Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries

Work Package 4 Final Report

A Pilot Study to Define the Footprint and Activities of Scottish Inshore Fisheries by Identifying Target Fisheries, Habitats and Associated Fish Stocks

Project code: SFS004SIF

EFF: MI-NC-3-0093

This project was supported by a grant from the European Fisheries Fund

Published by Marine Alliance for Science and Technology for Scotland (MASTS)

This report/document is available on The MASTS website at http://www.masts.ac.uk/research/sustainable-scottish-inshore-fisheries/ and via the British Lending Library.

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Recommended citation style Fox C.J., Valcic L. and Veszelovszki A. 2015. Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries: A Pilot Study to Define the Footprint and Activities of Scottish Inshore Fisheries by Identifying Target Fisheries, Habitats and Associated Fish Stocks. Published by MASTS. 190pp. ISBN 978-0-9934256-4-6

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Project commencement date: 30th June 2014
Project completion date: 31st July 2015

The final year and total project cost:
Final year: 2015
Total project cost: £88,164.96 (Exclusive of VAT)

Total staff input by grade:

Grade/Position	TOTAL TIME
Fisheries Ecologist / PI	0.2
Stakeholder Consultation	0.1
Marine Geologist	0.02
Benthic Ecologist	0.02
Oceanographer	0.02
Data/Visual Systems Developer	0.4
IT Field Support	0.04
Project Admin / Management	0.06
Total Time	0.86

Intellectual Property Rights arose: all Data Explorer programming code is based on OpenSource components.

Project/Work Package Objectives:

1) Working with the regional co-ordinators and overall program management team, identify the pilot areas within the key regions – these are likely to be in the Clyde and E Scotland.
2) Description and summary of the patterns in historic fishing in the selected pilot areas.
3) By consulting with the IFGs and their Advisory Groups for the selected pilot regions attempt to identify their likely data visualisation requirements to enable them to deliver effective inshore fisheries management.
4) Characterise relevant datasets for physical and biological oceanography and habitats.

5) Evaluate the available scientific knowledge on spawning, nursery and brood-stock areas within the pilot regions.
6) Determine outputs likely to assist in local fisheries management and marine planning and produce a demonstrator web-based system.
7) Investigate how such a data visualisation tool might be interfaced with the National Marine Plan Interactive portal (NMPi).

Primary milestones:

	Early Sept 2014	Confirm spatial co-ordinates within key regions to be studied.
	1st Oct 2014	Complete first set of site visits/stakeholder workshops.
	1st Oct 2014	Complete identification and characterisation of available oceanographic, biological and habitat data for selected locations – data meta-characteristics to be evaluated and passed to IT and gaps identified
	28th Feb 2015	Deliver test-version of the data visualisation web-tool
	15th Jun 2015	Deliver working demo-versions of data management and visualisation IT
	10th Jun 2015	Submission of draft final report to project management team for comment
	31st Aug 2015	Deliver final report

Report Title	Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries
Project Name	A Pilot Study to Define the Footprint and activities of Scottish Inshore Fisheries by Identifying Target Fisheries, Habitats and Associated Fish Stocks
Client/Customer	Sea Fish Industry Authority
SRSL Project Reference	P0827_01255

Document Number	P0827_0003

Revision History

Revision	Changes	Date
DraftA	Issue for internal review for comments	26/05/2015
DraftB	Second issue for internal review	11/06/2015
DraftIssue01	First official draft to client for comments (Exec. Summary, Part1and Part 2)	29/06/2015
DraftIssue01	First official issue to client for comments (Part3 and Part4, including overall Cover page)	10/07/2015
Issue02	Second issue to client, with comments addressed	26/08/2015
Issue03	Third issue to client, with comments addressed	31/08/2015

	Name & Position	Date
Author	Clive Fox	26/05/2015
Checked	Andrea Veszelovszki	10/07/2015
Approved	Andrea Veszelovszki (Issue 1)	10/07/2015
Approved	Lindsay Vare (Issue 2)	26/08/2015
Approved	Lindsay Vare (Issue 3)	31/08/2015

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Work package 4 report including:

- A summary of available published biological and environmental data relevant to inshore fisheries management in two pilot areas, the Firth of Clyde and Moray Firth (Parts 1 & 2)
- A consideration of the data which may prove useful for inshore fisheries management (Part 3)
- A description and evaluation of a web-based tool for visualising such data (Part 4)

Work Package Objectives

The original project tender envisaged an objective on summarising current fishing patterns in the pilot areas. However, the project sponsors subsequently wished more emphasis to be placed on potential integration with NMPI as that project had moved forward in the interim. A change in this objective was therefore proposed by the contractors, and agreed by the project sponsor (to Objective 3).

1. Working with the regional co-ordinators and overall program management team, identify the pilot areas within the key regions – these are likely to be in the Clyde and E Scotland.
2. Summarise the patterns in historic fishing in the selected pilot areas.
3. By consulting with the IFGs and their Advisory Groups for the selected pilot regions attempt to identify their likely data visualisation requirements to enable them to deliver effective inshore fisheries management.
4. Characterise relevant datasets for physical and biological oceanography and habitats.
5. For the pilot areas, evaluate the available scientific knowledge on spawning, nursery and brood-stock areas.
6. Determine outputs likely to assist in local fisheries management and marine planning and produce a demonstrator web-based system.
7. Investigate how such a data visualisation tool might be interfaced with the National Marine Plan Interactive portal (NMPi).

Project outputs will include:

- Provision of a demonstration environmental and fishery resource mapping platform and associated database.
- A final report that includes:
    - A data catalogue of the available information on relevant physical and biological datasets for the pilot areas.
    - Recommendations for further development and potential application of the demonstration system for use as a fisheries management tool and how it might be interfaced with NMPi.

Executive summary

This work was conducted under Work package 4 of the European Fisheries Funded program "Evidence Gathering in Support of Sustainable Scottish Inshore Fisheries". The overall aim of the program was to work in partnership with Marine Scotland Fisheries Policy and with the Scottish Inshore Fisheries Groups to help develop inshore fisheries management. Specifically the program aims were to establish the location of fishing activities within inshore areas; to identify catch composition and associated fishery impacts; to define the environmental footprint and availability of stocks; to develop economic value within local fisheries and; to establish an information resource base to assist the development of inshore fisheries management provisions.

The Clyde and Moray Firth were chosen as pilot areas (Objective 1) because they both have been relatively well studied (hence data are available), have existing inshore management plans but are also contrasting (the Clyde being an enclosed fjordic-type system on the west coast and the Moray Firth being more open and on the east coast).

Our aim was not to collate all the available data which might be relevant to inshore fisheries management in these regions but rather to select examples to illustrate how we might handle and visualise such data. The different data types included, firstly, finely resolved data in spatial terms (and hence large file sizes) but which would be updated infrequently e.g. bathymetry; secondly, finely spatially resolved but smaller file sizes with irregular updating e.g. hydrographic charts and marine protected area boundaries; thirdly, data which might be updated frequently e.g. vessel positions; fourthly, data which might be updated more regularly but is not in standard GIS formats e.g. catch records. Data were either obtained from existing publically available sources, purchased or obtained from other work packages within the wider project (principally WP1 Establishing the location of fishing activities within Scottish inshore areas using new vessel position reporting technology; WP2 Monitoring fishery catch to assist scientific stock assessments in Scottish inshore fisheries and WP3 Identifying catch composition to improve Scottish inshore fisheries management using technology to enable self-reporting).

The review of historic and present fishing patterns in the regions was based largely on published material but was updated in consultation with the relevant Inshore Fisheries Groups and their advisory groups. Meetings were held with the Clyde and Moray Firth IFGs to discuss how they saw inshore fisheries management in their areas developing. These discussions were then used to inform the sorts of data visualisations which might be required and to rank the various data identified in terms of their potential utility to different levels of inshore fisheries management.

A demonstration internet-based data visualisation tool (the Inshore-fisheries data explorer) was developed. Clyde and Moray Firth IFGs and the wider planning groups were invited to review the tool on-line in order to stimulate thinking about inshore fisheries management. In addition we solicited feed-back from potential users using an online survey about the different features shown in the web-based tool. The general need for access to such information was recognised by respondees although there was uncertainty regarding the levels of information they will require. This largely stems from the present uncertainties about how inshore fisheries management will operate in future in Scotland.

Finally consultations were held with Marine Scotland to evaluate how such interactive tools might be incorporated into the National Marine Planning Interactive website (NMPI). Such integration would avoid duplication of effort and would also potentially provide sustainability as resources are allocated to maintaining NMPI in the longer term.

Part 1: Information relevant for inshore fisheries management in the Firth of Clyde

Contents

Geographical boundaries of the Firth of Clyde pilot area

A simple polygon covering the area out to 6 nm (nautical miles) offshore was selected to define the boundaries of the Clyde pilot area. The selected region was aligned with existing areas proposed for Marine Planning in order to make data sharing easier. The area selected for this project is the same as that used in the Clyde Marine Plan (Donnelly et al. 2010) which also almost corresponds to the definition above (the southern corner being slightly to the north of Corsewall Point). These boundaries are for demonstration purposes only and may not reflect the final boundaries selected for use in inshore fisheries management or marine planning.

Various projects have defined the extent of the Firth of Clyde and have also used a variety of names. Marine Scotland defined the Clyde Sea as the marine tidal extent which encompasses the Firth of Clyde, the Clyde Estuary and the sea lochs to the north of the Firth and Loch Ryan in the south of the area. The islands of Bute, Arran, Ailsa Craig and the Cumbraes lie within the main body of the Firth. The outer boundary where the Firth of Clyde meets the Irish Sea extends from the southern tip of the Mull of Kintyre to Corsewall Point. In total the Clyde Sea encompasses an area of 3600 km^2 and has a volume of approximately 180 km^3.

The Clyde marine planning area is almost identical but with a slightly different outer boundary. The area encompasses the marine and tidal extents of the Firth of Clyde including the River Clyde, the Inner Firth and associated sea lochs and the outer Firth. The outer boundary extends from the tip of the Mull of Kintyre across to Finnarts Point, north of Loch Ryan. It extends north to the heads of Loch Long and Loch Fyne and east along the River Clyde to the tidal weir in the city of Glasgow (Table 1). The area covered is approximately 3,650 km^2. We defined our pilot area (Table 1) following this. In this report the names Firth of Clyde and Clyde are used interchangeably.

Table 1: Polygon boundaries for Firth of Clyde pilot area

Node	Latitude	Longitude
1	56.3161	-4.9159
2	56.2066	-4.7359
3	55.9217	-4.5423
4	55.4620	-4.5432
5	55.0450	-5.0529
6	55.2892	-5.7626
7	55.8053	-5.3927
8	56.0428	-5.5228
9	56.3161	-4.9159

Historical and recent trends in the Firth of Clyde fisheries

History of the Firth of Clyde fisheries

There have been considerable changes over the last two centuries in the fisheries in the Firth of Clyde which have been relatively well documented in a series of historical and scientific papers. Some of these analyses have caused considerable controversy regarding the scale and causes of the changes observed and also with regard to potential management approaches to reversing the situation (should that be agreed to be a desirable aim).

The earliest records of herring (*Clupea harengus*) as a commercial product in Scotland come from the early 12th century (Wood 1960). The fisheries from this time up to the 18th century were mainly conducted in inshore waters including Loch Fyne. Although local consumption would have been important, salted herring were traded internationally with fish from the Clyde being shipped to France (20,000 barrels in 1674) and later to the West Indies plantations. During this period the main method for catching herring was using drift nets although trammel nets were also deployed close to the Ayrshire coast, particularly on Ballantrae Bank. The ring-net was introduced in 1838 and soon led to conflicts with the drift-net fishers who claimed the new method caught large numbers of immature herring. In 1851 an Act was passed banning ring-netting but this was rather rapidly amended in 1867. Ring-netting was a more efficient fishing method and following the amendment the numbers of fishers using this technique increased. Historical fishing records from the Clyde from the mid-19th century have been analysed by Peter Jones (University of Strathclyde) who has shown changes in catch per unit effort (CPUE[1]) over the period 1845 to 1885. Over this time CPUE for herring showed a marked increase and CPUE for whitefish a decrease. It is not clear whether these changes reflected natural shifts in stock abundance or whether the scale of fishing, even at that time, was a causative factor (Jones 2014). After 1885 the landings of herring per boat again dropped reaching a very low level in 1894 (although note that the data reported are not strictly comparable) (Thurstan & Roberts 2010). The fishing at the end of the 19th century was presumably still worthwhile because in 1899 there were around 600 drift netters and 600 ring netters operating in the Clyde. By 1914 the number of drift-net vessels had fallen to a handful and the switch from sail to motor propulsion was also complete (Wood 1960). The period between the wars saw further changes in fishing technique with the introduction from Scandinavia of the ‘feeling wire’. A weighted copper wire was towed and the location and size of the herring shoals could be estimated from the vibrations caused as the wire was struck by passing fish. Apart from 1936, the herring fishery between 1930 and 1939 was relatively good (18,000 to 29,000 tons year^{-1}) with a number of strong year-classes entering the stock. It must be remembered that catches are not necessarily a good index of stock status because over-supply during the inter-war period was not unusual (Wood 1960). Post WWII saw more technical changes with the ‘feeling wire’

[1] In fact the data analysed in that study were Landings per unit effort (LPUE) but the term Catch per unit effort (CPUE) is often used interchangeably, as in that report. LPUE and CPUE may differ because reported landings to shore will not include any discarding which has occurred at sea. Both indices are calculated by dividing the reported landings (often assumed equivalent to the catch) by a measure of the fishing effort exerted, this has the effect of standardising to remove the effect of changes in the number of vessels. CPUE is likely to more closely reflect the state of the stocks compared with raw landings or catch data, but both indices will also be affected by changes in fishing technology.

being superseded by the echo sounder which derived from the Asdic submarine detection systems originally developed towards the end of WWI but used widely during World War II.

A detailed historical account of the fisheries in the Firth of Clyde in the 1950s has been provided by one of the participants - McCrindle (2006). Some of that account can only be understood in relation to changes in the regulations affecting fishing. Trawling for herring within the Firth of Clyde was prohibited until 1962, although trawling was not a widely used method for catching this species as pelagic towed gears had not been developed (Wood 1960, Bailey et al. 1986b). In 1962 a Byelaw was passed which prohibited fishing for herring by any method between midnight on Fridays and midnight on Sundays. The main spawning ground for herring on the Ballantrae Bank had originally been closed in 1860 but this was repealed in 1867 and the Bank stayed open to fishing until 1972, when a seasonal closure was introduced from 15 February until the 30 April each year. There was an exemption for anchored drift nets but they became included in the seasonal closure in 1977 (Bailey et al. 1986b).

In the late 1950s the fleet was mainly comprised of ring-netters which moved between grounds along the whole Scottish west coast depending on the time of year. Boats remained fishing in the Clyde over the summer before moving north to fish the Outer Hebrides in October. The main local herring fishery took place in early spring for arriving spawners on the Ballantrae Bank and on gravelly shallows at the south end of Arran. Although trawling was banned within the Clyde, small (<40 feet in length) seine netters could operate within the 3 nm limit and these targeted species such as haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*), whiting (*Merlangius merlangus*), hake (*Merluccius merluccius*), plaice (*Pleuronectes platessa*) and skate (Ritchie 1960). Outside the 3 nm limit larger seine netters operated, many from east coast ports and their numbers tended to increase during spring when they targeted spawning aggregations of cod, haddock and whiting. These larger seiners also targeted hake in late summer off Ailsa Craig. Despite the ban on local trawlers in the Clyde, McCrindle (2006) records that French and Spanish vessels could trawl in this area (outside the 3 nm limit), although it is not clear how many foreign vessels were involved.

In the 1960s the nature of the fleet changed dramatically. There was an increase in trawling for cod in the Minch (outside the Clyde) and a decline in seine netting due to the labour required. Fishing for herring became less popular. The nature of the herring fishery was also changing with mid-water pair trawling arriving in the Clyde around 1968. Initially two local vessels, along with boats from Northern Ireland (Kilkeel), Peterhead and Fraserburgh, pursued this type of fishing. Catches were higher compared with ring-netting because it would gather fish even when they were not concentrated in schools. In the early 1970s large catches of saithe (*Pollachius virens*) began to be made south of Arran using the relatively new mid-water trawls. Fishing intensity increased quickly with bottom trawlers also targeting this species south of Ailsa Craig but by the late 1970s catches of all species had declined. Although the main herring fisheries around the UK were closed in 1977 and 1978 to allow stocks to recover, a limited herring fishery was allowed to continue in the Clyde (Wood & Hopper 1984). Interestingly, McCrindle (2006) notes that larger cod, haddock and hake tended to be caught with the mid-water gear used at that time compared with ground-gear. He suggested that the older fish spent more time in mid-water and so started to be caught. In the early 1980s, McCrindle describes how mid-water pair trawling began to be replaced by single boat pelagic trawls. This method was even more efficient and rapidly spread through the Clyde and Northern Irish fleets. However the landings of herring from the Clyde were relatively small (about 2,500 tonnes) compared to the wider west of Scotland (about 35,000 tonnes) (Wood & Hopper 1984). By the late 1980s landings of finfish dropped away almost entirely. McCrindle (2006) concludes with great sadness that this is the result of the technology developing to the level where there was no refuge for the fish.

More comprehensive fisheries landings data has been compiled since the 1960s and the patterns in demersal landings up to 1984 were described by Hislop (1986). It should be noted that he included the outer Clyde, northern part of the North Channel and part of the Sound of Jura in his account (ICES statistical rectangles 39E4, 39E5, 40E4 and 40E5). The total demersal fishing effort (measured as hours) rose in the mid-1960s reaching a peak in 1973 but total effort (in hours) subsequently declined ending up at around the same level as in the early 1960s. There had however been an almost total shift from dominance of seine netting to *Nephrops* trawling, as described previously. In the early 1980s, around 20% of the hours fished were counted as 'light trawling', the difference being that *Nephrops* trawling caught a much lower proportion of finfish and used a different mesh size. Seine netting was still taking place but at a rather low level. The main species caught (by weight) were cod (10%), haddock (37%), whiting (8%), saithe (3%) and hake (16%) but in terms of value, cod and hake were the most important. Spurdog (*Squalus acanthias*), plaice, skates and rays and monk (*Lophius piscatorius*) were also landed to some extent. Prices of all major whitefish species rose steeply during the late 1960s and early 1970s because of the closure of the distant water fishing grounds to the English trawler fleet. Most demersal fishing effort occurred during winter and early spring after which the vessels switched back to targeting *Nephrops* or herring. Hislop (1986) also noted that the landings of individual species tended to fluctuate strongly and attributed this to the high fishing intensity meaning that the stocks were heavily dependent on the strength of the incoming year class. The rapid increase in saithe landings between 1970 and 1973 was attributed to a disproportionate price increase for this species.

Records of fishing rights for salmon (*Salmo salar*) go back to the 12th century and significant fisheries existed in the Clyde during the 1800s. Increasing industrialisation led to significant pollution of the Clyde itself (Buckland 1871) and by 1900 no salmon were entering the rivers Clyde, Kelvin and Cart, which drain into the estuary (Mackay & Doughty 1986). A number of factors were responsible but mainly the massive increase in organic pollution from the expansion of the city of Glasgow combined with the deepening of the shipping channel. A large number of weirs were also being constructed on the rivers which further hampered the passage of salmonid fish. Salmonids continued to be found in the lower reaches of the estuary spawning in rivers connected to Loch Lomond. Following a Parliamentary Review in 1876 sewage treatment works began to be constructed and the situation improved somewhat but even in the 1960s the upper estuary was still heavily polluted (Haig 1986). Improvements began in the 1960s and from 1983 onwards salmon began to be seen once again at the Blantyre Weir. A number of restocking exercises were undertaken and in the late 1980s juvenile salmon were caught upstream of the Blantyre Weir confirming that some successful spawning has taken place. In 1992 surveys also confirmed salmon spawning in the Black Cart and Kelvin catchments (Mackay & Doughty 1986).

By the late 19th century the inner estuary and River Clyde were heavily polluted although the water quality has been considerably improved recently. Henderson (1986) reported on sampling from the outer and upper estuary which caught a range of marine, euryhaline and freshwater species. Several species normally considered as marine including dab, whiting and saithe appeared to penetrate surprisingly far up the estuary. The presence of fish between Woodhall and the Erskine Bridge throughout the year was taken to indicate that dissolved oxygen levels were rarely depleted in this part of the estuary. From 2005, the annual surveys conducted by the Scottish Environmental Protection Agency (SEPA) were stopped and replaced by a program of less frequent monitoring in the river and upper and lower parts of the estuary (O'Reilly 2010). Prior to 1999 only around 5 to 10 species were being regularly caught but this increased strongly around 1999 and the count of total species has since fluctuated at between 15 to 25 species each year (Scottish Natural Heritage 2005). However, the new data-series associated with the Water Framework Directive indicators are not strictly comparable with the older time-series because of changes in the sampling effort and gears deployed. Because the main commercial fisheries take place further out into the Firth of Clyde itself, it was not considered that the SEPA data would be especially useful for inshore fisheries management, although relevant stakeholders should be kept aware of any major changes in the index.

The importance of shellfish in the Clyde fisheries has also changed dramatically over the last few decades. According to Mason and Fraser (1986), landings of shellfish up to around the mid-1940s were limited and mainly the result of local crofting associated fishing. Species caught included lobster (*Homarus gammarus*), and edible crab (*Cancer pagurus*) although the area of rocky habitat is limited in the Clyde. Mussels (*Mytilus edulis*) and native oysters (*Ostrea edulis*) were also collected to some extent. From 1950 onwards the commercial shellfisheries in the Clyde began to increase with values rising to more than £4.5 million by 1983. The fishery for Norway lobster (*Nephrops norvegicus*) developed quite rapidly so that landings reached a value of £3.75 million as early as 1983. A fishery for queen scallops (*Aequipecten opercularis*) developed in the mid-1960s (see also Mason and Fraser, 1986) using small, heavily twined nets fitted directly to the doors (McCrindle 2006). A dredge fishery for king scallops (*Pecten maximus*) also developed from the 1960s onwards but landings from the Clyde were relatively low compared with overall Scottish landings. Other species (mussels, oysters, lobster, edible crab and velvet swimming crab (*Necora puber*) made relatively small contributions to the landings overall. Considerable quantities of mussels were collected in the 19th century (1883-1897 about 12 kilotons per annum) for use as bait in line-fishing. However, this declined during the first part of the 20th century so that collection from some of the sea lochs remained the main fishery. Mason and Fraser (1986) noted that sewage pollution was a particular problem in certain parts of the Clyde and that no depuration facilities existed at that time. There was some limited exploitation of cockles (*Cerastoderma edule*) in the mid-1960s following a particularly cold winter (1962-63) which affected English and Welsh cockle beds. There is little evidence for extensive collection of oysters before the mid-1800s but by the early 1900s landings were around 80-100 tons yr^{-1}. Rights to collect oysters from Loch Ryan were granted to the Wallace family in 1701 by King William III. Some commercial development of the fishery took place in the 1970s and it still exists today as Scotland’s last remaining wild native oyster fishery. Oysters are also farmed in Loch Fyne. Periwinkles (*Littorina* spp.) have also traditionally been collected by hand from the shoreline of the Clyde and, at times, this constituted a surprisingly valuable fishery (annual landings 1974-83 estimated at about 380 tons yr^{-1} with a value of £82,000). Mason and Fraser (1986) also mentioned that catches of squid (*Loligo forbesii*) could be significant in some years but that this species only supported an opportunistic fishery.

During the last century there have been a large number of changes in fishing regulations in the Clyde. A ban on trawling was originally introduced in the late nineteenth century (1889) after it was suggested that the Firth of Clyde herring stocks were becoming depleted (the area covered by the ban was virtually identical to the Firth of Clyde pilot area used in this report (Thurstan & Roberts 2010). The Act was then amended in 1934 to include beam and otter trawling under the Illegal Trawling (Scotland) Act 1934. The closure remained in place until 1962 when the Sea Fisheries (Scotland) Byelaw (No.65) came into effect which permitted summer (1 May to 30 September) otter trawling within the Firth of Clyde, except within the 3 nm limit. Further legislation in 1968 (Sea Fisheries (Scotland) Byelaws No.'s 80 and 83) enabled fishing to take place throughout the year. The 3 nm limit remained in place until 1984 (the Inshore Fishing (Scotland) Act) when it was repealed under pressure from the industry during a time when demersal finfish landings were in decline.

In 1962 bottom trawling for Norway lobster was approved in areas more than 3 nm from the coast but in 1984 the trawl ban within 3 nm of the coast was repealed. The herring fishery had collapsed in the 1970s while the fishery for mid-water saithe went through a boom and bust in the late 1960s. Subsequent to this, from around 1982 onwards, landings of finfish declined strongly (Figure 3). The remaining dominant commercial fisheries were for *Nephrops* and scallops. Thurstan and Roberts (2010) argued strongly that these changes were mainly related to the re-opening of the Clyde to trawling citing habitat damage, as well as general over-exploitation. However, this has probably been the most contentious part of their conclusion and the impacts of the shellfish trawl and dredge fisheries in the Firth of Clyde continue to be debated.

A significant criticism of the paper by Thurstan and Roberts (2010) was that it was based entirely on fisheries landings. As well as being influenced by what is available to be caught landings data are also affected by changes in markets. There is a limited amount of research survey data available for the Clyde and these data have been analysed by Heath and Speirs (2011). They looked at changes in biomass density, species diversity and the length structure of the demersal fish community between 1927 and 2009. They concluded that as commercial yields declined, the demersal fish community moved from a state in which biomass was distributed across a large number of species (high species evenness) and where large fish were relatively common, to one in which small whiting comprised 90% of the biomass. The abundance of certain predators, such as spurdog also appeared to decline strongly following opening of the inshore waters to trawling. Following cessation of the directed finfish fishery, species evenness recovered quickly but 10 years later the community was still dominated by small fish, mainly whiting. These changes partly reflect patterns across a larger regional scale with similar shifts being seen in the Sea of Hebrides, but the changes do seem more extreme in the Clyde. The authors felt that the Clyde system is sufficiently isolated that it displays distinctly local responses, although they noted that tagging data for species such as dogfish and cod has demonstrated some level of population exchange with waters outside the Clyde. They also concluded that changes in the fish community had occurred around the time that the offshore trawling ban was repealed (1962) which led to a temporary increase in landings, and that these changes pre-dated the opening of the inshore zone (out to 3 nm) in the early 1980s. This point is also supported by McCrindle (2006) who suggests that the main factor was the change from ring-netting to mid-water pair trawling in the mid-1960s. McCrindle (2006) was also of the opinion that opening up the inshore (3 nm) zone to trawling probably had relatively little impact on the finfish stocks which were already heavily depleted. Heath and Speirs (2011) also noted that the lag in expected response of the ecosystem to changes in fishing pressure has implications for any attempts at managing a restoration the Clyde towards its former state. The paper includes some discussion of ‘alternate ecosystem’ states with the suggestion that it may be difficult to re-engineer such an altered ecosystem.

