verified, thus removing any data quality concerns that data users may have.

The sub-projects allowed specific items of electronic monitoring to be field tested and helped identify those that could be useful in addressing current data deficiencies.

The application of appropriate stock assessment methods for the inshore Scottish creel fisheries is hindered by the lack of good quality data on landings, fishing effort, length distributions, and discard data. This project has demonstrated that self-sampling and EM technology allows such data to be collected successfully providing significant benefits to the assessment of these data-deficient stocks. In particular, the approaches trialled in this project would allow the collection of representative indices of catch per unit effort (CPUE), information on bycatch and discards and more representative size distribution data for use in stock assessments. Obtaining estimates of total fishing effort would of course require all vessels to carry EM systems, although good quality landings declarations and EM systems deployed on representative vessels would allow the development of an index of total fishing effort .

The projects have clearly demonstrated that currently available EM systems can be deployed on small inshore vessels, and can reliably provide data that are integral to effective fisheries stock assessment and management. There were some minor initial operational problems with the systems, but by the end of the trial period, the project had demonstrated that the systems were robust enough to be deployed in the difficult working conditions often experienced on small inshore vessels and that the systems were very reliable. Long term robustness of the systems would need to be evaluated in a longer term project, but the systems (v5.0) are guaranteed by the manufacturers for two years (with optional extended warranties available), and there is no reason why systems cannot be used long term with appropriate periodic maintenance.

A major success of the project was the “buy-in” of the participating skippers to the approach of self-sampling and deployment of EM technology on board. In the past, the fishing industry has been sceptical about independent observation of fishing activities, but now all participants welcomed the opportunity to have their entire fishing activity monitored to demonstrate that they are fishing in a responsible manner. The project has undoubtedly developed a level of expertise and knowledge within the participants, and this engagement needs to be built upon throughout the inshore fleet. Participating skippers could be used as ambassadors for the approach when rolling out the programme on a wider scale.

In addition the approaches described in this project could provide the necessary evidence required to underpin new management regulations. For example, in 2012 the Scottish Government ran a consultation on new controls in the Nephrops, crab and lobster fisheries, with the key issue of whether stakeholders would support a limit on the number of creels used in the Nephrops and crab and lobster fisheries (Scottish Government, 2012). The overall consensus was that such creel limits were not supported at the moment, but that the Scottish Government would encourage any IFGs that wished to implement creel limits on a local basis. The methodologies trialled in this project would undoubtedly provide the sort of data on current numbers of creels in use which would be a key piece of information in deciding any limit on creel numbers. A similar consultation exercise was run in 2014/15 on the scallop fishery including whether fishing effort should be controlled through limiting time at sea (Scottish Government, 2015a) and the methods trialled in this project could provide important evidence underlying any future decision about limiting time at sea.

In 2015, the Scottish Government published its Scottish Inshore Fisheries Strategy (Scottish Government, 2015b). The Scottish Government’s vision is to support the development of a more sustainable, profitable and well-managed inshore fisheries sector in Scotland, and Marine Scotland wants management decisions based on sound evidence with input from fishermen and other stakeholders. The approaches trialled in this project can play an important role in contributing to delivering the following objectives set out in the Scottish Inshore Fisheries 2015;

“A strong scientific base, together with effective compliance arrangements and an appropriate management framework based on engagement with industry and non-industry stakeholders are the foundations for sound fisheries management.”

“Delivering a robust comprehensive evidence base for all commercial stocks in inshore waters will be challenging, especially given the geographical scale and the often remote nature of our fisheries. Improving the foundations of sound management through enhanced data collection, reporting and evidence of activity are key to improving management of our fisheries and their interactions with other marine users. Any reporting requirements placed on fishermen should be proportionate and provide added value.”

“Marine Scotland will make provision for complying with international fisheries obligations under the Marine Strategy Framework Directive (MSFD), moving towards Maximum Sustainable Yield (MSY) for key shellfish stocks by 2020 and managing our fisheries in line with MSFD and other marine conservation initiatives. Key commercial stocks will be scientifically assessed and those that are at risk of over exploitation will be effectively managed. We will emphasise the need for better data collection (landings and effort) to allow for enhanced management at a local level and for meeting MSFD obligations."

Based on the results and experiences of this project, Seascope recommends the following:

1. A combined EM and self-sampling project should be initiated on a larger scale to test the logistics of operating a long-term, large-scale programme on the inshore fleet. Approximately 50-100 vessels on a 2-5 year programme would allow the reliability and robustness of the equipment to be tested and determine whether fishermen would be able to supply good quality self-sampled data as a normal part of their fishing routine. Such a programme would require all stakeholders to work together to formulate training programmes, design specific sampling protocols, undertake cost analysis, consider how such large volumes of data could be handled and interpreted and initiate regular feedback mechanisms. This would be the final feasibility stage before a full scale roll-out if that is what was required. Alternatively it could form the basis of a data gathering reference fleet for supplying scientific data.