Table 2: Timeline of notable events in Firth of Clyde fisheries (Pieda and SMBA, 1988; Thurstan & Roberts, 2010; Clyde Inshore Fisheries Group, 2011)

Year	Event	Comment
1838	Introduction of seine net.	Increased numbers of herring caught, including juveniles.
1851	Circle netting for herring banned in Loch Fyne	
1860–67	Ballantrae Banks closed January–May.	An attempt to prevent the capture of spawning herring.
1867	All regulations on fishing in the open sea repealed as a result of the Royal Commission of 1863.	'Freedom of the seas' ensues, previous legislation and byelaws repealed.
1880s	Steam trawl vessels come into regular use.	Steam power enables trawlers to expand fishing opportunities.
1885	Fishery Board for Scotland granted powers to control beam trawling.	
1887	Fishery Board for Scotland conduct an enquiry into trawling.	Enquiry leads to calls from some fishery scientists for the Firth of Clyde to be closed to trawling.
1889	It becomes unlawful to trawl within three nautical miles of low water all around Scotland (Herring Fishery Scotland Act). Whole Firth of Clyde closed to steam trawlers.	Trawling (with the exception of sailing vessels less than eight tonnes) is stopped throughout the Firth of Clyde.
1889-1908		Trawling ban relaxed to allow beam trawling within certain areas of the Clyde.
1890s	Seine net becomes most common method of fishing for herring.	Widespread use of seine nets allow greater catches to be taken

Table 2: Timeline of notable events in Firth of Clyde fisheries (Pieda and SMBA, 1988; Thurstan & Roberts, 2010; Clyde Inshore Fisheries Group, 2011)

Year	Event	Comment
1898	Use of flounder seine and dragged nets banned within exclusive fishery limit except for the capture of herring.	
1901	Ban on use of circle nets to catch herring on Ballantrae Bank.	Ban relaxed for small vessels operating in some parts of the Clyde (1905).
1910	Circle net ban repealed	
1920s	Danish seine becomes more popular in Scotland. Seining permitted in Clyde for vessels under 40 feet length. Some Clyde boats fitted with a motorised winch.	Increases fishers' ability to haul larger and heavier nets.
1930s	Feeling wire put into use.	Enables fishers to 'feel' for herring shoals in the water column. Before this fishers had to locate herring by other signs such as seabirds feeding, appearance of the water.
1934	The Illegal Trawling (Scotland) Act 1934.	Beam and otter trawls banned in Firth of Clyde.
1950s	Introduction of echo sounders.	Enables fishers to more easily detect concentrations of herring.
1962	Autumn herring fishing season halted.	Fishing season halted due to a lack of herring.
1962	Sea Fisheries (Scotland) Byelaw 65.	Permitted summer (1 May to 30 September) otter trawling by vessels less than 70 feet in length within the Firth of Clyde, except within the 3 nautical miles limit. Also controls on size of otter boards and a 25% limit by weight for fish other than *Nephrops*.
mid-1960s	Mid-water trawl for herring comes into use.	Allows fishers to continue fishing for herring even when shoals are dispersed.

Table 2: Timeline of notable events in Firth of Clyde fisheries (Pieda and SMBA, 1988; Thurstan & Roberts, 2010; Clyde Inshore Fisheries Group, 2011)

Year	Event	Comment
1968	Sea Fisheries (Scotland) Byelaws 80 and 83.	Permitted trawling to take place throughout the year except within 3 nautical miles limit. Some technical modifications to controls on sizes of otter boards.
1969	Pair trawling permitted for herring except on Ballantrae Bank and between Feb and March.	Repealed earlier gentlemen's agreement prohibiting pair trawling in the Clyde.
1972	Seasonal closure implemented during spring herring fishery.	Attempt to increase protection for dwindling herring stocks.
mid-1970s	Trawl fisheries for cod, haddock and saithe intensity	Catches of saithe go through boom-and-bust.
1976	Quotas implemented in autumn herring fishery.	Attempt to increase protection for dwindling herring stocks.
1984	Inshore Fishing (Scotland) Act (came into force in 1985).	Repealed ban on trawling within the 3 nautical miles limit during a time when offshore demersal fin-fish landings was in decline. Conservation order restricted fishing vessels to less than 70 feet length except those catching herring, mackerel and sprat. Jan to 30 April all Clyde closed to herring fishing north of a line from Mull of Kintyre to Corsewall Point. The target species needs to represent at least 50% of the catch. Herring by-catch, maximum 50 kg per boat. Licencing system introduced for fishing on Ballantrae Bank.
1986	Schedule 1 of prohibition of fishing SSI	Weekend ban on mobile gear - midnight on Friday until midnight on Sunday from 1st January to 31st December in each year.
1989	Undersized Velvet Crab Order	Set minimum landing size of 65 mm carapace width.
1994	Inshore Fishing (Scotland) Act	Makes provision for control of fishing by vehicles or equipment.
1996	The Inshore Fishing (Monofilament Gill Nets)(Scotland) Order	Prohibits fishing for sea fish using monofilament gill nets in Scottish territorial waters.

Table 2: Timeline of notable events in Firth of Clyde fisheries (Pieda and SMBA, 1988; Thurstan & Roberts, 2010; Clyde Inshore Fisheries Group, 2011)

Year	Event	Comment
1999	The Lobsters and Crawfish (Prohibition of Fishing and Landing)(Scotland) Order	Prohibits landing of V-notched animals.
2000	The Undersized Lobsters (Scotland) Order	Prescribed minimum landing size of 87 mm carapace length.
2000	The Undersize Spider Crabs (Scotland) Order	Prescribed a minimum landing size for male spider crab (*Maia squinado*) of 130 mm carapace length.
2000	The Undersize Edible Crabs (Scotland) Order	Prescribed a minimum landing size for edible crab (*Cancer pagurus*) which on the west coast is set at 140 mm carapace width.
2000	Sea Fishing Industry (Fishing) Order 1962 Amended	Nets for *Nephrops* fishing must have a stretched mesh size of not less than 80 mm.
2001	Cod-box	The ‘cod box’ was a temporary measure introduced 1st March to 30th April 2001 designed to protect cod at spawning time. The ‘cod box’ is now a National Order on an annual basis. Minimum 35% of Nephrops target in catch.
2003	The Prohibition of Fishing for Scallops (Scotland) Order	Bans the use of a “French dredge” (or modification of a scallop dredge to obstruct the rings or netting) in Scottish territorial waters. Limit on number of scallop dredges that can be towed. Only eight scallop dredges may be towed each side of a fishing vessel, i.e. a total of 16 are towed.
2003	Annex XVII of Regulation (EC) No. 2341/2002 Additional conditions for monitoring, inspection and surveillance for the recovery of certain cod stocks.	Limit on vessels targeting Nephrops with 80-99 mm mesh size to 25 days at sea per month within the Clyde Area.

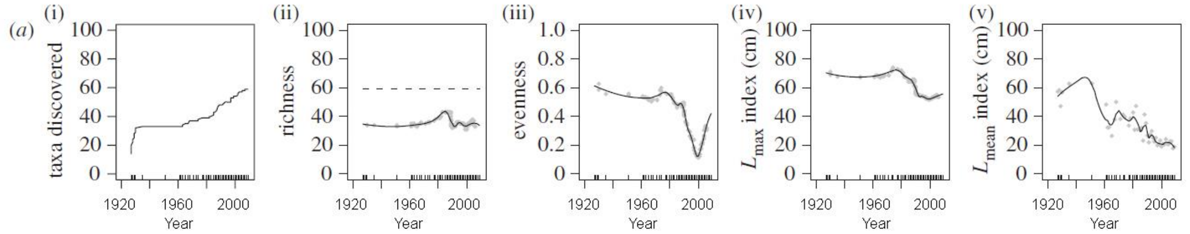
Table 2: Timeline of notable events in Firth of Clyde fisheries (Pieda and SMBA, 1988; Thurstan & Roberts, 2010; Clyde Inshore Fisheries Group, 2011)

Year	Event	Comment
2004	The Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order	Prescribes maximum landing size of 155 mm for female lobster; Provides prohibitions on creel fishing in specified areas. Vessel size prohibitions.
2004	Schedule 1 of prohibition of fishing SSI	Prohibition of fishing for any species of sea fish (except herring, mackerel and sprats) from a fishing boat with an overall length not greater than 70ft/21.34 metres. Ballantrae Banks prohibition of use of mobile or active gear from 1st February to 30th April in each year. Prohibition of mobile or active gear from 1st January to 31st December in each year except dredging for mussels and oysters in Loch Ryan.
2005	The Registration of Buyers and Sellers (RBS) Scheme	Has been fully operational in Scotland since 2005 and had the effect of reducing illegal landings of fish. The effect of this can also be seen in discarding data.
2008	The Inshore Fishing (Prohibition of Fishing) (Lamlash Bay) (Scotland)	Prohibition of all fishing for sea fish in Marine Protected Area of Lamlash Bay, Arran. Various areas of the seabed are used by the Navy/MOD or related e.g. testing range run by QuinetiQ. Prohibition of use of mobile or active gear from 1st January to 31st December in each year. Queens Harbour. Restricted access to Loch Long, Loch Long and Gare Loch. A permit has to be sought from the Queens Harbour Master.

In addition, UK commercial fisheries must comply with EU regulations, in particular those arising from the Common Fisheries Policy. For example, total allowable catches for several species of elasmobranchs, including spurdog, are presently set at zero, preventing them being landed.

The findings of Heath and Speirs (2011) are largely in line with those reported in Thurstan and Roberts (2010), although the conclusions are presented using more moderate language. The former study also provides a more complete picture of the changes in the actual fish community as a whole, rather than just those species landed commercially. Heath and Speirs (2011) demonstrate that finfish are still present in the Clyde (as shown in Figure 1) and that the total species richness has hardly changed since the 1920s. However, the community now has a different species composition and is presently dominated by small individuals. Recent analysis has further suggested that declines in the size at maturity in the Clyde could be a response to size selective fishing pressure (Hunter et al., 2015). Given the low abundance of larger, older mature fish in the Clyde this raises interesting questions as to the level of local spawning or whether the present fish community is more reliant on immigration from outside of the Firth of Clyde itself.

Figure 1: Changes in the surveyed demersal fish communities in the Clyde. Columns (i) cumulative number of demersal fish species identified in trawl samples; (ii) species richness per 20 tows; (iii) species eveness per 20 tows; (iv) annual L_{max} index and (v) annual mean length L_{mean} index. Symbols represent estimates for the mid-year of a 20-haul sliding window or for a given year, and the solid lines show the loess smoothers through the data. The dashed line in the richness panel shows the cumulative number of species identified in the surveys between 1927 and 2009. Tick-marks above the x-axes indicate sampling occasions (Heath & Speirs 2011).



In order to improve the data for the Clyde dedicated inshore surveys have been run from 2002-2004 by Marine Scotland Science (Gibb et al. 2008). A number of industry-science partnership surveys have also been conducted where commercial fishing vessels were chartered to collect scientific data. In 2010 such an exercise was run but most of the sampling was in the deeper waters to the west of the Inner Hebrides (Fernandes et al. 2011). In 2012 to 2014 a series of inshore surveys were initiated including better coverage of the Clyde. The results confirmed that the fish community was now dominated by smaller whiting although small haddock were also quite abundant. Some larger cod were caught using semi-pelagic commercial gear and it was suggested that these might represent a relict population within the deeper basin areas (Marine Scotland 2014b).

Discarding of whitefish in the *Nephrops* trawl fisheries has been highlighted as a potential issue affecting the stocks and was mentioned as early as Hislop (1986). Despite the perceived importance of this issue there seems to be very little recent data published in the scientific literature. Stratoudakis et al. (2001) reported that more than 90% of the trawling activity in the Clyde Sea has been targeted at *Nephrops* with most fin-fish landed from the Clyde Sea being caught as by-catch. However, that paper also estimated that only approximately 40% of the fish caught as by-catch was retained and landed. Much of the fish discarded consisted of undersized commercially important species with whiting being the most commonly discarded species and poor cod (*Trisopterus minutus*), long-rough dab (*Hippoglossoides platessoides*) hake and Norway pout (*Trisopterus esmarkii*) also featuring relatively frequently. Similar conclusions were reached by Bergmann et al. (2002) although they also pointed to differences between tows made in the north and south Firth of Clyde.

Some experimental studies have also been conducted on survival rates of discards in the Clyde (Bergmann et al. 2001, Bergmann & Moore 2001).

Since those studies the fish community in the Clyde has probably changed so discard patterns may also be different. Interest in levels of by-catch and discarding has recently increased due to the need to avoid excessive catches of cod (in line with cod recovery measures) and to the proposed introduction of the landings-obligation (2013 Common Fisheries Policy reform) which will require all catches from quota-managed stocks to be landed. Additional observer data from Clyde trawlers has since been collected under a Scottish Fishermens' Federation program to demonstrate compliance with cod recovery measures but these data have not yet been published in the peer reviewed literature (McIntyre et al. 2012).

Whether *Nephrops* trawling is affecting the wider fish community was one question addressed using an Ecopath with Ecosim multispecies model constructed by Heywood (2009). Comparing a no discards (assuming the *Nephrops* catches are totally clean) against a business-as-usual scenario appeared to show a large positive effect on predicted cod biomass, an intermediate effect on haddock and less effect on whiting. Simulating improved gear selectivity in the *Nephrops* trawls also produced similar, though lesser effects. The conclusion from the modelling was that discarding by the *Nephrops* fleet was impacting the stock levels of whitefish in the Clyde. In contrast, Alexander et al. (2014) modelled the wider west Scotland ecosystem but found that discarding by *Nephrops* trawlers was insufficient to explain the decline in gadoid species, such as cod. Their paper went even further in suggesting that a 'clean' *Nephrops* fishery could lead to a reduction in cod biomass. The reasons behind this were not fully investigated but it was suggested that discarding might be supporting the benthic community which in turn provides prey for larger cod (see also Heath et al. (2014) for other examples of trophic interactions related to discarding). Both Heywood (2009) and Alexander et al. (2014) pointed out the large number of assumptions and uncertainties within such multispecies models. The controversy over whether discarding has prevented a reversal of the observed changes in the Clyde whitefish community thus remains un-resolved (Thurstan & Roberts 2010, Heath & Speirs 2011).

Given that changes in the fish community in the Clyde seem to reflect a larger regional pattern (Heath and Speirs, 2011), Marine Scotland commissioned a study of wider environmental changes which could have impacted the stocks of gadoid fish in particular (Bailey et al. 2011). That report found that there had been noticeable changes in environmental conditions such as temperature but that these changes could not be conclusively linked to the failure of the gadoid stocks to rebuild. That report also considered whether increased predation by grey seals might be a factor. This issue has recently been re-examined by Cook et al. (2015) whose results suggest that increased natural mortality due to grey seals could explain the failure of the wider Scottish west coast cod stock to recover at a time when fishing effort has decreased[2]. However, the Clyde cod stock may be at least partially self-contained and levels of seal predation in the Firth of Clyde itself were not examined in that paper.

[2] The standard ICES Division VIa cod stock assessments have suggested high fishing mortality in recent years but this is at odds with perceptions that whitefish trawl fishing effort has declined. Changes in natural mortality, due for example to increased predation from seals, are not included in the standard stock assessment but could be leading to inflated estimates of the mortality due to fishing.

Recent trends in the commercial inshore fisheries of the Firth of Clyde

Apart from recreational angling, the main commercial fisheries in the Clyde now take place further out into the Firth, beyond Gourock. Commercial fishing is not permitted at all within the Gare Loch due to the presence of nuclear submarine facilities at Faslane.

Reported landings since 2001 were obtained from http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/RectangleData. Data were selected from ICES rectangles 39E4, 39E5, 40E4 and 40E5 which also covers part of the North Channel and Sound of Jura but this area was selected to be consistent with the 'Wider Firth of Clyde' data plotted in Thurstan and Roberts (2010) back to the 1960s (Figure 3). Some re-analysis of data (2001 to 2009) was undertaken by Marine Scotland to define landings specific to the Firth of Clyde for the inshore fisheries management plan (Clyde Inshore Fisheries Group 2011). Comparing data in the fisheries plan with Figure 3 shows very similar values for shellfish landings suggesting that use of the ICES rectangle data is not creating any very large distortion. As far as we are aware, apart from *Nephrops* and scallops, Clyde specific data are not being updated on a regular basis and this situation will probably not change unless more spatially detailed catch recording is introduced.

An important point to note is that the total fish / shellfish biomass removed annually by fishing from the Clyde has not actually decreased since the 1960s (Figure 2), but there have been substantial changes in the composition of the landings (Figure 3).

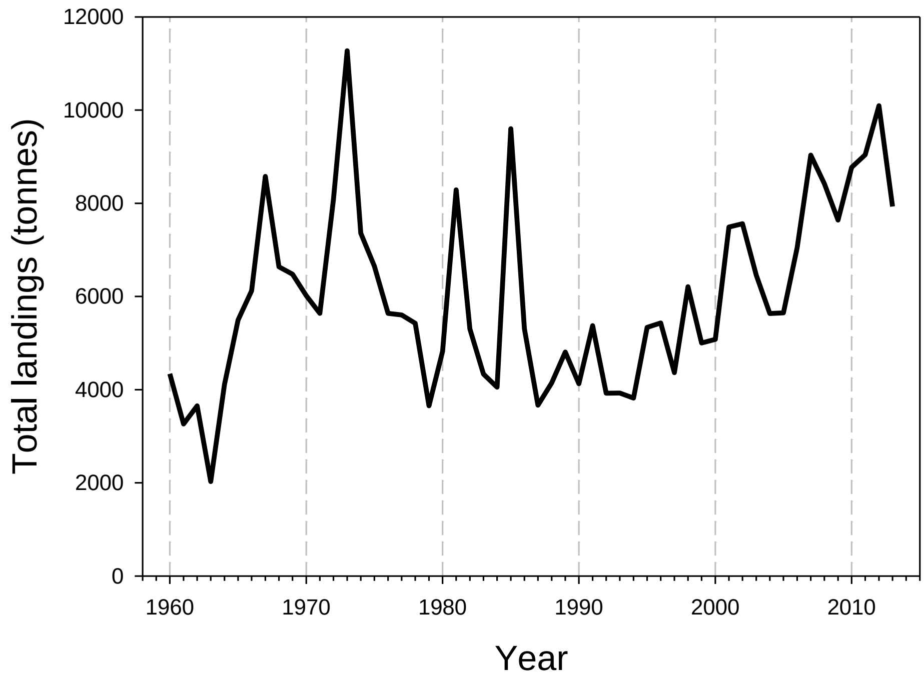


Figure 2: Total reported landings from the Clyde (all species). Note these values exclude additional mortalities due to discarding. Prior to the introduction of the Buyers and Sellers Registration scheme (2005), reported landings may have been under-estimates of the actual amounts landed.

The upper panel of Figure 3 shows reported finfish and the lower panel reported shellfish landings for the wider Clyde area – taken together the species shown cover 99% of the total landings over the period. Small amounts of shellfish other than *Nephrops* and scallops were being landed prior to 2001 but that is the earliest detailed data publically available. The update largely confirms the picture presented in Thurstan and Roberts (2010) with a dominance of shellfish in the landings since the mid-1980s. This change is not just in response to changes in stock availability, but also to changes in regulations and markets e.g. it is now not permitted to land spurdog and landings of cod are presently restricted. It was also not possible to match data on herring in Thurstan and Roberts (2010) with more recent landings data and this may require re-examination, although this would not change the overall picture significantly. In summary, *Nephrops* and scallops now dominate the landings in terms of weight with lesser amounts of a range of other shellfish species being landed (velvet crabs, lobsters). Historically some shellfish fisheries seem to have been very short lived, perhaps indicating a rapid removal of harvestable stocks, for example reported landings of periwinkles in 2001 and 2002 were significant (42.6 and 74.5 tonnes respectively) but have since been zero (it is possible that some un-reported harvesting is taking place). Reported landings of whelks[3] (*Buccinum undatum*) have also dropped during the mid-2000s. Recently landings of razor clams have been increasing (Clyde inshore fisheries group 2011) which may be a cause for concern given their slow growth rates (Hauton et al. 2007).

[3] In common Scots usage the names 'whelk' and 'periwinkle' are sometimes interchanged. The true whelk is often called a 'Buckie'.

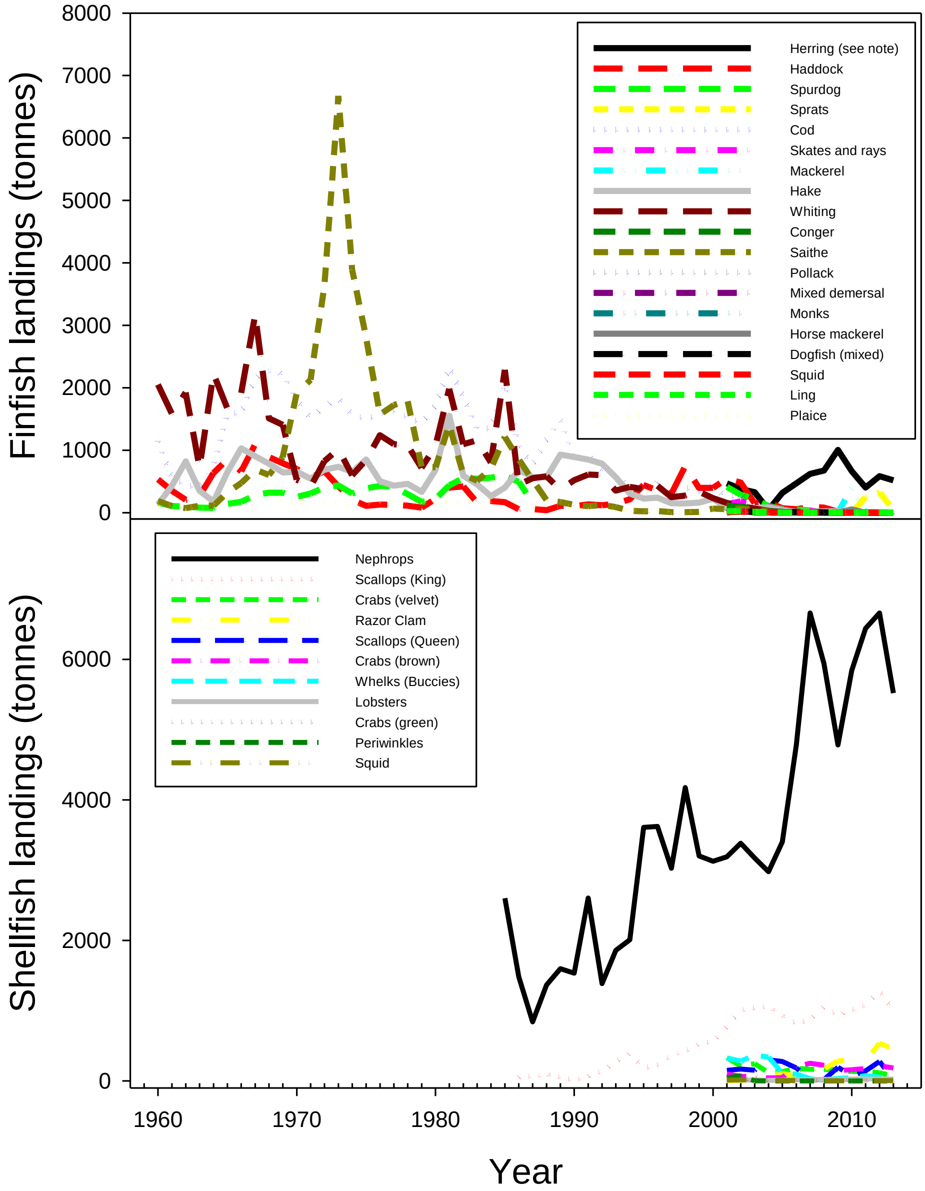


Figure 3: Update of landings data shown in Thurstan and Roberts (2010) from wider Clyde area – upper panel finfish, lower panel shellfish (Note that data for herring show discrepancies between the 2010 paper and Scottish government figures so have not been plotted prior to 2001, for spurdog there is a gap in the record).

Data from the ScotMap project based on interviews conducted with inshore fishers (vessels less than 15 m) were released in 2013 (Kafas et al. 2014). The outputs were spatially aggregated data on the number of vessels, number of crew, monetary value and relative value by fishery (species/gear) categories. For the Clyde significant activity was recorded due to the *Nephrops* trawl sector, a small amount of scallop dredging and crab and lobster potting. The ScotMap report and subsequent discussions with SIFT (Sustainable Inshore Fisheries Trust) and Clyde Forum have suggested that the data are incomplete for the Clyde due to the level of response to the ScotMap exercise although the overall spatial patterns are thought to be robust.

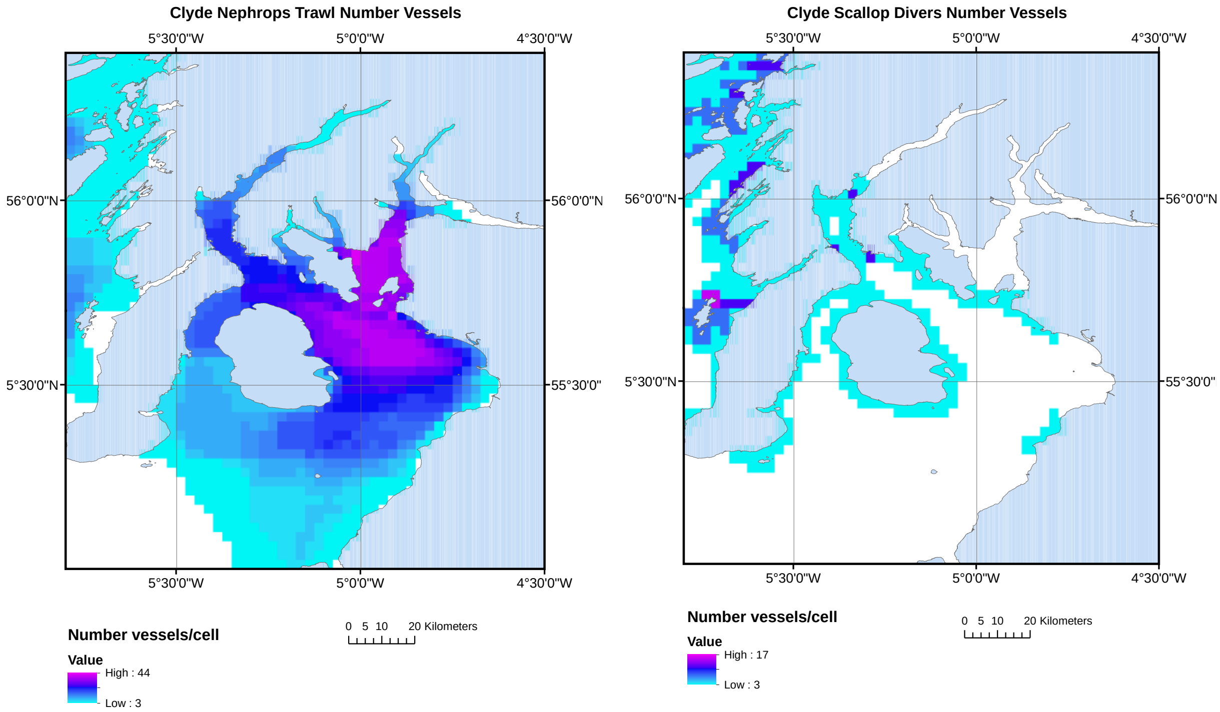


Figure 4: Example of output from ScotMap showing number of vessels fishing in the Clyde.

When combined with Vessel Monitoring Data from larger vessels, the numbers of vessels per cell analysis provides a picture of the spatial extent of fishing. However, it is not necessarily a good indicator of the spatial distribution of fishing effort (which needs to also take account of vessel power), nor does it show seasonal variations (http://www.scotland.gov.uk/Topics/marine/scienceMSInteractive/Themes/ScotMap/scotmap-description).

Most of the Clyde IFG area is fished at some point in any given year, although the Gareloch is permanently closed due to naval activity. In the 'cod-box' in the Outer Firth many types of fishing are substantially restricted. There is also a ban on use of mobile gear at weekends throughout the vast majority of the area (24:00 hrs Friday to 00:00 hrs Monday). The length of vessels permitted to fish within the Clyde is restricted to 70 feet/ 21.34 metres except for vessels specifically targeting pelagic species (Clyde Inshore Fisheries Group 2011).

Most vessels fishing in the Clyde are local although visiting vessels from Northern Ireland are also common. Summaries of registered vessels by port can be found in Clyde Inshore Fisheries Group (2011) plan (Table 3).

Table 3: Numbers of registered vessels according to Clyde Inshore Fisheries Group

Port	Campbeltown	Troon	Carradale	Tarbert	Girvan	Stranraer	TOTAL
< 10 m	10	9	2	13	5	8	47
> 10 m	13	10	10	15	1	2	51
Total	23	19	12	28	6	10	98

More recent analyses by Riddington et al. (2014) of background information relating to Scottish inshore fisheries were based on the IFG regions. The new southwest region includes the Clyde but extends further south to the Solway and north up to Oban. The numbers of registered vessels for the Clyde districts of Campbeltown and Ayr are shown in Table 4 based on Scottish Sea Fisheries Statistics for 2012 (Riddington et al. 2014). The discrepancy between the totals in Tables 3 and 4 will be due to vessels registered in these districts but based at other minor ports.

Table 4: Registered vessels – Clyde ports (2012)

	Campbeltown	Ayr
Nephrops trawl < 10 m	12	6
Creel < 10 m	52	80
Other < 10 m	11	8
Demersal trawl > 10 m	8	4
Demersal lines > 10 m	14	
Nephrops trawl > 10 m	18	28
Creel > 10 m	3	8
Other > 10 m	31	9
Total	156	143

Many of the smaller vessels will fish within the Clyde exclusively but the larger vessels will also operate outside the Firth. According to the Clyde Inshore Fisheries Group (2011) 492 FTE and 72 PTE fishers were employed in the Clyde. Riddington et al. (2014) suggests higher figures of 788 persons FTE and 108 PTE employed in fishing from Campbeltown and Ayr. Landings into Campbeltown and Ayr are shown in Table 5 but it must be remembered these will not all originate from the Clyde fishing grounds.

Table 5: Landings value (£'000) into Clyde ports (2012)

	Demersal	Pelagic	Shellfish	Total	Total by Scottish vessels
Ayr	6	15	13,915	13,936	12,693
Campbeltown	17	97	15,961	16,075	12,879
Total	23	112	29,876	30,011	25,572

Riddington et al. (2014) also estimated the proportion of landings likely to originate from the inshore versus offshore zones (Table 6). Note that this is for the whole of the South-west Inshore Fisheries Group area and relative proportions within the Firth of Clyde might differ from this.

Table 6: Distribution of landings by value (2012) between inshore and offshore zones – South-west Inshore Fisheries Group

	0-1 nm	1-3 nautical miles	3-6 nm	6-12 nm
Demersal trawl	0.1	0.2	0.2	1.9
Nephrops trawl	30.7	46.7	54.9	42.3
Pelagic trawl	0.6	0.1	-	-
Dredge	14.4	16.5	9.9	42.8
Pots	46.4	33.7	32.7	13.0
Hand dive	7.7	2.8	2.2	-

Some activities are likely to be data deficient and impacts may be under-estimated. The Clyde Inshore Fisheries Group noted that ‘hand-harvesting’ for bivalves from the shore falls into this category (Clyde Inshore Fisheries Group 2011).

Recent trends in the recreational inshore fisheries

With its proximity to major Scottish centres of population, the Firth of Clyde has long been an important location for recreational fishing. Declines in the abundance of fish, particularly cod, in commercial catches from around the mid-1960s onwards were mirrored in the experience of recreational anglers. By 1986 the White Horse Whisky sea angling competition (which in its heyday could attract up to 1,300 entrants) organised by the Saltcoats Angling Association experienced particularly poor catches. This prompted the Scottish Tourist Board to request information on the impact on sea angling of the Inshore Fishing (Scotland) Act of 1984. Data from angling clubs indeed showed a decline in aggregate catches but such data could not be disaggregated to provide information on how the abundance of fish of different sizes (ages) was changing. The concerns around sea angling led to a study conducted in the mid-1980s (Pieda and SMBA 1988) focussed on the status and prospects for sea angling in the Clyde. That report felt that the decline in cod was a result of a combination of over-exploitation combined with a run of poor year-classes. It was noted that the recreational sector would favour not only an increase in cod abundance but in the sizes of the fish. Furthermore, because improvements to cod might lead to a reduction in *Nephrops* (because of predator-prey interactions) there could be potential conflict between the desires of the commercial and recreational sectors. The analysis suggested that at the time recreational angling supported around 200 jobs in the Clyde area generating £8.9 million per year but that this might double if conditions improved. However, commercial fishing at the time was estimated to support 1,200 jobs so the authors felt that improvements in the sport sector would not be justified if they led to significant losses to commercial employment.

A more recent analysis of the value of recreational sea fishing was provided by Marine Scotland (2009). The amount spent on recreational angling from Glasgow and the western surrounding area was estimated at around £24 million (excluding capital expenditure). It was notable that of Scottish regions examined, Glasgow had the highest net outflow i.e. around £11 million of the total spend was in other regions. Most sea angling spend came from local fishers (87%) and it was noted that the area now fails to attract many visiting fishers. The number of jobs supported by recreational fishing in the Clyde was estimated to be 523 full time equivalents. In the text it is stated that fewer jobs are supported compared with the 1980s but the more recent figure seems much higher than the 200 estimated in the 1988 report (Pieda and SMBA 1988). These differences likely result from differing methodology because the more recent estimate is derived from a national economic activity model and the earlier estimate from a consideration of direct activities visible to the researchers. In addition the geographic areas covered by the two reports are slightly different. It is therefore difficult to evaluate whether the number of jobs supported by sea angling in the Clyde area has declined but overall the more recent economic data were taken to reflect the poor state of local sea angling in the Clyde and the fact that the state of the finfish stocks had not improved since 1988 (Pieda and SMBA 1988). During on-site visits to shore angling marks in the upper Clyde the majority of sea anglers were targeting mackerel (*Scomber scombrus*), although some pollock (*Pollachius pollachius*), dogfish (*Scyliorhinus* spp.), saithe and occasional cod and flatfish could be caught. Fish caught were relatively small compared to those observed in other locations. It was noted that sea trout (*Salmo trutta*) can also be a popular target and although a licence is required there was little information regarding levels of compliance.

As noted previously the pattern of change in the Clyde commercial fisheries has continued since the 1980s so that they are now almost totally dominated by *Nephrops* landings. There has also been an increase in awareness of the ecosystem changes which have occurred in the Clyde and increasing political desire to see some alteration towards a more balanced fish community (Marine Scotland 2014b). If such changes in the fish community can be affected they may present opportunities for improved recreational angling (Marine Scotland 2009) but the comment made by Pieda and SMBA (1988) that the presence of more, larger fish in the system might reduce the abundance of *Nephrops* is still pertinent. Such changes in the fish communities would therefore also probably lead to shifts in commercial shellfish stocks within the Clyde. Whether such changes would have overall positive or negative economic benefits requires further analysis. A further alternative management change could be to reintroduce restrictions on mobile gear (Riddington et al. 2014). The relevance to recreational fishing is that discards of finfish are generally lower from creel fisheries (Adey 2007, Ziegler & Valentinsson 2008) so such a change from mobile to static gear might lead to some recovery of larger fish in the Clyde, depending on the spatial extent of the gear change.

Economic analysis of the option of removing mobile gear from the 0-3 nautical miles zone was reported in Riddington et al. (2014). The analysis suggested overall net benefits across the whole of Scotland but the costs and benefits were not evenly spread. For the southwest IFG region (note this extends over a larger area than just the Clyde) there might be losses of up to 50 full-time equivalent jobs from the commercial sector but these could be offset by up to 1,692 FTEs in the recreational sector. It was predicted there would be an overall economic benefit of around £63 million under the least favourable commercial fishing jobs scenario, while the most favourable scenario suggested a benefit of £683 million (accrued over 20 years). The predicted benefits would come from a massively rejuvenated recreational sector. A major uncertainty acknowledged by the authors of the report is how the natural fish community would respond to the exclusion of mobile gears. Whether such a change in fishing practice would actually lead to a more balanced fish community (both in terms of species mix and individual size/age distribution) is unknown at this time (Heath & Speirs 2011, Marine Scotland 2014b). However, Riddington et al. (2014) argued that there could be advantages in implementing management changes, even with this uncertainty, because the costs of doing additional science would be minimised. Of course this does carry risk. If the ecosystem fails to respond in a positive manner, jobs would be lost in the commercial sector and there would be little gain in the recreational sector. However, Riddington et al. (2014) argued that, in that case, the ecosystem itself would not be in any poorer condition than before the change in fisheries policy. Under the ‘fail to recover scenario’, the original fisheries could be re-opened at some future date. However, re-opening fisheries which have been closed has not always proved successful, due to factors such as loss of markets and fishing expertise.

Biological information relevant to species of importance to the Firth of Clyde fisheries

Stock assessments

A number of stock assessments relevant to the Firth of Clyde are conducted by Marine Scotland Science and annual stock summaries published e.g. Marine Scotland Science (2015). Assessments include *Nephrops,* where TV burrow surveys are conducted and scallops, where a dredge survey is conducted. The surveys for *Nephrops* suggest that the Clyde stock has been relatively stable over the last decade. However, for scallops the age composition data were insufficient for carrying out a reliable analytical stock assessment. No specific advice on the status of scallops in the Firth of Clyde was provided (Dobby et al., 2012). Data on velvet and edible crab and lobster are also collected. These data have not been sufficient to allow biomass reference points to be estimated for these species in the Clyde but fishing mortality for velvet crabs and lobster is thought to be occurring at too high a level (Marine Scotland Science, 2015).

Fish health

The general recovery in the health of the river and estuary has been reported as an increasing number of fish species recorded in sampling between 1979 and 2006 by the Scottish Environmental Protection Agency (SEPA). However, the graph of cumulative number of species recorded presented by SEPA (Figure 5 dashed line) may be a bit misleading because it did not take account of species caught in early years but not subsequently. For example, although the return of salmon to the River Clyde in 1990 was widely publicised, they have not been recorded since. In fact the total number of fish taxa recorded in any particular year shows no clear trend over the time-series (Figure 5 solid line), apart from a slight decline up to the mid-1990s, which then reversed. Unfortunately the survey design was changed after April 2007 to deliver indicators for the Water Framework Directive, so recent trends cannot be easily compared with the historical data.

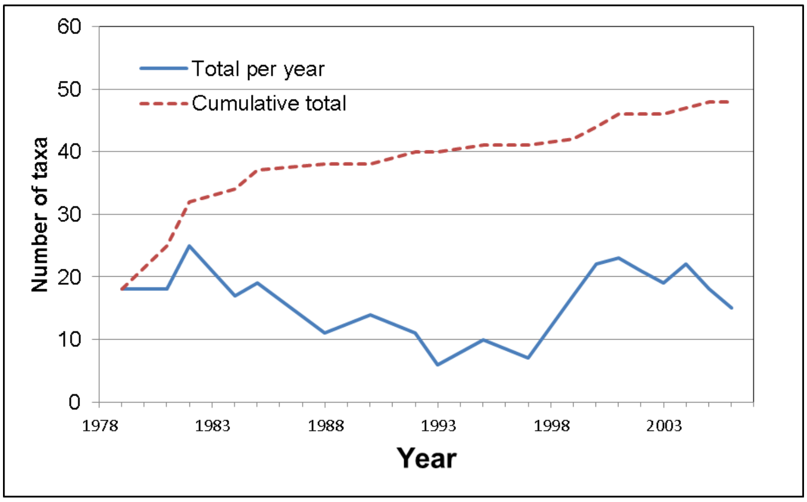


Figure 5: Total number and absolute number of fish taxa recorded in the Clyde estuary in SEPA surveys conducted between 1978 and 2006.

Occasional fish kills do still occur in the River Clyde and these incidents appear to be linked to low oxygen at some specific sites related to the river's industrial heritage (http://www.midclydeanglingassociation.org /news.html).

Levels of biotoxins and potentially harmful bacteria are monitored regularly in harvested shellfish by the Scottish Food Standards agency.

Fish and shellfish spawning grounds

Spawning grounds of pelagic species

Spawning of Clyde herring has been studied since the 1880s (Ewart 1984). At that time Clyde herring spawned during spring at the large Ballantrae Bank ground which lies just inside the south-eastern edge of the Firth of Clyde adjacent to Loch Ryan. On the basis of the presence of spawning fish it was also suggested that a second smaller ground exists to the south of Arran (Clark 1933, Parrish et al. 1959). This was later confirmed when spawn was sampled at that site by Morrison et al. (1991). A number of studies have been conducted at Ballantrae Bank including estimates of egg and larval abundance (Bailey et al. 1986b) and mortality (Parrish et al. 1959). The dispersal of larvae from the Bank was also investigated and inter-annual differences noted which were ascribed to differing wind-forcing (Parrish et al. 1959). Because there were a number of research institutes close to the area, Clyde spring-spawned herring were a popular model for studies on fish larval early life history. Studies included their size at hatch (Rankine et al. 1990), development of vision (Blaxter 1968), diet and growth rates (Marshall et al. 1937, 1939, Bainbridge & Forsyth 1971), responses to changes in temperature, salinity and starvation (Ehrlich et al. 1976, Yin & Blaxter 1987b, Yin & Blaxter 1987a, Pedersen et al. 1990, Johnston et al. 2001), interactions with predators (Bailey & Batty 1984, Rankine & Morrison 1989) and age determination (Geffen 1986). Around the late 1960s productivity of the Ballantrae Bank appeared to decline resulting in a gradual reduction of the spring-spawning component of the Clyde herring. An increasing proportion of the herring found in the Clyde were autumn-spawners which moved into the Firth to feed (Bailey et al. 1986b). Herring are a remarkably adaptable species and re-occupation of abandoned spawning grounds has been noted in the North Sea (Schmidt et al. 2009). However, there is little sign so far of a rebuilding of the spring-spawning herring component (McIntyre et al. 2012).

Bailey et al. (1986b) reported that a short-lived ring-net sprat (*Sprattus sprattus*) fishery was prosecuted in the 1960s and a pair-trawl fishery began in the early 1980s. This was catching fish in their second to fifth winters. During winter the fish were in the inner reaches of the Firth and in spring moved to spawning grounds to the south of Arran (Bailey & Braes 1976). According to McIntyre (2012) there is no updated information on the stock status of either herring or sprat in the Clyde and it was recommended that acoustic/trawl surveys be conducted in order to fill this data gap.

Spawning grounds of demersal species

Regarding demersal species, Hislop (1986) mentioned that the fisheries in the Clyde took spawning females of cod, haddock and hake. Early records of ripe and running hake reported by Hickling (1927) and (1930) show they were caught between Sanda and Aisla Craig in July 1929. The spring fishery for whiting exploited maturing fish but, as discussed earlier in relation to movements of tagged animals, the majority of these fish may have moved out of the Clyde to spawn although the location of the offshore spawning grounds was unknown. These accounts largely accord with information in McCrindle (2006) who mentions cod, whiting and haddock being targeted by the seine netters as they gathered on the spawning grounds along the Ayrshire, Arran and Kintyre coasts, as well as saithe being caught at spawning time south of Aisla Craig (the author does not state that the fish were in spawning condition but this is implied). These reports show that most of the common demersal species were spawning in the Clyde.

A limited number of fish egg surveys were conducted in the Clyde prior to 1986. These include Kyle (1897) and Williamson (1899). Poxton (1986) focussed on the distribution of plaice eggs and larvae in the south-eastern part of the Firth whilst Hislop (1986) notes that the eggs and larvae of other species have been found widely scattered over the area preventing the identification of precise spawning grounds. The situation with regard to whiting seemed variable, although Garrod and Gamble (1965) found most whiting larvae off the Ulster coast i.e. outside the Clyde proper, other surveys did find significant numbers of whiting eggs and larvae within the Firth of Clyde itself.

Mackay and Doughty (1986) presented data for catches of salmon and sea trout showing that, in 1983, a total of 9,679 salmon and grilse and 4,399 sea trout were caught. Salmon transit the Firth on their way to breeding sites in the rivers draining into the Clyde Basin, whilst sea trout possibly are resident in the Firth, although there is little data on their movements.

Spawning grounds of shellfish stocks

Nephrops are largely resident once beyond the juvenile stage. Spawning will thus take place throughout the muddy areas of the Clyde where *Nephrops* are found (Bailey et al. 1986a). Smith (1987) conducted a PhD on the biology of the larval and juvenile stages in the Clyde which included studying the reproductive cycle and measuring fecundity. That study found that female *Nephrops* brood eggs under their pleopods during the winter months and that hatching peaked in May. Fecundity was estimated to range from 985-1115 eggs hatched per female allowing for egg losses during incubation (a fecundity to carapace length relationship was also derived). Larval surveys were also conducted in the lower Firth allowing an estimate of the spawning stock abundance at between 15.9 to 18 million females. Larval surveys can therefore provide an alternate stock assessment tool to underwater video (TV) surveys for *Nephrops* burrows, although the costs of the larval method tend to be rather high (Briggs et al. 2002) (due to need to conduct surveys through the season and sort the plankton samples). The two approaches have been compared, although using data from different years, by Tuck et al. (1997) and the results from the two methods were considered to be comparable. Because of the costs of the larval production method, the TV survey approach has been generally adopted for *Nephrops* stock assessments. One possible advantage of the larval approach is that if eggs/larvae of other species are also sorted and identified, then the same set of samples can be used to produce a spawning stock biomass estimate for several species simultaneously (Armstrong et al. 2001, Briggs et al. 2002). To reduce costs of this method, the plankton sampling could potentially be undertaken by fishers as part of a collaborative stock monitoring program.

Post-settlement king scallops do not move over large distances although queen scallops (*Aequipecten opercularis*) tend to be more mobile (Mason 1983). Because of their limited mobility, spawning is likely to occur in all areas where mature scallops are found. The distribution of scallops can be inferred from fishing activity patterns combined with knowledge of sediment distributions. However, because suitable habitat can be patchily distributed, this is often reflected in the distribution of scallops. ScotMap shows some scallop dredging activity in the Firth of Clyde and some scallop diving confined to the northern parts of the Firth. However, these data come from a subset of fishers operating in the area and do not provide a complete picture.

Fish and shellfish nursery grounds

Historically the Firth of Clyde acted as a nursery ground for spring-spawned herring larvae from Ballantrae Bank and the south of Arran although patches of larvae could also be transported out of the Firth (Parrish et al. 1959). Since the late 1960s the importance of the spring-spawning component has declined and most herring found in the Firth of Clyde come from autumn-spawning further offshore (Parrish & Sharman 1958, Bailey et al. 1986b). Based on dispersal modelling the Firth of Clyde is a predicted recipient of herring larvae from eight herring spawning areas around the north and west coasts of the Republic of Ireland (O'Sullivan et al. 2013). The appearance in the inner lochs in summer of juvenile herring possessing autumn-spawned characteristics was noted by Bailey et al. (1986b). The Firth of Clyde thus functions as a herring nursery ground in a similar manner to other sea-lochs along the Scottish west coast although the balance between local spring and immigrant autumn-spawned fish has changed over time (de Silva 1973).

More recent data on other ‘0’ group fish in the Clyde come from the 2002-2004 Scottish Inshore Fish surveys, from some limited sampling by Ware (2009) in the eastern half of the Firth and from a series of beach surveys conducted by the Scottish Association for Marine Science (Fox et al. 2014). Apart from these surveys there seems to be little further fine-scale data on the location or use of fish nursery areas in the Clyde.

Ryan et al. (2011) reviewed the importance of various inshore habitats around the Scottish west coast as nursery grounds for commercial gadoids. Juvenile cod and whiting are known to inhabit near-shore waters during their first year of life with complex habitats, such as maerl (Kamenos et al. 2004a) and eelgrass being preferred. Preference for such habitats may be due to active selection but can also result from differential predation when compared with less complex habitats. Such complex habitats are relatively difficult to survey being easily damaged by techniques, such as trawling or beach seining and usually require alternate methods such as fyke nets (Kamenos et al. 2004a), visual surveys by divers (Magill & Sayer 2004) or baited cameras (Dunlop 2013). Trawl surveys in the Clyde have however provided some evidence of where juvenile gadoids occur (Gibb et al. 2007, Ware 2009)

Ware (2009) sampled with a Harkiss rock hopper trawl and analysed catches for species composition and fish size. The ages of the fish were confirmed by analysis of a subset of otoliths and the diet of cod was also examined. Much of the report is taken up with multivariate comparisons between the Clyde and adjacent Firth of Lorn (which are not particularly informative in relation to nursery grounds in the Clyde) but Ware (2009) does show that ‘0’ group cod, haddock and whiting were in the Clyde in the years sampled. The settlement and subsequent shifts in habitat for cod, haddock and whiting were reported to be rather similar. ‘0’ group fish began to appear in the catches made during July with the highest densities being recorded at shallower sites characterised by high complexity, relatively large sediment particle size and relatively high algal abundance. There was a slight difference between cod, haddock and whiting in their distribution following the first winter with whiting moving to deeper sites a little earlier compared to cod and haddock. Nevertheless from the summer onwards the highest abundances of ‘1’ group fish were found at the relatively deeper sites characterised by lower complexity, small particle size and low algal abundance (Ware 2009).

Stomach contents of summer sampled age 0+ cod from all Clyde Sea sites were dominated by crustacea comprising mainly Copepoda and Decapoda larvae were relatively high at all sites with several additional groups (e.g. Amphipoda and decapod crabs, *Liocarcinus* sp.) featuring more frequently in the stomach contents of individuals from one site. The relatively early shift in age 0+ cod diets at this site seemed to be related to the size of the predators. Samples collected during the autumn showed similar diet while winter samples (classified as 1 group fish) showed some shift towards more polychaetes. Fish began to appear as dietary items as the '1' group fish grew.

Juvenile cod were also caught in the Firth of Clyde during the 2002-2004 Inshore Fish Surveys and they could be distinguished from adjacent populations on the basis of their otolith chemical composition. This was further evidence for limited mixing of juvenile Clyde cod with young cod from other adjacent areas (Gibb et al. 2007).

Inshore sandy beaches in the Clyde are used as nursery grounds by plaice (Poxton et al. 1982) and several sites within the region have been surveyed over a 10 year period by Fox et al. (2014). The authors were not able to assign settled juvenile fish to spawning sites but given the known oceanographic circulation patterns in the region the majority probably originate from localised spawning within the Firth of Clyde (Poxton 1986).

Shellfish larvae generally metamorphose into juvenile forms which settle directly into suitable habitat and most shellfish do not therefore have nursery grounds in the same manner as finfish. However some post-settlement dispersal can occur in mobile species, such as crabs. The rates of post-settlement dispersal may also be affected by factors such as crowding (Moksnes 2004).

Fish and shellfish stock discreteness

Stock discreteness of pelagic species

Historically the Clyde herring were regarded as a distinct, spring spawning race but the population structuring of herring is complex and has been subject to frequent revision due to advances in techniques such as genetics and otolith microchemistry (Geffen et al. 2011). King (1987) reported that, based on allozymes, Clyde herring grouped with Minch autumn spawners. However, it is worth noting that the Clyde sample used in that study was ripe in September suggesting that it was an autumn spawning, rather than a local spring-spawning, herring. The presence of some ripe autumn-spawning herring in the Clyde in September was also noted by Bailey et al. (1986b) who suggested that most of these fish moved out of the Firth of Clyde to spawn. Tagging of herring in the Clyde showed that the fish sometimes returned over at least two summers, presumably to take advantage of good feeding conditions. The size of juvenile herring appearing in the inner lochs in the summer months was also more consistent with them being from spawning the previous autumn. Very small amounts of autumn spawning may also have taken place within the Firth itself at the southern part of Kilbrannan Sound, as indicated by the presence of running fish (Bailey et al. 1986b).