2. The subprojects investigated 5 different data gathering tools, some of which duplicate information that can be gathered from other sources e.g. soak time can be obtained from self-reported data if validated, from RFID tags or from temperature DSTs. Specific experimental trips to test the efficiencies of those tools thought to be worth further investigation should be undertaken to investigate the accuracy of data gathered by each method and the associated costs.
    a. RFID tags – these worked effectively but suffered from a deterioration in quality with time. These could be developed further to ensure that durability and reliability is not an issue.
    b. Bluetooth callipers provided self-reported length and sex data relatively cheaply and with minimal impact on the crew's time. It is recommended that they be tested on a widespread and long term self-sampling project. The callipers should be developed to allow berried females and species to be identified at the press of a button. The reliability of the equipment can be improved, as can the means of recharging the batteries e.g. develop a docking station for the wheelhouse. In addition a computer app. could be developed to allow data to be stored at sea and sent automatically to a shore based database on docking.
    c. The modified discard chute was tested as a prototype as a proof of concept study. The results produced were extremely encouraging. Further development should create a catch-handling add-on that would allow all discards to be counted, sexed and measured linked to time and location of capture (ideally integrated with the EM system but through video review if necessary) and with no real change of operation for the fishermen. A project specifically to design this system is recommended. If successful it could become an income generating product.
    d. Weighing at sea is not recommended to be taken forward at this stage unless a manufacturer can be persuaded to invest in product design and testing.
    e. The DST is simple and effective, no development is required but it would be interesting to test the widespread use of this tool and the associated costs (loss of tags, recovery of data etc.). Perhaps a tag that logs information could also be considered.

3. New technologies for monitoring fishing activities are emerging all the time and it is essential to investigate whether there are new technologies such as laser measuring that may be more appropriate than current approaches or which could be integrated with EM Technology.

4. If a long-term large-scale project is undertaken (Recommendation 1) the main aim should be that the data are collected in such a way that scientists and managers can use the self-reported data with confidence in stock assessments and/or management processes. This will require verification to ensure the data is trusted. A full stock assessment using these additional data should form part of the main aims of the project.

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Annex 1

Data recording sheets for self-sampling

Vessel Name:			**Gear Description:**								
Skipper:											
Trip dates:											
	HAUL No.	1	2	3	4	5	6	7	8	9	10
Retained	Date										
	Whole Nephrops kg										
	Tailed Nephrops kg										
	Brown Crab kg										
	Lobster kg										
	Scallops kg										
	Cod retained kg										
Discarded	Nephrops kg										
	Brown Crab kg										
	Lobster kg										
	Scallops kg										
	Cod kg										

Figure A.1 Skipper's logsheet for Nephrops trawl.

Vessel Name:

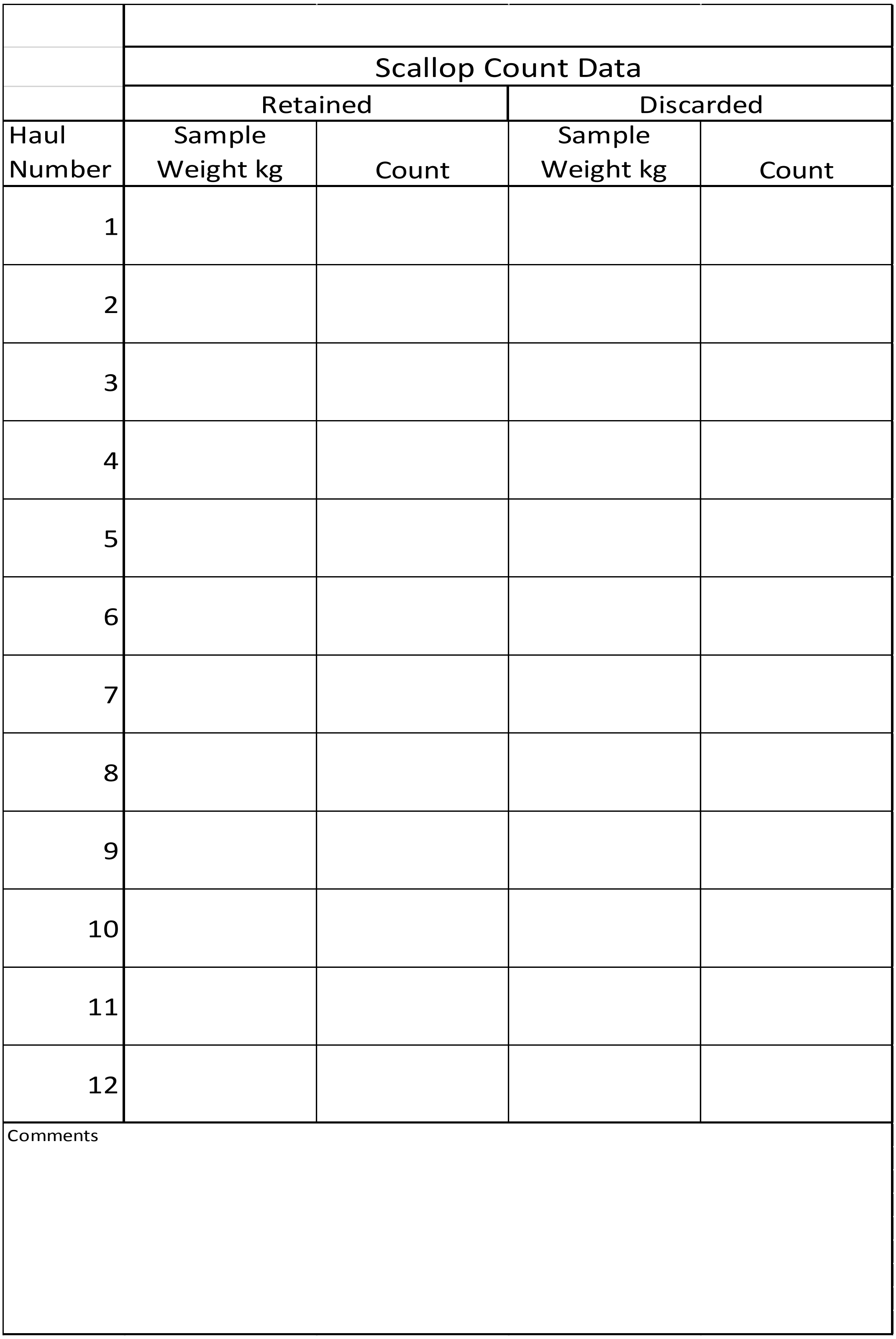
Gear Description:

Skipper:

Trip dates:

	HAUL No.	1	2	3	4	5	6	7	8	9	10	11	12
RETAINED	Scallops kg												
	Brown Crab kg												
	Lobster kg												
	Squid kg												
	Haul	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DISCARDED	Scallops kg												
	Brown crab kg												
	Lobster kg												
	Squid kg												

Figure A.2 Front side of the skipper's logsheet for scallop dredge.



	Scallop Count Data			
	Retained		Discarded	
Haul Number	Sample Weight kg	Count	Sample Weight kg	Count
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Comments				

Figure A.3 Reverse side of a scallop dredge logsheet to allow counts from a known subsample weight to be recorded.

Vessel Name:	**Date:**		**Day:**	
	Statistical Rectangle			
	Number of Strings			
Skipper Name:	**Total Number of Pots Lifted**			
	Total Soak Time (hrs)		**Bait**	

RETAINED CATCH

Species	Sex (M/F/U)	Size or Grade (eg L/M/S/U)	Number of Retained Boxes	Estimated Total Retained Wt (Kg)	Sample box wt (kg)	Females in Sample	Males in Sample

Discarded Catch

Species	Estimated Total Wt (Kg)	Sample Box Weight (kg)	Males in Sample	Females in Sample	Berried in Sample
Brown Crab					
Lobster					
Velvet Crab					
Nephrops					
Scallops			Count of Unsexed:		

Comments

Figure A.4 Skipper's logsheet for creeling vessels.

VESSEL:			TRIP NUMBER:			STRING:			ANALYSIS TIME (HRS):				COMMENTS				
SPECIES:			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	DISCARDS	M															
		F															
		B															
		U															
	RETAINED	M															
		F															
		B															
		U															
		M large															
SPECIES:			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	DISCARDS	M															
		F															
		B															
		U															
	RETAINED	M															
		F															
		B															
		U															
		M large															

Figure A.5 Creel video analysis catch recording sheet: pot by pot.

Vessel Name	HD Start Date	HD End Date		Sampled Trip Code	Departure Date	Return Date	Tows Declared	Total Towing Time Declared	Tows Observed	Total Towing Time Observed		

Tow Number	Towing Time	Species	Ret/Dis?	Category	Sex (U/M/F/B)	Tally	Number Counted	Estimated Weight KG	Time to analyse (hrs)	EM System Comments	General Comments

Figure A.6 Towed gear video analysis catch recording sheet: tow by tow.

Table A.1 Maximum and minimum temperature and depth readings for each day the DST was deployed.