Otolith microchemistry of spawning herring sampled in the Clyde was successful to some extent in discriminating these fish from other areas (Geffen et al. 2011). However, the time of year these herring were sampled is not stated so it cannot be confirmed that these were spring-spawning fish. The authors suggest that overall the evidence for stock discreteness in herring is limited and that the stock structure around the west of the UK likely conforms to the adopted-migrant hypothesis (McQuinn 1997). This concept states that herring form local populations within a meta-population, and that the progeny of a given local population do not necessarily recruit to their natal (parental) population, but may become migrants, contributing to an adopted population and developing their reproductive season. A large proportion of the juvenile herring sampled from the Firth of Clyde had otolith chemistry signals consistent with originating from the western Irish Sea (Geffen et al. 2011).

Bailey et al. (1986b) describe how the amount of larvae hatched from Ballantrae Bank, and the proportion of spring-spawning fish in the catches from the Firth of Clyde, gradually declined from around 1971 onwards. An increasing amount of the herring in the Firth after this period appeared to be autumn spawned fish moving in from areas outside the Firth.

In conclusion, the herring fishery was historically almost entirely dependent on spring-spawning herring until about 1969 when the proportion of autumn-spawning herring in the landings increased. By 1972 this latter component was predominant in the catches. Although the autumn-spawned herring formed a greater part of the Clyde population by this time, there was no evidence of significant autumn spawning occurring within the Firth itself.

Stock discreteness of demersal species

Hislop (1986) considered whether the stocks of the main demersal species were local or relied on influx from outside the Clyde. Spawning female fish of most commercial species seem to have been present in the Clyde (see also McCrindle (2006) who describes targeted fishing on spawning aggregations). Hislop (1986) looked at direct evidence of migration of fish into and out of the Clyde based on tagging. For plaice there was evidence of movements, albeit limited as a percentage of the total number of fish tagged, predominantly with the Irish Sea but also further up the west coast (Poxton 1976). A proportion of whiting tagged in the Clyde were recaptured outside suggesting that mature whiting moved away to spring spawning grounds at around the end of the second year of life (Garrod & Gamble 1965). However, when combined with later studies the estimated percentage of emigration was only 4.3% (out of 388 tagged fish). Limited data were available for cod although some Clyde tagged fish were recovered from the South Minch/Stanton Bank area and one from the Irish Sea. The more recent re-analysis of the historical tagging data by Wright et al. (2006) is somewhat confusing in that the text suggests that the majority of cod tagged in the Clyde were recaptured in the same region but Figure 6 in that paper seems to suggest that 73-88% of the tagged fish moved out of the Clyde and slightly northward into the outer Firth of Lorn. It is not clear from the paper exactly where these fish were tagged (i.e. whether it was really within the Clyde). For saithe, of 109 fish tagged in the Clyde only one was caught outside the area (Newton 1984). Results from a limited haddock tagging study have also been reported where a single fish was captured off Kerry (Eire). Although these studies suggested rather limited exchanges of fish between the Clyde and adjacent waters, Hislop (1986) cautioned against over-interpreting these results as sample numbers were often low and for many of the recaptures the time at liberty, post-tagging, was also short.

Comparison of the shape of otoliths of spawning cod sampled from the Clyde with those sampled from the South Minch and Irish Sea has also lent support to the idea that the Clyde fish are a largely separate resident stock (Galley et al. 2006). Further research using otolith microchemistry is being undertaken to try and estimate the residence and mixing rates of cod and whiting within and outside of the Firth of Clyde (Burns 2014).

Stock discreteness for shellfish species

For the shellfish, most are relatively sedentary once recruited to their benthic habitat. This is certainly the case for oysters, mussels, *Nephrops* and king scallops although queen scallops can be somewhat more mobile (Mason 1983). The long-term sustainability of localized stocks of these species will therefore rely upon either self-recruitment or settlement of juvenile animals from spawning grounds outside of the Clyde. There does not seem to be much information on how discrete Clyde shellfish stocks might be.

Physical and biological datasets relevant to the Clyde inshore fisheries

There are a large number of physical and biological parameters for which data can be sourced. For example, overall summaries of a wide range of data used for an Environmental Baseline for the Clyde are described in Ross et al. (2009). An increasing number of these datasets are visualised in the National Marine Planning Interactive (NMPI) which is designed to make such data available for the purposes of marine planning. However, not all of the large amount of data types available will be of relevance, or of obvious use to inshore fisheries management. Therefore a number of key datasets were identified in discussion with the IFGs and include the following:-

- Admiralty charts – these provide lower spatial representation of bathymetry but include additional information which may need to be taken into account e.g. shipping routes, navigation marks, submarine exercise areas etc.
- Bathymetry – increasingly detailed maps of the seafloor are becoming available and are useful as a base-layer in data-visualisation systems.
- Seabed sediments – sediment data are typically less well spatially resolved than bathymetry but can assist with interpreting fishing locations and identifying sensitive habitats.
- Oceanography – sea temperature and salinity, general circulation patterns. Any large changes in these parameters over time could impact fish communities although interpretation of these data in relation to such changes is usually difficult and often inconclusive.
- Water quality – nutrients, primary productivity, dissolved oxygen, microbiology and pollutants – generally monitored nationally to ensure levels are at acceptable standards (e.g. Water Framework Directive) but changes might affect shellfish harvests in particular. As with oceanographic parameters interpretation of indirect impacts of changes in water quality on fish stocks is usually difficult and often inconclusive except for obvious shift such as water quality in the upper River Clyde.
- Litter – Fisheries are one source among many of litter through discarded or lost gear but fishers can also contribute to clear up. This is encouraged as part of the Responsible Fishing Scheme. Monitoring of marine litter is not very comprehensive but the Marine Conservation Society organises annual beach surveys which also attempt to classify the source of items collected. Litter often collects in hotspots due to ocean circulation patterns and IFGs may want to consider if their industry is causing any particular problems in their area and propose remedial actions.
- Seabed habitats - Changes in habitats due to fishing e.g. sorting of sediments due to scallop dredging or trawling, may need to be taken into account. In addition, sensitive habitats, such as maerl beds, may require additional protection.
- Seabirds – trends in seabird numbers may be indicative of interactions with fisheries whilst some fishing activities in seabird sensitive areas may need to be restricted (usually through an MPA).
- Marine mammals – interactions with marine mammals and fishing gear and impacts of marine mammals on commercial fish stocks may need to be taken into account.

- Marine protected areas – IFGs will need to be aware of statutory and voluntary marine protected areas in their regions and the types of fishing activity which may impact protected features.

The sources for these data are given in Table 7. Being able to source and combine such datasets with visual summaries of where different type of fishing are occurring, fishing intensity and spatially resolved catch records could aid the development and delivery of fisheries management plans for the inshore areas.

Bathymetry

Historically bathymetry (seabed depth) has been determined from simple lead-line data, even in well surveyed areas such data derived from early (pre-20th century) surveys is still often used in the Admiralty hydrographic charts. Data derived in this way comprises a series of spot measurements which were then contoured by hand for charting. The introduction of echo-sounders has allowed data to be gathered continuously along vessel tracks. Earlier data were gathered using single-beam sounders and these instruments are still used on many vessels. Although the familiar Admiralty charts derived from these methods capture the main seabed features, they often miss fine-scale seabed features, many of which will affect the patterns of inshore fisheries.

For full survey work the modern approach is multi-beam which allows a swath to be mapped as the vessel moves along the survey track. The generally accepted highest mapping standard is UKHO Order 1 and data collected and processed to this standard will have a guaranteed level of quality (in terms of the accuracy and precision of the measurements in both horizontal and vertical axes). So far not all the UK coast has been mapped in this manner although coverage is increasing steadily with projects such as the Marine Environmental Mapping Program (MAREMAP, www.maremap.as.uk) filling in many gaps. A further step-change is likely to come with wider use of improved methods for predicting the nature of the seabed habitat using multi-beam data (Diesing et al. 2014).

The UKHO website INSPIRE acts as a portal for available bathymetric data (http://www.ukho.gov.uk/inspire/pages/home.aspx). The website allows data to be downloaded along with full metadata describing the relevant surveys.

Multi-beam coverage within the Clyde is mixed (Figure 6) with some areas surveyed by multi-beam but other areas only covered by single beam or older soundings. Details of the available data are in Table 8 at the end of this document.

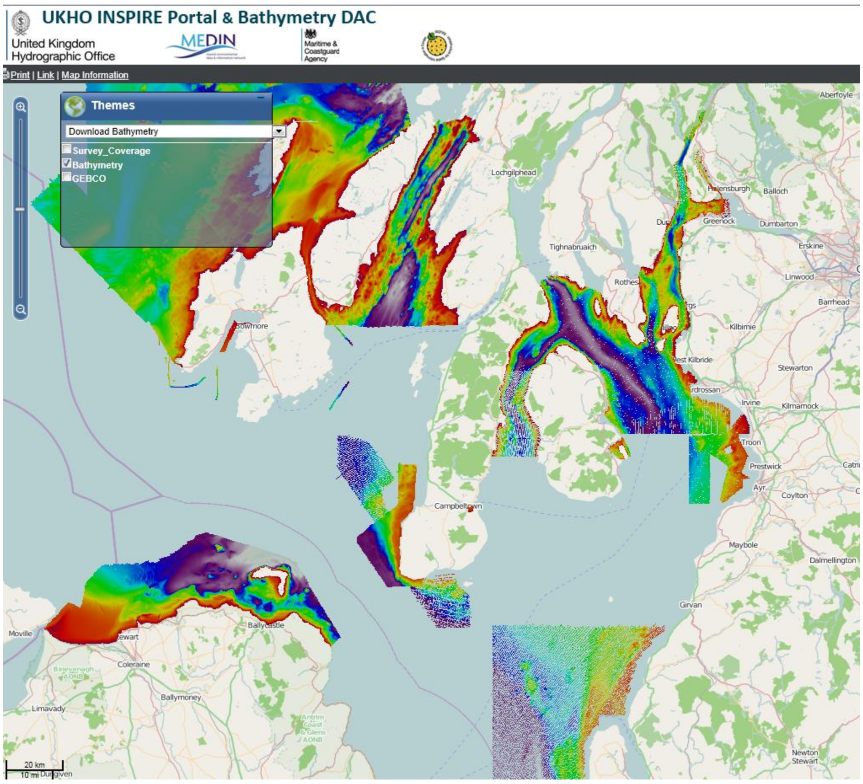


Figure 6: Available bathymetric survey data (excluding older Admiralty chart soundings) for the Clyde region

Sediments

Sediment data from grabs and cores collected around the UK are held by British Geological Survey and are downloadable from http://mapapps2.bgs.ac.uk/geoindex_offshore/home.html#. However, these data are not gridded and require to be downloaded on a sample-by-sample basis. Gridded sediment data at 1:250,000 scale are available as a product called DigSBS250 at http://www.bgs.ac.uk/discoverymetadata/13605549.html. There is a charge for downloading these data.

Gridded sediments (DigSBS250) are also one of the base layers used in the JNCC EUNIS Habitat classification (http://jncc.defra.gov.uk/page-2117). The original UKSeaMap project and the MESH project used the following substrate classification to reflect the broad substrate types used in seabed habitat classifications: Rock, course sediment, mixed sediment, sand and muddy sand and, mud and sandy mud. The four sediment types in this classification are based on the British Geological Survey (BGS) Folk Sediment Trigon. Five datasets were used in the construction of the UKSeaMap 2010 substrate layer. BGS were contracted to produce a substrate layer for the project area from these datasets: DigSBS250; the Defra data contract MB0103 hard substrate layer (Gafeira et al. 2010); the Water Framework Directive (WFD) typology layer (Rogers et al. 2003). Minor gaps between the substrate layer and the mean low water mark were subsequently filled using data from Marine Nature Conservation review (NMCR) surveys.

Further improvements in sediment mapping should be possible utilising additional information e.g. backscatter signal (Diesing et al. 2014), from the fine-scale bathymetry being collected under MAREMAP and associated programs (Howe et al., unpublished data).

Sediments in some areas of the Clyde are relatively mobile so that the major shipping channels are regularly re-surveyed under the auspices of the Port of Clyde authority. However, the Firth of Clyde proper remains to be fully surveyed to UKHO Order 1 (such surveys are being proposed under a follow-on project to MAREMAP).

Sediment classifications according to UKSeaMap are shown in Figure 7.

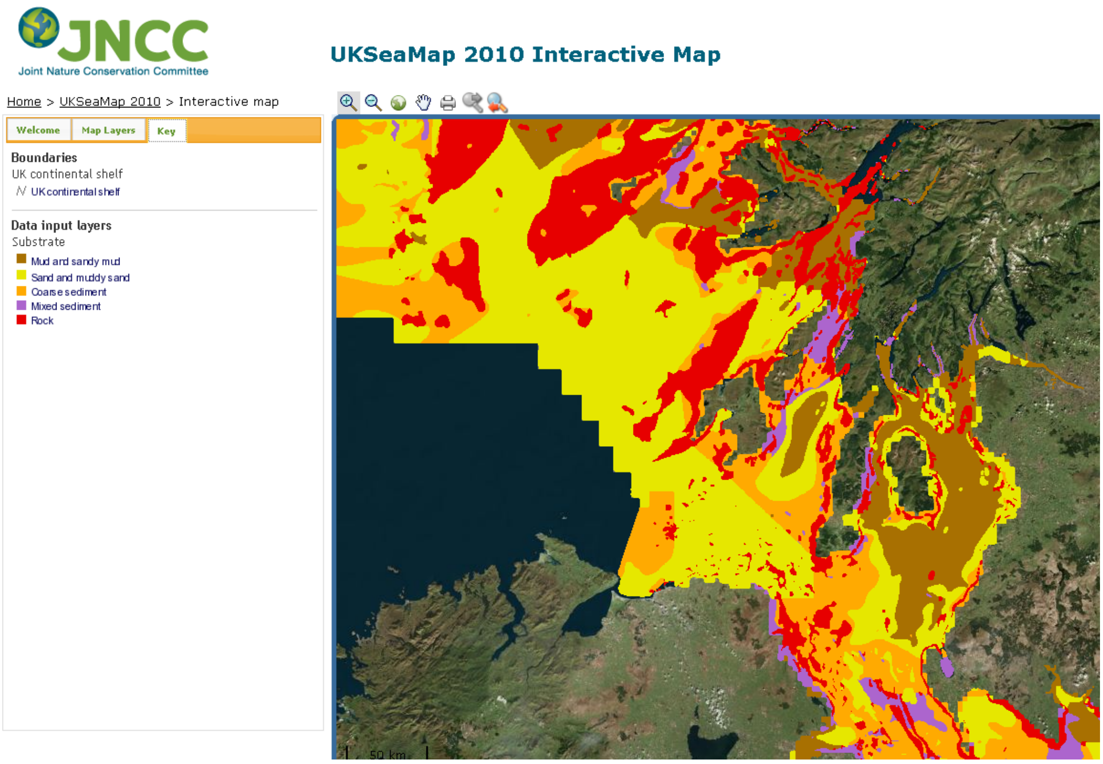


Figure 7: Sediment map for Clyde region

Benthic habitats

The distribution of benthic habitats is of interest for inshore fisheries management because it is one of the main factors affecting the distribution of fish and the types of fishing which can be undertaken. Furthermore the health of certain benthic habitats will influence the degree to which they can act as nursery grounds for young fish. The quality of some benthic habitats may be adversely affected by some types of fishing and the occurrence of certain benthic habitats is a major reason for designation of areas as marine protected areas. Designation as a marine protected area may affect the types of or intensity of fishing activity which are permitted within such areas.

There has been a long history of marine biological studies in the Clyde beginning in the late 1880s with what became the Marine Biological Station at Millport (now Field Studies Council). Despite this long history, the Firth of Clyde benthic populations have been given selective attention according to the habitat type, location and research interests in relation to specific environmental problems (Ross et al. 2009, McIntyre et al. 2012). A general overview of the benthic communities has been provided by Connor and Little (1998). More recently detailed surveys have been conducted in relation to MPA search (Duncan 2003, Axelsson et al. 2009, Axelsson et al. 2010, Moore & Atkinson 2012, Allen 2013, Moore 2013). Despite these efforts available habitat maps for the Firth of Clyde are based on limited amounts of observational data. In these cases modelling is often used to produce a 'predicted habitat map' based on combining information such as water depth, seabed aspect ratio etc. Such maps require validation against real observations to test their predictive skill and this allows a separate 'confidence' map to be produced. Nevertheless, the spatial resolution of the prediction will be largely determined by the spatial resolution of the main driving factors and finer-scale patchiness is unlikely to be captured.

A particular habitat which presents this problem is maerl[4]. Although there have been several observations of both living and dead maerl beds in the Clyde (Hall-Spencer 1998, Kamenos et al. 2004b), comprehensive mapping of their locations, extent and condition is lacking. Maerl beds are living sediments characterised by accumulations of unattached calcareous red algae (Corallinales, Rhodophyta). Maerl beds are spatially complex which encourages higher biodiversity due to the shelter provided for other organisms. They are also thought to act as valuable nursery habitats for commercially important, as well as non-commercial species (Kamenos et al. 2004a, Kamenos et al. 2004b). Maerl beds are however fragile and easily damaged by physical disturbance (Hall-Spencer 1998). A comprehensive study of the depth range within which maerl beds are found in the Clyde has not been performed, although 6 to 18m has been suggested (Birkett et al. 1998). Predictive mapping of where maerl may occur is thus difficult because of the combination of factors which determine where it is found (McIntyre et al. 2012). Thus although maerl does not appear on the EUNIS Predicted Habitat map for the Clyde (maerl is coded as A5-51 in the EUNIS system) this does not mean that this habitat does not occur in the Clyde.

EUNIS and deep-sea habitat types as predicted by the UK Sea Map 2010 model can be found at http://jncc.defra.gov.uk/page-2117. Predicted habitat data can also be downloaded from http://www.emodnet-seabedhabitats.eu.

Marine habitats are often patchy so an obvious question which arises is what is an adequate spatial resolution for sampling and monitoring? The costs of conducting habitat surveys are particularly relevant in relation to monitoring because it is not just a one-off survey which is required, but regular repeats (Frost et al. 2013). Even though large amounts of video-based observations can often be collected relatively cheaply, the costs of analysing these data are often quite high. Whether non-scientific stakeholders could be involved in collecting and analysing such data should be explored further (citizen science). Within shallow habitats use of 'amateur' divers has proven useful in this regard (for example the Sea-Search program www.seasearch.org.uk). The key point is that adequate training and quality control is essential so that the data are reliable (SeaSearch data are lodged on the National Biodiversity Network site). In deeper waters a similar approach, but using new relatively cheap video cameras and streaming data over the internet to analysts, might be feasible.

The increasing availability of fine resolution bathymetry derived from multi-beam acoustics described previously can also improve habitat maps, especially for deeper areas. Habitat type can, to some extent, be derived from multi-beam data although the survey may need to be optimised for back-scatter detection. It is important to remember therefore that a survey conducted primarily for improving bathymetry in relation to navigation may not be optimal for evaluating sediment or habitat type (Diesing et al. 2014).

[4]Maerl denotes loose-lying coralline red algae. Maerl beds are composed of living or dead unattached corallines forming accumulations with or without terrigenous material. Maerl develops when crust-forming coralline red algae, impregnated with calcium carbonate, become free-living due to fragmentation. Although very slow-growing, the maerl thalli (also known as rhodoliths, meaning red stones) sometimes accumulate into flat beds or large banks. These beds have considerable conservation value because of the very high diversity of organisms found within them (Birkett et al., 1998).

Physical Oceanography

Physical oceanography is the study of the processes giving rise to the properties of seawater. Typical measurements made include seawater temperature, salinity and currents but can also include chemical parameters such as the concentrations of various nutrients and gases. Although the temperature and salinity of seawater are largely determined by physical processes, biological processes strongly affect other properties, for example the concentrations of nutrients and oxygen. This is because the organisms living in the water and seabed both consume and produce these chemicals and so alter their concentrations in the water and sediment. Because the abundance and productivity of marine organisms varies both spatially and during the year these physical and biological interactions give rise to gradients in sea water properties. Although the collection and interpretation of the full range of oceanographic data tends to be a specialised task, the availability of relatively cheap instruments capable of accurately recording at least some oceanographic parameters (temperature at depth for example) means that useful data can now be collected by suitably trained non-scientists. Because fishing vessels spend large amounts of time at sea they could provide ideal platforms for the collection of oceanographic data (World Ocean Council 2011). However, to be of value, instruments would need to be well maintained and calibrated.

The general oceanography of the Firth of Clyde is reasonably well known (McIntyre et al. 2012). The region can be subdivided into the Clyde Estuary, the sealochs and the Outer Firth. The estuary tends to be well mixed by tides. The upper parts of the Firth and the associated sealochs are influenced by freshwater run-off from the surrounding highlands (Poodle 1986). The water in the sealochs often shows haline stratification and the restricted exchanges due to the shallow sills of these fjords leads to periodic stagnation of the deeper waters. The Firth itself has an outer shallow sill which also restricts the exchange of water with that of the North Channel (Edwards et al. 1986). Because of this limited exchange, waters in the Firth of Clyde tend to be fresher, and warmer in summer and colder in winter. This partial separation of water masses is accompanied by a surface front. Most of this understanding of the oceanography of the Firth of Clyde was gained from a series of cruises and moorings deployed in the later 1980s (Edwards et al. 1986) with some other projects taking place in the mid-1990s (Jones et al. 1995, Rippeth et al. 1995).

More recently regular monitoring of the oceanography of the region, and indeed of the whole Scottish west coast, has been rather limited (Fox & Howe 2011). Sea temperature has been monitored at Millport since 1909 and more regularly since 1953 (Figure 8). Comparing these data with other west of Scotland inshore temperature records collected since 1999 (Loch Ewe, Mallaig, Loch Maddy) showed good agreement (Fox & Howe 2011) suggesting that the main patterns are driven by regional-scale atmospheric and oceanic forcing. Such forcing often has cyclical components and this is seen in the temperatures recorded at Millport but with an underlying increasing trend of approximately 0.8^{o}C over the last century. The number of years when the summer maximum has exceeded 15^{o}C has increased in recent years, whilst the frequency of extremely cold winters has decreased. These changes may be of some significance for the fisheries since relationships between winter sea temperatures and subsequent year-class strength have been suggested for a number of commercial finfish species (Planque & Frédou 1999, Fox et al. 2000). Environmental influences on early life survival also seem to become more important when spawning stock biomasses are at relatively low levels (Brander 2005).

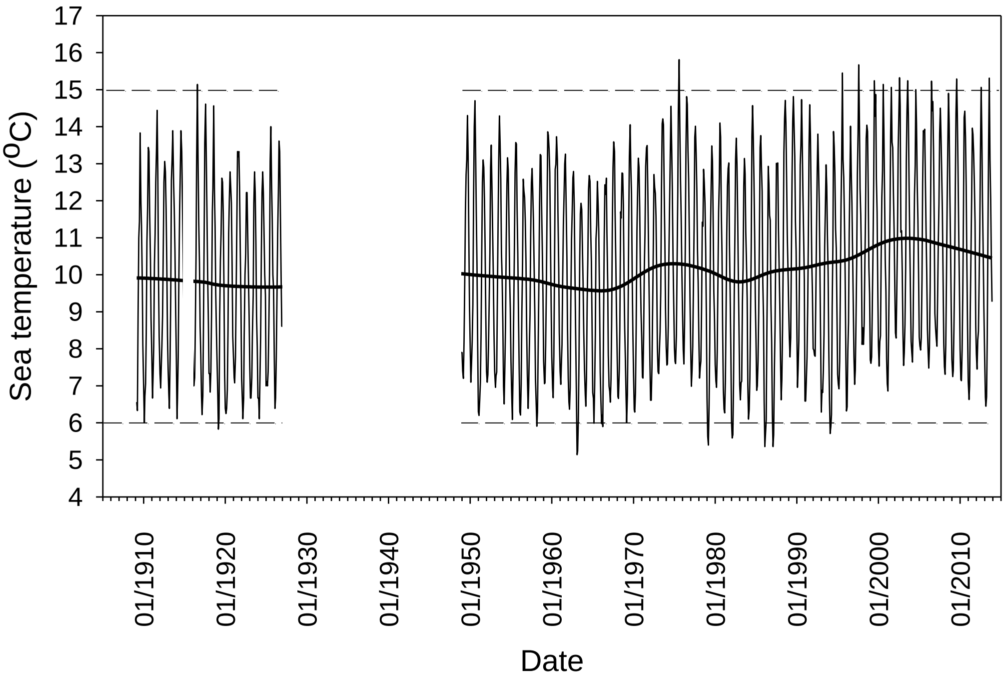


Figure 8: Monthly sea temperatures recorded at Keppel Pier, Millport (heavy line is a loess smooth to show the general trend, the dashed lines indicate the level of exceptionally warm and cold years).

In terms of oceanographic models, the Firth of Clyde has often been excluded because of its relatively small size, especially in models at courser scales. Finer-resolution models covering the Clyde are now being developed (Sabatino 2014) and such models can be used to study a range of processes including sediment transport, organism dispersal and biological connectivity. One significant issue though is that running and using the output from such models requires expertise and research level computing resources.

Water quality

Good water quality is clearly important for aquatic ecosystems to support living organisms. It is also import for the production of shellfish for human consumption and for the use of the inshore waters for recreation. Water quality is assessed in terms of its Ecological (Biological, Physical, Chemical and Hydromorphological[5] elements) and Chemical status. Present status is assessed in relation to 'reference values' taken to be representative of minor alteration as a result of human disturbance (UKTAG 2007). Biological indicators are used because certain organisms are sensitive to poor water quality, whilst the presence of others may be indicative of poor conditions (UKTAG 2013). Phytoplankton are also monitored because changes in standing stocks and/or community composition can be indicative of problems with nutrient enrichment. Parameters typically monitored under the Physical and Chemical headings include temperature, oxygen and nutrient levels. Member states are also required to identify and monitor specific pollutants. All these factors will interact and if below optimal levels can negatively affect aquatic life. Water quality is also very important with regard to

[5] Hydromorphology refers to the shape of the rivers and coastlines and implies that changes in water quality due to dredging or the construction of dams, ports, flood defences etc. must be taken into account.

shellfish which can accumulate pollutants and biotoxins (e.g. from harmful algal blooms) if they are present.

Water quality as captured in the EU Water Framework Directive (WFD) covers rivers, lakes, transitional (estuaries) and coastal waters. There are five classes for ecological status under the WFD; 'high', 'good', 'moderate', 'poor' and 'bad'. The Directive requires that the overall ecological status of a water body be determined by the results for the biological or physicochemical quality element with the worst class (UKTAG 2007).

Waters from which shellfish are harvested receive special attention under the Shellfish Growing Waters Directive (SGWD) but additional areas may also be included under the WFD for the protection of economically significant aquatic species.

In Scotland the body responsible for monitoring water quality for WFD and SGWD purposes is SEPA (Scottish Environmental Protection Agency) although Marine Scotland Science contributes monitoring data for intermediate and coastal waters. Management actions are co-ordinated through a management plan for each river basin (http://www.sepa.org.uk/water/river_basin_planning/area_advisory_groups.aspx).

The first river basin management plan for the Clyde covered 2010-2015 (SEPA 2010) and the Advisory Group is working on the second plan. The historically poor water quality in the River Clyde and upper estuary, as a result of industrial and urban pollution, has been well documented (Haig 1986, Ross et al. 2009). In recent years water quality has been much improved (Figure 9) although local transient problems persist, often associated with areas of reduced hydrological flow at weirs (http://www.midclydeanglingassociation.org/news.html). Several parts of the outer Firth region were evaluated in 2008 as having moderate water quality. Firth of Clyde Inner–Cumbraes, East and South Arran failed to reach good status due to morphological alteration of the seabed due to fishing (http://gis.sepa.org.uk/rbmp/). For other areas classed as moderate; Sound of Bute, Seamill and Ardrossan - point source pollution (sewage) and for Irvine Bay, sewage and construction disturbance were responsible.

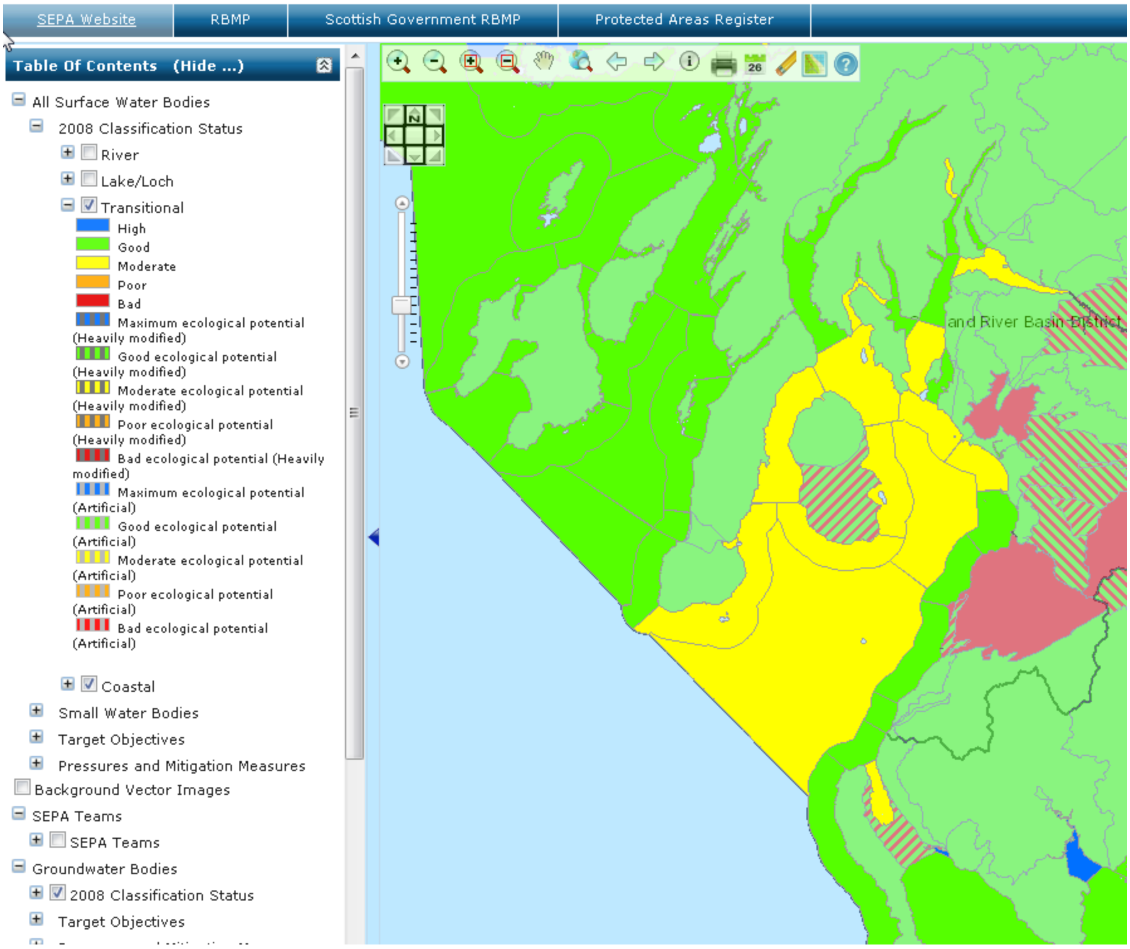


Figure 9: Classification of transitional and coastal waters in the Clyde region (2008)

The Clyde contains a number of shellfish harvest areas which are covered under the Shellfish Growing Waters Directive

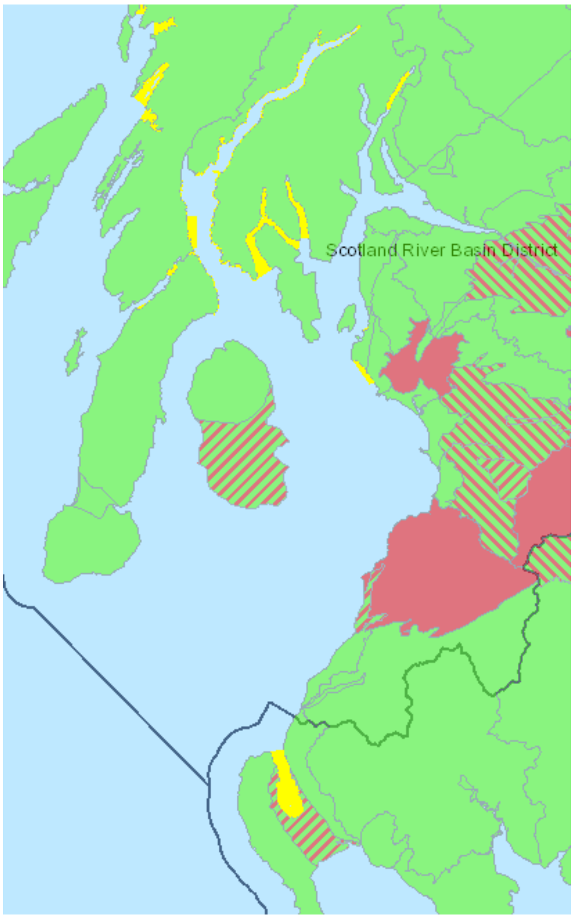


Figure 10: Locations of waters designated for the purpose of shellfish growing in the Clyde region

Webster et al. (2007) reported on pollutant measurements of samples taken in the Outer Clyde between 1999 and 2006 as part of a process of developing a national monitoring program (Clean Seas Environment Monitoring Program). Station NMMP 35 is now sampled annually and forms part of the UK National Marine Monitoring Programme (NMMP) which also contributes to the OSPAR Co-ordinated Environmental Monitoring Programme. Data are held in the UK Marine Environment Monitoring and Assessment National (MERMAN) database which is run by BODC (British Oceanographic Data Centre). Data are also submitted to International Commission for the Exploration of the Seas (ICES) and the European Marine Observation Data Network. Data overviews are available directly from the MERMAN site but accessing the underlying data requires a request to be sent to BODC. Interpretation of pollutant data in relation to health standards requires expertise.

Nutrients

Across the west of Scotland anthropogenic nutrient contributions to coastal waters are generally low. Although fish farming adds considerable quantities of feed to many of the inshore areas, the effect of this on water column nutrient concentrations can only be detected at very close proximity (< 100 m) to the cages (Price et al. 2015). However, this general lack of nutrient enrichment does not apply to the Clyde Estuary. Because it is adjacent to several major population centres, including Glasgow, and its bathymetry restricts water exchange with the North Channel, the Clyde estuary is considered to be nutrient enriched (Simpson & Rippeth 1993, Tett et al. 2003). Rippeth and Jones (1997) and Kennington and Johns (2007) observed that an earlier post-bloom (September/October) recharge of dissolved nitrate occurs in the surface waters of the Clyde estuary compared with offshore waters. A strong inverse relationship had previously been demonstrated between salinity and nitrate concentration in the Clyde suggesting that the main source of nitrates accumulating in the surface waters in the autumn was from terrestrial run-off. This was supported by the fact that river-flow in the Clyde estuary catchment increases in September/October and does not decline until the following February. In the deeper waters of the Clyde Estuary, Jones et al., (1995) and Rippeth and Jones (1997) showed a steady increase in dissolved nitrate during the year reaching a peak around October. Since the origin of the deep-water is inflow of higher salinity North Channel water over the sill and this inflow is limited during the summer months due to thermal stratification, the accumulation of deep-water nitrate during the year appears to be due to localised regeneration. With regard to dissolved inorganic phosphate and silicate, winter concentrations in the Clyde are generally higher than for the offshore areas, again resulting from terrestrial run-off. In winter-time the exchange of water between the North Channel and the outer Firth increases due to the breakdown of thermal stratification which allows stronger density driven flows (inwards at depth over the sill and outwards near the surface). The Clyde Estuary may therefore act as a source of nutrients to the adjacent coastal waters during the winter (Fox & Howe 2011).

Station 35 (Webster et al. 2007) is now sampled annually and forms part of the UK Clean Seas Environment Monitoring Program (CSEMP) which also contributes to the OSPAR Co-ordinated Environmental Monitoring Programme.

Pollutants

Heavy metals and persistent organic pollutants

A number of studies have shown that there is a noticeable increase in contamination in the area used for dumping dredge spoil in the Inner Firth, close to the mouth of the Holy Loch (Baxter et al. 2008). In the 2009 environmental baseline review for the Clyde (Ross et al. 2009) it was concluded that some areas of the Clyde Estuary have also been degraded due to elevated levels of persistent substances such as lead, chromium and polychlorinated biphenyls (PCBs). Several potential pollutants were also measured in tissue samples, for example, in mussels collected in the Clyde. Cadmium and lead concentrations in these samples fell significantly between 1980 and 1997. This downward trend for cadmium may reflect a general decline in heavy industry in the area, whilst the decrease in lead levels may have been linked to the introduction of lead-free petrol. Data from SEPA’s 2006 estuarine classification scheme shows that contaminant concentrations in mussels from the Clyde Estuary were generally declining at that time. In particular chromium concentrations at previous pockets of unsatisfactory waters at Cardross, Woodhall, Port Glasgow, Helensburgh, Portkil Bay, Ardmore and Dunoon East had all fallen, to an extent that water quality at these locations was classed as good (Ross et al. 2009).

Levels of persistent organic pollutants have also been measured in samples of eels (*Anguilla anguilla*) collected at a number of sites within the Firth of Clyde and River Clyde (Macgregor et al. 2010). Across all the Scottish sites overall PCB contaminant levels were considered low relative to samples from other European rivers but contaminant levels in eels caught in the River Clyde were higher. The study was not specifically designed to examine aspects of human health but contaminant levels in all but two individual eels from the River Clyde were below the maximum tolerance limit for PCBs (2 mg kg^{-1}) stipulated by the US Food and Drug

Administration with regard to human consumption. For DDT and its metabolites none of the eels examined would exceed the USFDA limit set for all fish types (5 mg kg^{-1}).

As well as nutrients, levels of pollutants are also measured regularly at station 35 as part of the UK CSEMP. Recent data can be accessed at the Marine Environment Monitoring and Assessment National database (MERMAN) held at the British Oceanographic Data Centre (BODC). See also Baxter et al. (2011) for an overall summary.

Litter

Marine litter is acknowledged as a serious problem (Potts & Hastings 2012, Ivar do Sul & Costa 2014). Litter can endanger marine life, cause damage to shipping and other offshore industries but it also reduces the enjoyment people gain from living on or visiting the coast with consequent economic and social impacts. As well as visible litter there are increasing concerns about plastics which have become dispersed throughout the oceans eventually degrading into micro-particles and fibres (Woodall et al. 2014). The long-term impact of these fibres and particles on marine life is largely unknown but particles have been found in the guts of various marine organisms (Wright et al. 2013). Although most litter has terrestrial origins a significant percentage does derive from fisheries and takes the form of lost or discarded netting, rope, creels etc. Apart from the dangers to wildlife, the presence of such material on beaches gives a bad public perception of fisheries. For these reasons local management and stakeholders may wish to monitor this aspect. Litter indices will also be required to be reported under the EU Marine Strategy Framework Directive. However, marine litter is one area with relatively poor monitoring (Potts & Hastings 2012) although the Marine Conservation Society organises annual beach surveys and records regional trends in these data (Table 7).

Seabirds

Seabirds can be affected both directly and indirectly by fisheries. For example direct interactions may include entanglement in gear and this is the primary reason behind management proposals for some of the Marine Protected Areas (MPAs). Indirect effects include provision of additional food for seabirds via discards. Proposed changes in discarding under reform of the Common Fisheries Policy are likely to affect some seabirds and this has been examined using food-web models (Heath et al. 2014). Another indirect effect which has received much attention is fisheries-induced reductions of prey, such as sandeels (Ammodytidae), impacting seabird feeding and breeding success. The general conclusion of such studies in the North Sea has been that changes in sandeel abundance and nutritional condition seem more related to changes in the environment rather than fisheries (Poloczanska et al. 2004, Heath et al. 2012). However, this does not mean that all other prey-related fisheries-seabird impacts can be dismissed and research would have to be conducted on a case-by-case basis.

The Firth of Clyde contains several important seabird colonies although many of the breeding colonies in the area are relatively small (Monaghan & Zonfrillo 1986, McIntyre et al. 2012). Ailsa Craig is an exception where the granite cliffs provide breeding sites for around 12% of Europe's gannets (*Sula bassana*). Since fisheries have the potential to interact with many seabird species this must be taken into account by inshore fisheries managers. Interactions can take the form of direct negative impacts, such as by-catch of birds in some gears or indirect impacts through competition for prey between fishers and birds (negative impact) or enhancement of prey via discards (positive impact).

Of the twenty-four species of seabirds which breed on British coasts, twenty-one have bred in the Firth of Clyde (Monaghan & Zonfrillo 1986). Anecdotal evidence prior to the 1930s suggests large changes in seabird abundance had occurred but regular reliable count data really begin in the 1950s. Breeding roseate terns (*Sterna dougalli*) have been recorded in the Firth historically, but not in recent years. Monaghan and Zonfrillo (1986) described the changes in abundance for the main species between 1950 and the mid-1980s. Species showing notable increases included Great black-backed gull (*Larus marinus*), gannet, herring gull (*Larus argentatus*) and fulmar (*Fulmarus gracialis*). The latter two species showed expansion throughout the north-eastern Atlantic from the 1850s onwards. This expansion was possibly linked to increases in fish discards. Another species showing some increase from 1950 to 1985 was the black guillemot (*Cepphus grylle*). In contrast, most of the tern species (common, *Sterna hirundo*; Arctic, *Sterna paradise*; and Sandwich, *Sterna sandivencis*) showed strong declines as did kittiwake (*Rissa tridactyla*). Counts for remaining species were either relatively constant, showed cyclical patterns or had insufficient data to draw conclusions. Monaghan and Zonfrillo (1986) commented that a lack of data on the status of fish stocks in the Clyde meant that interpreting possible reasons for some of these changes in seabird abundance was difficult. The smaller surface-feeding birds, such as the terns, appeared to be doing particularly poorly and it was suggested this might be linked with declines in abundance of sandeels and small clupeoid fish such as sprat and herring. Further shifts in seabird abundance may be expected as a result of the planned changes to reduce fisheries discarding are likely to have knock-on effects to other marine organisms, in particular seabirds (Votier et al. 2013, Heath et al. 2014).

Since Monaghan and Zonfrillo (1986) monitoring at the main seabird colonies in the Firth of Clyde has continued and data are collated by the JNCC's Seabird Monitoring Program (http://jncc.defra.gov.uk/smp/). Overall trends for Scotland are summarised at http://jncc.defra.gov.uk/page-3201 but patterns to regional level require further data analysis.

Several areas within the Firth of Clyde have protected status in relation to birds. The Inner Clyde is a Ramsar[6] site and an SPA (Special Protected Area) in relation to redshank (*Tringa tetanus*) and other wading birds whilst the Black Cart is an SPA in relation to whooper swans (*Cygnus cygnus*). Ailsa Craig and Sanda Island are both Sites of Special Scientific Interest and Ailsa Craig is also an SPA. In 2009 the boundary of this site was extended to include a marine component out to approximately 2 km from the original site boundary (http://www.snh.org.uk/pdfs/directives/b269953.pdf). The Clyde Sill is a designated MPA (Marine Protected Area) for protection of Black guillemot (*Cepphus grille*) feeding grounds (plus circalittoral sand & coarse sediment communities, and fronts) (Scottish Natural Heritage 2013a). The management plan for the Clyde Sill has not yet been developed but is likely to include some restrictions on the types of fishing gear which can be deployed within the boundary.

Bird colony count data for the Clyde can be found at the JNCC website and the National Biodiversity Network site (http://www.nbn.org.uk/). Seabird counts are also recorded periodically at sea and these data can be found at http://seamap.env.duke.edu/. It is however difficult to interpret trend data from this website.

[6]Ramsar sites are wetlands of international importance, designated under the Ramsar Convention. Special Protection Areas (SPAs) are strictly protected sites classified in accordance with Article 4 of the European Birds Directive (EC Directive on the conservation of wild birds - 79/409/EEC).

Marine mammals

As with seabirds, fisheries may interact with marine mammals in both a direct and indirect manner. Entanglement of mammals in certain fishing gears can occur whilst fisheries themselves can be affected by predation and gear damage due to mammals such as seals. Because marine mammals (excepting seals) do not breed on land it is more difficult to census their population sizes through direct observation. There are exceptions e.g. groups which tend to be more resident in inshore waters such as the Moray Firth dolphins. The Sea Mammal Research Unit based at University of St. Andrews produces regular reports on marine mammal populations around the UK. Annual reports are produced and available from their website which summarise recent population trends including for seals. Major grey seal (*Halichoerus grypus*) breeding colonies are found in the inner and outer Hebrides. Harbour seal (*Phoca vitulina*) haul-out sites are found around the Scottish coast including in the Moray Firth but the Scottish west coast supports a greater number of colonies (Special Committee on Seals 2014). Grey and harbour (common) seals can show differing population trends although fishers may not always distinguish between the two species Moore (2003).

The biggest concentrations of harbour (common) seals in the Firth are on Sanda at the southern end of the Mull of Kintyre, the west and south coasts of Arran, around Bute and on Lady Isle off Troon. The remaining animals are found scattered around the rest of the Firth, although their density is considerably lower. In recent years there have been marked declines in common seal numbers at a number of sites (Special Committee on Seals 2014). There are no major grey seal breeding colonies in the Firth of Clyde and the nearest breeding colonies of any substance are on Nave Island, off northwest Islay, and on islands off the coast of Oronsay.

Numbers of grey seals across Scotland seem to be stable (Inner and Outer Hebrides) or slowly increasing (Orkney) (Special Committee on Seals 2014). This is in contrast to the North Sea where the population is still increasing strongly.

Seal interactions with fisheries in the Firth of Clyde were reported on by Moore (2003). On the basis of surveys conducted with fishers, Moore reported that seals took catches from both trawls and creels. Damage to gear was more prevalent in creels. The majority of fishers favoured some form of culling to control seal numbers but they did not normally distinguish between grey and harbour seals. An annual grey seal cull was maintained in the UK from 1962 until 1979 but it was abandoned in the face of sustained public protest. The question of whether seals are restricting the ability of gadoid stocks on the west coast of Scotland to rebuild has recently been examined by Cook et al. (2015). They concluded that increased predation mortality on Scottish west coast cod might have been sufficient to offset recent reductions in fishing mortality. Overall mortality levels would therefore not have dropped which could explain why the west Scotland cod stock has failed to rebuild as anticipated.

A variety of other marine mammals have been recorded in the Firth of Clyde including minke whale (*Balaenoptera acutorostrata*), harbour porpoise (*Phocoena phocoena*) and occasional other species. The harbour porpoise is now the most abundant of the Scottish cetaceans, with the highest reported concentrations around the western and north-eastern coasts (Evans, 1992). According to Ross (2009) harbour porpoise are not reported as regularly or consistently as whales and dolphins in the Firth of Clyde. The number of minke whales in the Firth appeared to have increased by 2006 compared with earlier data, but a pod of 27 bottlenose dolphins that visited in 2004 and 2005 did not return in 2006. In 1996 an immature humpback whale remained in the Firth from January to March, where it was observed feeding on sprat and herring. A humpback whale also appeared in Loch Long in October 2006 and remained for four days but this species is a rare visitor.

Marine Protected Areas (MPAs)

The UK and Scottish Governments are committed to establishing an ecologically-coherent network of Marine Protected Areas (MPAs). The areas are designated under various legal frameworks which can be confusing. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) fall under European Directives. Across Europe such sites form part of a wider network called Natura 2000. The UK (and Scottish) government are obligated to maintain the quality of these sites and to report periodically on their condition to the European Commission.

In addition there are a variety of international and national frameworks such as Ramsar Convention sites and Sites of Special Scientific Interest. These sites are mainly terrestrial but can include coastal and inter-tidal areas.

Additional marine protected areas are being established around the UK to supplement these existing networks. The high level policy aim is to protect rare, representative and productive species and habitats on the basis of sound science so that the rich diversity of life in the waters around Scotland and the benefits they bring can be enjoyed in the future. In Scotland the powers to designate these sites rest with the Cabinet Secretary for Rural Affairs, Food and Environment acting via powers granted under the Scottish Marine Act (2010). The collection of supporting scientific evidence is undertaken mainly by Scottish Natural Heritage for sites within the 12 nautical miles limit. Advice on offshore sites comes from the Joint Nature Conservation Committee (JNCC). In addition, local communities can propose sites, an example being the proposals for South Arran building on the no-take zone established in 2008 in Lamlash Bay. At present management plans for these sites, including most Natura sites with marine components, are being developed by Marine Scotland. Some restrictions on fishing activities may therefore be put in place at some sites but the management plans will be put out to public consultation prior to adoption.

As mentioned above, the Firth of Clyde contains one of Scotland’s first marine no-take zones (Lamlash Bay) as well as three new statutory MPAs: the Clyde Sill (Scottish Natural Heritage 2013a); South Arran (Scottish Natural Heritage 2013b, c, Howson & Steel 2014) and Upper Loch Fyne and Loch Goil (Moore et al. 2013, Scottish Natural Heritage 2013d, Moore 2014).

The proposed management measures for these MPAs are still under consultation and so, although the MPA boundaries (Table 9) are included in our web-viewer, associated information on possible restrictions to fisheries, or other activities, in these areas are not shown (Marine Scotland 2014a).

Data characteristics

A summary of the characteristics of the different datatypes discussed above is provided in Table 7. Metadata for the high resolution bathymetry datasets available for the Clyde are shown in Table 8. Metadata for the Marine Protected Areas in the Clyde are shown in Table 9. A number of these datasets are included as layers in the demonstration web-based data viewer developed as part of the overall Work Package. Further discussion of the web-based data viewer can be found in Parts 3 and 4 of this report.

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Fish and shellfish	Stock assessments	ICES, Marine Scotland Science 2015, Dobby et al. 2012	Reports	Some data available on-line via MEDIN	Varies with species	Unknown	Referred to in the report text
	General changes in fish community	Thurstan et al. (2010)	Time-series fisheries landings by taxa (1960 – 2009)		Annual with lag	< 100 kB	Updated landings dataset included.
	General changes in fish community	Heath & Speirs (2011)	Time-series of trawl survey (46 y from period 1927-2009)	Underlying data collected by Marine Scotland, survey data submitted to ICES and available to download from DATRAS (from 1985 – now)	Annual with lag	< 100 kB	Time-series can be updated relatively quickly although calculation of the indices presented in Heath and Speirs would require additional work.
	Spawning grounds	(Poxton 1986)	Plankton surveys, mainly 1972 and 1974	Published maps which can be digitised	Historical	< 100 kB	Needs digitising
	Nursery areas	Gibb (2007)	2002-2004 Scottish inshore survey		Historical	< 100 kB	Needs sourcing

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Fish and shellfish con/td	Nursery areas con/td	Ware (2009)	Inshore survey	Data graphed in report	Historical	< 100 kB	Could be digitised relatively quickly.
		Fox et al. (2014)	Beach surveys targeting plaice and dab from 2001 to 2011	On request	To 2011	< 100 kB	Data for Clyde region needs summarising into suitable format
	Diseases		Short time-series on *Hematodinium* (dinoflagellate) parasite infections of *Nephrops norvegicus* 1995 to 1997.	http://portal.oceannet.org/search/full/	Historical	< 100 kB	Data was held at Millport – not clear if data are still available
		FSA Scotland	Levels of biotoxins and potentially harmful bacteria in harvested shellfish	http://www.foodstandards.gov.scot/shellfish-monitoring-180815	Weekly	< 200 kB	Weekly reports can be easily downloaded but timeseries of results would need to be requested

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
	Ecosystem indicators	Generally only calculated for larger ecoregions e.g. www.indiseas.org. Calculation of indicators for smaller regions is possible providing underlying data are available but interpretation of results can be complex. Ecosystem indicators are still in development and there is little agreement on which of the large number of proposed indicators are appropriate. Suites of indicators to date normally include consideration of the status of commercial and non-commercial fish and shellfish, but will also include indicators for a wide range of other environmental and human-based factors.					
Fisheries	Location of <10 m vessels	SuccorFish or similar vessel position monitoring system	Time-series	Variable - dependent on confidentiality agreements with vessel owners	Daily though receiver coverage can lead to data delays depending on data transmission method used	< 1kB upwards	Demo data included in web-viewer demo
	VMS > 10 m vessels	Statutory vessel monitoring system	Time-series	Needs data access agreements	Seasonal updates although data delivered to MS more frequently	> 10 kB	Not included in web-viewer demo – access to underlying data restricted due to confidentiality agreements
	Spatial distribution of fishing	ScotMap	Snapshot	On-line	One off exercise	< 1kB	Included in web-viewer demo – also in NMPI

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Fisheries con/td	Reported landings	http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/RectangleData	Tabulated data by ICES rectangle but further processing needed to adjust to IFG boundaries	On-line	Annual but lag due to data collation and processing	< 2 kB	Summarised in this report
Base maps	Admiralty charts	www.seazone.com	Hydroview geoTiff	Licenced product	Infrequent	< 10MB	Included in web-viewer demo but not for public release
	Single and multibeam acoustics	UKHO-INSPIRE	Bathymetry	Public (https://www.nationalarchives.gov.uk/doc/open-government-licence/version/2/)		kB to Gb depending on area and survey type	Latest data downloaded and incorporated into web-viewer demo (Table 8). Data tiles can be incorporated into NMPI
		Olex	Bathymetry	http://www.olex.no/index_e.html	On-going	> 1 MB	Not included at this time
	ICES Statistical rectangles and sub-rectangles	ICES	GIS	Public	Never	< 1 kB	Customised grids can be incorporated into web viewer
Sediments	Gridded sediment maps	JNCC		Public (http://jncc.defra.gov.uk/page-2117)			Static data layer could be incorporated into web viewer as for bathymetry.