Date	Max Temp	Min Temp	Max Depth	Min Depth	Batt Volts
19/06/2015	20.188	11.75	0.43	0.06	3.11
20/06/2015	15.656	11.359	0.46	0.31	3.16
21/06/2015	12.906	10.453	0.43	0.31	3.15
22/06/2015	15.531	9.703	24	0.12	3.15
23/06/2015	12.688	12.203	24.31	20.06	3.15
24/06/2015	12.828	12.391	24.12	20.43	3.15
25/06/2015	12.891	12.484	23.96	20.43	3.15
26/06/2015	13.031	12.625	23.96	20.59	3.15
27/06/2015	13.297	12.906	24.25	20.65	3.15
28/06/2015	13.547	13.094	24.59	20.62	3.15
29/06/2015	13.609	13.078	25.03	20.46	3.15
30/06/2015	13.719	13.172	25.46	20.43	3.15
01/07/2015	13.875	13.188	26.09	20.5	3.15
02/07/2015	14.047	13.266	26.37	20.65	3.15
03/07/2015	14.109	13.328	26.68	20.84	3.15
04/07/2015	14.281	13.5	27.12	21.06	3.15
05/07/2015	14.188	13.734	27.62	21.4	3.15
06/07/2015	14.063	13.313	28.03	2.9	3.15
07/07/2015	14.063	13.672	27.5	21.37	3.15
08/07/2015	14.172	13.828	27.09	21.5	3.15
09/07/2015	14.219	13.672	26.75	21.84	3.15
10/07/2015	14.578	13.813	26.62	21.96	3.15
11/07/2015	14.641	13.891	26.4	21.93	3.15
12/07/2015	14.75	13.938	26.31	21.71	3.15
13/07/2015	14.609	14.016	26.28	21.68	3.16
14/07/2015	14.516	14.063	26.4	21.37	3.16
15/07/2015	14.813	13.547	27.68	2.31	3.16
16/07/2015	14.516	14.188	27.75	22.28	3.16
17/07/2015	14.516	14.281	27.9	22.25	3.16
18/07/2015	14.516	14.016	28.06	22.03	3.16
19/07/2015	14.453	14.063	27.87	22.31	3.16
20/07/2015	14.359	14.188	27.53	22.34	3.16
21/07/2015	14.453	14.188	27.59	22.5	3.16
22/07/2015	14.531	14.25	27.21	22.71	3.16
23/07/2015	14.594	14.234	26.96	22.9	3.16
24/07/2015	14.703	14.344	26.71	23.03	3.16
25/07/2015	15.656	14.047	26.4	2.18	3.16
26/07/2015	14.828	14.484	26.12	22.9	3.16
27/07/2015	14.688	14.25	26	2.03	3.16
28/07/2015	14.766	14.469	26.34	22.21	3.16
29/07/2015	14.828	14.516	26.68	21.93	3.16
30/07/2015	14.844	13.906	27.43	0.03	3.16
31/07/2015	14.828	14.656	27.46	21.78	3.16
01/08/2015	14.781	14.469	27.59	21.28	3.16
02/08/2015	14.766	14.281	27.53	20.93	3.16
03/08/2015	14.813	14.344	27.75	20.96	3.16
04/08/2015	14.844	14.219	28.03	21	3.16
05/08/2015	14.922	14.422	27.5	21.25	3.16
06/08/2015	16.063	14.406	27.21	0.03	3.16
07/08/2015	16.391	14.141	26	2.06	3.16
08/08/2015	15.219	14.875	26	21.78	3.16
09/08/2015	15.234	14.938	25.9	21.96	3.16
10/08/2015	15.297	15.047	25.9	21.93	3.16
11/08/2015	15.422	15.125	26.03	21.75	3.16
12/08/2015	15.516	15.188	26.21	21.53	3.16
13/08/2015	28.656	15.281	26.09	0.56	3.16
14/08/2015	24.328	14.406	0.96	0.71	3.16
15/08/2015	42.969	10.438	1.09	0.18	3.16
16/08/2015	41.781	13.828	0.93	0.34	3.16
17/08/2015	37.234	10.953	1.4	0.24	3.16
18/08/2015	45.734	12.656	1.87	0.4	3.16
19/08/2015	24.609	12.016	1.34	0.74	3.17
20/08/2015	40.484	14.594	1.21	0.31	3.17
21/08/2015	34.359	16.016	1.06	0.34	3.17
22/08/2015	23.203	15.078	1.06	0.71	3.17
23/08/2015	35.375	16.578	0.93	0.18	3.17
24/08/2015	37.172	14.875	0.9	0.18	3.17
25/08/2015	26.109	19.25	0.78	0.49	3.17
26/08/2015	22.328	21.125	0.65	0.56	3.17
27/08/2015	21.578	20.359	0.74	0.62	3.17

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