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Oceanography	Sea temperature	Hadley ISST http://www.metoffice.gov.uk/hadobs/hadisst/	netCDF	Public non-commercial use but requires specialist analysis	Annual	< 1 Mb yr^{-1}	Historical data described in this report
Water quality	Water Framework Directive Ecological Status assessments	http://gis.sepa.org.uk/rbmp	Text summaries	Summaries are public	Infrequent	kB	Consulted and described in this report
Water quality con/td	Contaminants in sediments and fish samples	http://www.bodc.ac.uk/projects/uk/merman/	Graphic summaries	Summaries are public but underlying data require data request	Annual	< 1kB	Consulted and described in this report
Litter	Trends	www.mcs.org	Graphic summaries	Underlying data require data request	Annual	< 1MB	Consulted
Seabirds	Count data	http://jncc.defra.gov.uk/page-1550 and https://data.nbn.org.uk/ and http://seamap.env.duke.edu/	Graphic and numeric Summaries	On-line	Variable	< 1MB	Websites consulted – data for specific sites available but production of trends requires further extraction and compilation
Marine mammals	Population trends	(Special Committee on Seals 2014)	Summaries	Public	Annual	< 1kB	Current status described in this report; available in NMPI

Table 7: Summary of data characteristics for information relevant to inshore fisheries management for the Firth of Clyde pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Marine Protected Areas	Designated	(Scottish Natural Heritage 2013a)	Report	Public	Irregularly	< 1kB	Current status described in this report; available in NMPI

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1972 K6547 North Channel to the Calf of Man	19721115	19720215	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMS Fawn	Echosounder - single beam	Hifix	Ministry of Defence	2006091
Downloaded 18 Aug 2014	1976 K7719 Firth of Clyde Ayr to Ardrossan	19760614	19760427	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Woodlark	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008705
Downloaded 18 Aug 2014	1984 HI165B Firth of Clyde	19841126	19840311	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Beagle	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008627
Downloaded 18 Aug 2014	1984 HI165 Gareloch	19840301	19840127	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Trisponder	Ministry of Defence	2005007
Downloaded 18 Aug 2014	1985 HI165C Firth of Clyde Little Cumbrae Island to Toward Point Sheet 1	19850718	19850430	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008618

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1985 HI165C Firth of Clyde Little Cumbrae Island to Toward Point Sheet 2	19850718	19850430	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.0001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008619
Downloaded 18 Aug 2014	1985 HI165B Scotland West Coast Sanda Island to Bute Sheet 5	19851031	19850609	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008616
Downloaded 18 Aug 2014	1985 HI165B Scotland West Coast Sanda Island to Bute Sheet 6	19851031	19850609	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008617
Downloaded 18 Aug 2014	1985 HI165 Islay to Sanda Island	19850607	198505 18	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Hifix	Ministry of Defence	2006099
Downloaded 18 Aug 2014	1986 HI322 Firth of Clyde Toward Point to Greenock	1986070 8	198605 09	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Hecla	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008610

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1993 HI597 Rosneath Point	19930511	19930304	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - single beam	Trisponder	Ministry of Defence	2005921
Downloaded 18 Aug 2014	1996 HI709 Scotland West Coast Loch Long	19960618	19960422	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Roebuck	Echosounder - single beam	Unknown	Ministry of Defence	2008450
Downloaded 18 Aug 2014	1997 HI778 Ardmore Channel to Greenock Bank	19971022	19971007	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - single beam	DGPS	Ministry of Defence	2005828
Downloaded 18 Aug 2014	1997 M2940 Gareloch	19971028	19971028	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - single beam	DGPS	Ministry of Defence	2005827
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk1	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.257 2201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.00 00001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005933

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk2	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005934
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk3	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005935
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk4	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005936
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk5	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005937
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk6	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005938

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk7	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005939
Downloaded 18 Aug 2014	2001 HI762 Loch Long and Approaches to Loch Finnart Blk8	20010712	20010505	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2005940
Downloaded 18 Aug 2014	2003 HI779 Lamlash Bay	20030330	20030213	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMSML Gleaner	Echosounder - multibeam	DGPS	Ministry of Defence	2006061
Downloaded 18 Aug 2014	2012 HI1355 Kintyre 2m SB	20121107	20121011	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	WADGPS	INIS Hydro	2008926

Table 8: Metadata for Firth of Clyde bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Only TIFF available	2013 2013-189356 H102 03/13 Ardmore Channel Gareloch 2m SB	20130411	20130411	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	HMS Echo	Echosounder - multibeam	WADGPS	Ministry of Defence	2008968

Table 9: Metadata for Firth of Clyde Marine Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

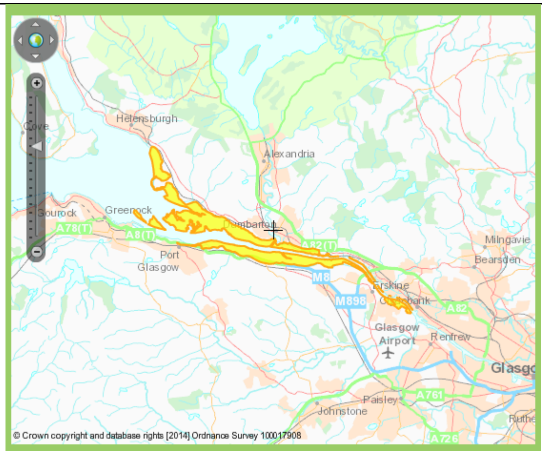
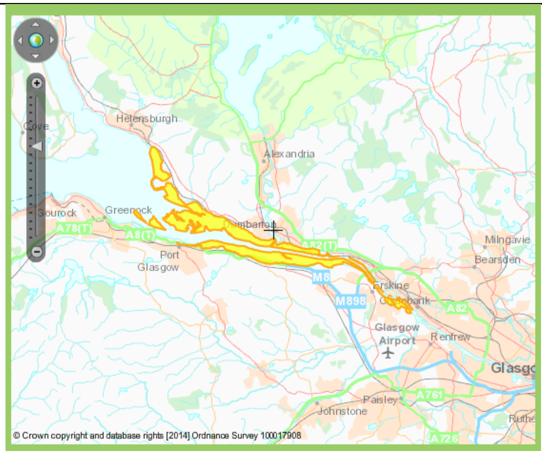
Site	Description and features	Map
Inner Clyde, SSSI	Area designated as Site of Special Scientific Interest. Cormorant (*Phalacrocorax carbo*), Oystercatcher (*Haematopus ostralegus*), Red-breasted merganser (*Mergus serrator*), Redshank (*Tringa totanus*), Golden-eye (*Bucephala clangula*), Eider (*Somateria mollissima*), Red-throated diver (*Gavia stellata*), non-breeding. Littoral sediment (Coast) Saltmarsh	
Inner Clyde, Ramsar	Area designated as an internationally important wetland habitat. Over-wintering redshank (*Tringa totanus*)	

Table 9: Metadata for Firth of Clyde Marine Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

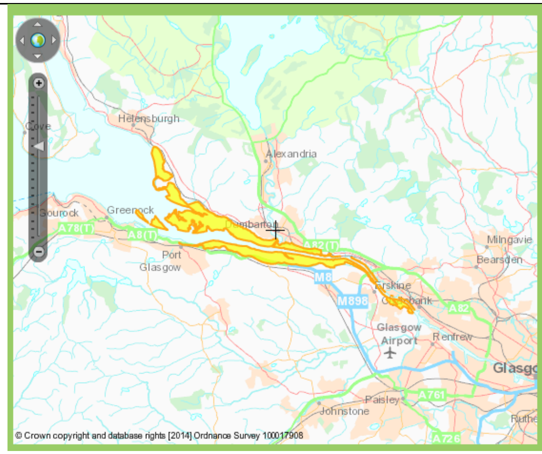
Site	Description and features	Map
Inner Clyde, SPA	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Over-wintering redshank (*Tringa totanus*)	
Black Cart, SPA	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Over-wintering whooper swan (*Cygnus cygnus*)	Not included on web viewer

Table 9: Metadata for Firth of Clyde Marine Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

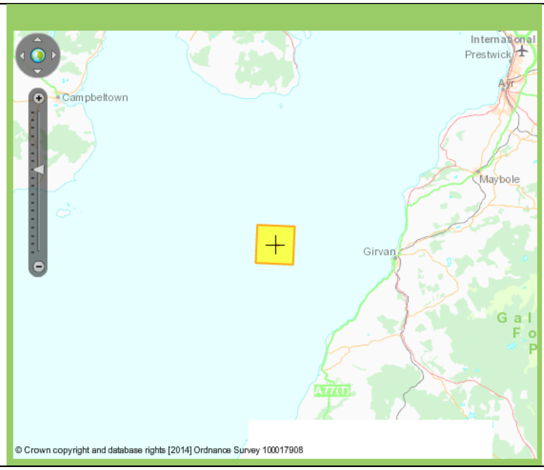
Site	Description and features	Map
Ailsa Craig, SPA	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Breeding gannet *Morus bassanus;* Lesser Black-backed gull (*Larus fuscus*). Breeding assemblage: Guillemot (*Uria aalge*), Kittiwake (*Rissa tridactyla*), Herring Gull (*Larus argentatus*), Lesser Black-backed Gull (*Larus fuscus*), Gannet (*Morus bassanus*).	

Table 9: Metadata for Firth of Clyde Marine Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

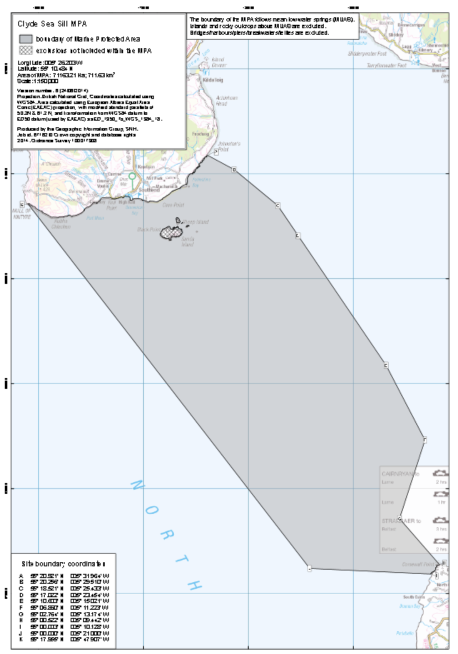
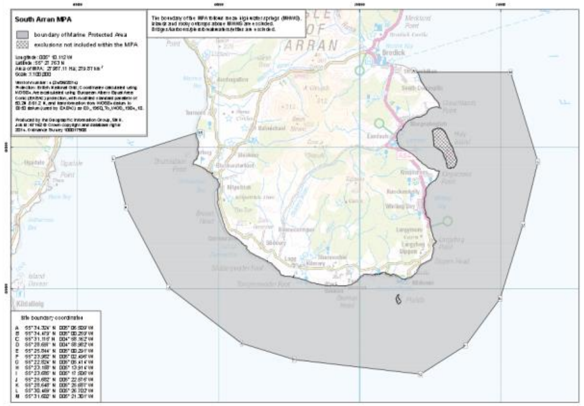
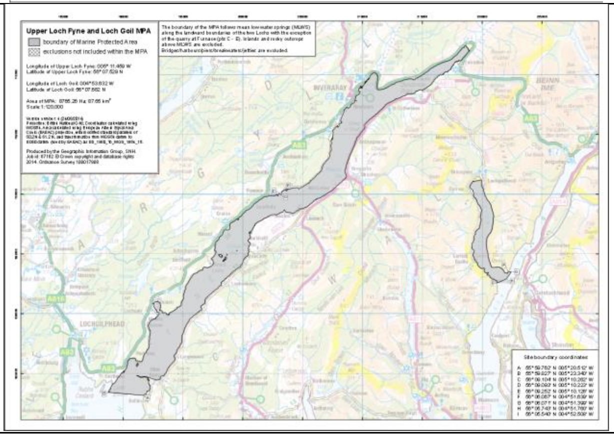
Site	Description and features	Map
Clyde Sill, MPA	This MPA encompasses a persistent thermal front located where the waters of the Irish Sea meet the calmer, less saline waters of the Clyde Sea. The designation also recognises the importance of the area for black guillemots. The boundary of this MPA stretches from the Mull of Kintyre to the Rhins of Galloway and includes the waters around Sanda, Sheep and Glunimore Islands. Black guillemot, circalittoral and offshore sand and course sediment communities, fronts and geodiversity feature: Marine Geomorphology of the Scottish Shelf Seabed - sand banks, sand ribbon fields, sand wave fields	

Table 9: Metadata for Firth of Clyde Marine Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

Site	Description and features	Map
South Arran, MPA	Designated for its diversity of animals and plants including maerl beds, kelp and seaweed communities and possibly the largest seagrass bed in the Clyde, this MPA protects some of Scotland's most important and productive seabed habitats. Covering over 250 km2 and encompassing the current Lamlash Bay No Take Zone, the South Arran MPA will provide long term support for our seas. Burrowed mud; kelp and seaweed communities on sublittoral sediments; maerl beds; maerl or coarse shell gravel with burrowing sea cucumbers; ocean quahog aggregations; seagrass beds; shallow tide-swept coarse sands with burrowing bivalves.	
Upper Loch Fyne and Loch Goil, MPA	Designated to protect an assembly of seabed habitats, these long narrow sea lochs are home to the spectacular fireworks anemone, brightly coloured flame shells and the ocean quahog - one of the longest lived animals on the planet. Inclusion of these two sea lochs within the MPA network will help safeguard the Clyde's diverse range of animals, plants and seabed habitats. Burrowed mud; flame shell beds; horse mussel beds; ocean quahog aggregations; sublittoral mud and specific mixed sediment communities	

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Part 2: Information relevant for inshore fisheries management in the Moray Firth

Contents

Geographical boundaries of the Moray Firth pilot area

A simple polygon covering the area out to 6 nm (nautical miles) offshore was selected to define the boundaries of the Moray Firth pilot area. The selected region was aligned with existing areas proposed for Marine Planning in order to make data sharing easier. These boundaries are for demonstration purposes only and may not reflect the final boundaries selected for use in inshore fisheries management or marine planning.

The boundaries selected were designed to align with those of the Moray Firth Partnership. The northern boundary runs from Duncansby Head out to the 6 nm limit (note the Moray Firth Partnership boundary is at the 12 nm limit) while the southern boundary runs northwards from just east of Fraserburgh (Table 1). The seaward boundary encompasses the waters out to 6 nm.

Table 1: Polygon boundaries for Moray Firth area

Node	Latitude	Longitude
1	58.6434	-3.0233
2	58.6423	-2.8445
3	58.3218	-2.8647
4	57.9617	-3.6538
5	57.8372	-3.5292
6	57.8109	-1.9251
7	57.6898	-1.9348
8	57.5214	-3.9491
9	57.4241	-4.5044
10	57.9338	-4.4465
11	58.6434	-3.0233

Historical and recent trends in the Moray Firth fisheries

History of the Moray Firth Fisheries

The history of fishing in the Moray Firth has been documented although perhaps less recent attention has been paid to this region compared to the Clyde. Crowe (1928a) reports an interesting fact that in 1631 no English fishers, nor other foreigner, were allowed to fish within 14 miles beyond a line from Buchan Ness to Duncansby Head. The local fishers were clearly interested in protecting access to the Firth for their own use at this time.

In 1707, the local fleet comprised 500-700 boats each of which was manned by six or seven crew (Crowe 1928a). The principal species caught was the herring (*Clupea harengus*) and the total number of people involved in this fishery would therefore have been around 3,000 to 5,000.

Following a Report by a Royal Commission in 1885, the Fishery Board of Scotland were given powers under the Sea Fisheries (Scot.) Amendment Act of 1885 to make byelaws restricting any method of fishing deemed to be 'injurious to any other kind of sea fishing'. Areas of the east coast, including the Moray Firth were closed under these powers to beam trawling in 1887. A further bye-law in 1898 (Bye-Law no. 17) made it illegal to use any net trailed or dragged along the sea floor (including seine or circle nets) to capture any species other than herring, sprat, sparling or shellfish. In 1889 the Herring Fishery (Scotland) Act prohibited beam and otter trawling within 3 miles of the low-water mark along the open coast. Trawling in Scottish extra-territorial waters (beyond 3 nm of the coast) was banned in 1889/1890 in response to concerns about the damage it might do to the grounds (trawl caught fish in Scotland had been first landed at Aberdeen in 1874). The Firth enclosed 503 square miles of territorial water and 1,517 square miles of extra-territorial water taking the boundary of the Firth as a straight line from Duncansby Head to Rattray Head (Crowe 1928b)[1]. However, in response to protests from some fishermen this regulation was modified to allow seine netting in the inshore waters of certain areas including the coast south of the Moray Firth, but not in the inshore waters (within 3 nm of the coast) of the Moray Firth itself (Crowe 1928b).

A particular anachronism was that after a period the bans on trawling were only applied to British vessels (Bowman 1928f). Numbers of foreign trawlers regularly fished in the Firth from 1895 onwards. By 1899 the number of visiting foreign vessels had increased to 49 but dropped to zero during the First World War. After 1918 numbers did not quite reach the pre-war levels with between 11-33 vessels being recorded (up to 1926). Before the war visiting fishers mostly originated from Belgium and the Netherlands and occasionally Germany. They tended to arrive to fish during winter and early spring although some activity occurred year-round. As mentioned for the local fisheries, the main targets were the spawning aggregations of plaice (*Pleuronectes platessa*), cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Once the main spawning was over, vessels would shift their grounds to target other species, such as lemon sole (*Microstomus kitt*). In addition, the relative shelter of the inner Firth, at a time of year when weather conditions in the wider North Sea could be poor, would attract vessels. The fact that the grounds targeted by the

[1] Note that this was the definition for the Moray Firth used in the 1928 ICES report and that 6 or 12 nautical miles from the coast is now commonly used to define the extent of inshore fisheries in line with present national and EU fisheries management practice.

visiting trawlers, particularly in relation to the spawning cod, were the same as worked by the local anchor-net fishers much have caused a deal of resentment. There is some anecdotal evidence that this trawling activity led to detrimental impacts because Bowman (1928f) provides an account from a German skipper concerning local depletion of plaice during a single season. According to that account the following year the plaice had largely disappeared from the Moray Firth and the implication was that they had been fished out. The catches tended to be landed in English ports, such as Hull and Grimsby.

By 1925 there were 1,828 vessels registered to ports in the Firth and the number of resident fishers numbered 8,672, around one-third of the Scottish total at that time (Crowe 1928a). Although much of the fishing took place in the Firth itself, herring vessels in particular also worked outside this area. In 1928 about half of the 8,500 fishers in the Moray Firth were dependent on catching herring whilst this fishery was a significant source of income for another 3000 people (Crowe 1928a). This was principally a winter drift-net fishery which targeted the young fish (Hopkins 1986). Steam drifters had been introduced in 1895 but were rather rapidly, from 1909 onwards, replaced by more efficient motor drifters (Crowe 1928b).

The effectiveness of the Moray Firth closure was examined by a Scottish Departmental Committee in 1923 who recommended that international agreement be reached so that non-British trawlers could also be excluded. The trawling ban within the territorial waters of the Moray Firth was then passed for review in 1928 to an international ICES (International Council for the Exploration of the Sea) committee (Crowe 1928b, a). However, they were unable to reach any strong conclusions about either the effects of the trawling ban on the wider North Sea fish stocks, nor on the economic or social impacts. It was especially noted that the failure to exclude non-British trawlers and that the previous two decades had been a period of massive technological change complicated the analysis. The committee did however conclude that the bans on trawling and seine netting were likely to benefit the plaice in particular and for this reason the prohibition should be maintained. Another point made was that gear conflicts in the inner Firth frequently arose. Trawling was stated by the committee to be a “wasteful method of fishing” and it was suggested that preference be given to other methods in the local waters.

The geography of the Firth meant that the waters were relatively sheltered so numerous fishing communities had developed along its coast. Hopkins (1986) produced a summary of the fisheries from around the time of the ICES review to the 1980s. Up until the mid-1900s, fishing was mostly inshore and the ports of the Moray Firth were of prime importance before becoming over-shadowed by Peterhead and Fraserburgh.

The herring drift fishery declined somewhat during the inter-war period due to a loss of export markets and increasing use of seine nets. Following the end of WWII the fishery picked up and by the mid-1960s herring landed from the Moray Firth formed the bulk of the Scottish landings of this species from the North Sea. However, over-exploitation then led to a strong decline in catches after 1967 to the point where the wider North Sea fishery was closed in 1977. Following this closure the stock rebuilt quite rapidly and the fishery was re-opened in 1983 although by this time some of the traditional markets for the herring had disappeared (Simmonds 2007, Dickey-Collas et al. 2010). Although the stocks initially continued to rebuild, by the mid-1990s there were signs that stock productivity was declining. However, in this case more effective management action was taken, the fishing mortality was reduced and the stocks responded by rebuilding once more (Simmonds 2007). Although this story is often been told in terms of a single stock, it is important to realise, that the North Sea herring is in fact comprised of a large number of sub-stocks with potentially asynchronous dynamics (Cushing 1980, Dickey-Collas et al. 2010). Although ICES does not routinely report a breakdown of the overall North Sea herring stock status to component level (ICES 2013a), an idea of the relative changes in the main sub-stocks over time can be gained from results from the International Herring Larval surveys[2], which have been conducted since the early 1970s (Schmidt et al. 2009). These data suggest that during the main crash in the mid-1970s all the main sub-stocks were at very low abundance. There was subsequently a stronger increase in the Shetland/Orkneys component and a more delayed recovery of the Buchan component (Schmidt et al. 2009). The decline around the mid-1990s appears more linked to a decrease in the central North Sea sub-stock, although at this time the Buchan component also appears to have been low. From the literature it is not clear whether the smaller spawning area in the northern Moray Firth represents another sub-stock although there is some evidence that it may be separate (Heath et al. 1989).

Hopkins (1986) also noted that a small-scale fishery for sprats (*Sprattus sprattus*) had long existed in the Firth, mainly targeting over-wintering fish. Pair-trawling was introduced in the 1960s and landings of this species increased dramatically reaching 60,000 tonnes in 1966. Over the period 1965 to 1980 catches from the Moray Firth contributed the bulk of Scottish sprat landings although there were some periods, for example 1968-1970, when Moray Firth catches were less important. From the late 1970s the North Sea sprat stock underwent a strong decline and the winter sprat fishery was banned in order to protect young herring in the inner firth.

Despite the decline in the importance of the pelagic fisheries, herring, sprat and sandeel (*Ammodytidae*) remain important in the marine food-web in the Moray Firth. Greenstreet et al. (1998) estimated that these species contributed 37 to 86% of the fish biomass in the area over a three year period and, as in other areas of the North Sea, these pelagic fish form an important dietary component for pisciverous species (Greenstreet et al. 1998).

Other important fishing techniques used in the Moray Firth around the turn of the last century were great-lines, small-lines and hand-lines (Bowman 1928d). The overall importance of line fishing had apparently declined after 1896 due to a combination of effort being re-directed to the herring fisheries and the introduction to the Firth of anchored cod-net fishing and Danish seine-fishing. However, line-fishing was still an important activity in the Moray Firth in the early 20th century with the total amount of fish landed between 1904 and 1916 generally being between 4.8 to 6.2 thousand tonnes[3] per year (although landings were lower in 1909, 1910 and 1913 and during the first world war). Of these landings the majority came from the small-line fishery. Small-lining was conducted relatively close to port generally in water less than 60 m deep and each vessel would shoot between 4 and 10,000 hooks. The main species caught were haddock (around 70% of weight landed) with lesser amounts of codling (small cod). Using this technique the levels of by-catch of under-market size fish were apparently low and the 1928 Commission concluded that line fishing had negligible effects on the state of the stocks (Bowman 1928c). Plaice were also targeted on the south coast and also to the north of Tarbet Ness and in Sinclair's Bay just north of Wick using small and hand-lines but the quantities landed were recorded as being "relatively unimportant" whilst lemon sole were not generally susceptible to this method of fishing (Bowman 1928c). Hand lining was conducted year round although most intensively in the summer months and in relation to the small lines was much less important. Hand-lining seems to have been very much a part-time activity pursued by semi-retired fishers. In late 1800s great lines were deployed from larger vessels operating further offshore to catch species such as cod, ling, halibut and skate but this fishing technique seems to have gone into rapid decline as the

[2] Across a large number of herring stocks there appears to be a strong linear relationship between the abundance of early stage larvae and the size of the spawning stock. The relative numbers of larvae produced each year in an area can thus be used as an index of the abundance of the parental spawning fish.

[3] Converted from long hundred-weight (cwt) equivalent to about 50.8 kg

herring fleet converted from sail to mechanical propulsion. Some of the smaller lining vessels converted to motor beginning around 1912 and others rapidly followed so that by 1920 the use of sail for small line-fishing in the Moray Firth had almost completely ceased. Potential conflict between the line fisheries and trawling was one of the reasons behind the 1890 legislation restricting trawling (Crowe 1928b).

Anchor netting was introduced to the Firth in the early 20th century although it was commonly practised on the Scottish west coast before that time (Bowman 1928g). Initial efforts were small-scale but this coincided with a down-turn in the herring fishing so that more fishers adopted this technique and, combined with increased mechanisation, by 1910 around 3,500 tonnes were landed. At this time the contribution to the landings from sail and steam powered vessels was about equal and landings from sail vessels did not drop sharply until after 1918. The contribution to landings from motor vessels also increased steadily from 1912 onwards. The peak catch attained in 1910 was not maintained however and there was a strong drop in 1911. Although fishing the following year was better, there was another decrease during the war[4], followed by a slight increase but then a steady decline so that by 1926 less than 1,000 tonnes were landed from the anchor net fishery. This type of fishing tended to take place from January to April to the west of longitude 003^{o} and generally within 15 miles of the northern shore. The nets were usually set overnight and in a rather loose manner so that the fish became entangled. Most of the catch was not consumed locally but transported as far as London. At its peak the fishery was prosecuted by a wide range of vessel types which targeted mature cod entering the Firth to spawn. Given that 225 boats might be involved deploying 40 to 50 nets of 60 m length there would have been a considerable amount of gear in the water during the cod spawning season (Crowe 1928b). The decline in anchor net landings of cod was attributed to the increasing popularity of another fishing method – namely the Danish seine particularly among the larger vessels. However, it was also noted that the abundance of cod in the Firth would fluctuate strongly on an inter-annual basis and that the fish had become less common during the 1920s.

Seine netting was introduced to Scotland from Denmark in 1921 (Bowman 1928a). Difficulties in the herring fishery at that time persuaded a number of vessels, principally from Buckie, to try the new gear in the waters beyond 3 nautical miles of the coast. Continued problems in the herring fishery encouraged further vessels to fully convert or at least to adopt seine netting during the early part of the year. An additional factor mentioned by Bowman was that the steam and motor drifters had to be kept fishing year-round and could not be laid up for a time in the same manner as the sailing vessels. The light Danish seine was ideally suited for deployment from drift net vessels and conversion to this form of fishing was relatively inexpensive. This new technique therefore became quite popular throughout the fleets operating form the Moray Firth ports. However, during the 1920s total Scottish landings from seining only increased slightly as many vessels returned to an improved herring drift-net fishery. The introduction of seine netting to the Moray Firth also led to landings of plaice becoming important because the quantities of this flatfish caught by the alternative fishing techniques in use at the time were negligible (Crowe 1928b). In 1924 steam seine vessels landed a total of 2,000 tonnes (all species) from the Moray Firth although in most years landings were somewhat lower. In the same period annual landings by motor seine vessels were rather lower at between 150 to 600 tonnes. During the 1930s specialised diesel seine net vessels became more common and the age of mixed seine and drift-netting was largely over. Seine netting became of increasing importance in the Moray Firth contributing around three quarters of all Scottish landings made with this gear between 1935 to 1938 (Ritchie 1960). Fishing activity during the war (1939-1945) was reduced but per vessel catches were higher. A temporary peak was reached in 1945 but there followed a

[4] It was notable during the war that although the landings volume decreased the prices achieved had increased nearly five-fold (comparing 1912 to 1918).

rapid decline (1948-1950), although total landings then increased again up to 1955. The period following the war saw more powerfully equipped vessels and the extension of the grounds with shoals being harder to find within the Firth itself. The relative importance of the Firth also declined as seine net landings increased from other areas, but as late as 1955 the Moray Firth was still contributing around 50% of national seine net landings. Seine netting continued in the Moray Firth after World War II due to the ban on trawling but after the mid-1960s, annual landings of cod, haddock and whiting (*Merlangius merlangus*) from the Moray Firth declined strongly from around 10 to 15,000 tonnes (1965 to 1975) to less than 2,500 tonnes in 1984 (Hopkins 1986). Although this was partly caused by a shift in fishing effort to more offshore locations it also mirrored the general decline in the North Sea whitefish stocks after the period of abundance which began in the early 1960s that is sometimes called the 'gadoid outburst' (Cushing 1984, Hislop 1996).

Seine netting can only be undertaken on smooth unobstructed seabed and suitable grounds were more limited compared with tow trawling. Seining was generally conducted during daylight, most intensively from December to March. During late spring the fishing in the Firth became less lucrative and the vessels moved to other grounds but the seine netters would often return in the summer or autumn, particularly in years when hake (*Merluccius merluccius*) were common in the Firth. Some of the grounds indicated in Bowman (1928a) coincided with areas where anchor netting had been undertaken although seining was undertaken along a greater proportion of the southern edge of the Firth. Most seining took place in water less than 60 m deep. This type of fishing captured a wide range of species although plaice, lemon sole, haddock, witch (*Glyptocephalus cynoglossus*), hake, cod and skate dominated the reported landings (Bowman 1928a). There was a distinct seasonality in the composition of the landings. Plaice, lemon sole and cod dominated up to March, the proportion of witch tended to increase during April, followed by hake during the summer with haddock increasing around August. These changes not only reflected shifts in the abundance of the different species in the Firth but also market conditions with fishers focussing on the most valuable species at any time. Bowman (1928a) also noted that two distinct designs of seine were in use, one which preferentially targeted plaice and the other haddock. The exact proportions of species also varied with landing port in relation to their proximity to the main grounds supporting different species (Ritchie 1960).

During the early 20th century trawl design itself was evolving with the addition of sweeps between the otter boards and net-wings and the use of glass floats to raise the headline (the Vigneron-Dahl design of trawl). Although the new trawl was likely to be more efficient (due to the wider door spread), the actual size selectivity comparing the new trawl design and the older sweep-less design appeared to be similar (Bowman 1928c).

The Moray Firth is also used by several anadromous fish including salmon (*Salmo salar*) and sea trout (*Salmo trutta*). Historically the rights to fish for salmon belonged to the Crown but these rights were often conveyed to land-owners in return for political support. Alternatively coastal netting stations could be let for a period (often up to 10 years). In many instances this history continues to the present day with the net fisheries which are still operating in the Firth having been in the same family for generations. A variety of nets and traps were used for catching salmonids including sweep nets (net and coble[5]) and cruives (weirs) built across the smaller rivers. In the early 1820s stake-nets (where the leader net and catching net are supported on vertical wooden poles) were introduced to the Scottish east coast leading to disputes with fishers further up the rivers. Eventually stake-netting was declared to be legal but only outside of estuaries so that only sweep netting was allowed within estuarine limits. On rocky areas "bag" nets were also deployed, the nets being held in place by a combination of floats and stakes. A brief salmon drift-net fishery also took place in the early 1960s in the

[5] A coble is a small flat-bottomed boat

Moray Firth but this method was banned in 1962. Long-lining for salmon is also prohibited in the area (Hopkins 1986).

Eventually a system of District Salmon Boards was established to manage the salmon fisheries. However, the focus of the boards gradually shifted from commercial or semi-commercial to recreational fishing as the economic returns from angling increased. When catch statistics were first collected in 1952, 84,773 salmon were caught by nets in the Moray Firth salmon district and 11,675 were caught by anglers. In 1996 only 1,203 salmon were taken by net and 18,608 by rod, of which 1,246 were returned by anglers to the river. These statistics show a significant reduction in both the total number of salmon caught, and a shift from semi-commercial to recreational sectors. This trend appears to have continued because no salmon were taken by netting in the Inverness Firth in 2013-2014, in line with a salmon conservation agreement (Ness District Salmon Fishery Board 2014). For sea trout, catch rates from the rivers connecting to the Moray Firth appeared to be relatively steady until 1997, after which they appear to have been declining (Walters 2011).

As in many other inshore areas there has been a great increase in the importance of the shellfish fisheries. Exploitation began in 1962 when a concession was granted allowing vessels under 70 feet in length to trawl for prawns (*Nephrops norvegicus*) in the Moray Firth. Landings increased rapidly but stabilised at around 500-1000 tonnes annum^{-1} by the 1980s (Hopkins 1986).

Whitefish trawlers first began reporting significant catches of scallops (*Pecten maximus*) from the Moray Firth in the late 1970s. Whether they had always been there but had not been previously exploited is unclear, but landings increased rapidly reaching over 1000 tonnes in 1980 and 1981 (Hopkins 1986). It seems likely that either the beds were over-harvested, or there was subsequent poor recruitment, because landings decreased to 300 tonnes or less by the mid-1980s.

According to Hopkins (1986) blue mussel (*Mytilus edulis*) beds in the Dornoch Firth had been exploited for many years, although at a relatively low level. It was also noted that there had been some interest in re-stocking the beds with spat.

Squid (mainly *Loligo forbesi*) have been pursued in the inshore waters by the Scottish fleet since the early 1980s. The fishery tends to be seasonal targeting pre-breeding animals during September to November. Young et al. (2006) reported that a targeted fishery developed in the Moray Firth with boats operating from ports between Nairn and Fraserburgh. Although generally a small-scale fishery, in some years such as 2003, a substantial number of vessels could be involved. Young et al. (2006) further stated that the spawning grounds had not been documented but analysis of spatial patterns in the fishery data suggests that this species moves from the West Coast of Scotland into the North Sea to spawn. Young et al. (2006) also thought that it is very likely that the Moray Firth includes some spawning grounds for this species.

Table 2: Principal pieces of Legislation and non-legislation affecting fishing in the Moray Firth (Moray Firth Inshore Fisheries Group 2011)

Act, order or code	Comment
Inshore Fishing (Scotland) Act 1984	The Act makes provision for Scotland with respect to the regulation of inshore sea fishing and connected purposes. Orders under the Act may prohibit fishing for; all sea fish; a specified description of sea fish; by a specified method; from a specified description of fishing boat; specified periods or in specified areas.
The Undersized Velvet Crab Order 1989	The Order sets within Great Britain a minimum landing size for velvet crab (*Liocarcinus puber*) of 65 mm carapace width. The Order applies to both the carriage and sale of the species.
Inshore Fishing (Scotland) Act 199	The Act makes provision for the control of fishing by vehicles or equipment.
The Inshore Fishing Monofilament Gill Nets) (Scotland) Order 1996	The Order prohibits fishing for sea fish with a monofilament gill net in Scottish territorial waters and the carriage of any such net with a mesh size of less than 250mm in any British fishing boat.
The Lobsters and Crawfish (Prohibition of Fishing and Landing) (Scotland) Order 1999	The Order prohibits the landing of lobster (*Homarus gammurus*) and crawfish (*Palinurus* spp.) bearing a V-notch or mutilated to obscure a V-notch.
The Undersize Spider Crabs (Scotland) Order 2000	The Order prescribes a minimum landing size for male spider crab (*Maia squinado*) of 130mm carapace length. The Order applies to both the carriage and sale of the species.
The Undersize Edible Crabs (Scotland) Order 2000	The Order prescribes a minimum landing size for edible crab (*Cancer pagurus*) in selected Scottish waters. The east coast south of 56 degrees North (excluding Firth of Forth) 130 mm carapace width.
The Prohibition of Fishing for Scallops (Scotland) Order 2003	The Order bans the use of a “French dredge” (or modification of a scallop dredge to obstruct the rings or netting) in Scottish territorial waters.
The Inshore Fishing (Prohibition of Fishing and Fishing Methods) (Scotland) Order 2004	The Order amends the same titled Order 1989 by: defining parlour creel and setting a minimum mesh size of 60mm; setting a maximum landing size of 155mm for female lobster; introducing seasonal and vessel size prohibitions on creel fishing in specified areas; prohibits fishing with mobile or active gear in specified areas and at specified times; and other specified provisions.

Table 2: Principal pieces of Legislation and non-legislation affecting fishing in the Moray Firth (Moray Firth Inshore Fisheries Group 2011)

Act, order or code	Comment
The Prevention and Monitoring of Cetacean Bycatch (Scotland) Order 2005	The Order implements in Scotland the EU Council Regulation EC812/2004(c) measures concerning incidental catches of cetaceans in fisheries.
The Inshore Fishing (Prohibition of Fishing for Cockles) (Scotland) (No.2) Order 2006	The Order prohibits fishing for the cockle (*Cerastoderma edule*) by means of any vehicle, except in specified areas.
The Sharks, Skates and Rays (Prohibition of Fishing, Transshipment and Landing) (Scotland) Order 2012	Prohibits fishing for tope, other than by rod and line or hand-line, by any such boat in the Scottish zone
2015/2016 Revised scallop harvesting rules	Scottish Government is proposing some changes to scallop harvesting rules to increase the minimum conservation size and limit the number of dredges which can be towed by a vessel.
Dornoch Firth	Dredging (but not suction dredging) for mussels prohibited
Cromarty Firth	Dredging (but not suction dredging) for cockles and mussels prohibited
Inverness Firth	Dredging (but not suction dredging) for cockles and mussels prohibited
Voluntary code of conduct	A voluntary code has been developed within the Moray Firth to reduce conflicts between mobile and static gear fishing

In addition, UK commercial fisheries must comply with EU regulations, in particular those arising from the Common Fisheries Policy. For example, total allowable catches for several species of elasmobranchs, including spurdog, are set at zero, preventing them being landed.

Recent trends in the commercial inshore fisheries

Historically the species caught within the waters of the Moray Firth itself included pelagics, such as over-wintering herring and sprats, gadoids, such as cod, haddock and whiting, and flatfish, including plaice and lemon sole. As described above there have been significant changes in the fisheries, particularly in the latter part of the 20th century, with a decline in the importance of finfish and an increase in the importance of shellfish.

Data from the ScotMap project based on interviews conducted with inshore fishers (vessels less than 15 m) were released in 2013 (Kafas et al. 2014). The outputs were spatially aggregated data on the number of vessels, number of crew, monetary value and relative value by fishery (species/gear) categories. For the Moray Firth significant trawl activity was recorded, quite a lot of potting for crabs (*Cancer pagurus* and *Necora puber*) and lobster (*Homarus gammarus*), a small amount of *Nephrops* creeling and some mackerel (*Scomber scombrus*) line fishing (Figure 1). The ScotMap report and subsequent discussions with the Moray Firth Partnership have suggested that these data represent a reasonably complete picture for inshore fishing activity patterns in the Moray Firth, although it was pointed out that a potentially large number of un-registered/un-licenced vessels also fish in the area (Moray Firth Inshore Fisheries Group 2011).

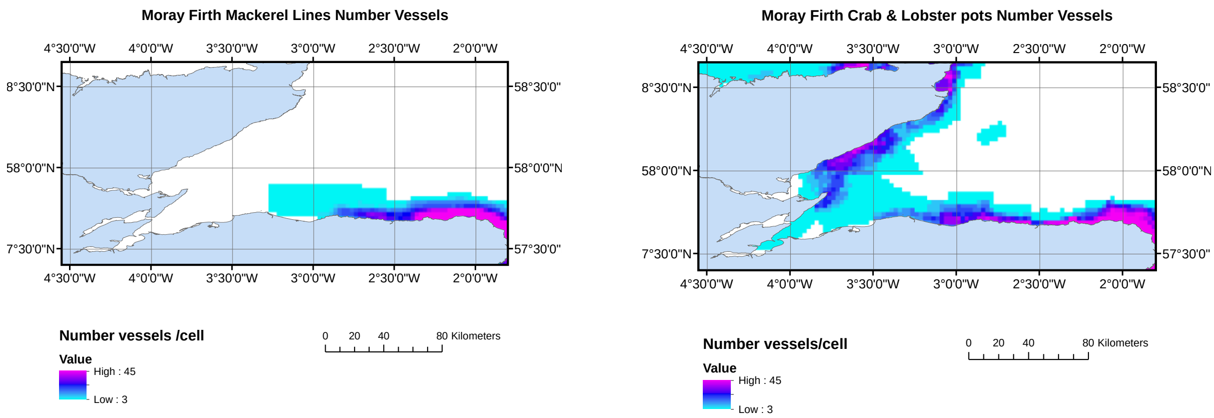


Figure 1: Example of output from ScotMap showing number of vessels fishing in the Moray Firth.

When combined with Vessel Monitoring Data from larger vessels, the numbers of vessels per cell analysis provides a picture of the spatial extent of fishing. However, it is not necessarily a good indicator of the spatial distribution of fishing effort (which needs to also take account of vessel power), nor does it show seasonal variations (http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes/ScotMap/scotmap-description). National landings data can be regionalised to some extent but, as pointed out in Moray Firth Inshore Fisheries Group (2011) fisheries management plan, spatially detailed catch records are not, at present, available.

More recent analyses by Riddington et al. (2014) of background information relating to Scottish inshore fisheries were based on the IFG regions. The Moray Firth and North Coast IFG region encompasses most of the Moray Firth but also includes the coast between John

O'Groats and Cape Wrath. The total number of vessels registered to ports in the Firth is shown in Table 3. However, personal communications with the IFG suggested there could be a significant number of additional small, un-registered vessels fishing in the area (hobby fishing using creels or pots).

Table 3: Registered vessels – Moray Firth (2012)

	Scrabster	Buckie	Fraserburgh
Nephrops trawls < 10 m	1	10	1
Creel < 10 m	80	35	77
Other < 10 m	-	5	22
Purse seine > 10 m	-	-	2
Pelagic trawl > 10 m	-	-	9
Demersal trawl > 10 m	1	13	52
Seine > 10 m	2	4	5
Line > 10 m	-	1	-
Other > 10 m	-	-	1
Nephrops trawls > 10 m	-	2	30
Creel > 10 m	6	2	1
Other > 10 m	1	5	2
Total	91	77	202

Many of the smaller vessels will fish within the Moray Firth exclusively but the larger vessels will also operate outside the Firth. According to Riddington et al. (2014), based on Scottish Sea Fisheries statistics for 2012, 890 persons were regularly employed and 202 irregularly employed in fishing from Buckie, Scrabster and Fraserburgh. Landings into these ports are shown in Table 4 but it must remembered, these will not all originate from within the Moray Firth fishing grounds.

Table 4: Landings value (£'000) into Moray Firth ports (2012)

	Demersal	Pelagic	Shellfish	Total	Total by Scottish vessels
Scrabster	18,730	4	6,546	25,279	20,298
Buckie	115	34	3,012	3,161	3,136
Fraserburgh	6,126	10,907	19,537	36,570	35,459
Total	24,971	10,945	29,095	65,010	58,893

Riddington et al. (2014) also estimated the proportion of landings likely to originate from the inshore versus offshore zones (Table 5). Note that this is for the whole of the Moray Firth and North Coast IFG area and relative proportions within the Moray Firth might differ from this.

Table 5: Distribution of landings by value (2012) between inshore and offshore zones in Moray Firth and North Coast IFG

	0-1 nautical mile	1-3 nautical miles	3-6 nautical miles	6-12 nautical miles
Demersal trawl	7.5	19.3	18.9	27.4
Nephrops trawl	29.3	34.3	34.5	46.0
Pelagic trawl	-	0.4	13.1	1.9
Pelagic lines	2.7	2.1	1.3	0.5
Other trawl	7.3	11.3	4.7	3.5
Dredge	3.3	12.8	12.7	14.1
Pots	48.2	18.4	14.9	6.5
Hand dive	1.8	1.2	-0.1[6]	-

The northern shore of the Moray Firth pilot area falls within the Scrabster fishery district. This area is characterised by numerous small landing places. Demersals and shellfish account for virtually all the landings and about 90% of the vessels are less than 10 m in length (Table 3).

The southern shoreline of the Inner Moray Firth falls within the Buckie fishery district. There are fewer landing places with Buckie and Burghead being the main ones. Shellfish dominate the landings with lesser amounts of demersals compared to Scrabster but there is a more even split between under and over 10 m vessels (Table 3). Small but significant landings of pelagics also come through Buckie (Table 4).

Ports to the east fall within Fraserburgh fishery district. Again shellfish dominate landings but pelagics are more important than in the other two districts. The split between under and over 10 m vessels is about 50:50 (Table 4).

In terms of annual landings from the Moray Firth itself it has been estimated that they have value of around £5.3 million (Moray Firth Inshore Fisheries Group 2011) with £4 million of this coming from the 0-6 nm zone. These estimates compare with around £10 million for the whole of the Moray Firth and North Coast IFG from the 0-6 nm area (Riddington et al. 2014).

There are some specific niche fisheries in the Moray Firth. For example, hand-lining for mackerel takes place along the south-eastern part of the coastline (ScotMap). This fishery attracts a higher value per weight landed but is limited in quantity by quota management. The local *Nephrops* fishery is also slightly different from the west coast as there is virtually no creeling (apart from hobby fishing) and the bulk of the product goes into the scampi (breaded) market (Moray Firth Inshore Fisheries Group 2011). Local conditions can also result in below-average prices being obtained e.g. haddock due to relatively low volumes landed as by-catch.

As mentioned above there is now limited salmon netting activity within the Moray Firth. However, this technique still supports some commercial activity with the Scottish Wild Salmon Company (Usan Salmon Fisheries Ltd.) owning the netting rights in the Moray Firth and marketing the products.

The landings in the Moray Firth are now dominated by shellfish. The main species landed in recent years are *Nephrops*, lobster, crabs, blue mussel, King scallop (*Pecten maximus*) and whelk (*Buccinum undatum*). However, squid (*Loligo forbesii*) can be dominant in occasional

[6] The small negative for hand diving in the 3-6 nm zone appears to have arisen as a result of rounding errors in the original report.

years. The squid fishery typically commences in early summer in the inner Moray Firth and gradually moves offshore (6-12 nm zone). The vessels involved tend to be larger than 8 m length and use towed gear.

Landings of lobster originate mainly from the 0-6 nm zone. The main method for catching is potting although some may also be taken by divers. In 2009 these landings obtained the second highest value overall. This fishery includes smaller vessels operating on a day basis.

Brown crab have slightly different habitat preferences to lobster favouring hard to course sand and reef edges. Most of the crab fishing in the Moray Firth takes place in the 0-6 nm zone from smaller vessels operating on a day basis. There is little activity by larger live-trade (vivier) vessels. In 2009 brown crab was the second species landed by volume and third by value. There have been changes in the market for brown crab in recent years which has affected the prices which can be obtained.

King scallops generated the fourth highest value in 2009 but the bulk of landings come from the 6-12 nm zone. Most landings come from larger (> 10 m) purpose-built dredgers. There is also a limited hand-diving fishery inshore.

The *Nephrops* fishery has a similar value to king scallop but is more evenly spread across the 0-6 nm and 6-12 nm zones. The predominant fishing method is towed trawl with creeling largely limited to hobby fishers. The size of the prawns from the Moray Firth tends to be smaller than from the Scottish west coast therefore most of the landings are destined for processing as scampi. The relative proportion landed as ‘tails’ or ‘whole’ affects the price obtained.

Velvet crabs are caught mainly in the 0-6 nm zone by smaller vessels (<8 m) over similar habitat to the lobster. It has become an important catch in creels but there are limited marketing opportunities in the UK and nearly all the catch is destined for export to Europe.

Whelks are fished almost exclusively within the 0-6 nm zone. The species is found in a wide range of habitats including muddy/sand, boulder and shingle banks. The animals are caught using baited pots.

The bulk of mussel landings come from a private fishery in the Dornoch Firth. Only small amounts are collected from other areas within the Firth. Razor clam and green crab are also reported as being harvested from the 0-6 nm zone, probably in small quantities although the statistics may be incomplete.

Reported landings of demersal fish from the Moray Firth since the mid-1990s were extremely low, apart from haddock. This species is typically landed as a bycatch from the *Nephrops* trawl fishery but might also come from the squid fishery. Harvesting of demersal fish may be occurring at a higher rate than recorded in the official landings statistics but being diverted into use as bait. In addition, data for demersal catches from sport and hobby sectors were not available (Moray Firth Inshore Fisheries Management Group 2011).

Within the Moray Firth Inshore Fisheries Management Group 2011 plan there was an attempt to analyse changes in fishing patterns (based on landings data from 2004 to 2009) but the report acknowledged that the conclusions were hampered by a lack of data on fishing effort over this period. The report also included a useful Strengths Weaknesses Opportunities and Threats (SWOT) analysis for the main fished species. This analysis also identified a few additional potential opportunities including for sprat, cockle (*Cerastoderma edule*) and oyster although significant potential problems were also identified in each case.

Recent trends in the recreational inshore fisheries

The importance of recreational fisheries in the Moray Firth has not received as much attention as for the Clyde. In their analysis of the economics of sea angling Marine Scotland (2009) split the Moray Firth partly between the Northern Highlands Region (which included a large area of the west coast down to Skye) and the North-eastern area (Grampian, Moray, Angus and Dundee). The total value of sea angling was estimated at around £11 million in the Northern and £15 million in the North-eastern regions (excluding capital expenditure) of which around £9 million came from visitors from outside the area. The number of jobs supported in the combined areas by sea angling was estimated at 642 full time equivalents. However, only a fraction of these will be for the Moray Firth itself. In both regions, species such as cod, pollack (*Pollachius pollachius*) and mackerel, were the most popular targets.

Because of the large areas covered and the lack of a specific case study, the data in Marine Scotland (2009) are not particularly informative with regard to the importance of sea angling in the Moray Firth itself.

Possible effects of restrictions of mobile gear in the inshore areas across the whole of Scotland were considered in Riddington et al. (2014). Across the whole of Scotland long-term net benefits were predicted from such a change but the estimated benefits and costs, and jobs created (or lost) are not evenly spread across Scotland's IFG areas. The Moray Firth and North Coast showed a net loss in commercial jobs for most scenarios modelled but these were offset with predicted increases in employment in the recreational sector - for all but the worst-case scenario. Even under the least favourable jobs scenario, it was predicted there would be an overall economic benefit of around £4 million, while the most favourable scenario suggested a benefit of £98 million (over 20 years). An important caveat is that the predictions were based on certain assumptions regarding how the natural fish community would respond to the removal of mobile gears inshore. Implementing such a management change would of course be a calculated risk. If the ecosystem failed to respond as predicted then jobs would be lost in the commercial sector for little gain in the recreational sector. However, Riddington et al. (2014) argued that, in that case, the ecosystem itself would not be in any poorer condition than before the change in fisheries policy. Under the 'fail to recover' scenario, the original fisheries could be re-opened at some future date. However, re-opening fisheries which have been closed has not always proved successful, due to factors such as loss of markets and fishing expertise.

Several important river systems for salmon exit into the Moray Firth. The economic value of these freshwater fisheries is not reviewed here but as noted below a healthy coastal zone is of course vital to migrating salmonids. Annual status reports on salmon and sea trout are published by Marine Scotland Science although that report acknowledges weaknesses in the underlying data, particularly with regard to sea trout (Marine Scotland Science 2014). This report includes trends over the last 20 years for the Moray Firth area. For salmon there is generally no clear trend although some increases in northern Moray Firth catchments have been observed. For sea trout only rod return data are available which indicates no clear trend in the northern Moray Firth catchments but a decline in the southern catchments.

Biological information relevant to species of importance to the Moray Firth fisheries

Stock assessments

A number of stock assessments relevant to the Moray Firth are conducted by Marine Scotland Science and annual stock summaries published e.g. Marine Scotland Science (2015). Assessments include *Nephrops,* where TV burrow surveys are conducted and scallops, where a dredge survey is conducted. The surveys for Nephrops suggest that the Moray Firth stock has been relatively stable since 2006. For scallops the Moray Firth is included as part of the slightly wider North East coast assessment unit. Survey results suggest the highest abundances of scallops are found in the inner parts of the Firth. The assessment results suggest that the spawning biomass for scallops has been increasing slightly in this functional management unit (Dobby et al., 2012). Data on velvet and edible crab and lobster are collected, but the Moray Firth is included as part of the wider East coast assessment unit (Marine Scotland Science, 2015). Across the wider assessment unit fishing mortality for all three species is thought to be occurring at too high a level for sustainability ($F>F_{msy}$).

Fish and shellfish health

Levels of persistent organic pollutants have been measured in samples of eels (*Anguilla anguilla*) collected at two sites within the Moray Firth (Macgregor et al. 2010). Overall levels of polychlorinated biphenyl (PCB) contaminants were considered low relative to samples from other European rivers while BDE levels were similar. Although the study was not specifically designed to examine human health aspects all individual eels sampled from the Moray Firth were below the maximum tolerance limit for PCBs (2 mg/kg) stipulated by the US Food and Drug Administration. For DDT and its metabolites none of the eels examined would exceed the USFDA limit set for all fish types (5 mg/kg). Apart from this study there does not appear to be much published data relevant to fish health from the Moray Firth.

Levels of biotoxins and potentially harmful bacteria are monitored regularly in harvested shellfish by the Scottish Food Standards agency e.g. in mussels harvested from the Dornoch Firth.

Fish and shellfish spawning grounds

Spawning grounds of pelagic species

Herring spawn benthic eggs usually on areas of course gravel so the spawning locations are generally well known. The spatial extent of spawning within these sites does however change over time in response to changes in stock abundance. Grounds can also be abandoned and re-colonized over time (Schmidt et al. 2009). Herring spawn in the northern part of the Firth from Wick (Heath et al. 1989) down to the Dornoch Firth (Schmidt et al. 2009). However, there are larger spawning grounds outside the Firth itself around Orkney (Shetland/Orkney sub-stock), and off the north-east coast south of Peterhead (the Buchan sub-stock).

In contrast to herring, sprat eggs can be found in plankton samples taken during a large part of the year, although spawning tends to commence later in the year and take place over a shorter period compared to further south (Bailey & Braes 1976). According to Bailey and Braes (1976), sprat eggs were found in the plankton of the outer Moray Firth from May onwards with a peak of spawning in June or July. In the 2004 North Sea ichthyoplankton survey, large numbers of sprat eggs were recorded from the outer Firth in mid-February to early March (Taylor et al. 2007), so spawning appears to have commenced somewhat earlier than indicated by Bailey and Braes (1976). This suggests that the outer Moray Firth is a favoured spawning ground for sprat and that the location of the spawning area has been relatively stable over time, although the timing of spawning may have shifted.

Sandeel larvae were recorded in quite high numbers in samples collected in 2004 in the outer Moray Firth (Taylor et al. 2007). Sandeel larvae are also recorded by the Continuous Plankton Recorder (CPR) program (www.sahfos.ac.uk) and some samples have been collected across the outer Moray Firth (Edwards et al. 2011). These may give an indication of historical trends in larval production, at least for the outer Firth, although the intensity of CPR sampling is somewhat low in this location (Lynam et al. 2013).

Spawning of demersal species

In the 1920s there seems to have been a significant winter-spring fishery for spawning cod in the Firth using anchor nets (Crowe 1928b). Bowman (1928b) considered that the cod shoals which entered the Moray Firth were part of the main North Sea stock. Hopkins (1986) mentions the fact that cod in spawning condition were found in the Moray Firth but not in great quantities. He further stated that the cod tended to move into shallower water to spawn in later winter returning to deeper water in the summer. Seasonal changes in catch per unit effort for cod provided some support for this assertion but direct evidence that the inner Moray Firth is still a significant cod spawning area is limited. It has also long been known that cod eggs could be found in plankton samples collected off the Moray Firth (Wright et al. 2006) and Fox et al. (2008) also found some concentration of eggs in these localities, but at rather low levels compared to other parts of the North Sea. The planktonic eggs may be carried further into the Firth itself by the local water circulation (Adams & Martin 1986) although Fox et al. (2008) did not survey the inner waters.

Although maturing haddock were historically caught throughout the Firth, Crowe (1928b) suggested that the amount of spawning occurring within the Firth was negligible. The early stage eggs of haddock are hard to distinguish from those of cod without the use of modern molecular techniques which were applied in the series of surveys covering the North Sea in 2004 (Taylor et al. 2007). Positively identified early stage haddock eggs were found in high abundance across a wide area of the northern North Sea including the outer southern part of the Moray Firth (Fox et al. 2005a). In contrast to the eggs, haddock larvae can be identified visually and were quite abundant in samples collected in the outer southern part of the Firth (Taylor et al. 2007). This pattern largely accords with accounts from the early 20^{th} century suggesting there has been little change in the locations of the main haddock spawning grounds during this time (Bowman 1928b, Crowe 1928b).

The early stage eggs of whiting can also be hard to distinguish from those of cod and haddock without the use of modern molecular techniques (Fox et al. 2005b). In the 2004 pan-North Sea survey early stage whiting eggs were found in the outer Moray Firth, but in very low numbers (Fox et al. 2005a). In contrast, whiting larvae were quite abundant in the southern part of the outer Moray Firth and these could have resulted either from earlier spawning in the area or from being transported in from outside the Firth itself (Taylor et al. 2007).

The importance of the Moray Firth as a spawning ground for plaice was described by Crowe (1928b) and Bowman (1928b). The maturing plaice were reported to move into the Firth in the winter months with spawning concentrated off Tarbet Ness in water deeper than 35 m. Other spawning locations were said to be off the northwest shore and between Lossiemouth and Buckie. Spawning tended to begin in December and be over by April. Eggs and larvae were subsequently found throughout the shallow coastal waters. More recent data showed a concentration of plaice eggs in the outer Moray Firth although densities were much lower than in the more important spawning grounds in the southern North Sea (Taylor et al. 2007). Since there was limited plankton sampling west of 002^{o}50' W, it is impossible to say whether the inner parts of the Moray Firth remain important for plaice spawning.

Rae (1953) suggested that the outer Moray Firth was one of the more important spawning grounds for lemon sole in the North Sea and patches of lemon sole larvae were found in this area in the 2004 plankton surveys (Taylor et al. 2007). Since the peak of spawning of lemon sole is somewhat later than the surveys, the abundances and spatial extent of the larvae might be expected to increase later in the year.

Adult *Nephrops* are largely resident so spawning will take place throughout the muddy areas of the Moray Firth where they are found. Whether the larvae are retained within the Firth and recruit to the parental grounds does not appear to have been studied. However, Heath et al. (1989) studied the dispersal of a patch of herring larvae off of Clythness (northern Moray Firth) and suggested that the larvae would be retained in the Firth for up to several months. This amount of time which would also be sufficient for *Nephrops* larvae to reach the settlement stage (Powell & Eriksson 2013). However, dispersal patterns from the more southerly *Nephrops* grounds might be different so it is hard to conclude from this whether the Moray Firth *Nephrops* populations are self-sustaining or rely on immigration of juvenile stages from outside the Firth.

Post-settlement king scallops do not move over large distances although queen scallops (*Aequipecten opercularis*) tend to be more mobile (Mason 1983). Because of their limited mobility, scallop spawning is likely to occur in areas where mature scallops are found. The distribution of scallops can be inferred from fishing activity patterns combined with knowledge of sediment distributions.

Compared with *Nephrops* and scallops, some species of crab can show extensive migrations as adults (Hunter et al. 2013). There may therefore be movement between sub-stocks within the Moray Firth or exchange of animals with areas outside the Firth. Tagging can be used to study such movements but such studies do not appear to have been conducted in the Moray Firth, as far as we know.

Fish and shellfish nursery grounds

Although extensive herring spawning grounds lie outside of the Moray Firth (Schmidt et al. 2009, Dickey-Collas et al. 2010), the Firth itself has long been noted as a herring nursery area (Hopkins 1986). Despite the fact that the major Shetland/Orkney and Buchan spawning grounds are in close proximity, several lines of evidence suggest that most of the juvenile herring found in the Firth probably originate from the west coast of Scotland being transported into the northern North Sea by the Scottish coastal current (Parrish & Sharman 1959, MacKenzie 1975, Heath 1989).

The Moray Firth also appears to be an important nursery ground for sprat based on recent plankton data (Taylor et al. 2007) and accounts of the historical drift and pair-trawl fisheries for this species (Hopkins 1986).

The presence of significant local anchor-net and non-British trawl fisheries for spawning cod in the Moray Firth in the 1920s has already been mentioned suggesting that the area was at one time a reasonably important cod spawning ground. After spawning, most of the spent adults were reported to leave the Firth but the young cod moved inshore seeking cover in the sea-weed zone (Bowman 1928b, Crowe 1928b). Growth was reported to be rapid so that by the second summer the size of the young codlings exceeded that of haddock of similar age. By age three the cod had moved into deeper water and began to leave the Firth for the North Sea. More recent surveys suggest that the Firth is no longer a consistently important cod nursery area as Gibb (2007) reported elevated abundances of 0-group cod in the Firth in 2003, but not in 2004 or 2007 (Gibb et al. 2008). This suggests that although the Moray Firth has historically acted as a cod nursery ground it is not used as regularly as some other locations around the northern North Sea. Some of these changes over time are of course likely to reflect changes in the abundance of the cod stocks in the wider North Sea or changes in the inter-tidal habitat (Ryan et al. 2011).

In contrast to cod, haddock larvae tend to settle in deeper water and the Moray Firth was never considered an important nursery ground for this species (Thompson 1928).

Shallow sandy areas within the Firth are known to provide nursery habitat for flatfish such as plaice and flounder (*Platichthys flesus*) (Bowman 1928b, Crowe 1928b, Mendonça et al. 2009). However, the relative importance and quality of these habitats has not been investigated to the same extent as flatfish nursery grounds in the southern North Sea, Irish Sea or west of Scotland (Ciotti et al. 2014, Fox et al. 2014).

Shellfish larvae generally metamorphose into juvenile forms which settle directly into suitable habitat. Most shellfish do not therefore have nursery grounds in the same manner as finfish. However, for some mobile species, such as crabs, post-settlement dispersal can occur. The levels of post-settlement dispersal may vary in response to factors such as crowding (Moksnes 2004).

Fish and shellfish stock discreteness

Stock discreteness of pelagic species

There is evidence, based on the presence of internal parasites, that the herring spawned in the northern Moray Firth (Clythness herring) may be a separate sub-stock from the Orkney/Shetland, Buchan components or west of Scotland components (MacKenzie 1985). Heath (1989) tracked a patch of larvae released from this spawning ground and estimated the daily drift at 1.5 km to the southwest which would retain the larvae within the Moray Firth for several months potentially allowing self-recruitment back to a local stock. However, it has been hypothesised that the majority of the over-wintering herring in the Moray Firth derive from west coast spawning sites. To form a distinct sub-stock, the fish would later have to separate and return to their natal origins and it is not known whether this occurs. Although there is genetic evidence for a degree of natal-homing at larger spatial scales within the North Sea (Ruzzante et al. 2006, Gaggiotti et al. 2009), it is still not known how the adult fish manage to navigate back to the site of their birth nor how effective such homing is (McQuinn 1997).

ICES currently assesses sprat in the North Sea as a single stock. There does not appear to be much known regarding sub-stock structuring of this species although samples collected from Norwegian fjords appeared to be genetically distinct when compared with samples from the North, Celtic and Baltic Seas (Glover et al. 2011). ICES (2013b) suggested that sprat in coastal areas such as the Moray Firth might be similarly distinct, noting the apparent lack of connectivity with the wider North Sea stocks, but no specific studies have been conducted to test this. The Expert Group recommended that such work should be undertaken. ICES (2013b) also commented that “the Moray Firth sprat stock supports internationally important populations of birds and marine mammals. Part of the area has been designated as a Special Protection Area for aggregations of sea ducks (especially red-breasted mergansers). Sprat abundance in the Moray Firth is believed to have fallen to low levels in the 1990s, and most of these birds have left the area.” However, no reference was given to support this latter statement.

For sandeel, there are extensive beds off north-eastern Scotland particularly around Orkney and Shetland. Modelling the transport and dispersal of larvae from these sites has been undertaken (Proctor et al. 1998) but did not focus particularly on the Moray Firth. It is therefore difficult to say to what extent the sandeel populations in the Firth are self-recruiting.

Stock discreteness of demersal species

For gadoids there have been a number of tagging studies in, or close to, the Moray Firth. Results for cod, haddock, whiting and plaice are referred to by Hopkins (1986) who suggested that there were distinctly coastal stocks separated from the more offshore stocks of the central and northern North Sea. Along with depth, the presence of the Fair Isle current was suggested to delineate the inshore and offshore regions (Adams & Martin 1986).

For cod, Wright et al. (2006) presented a summary of historical tagging data and showed that with increasing time from release in the Moray Firth, distance to the recapture locations increased up to around 50 km, with a few fish ranging up to 80 km. However, these displacement distances are relatively small compared to the scale of the wider North Sea providing some evidence that localised cod stocks may exist in the vicinity of the Moray Firth. Using the genetic techniques available at the time, Child (1988) failed to find evidence for genetic structuring in North Sea cod. However, these older analyses were based on a limited number of allozymes and using newer techniques Hutchinson et al. (2001) produced some evidence for genetic discreteness of cod sampled in the Moray Firth area. More recently Heath et al. (2014b) included samples from the Moray Firth in a genetic analysis using a different suite of molecular markers known as single nucleotide polymorphisms (SNPs). This more recent analysis suggested that the Moray Firth samples form part of the ‘Dogger’ sub-group but that this was clearly separated from samples from the north-eastern North Sea “Viking” sub-group. These results suggest there is some degree of mixing of Moray Firth cod with fish from other parts of the inshore, central and southern North Sea. It is not uncommon to get divergent results using different genetic markers but it seems likely that there is some degree of mixing between Moray Firth cod and those from the shallower parts of the wider North Sea, but negligible inter-breeding with cod from the offshore Viking Bank area.

For haddock, Jones (1959) suggested that older fish tagged south of the Moray Firth during winter and spring often moved into the Firth but that the dispersal of haddock tagged during summer months seemed more random. Compared with cod, these results suggest that the haddock probably comprise a single mixed stock which populates a large part of the northern North Sea around to the west of Scotland in line with earlier (Child 1988, Jamieson & Birley 1989) and more recent genetic results referred to in Holmes et al. (2014).

For whiting, Hopkins (1986) suggested there might be distinct coastal and offshore stocks but more recent interpretations do not tend to support this idea (Holmes et al. 2014). The population structuring of whiting in the North Sea is now thought to reflect a north-south split (Charrier et al. 2007), an interpretation which is consistent with the oceanography of the North Sea, the distribution of whiting eggs and larvae (Fox et al. 2005a, Taylor et al. 2007) and what is known about the dispersal of post-larval whiting. Differences in parasite loading in different age classes of whiting from Shetland indicating a coastal origin (Hopkins 1986) may reflect offshore movements whilst not being indicative of genetic isolation.

The Moray Firth has long been known to be an important spawning ground for plaice (Bowman 1928b, Lamont 1963). Similarly to haddock, many plaice tagged on the Scottish east coast south of the Moray Firth were recaptured in the Firth itself (Bowman 1928c, Armstrong 1971). This suggested that the fish found in the Firth form part of the wider North Sea stock. Prior to spawning there was a general tendency for maturing plaice to move northwards although Bowman (1928b) also pointed to some exceptions with individuals tagged in Shetland and Fair Isle also being recovered from the Moray Firth. Since the 1970s there has not been much further research on movements of plaice in the north-western North Sea. A considerable amount of new research on plaice movements has been conducted using modern data-storage tags, but this has been focussed on the more commercially important stocks in the southern North Sea (Metcalfe et al. 2006).

Early tagging work suggested that lemon sole are relatively sedentary (Bowman 1928b) although some of the tagged fish showed a northward pre-spawning migration similar to that shown by plaice.

Salmon are caught on most rivers emptying into the Moray Firth and the emigrating juveniles presumably make use of the inshore waters of the Firth before heading out to sea (Hopkins 1986). There are a large number of burns and rivers emptying into the Moray Firth including on the southern side the Deveron (enters at Banff), the Spey (enters at Garmouth); the Lossie (enters at Lossiemouth) the Findhorn (enters at Findhorn); the Nairn (enters at Nairn); the Ness (enters at Inverness as does the River Beauly). On the northern side the main rivers include the Conon (which enters to the east of Dingwall); the Averon (enters south of Alness), the Balnagown; and then moving round into the Dornoch Firth, the Carron and Kyle of Sutherland; the Brora and the Helmsdale and Dunbeath Water. Several of these river systems are regarded as major salmon rivers e.g. the Spey. The relevant rivers trusts normally conduct surveys using electrofishing but only in the freshwaters. Seine net surveys may be conducted in the lower reaches of the major river systems. Sea trout also use the Firth in addition to salmon (Walters 2011).

Stock discreteness of shellfish species

With regard to shellfish, Hopkins (1986) stated that lobster, scallop, brown crab and *Nephrops* could all be found on areas of suitable habitat. Movements of all these species (with the exception of the brown crab) are rather limited as adults so larvae are likely to be released into the local waters where the adults are found. There appear to be no studies on the dispersal of the larvae of these species in the Moray Firth area so it is impossible to speculate on whether the stocks are largely self-contained or rely upon immigration of juveniles from outside the area. For the purposes of stock assessment, *Nephrops* in the Moray Firth are treated as a functional unit i.e. there is an assumption that they are essentially self-contained. Scallops are assessed as a north-east coast unit and crabs and lobsters managed across a wider east coast unit (Marine Scotland Science 2015).

Physical and biological datasets relevant to the Moray Firth inshore fisheries

There are a large number of physical and biological parameters for which data could be sourced. An increasing number of these datasets are visualised in the National Marine Planning Interactive (NMPI) which is designed to make such data available for the purposes of marine planning. However, not all of the large amount of data types available will be of relevance or obvious use to inshore fisheries management (which is the primary focus of this report). A number of key datasets were identified in discussion with the IFGs and include the following:

- Admiralty charts – these provide lower spatial representation of bathymetry but include additional information which may need to be taken into account e.g. shipping routes, navigation marks, submarine exercise areas etc.
- Bathymetry – increasingly detailed maps of the seafloor are becoming available and are useful as a base-layer in data-visualisation systems.
- Seabed sediments – sediment data are typically less well spatially resolved than bathymetry but can assist with interpreting fishing locations and identifying sensitive habitats.
- Oceanography – sea temperature and salinity, general circulation patterns. Any large changes in these parameters over time could impact fish communities although interpretation of these data in relation to such changes is usually difficult and often inconclusive.
- Water quality – nutrients, primary productivity, dissolved oxygen, microbiology and pollutants – generally monitored nationally to ensure levels are at acceptable standards (e.g. Water Framework Directive) but changes might affect shellfish harvests in particular. As with oceanographic parameters interpretation of indirect impacts of changes in water quality on fish stocks is usually difficult and often inconclusive except for obvious shift, such as water quality in the upper River Clyde.
- Litter – Fisheries are one source among many of litter through discarded or lost gear but fishers can also contribute to clear up. This is encouraged as part of the Responsible Fishing Scheme. Monitoring of marine litter is not very comprehensive but the Marine Conservation Society organises annual beach surveys which also attempt to classify the source of items collected. Litter often collects in hotspots due to ocean circulation patterns and IFGs may want to consider if their industry is causing any particular problems in their area and propose remedial actions.
- Seabed habitats - Changes in habitats due to fishing e.g. sorting of sediments due to scallop dredging or trawling, may need to be taken into account. In addition, sensitive habitats, such as maerl beds, may require additional protection.
- Seabirds – trends in seabird numbers may be indicative of interactions with fisheries whilst some fishing activities in seabird sensitive areas may need to be restricted (usually through an MPA).
- Marine mammals – interactions with marine mammals and fishing gear and impacts of marine mammals on commercial fish stocks may need to be taken into account.
- Marine protected areas – IFGs will need to be aware of statutory and voluntary marine protected areas in their regions and the types of fishing activity which may impact protected features.

The sources for these data are given in Table 6. Being able to source and combining such datasets with visual summaries of where different fishing is occurring, its intensity and spatially resolved catch records should aid the development of management plans for inshore fisheries.

Bathymetry

Historically bathymetry (seabed depth) has been determined from simple lead-line data, even in well surveyed areas, such data derived from early (pre-20th century) surveys is still often used in the Admiralty hydrographic charts. Data derived in this way comprises a series of spot measurements which were then contoured by hand for charting. The introduction of echo-sounders has allowed data to be gathered continuously along vessel tracks. Earlier data were gathered using single-beam sounders and these instruments are still used on many vessels. Although the familiar Admiralty charts derived from these methods capture the main seabed features, they often miss fine-scale seabed features, many of which will affect the patterns of inshore fisheries.

For full survey work the modern approach is multi-beam which allows a swath to be mapped as the vessel moves along the survey track. The generally accepted highest mapping standard is UKHO Order 1 and data collected and processed to this standard will have a guaranteed level of quality (in terms of the accuracy and precision of the measurements in both horizontal and vertical axes). So far not all the UK coast has been mapped in this manner, although coverage is increasing steadily with projects, such as MAREMAP (www.maremap.as.uk) filling in many gaps. A further step-change is likely to come with wider use of improved methods for predicting the nature of the seabed habitat using multi-beam data (Diesing et al. 2014).

The UKHO website INSPIRE acts as a portal for available bathymetric data (http://www.ukho.gov.uk/inspire/pages/home.aspx). The website allows data to be downloaded along with full metadata describing the relevant surveys.

Coverage within the Moray Firth is relatively good with most areas being covered by multi-beam but some areas only covered by single beam or older soundings. Details of the available data are in Table 8.

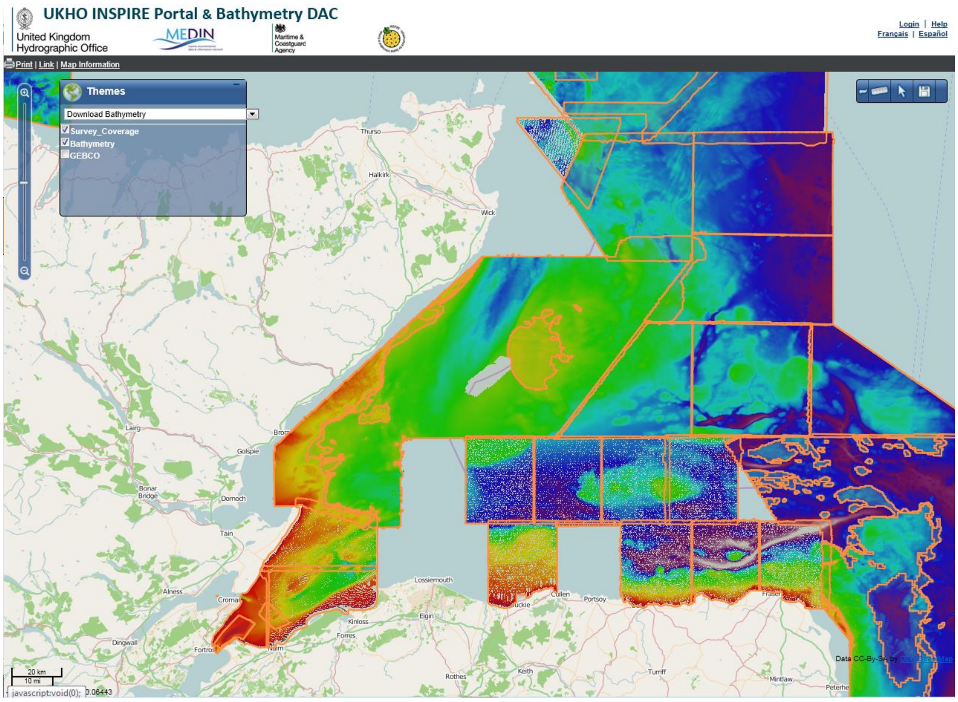


Figure 2: Available bathymetric survey data (excluding older Admiralty chart soundings) for the Moray Firth region

Sediments

A map of the sediments of the Moray Firth was produced as early as 1928 (Bowman 1928e). The sediments were grouped into three classes: rock, stones and gravel; mud and clean sand. The majority of the sediment in the Moray Firth is composed of sand and muddy sand with smaller patches of mud and sandy mud. The northern coastline has some larger areas of rocky substrate.

Sediment data from grabs and cores collected around the UK are held by British Geological Survey. However, these data are not gridded and require to be downloaded on a sample-by-sample basis. Gridded sediment data at 1:250,000 scale are available as a product called DigSBS250 (Table 6). There is a charge for downloading these data.

Gridded sediments (DigSBS250) are also one of the base layers used in the JNCC EUNIS Habitat classification (http://jncc.defra.gov.uk/page-2117). The original UKSeaMap and the Mapping European Seabed Habitats (MESH) project used the following substrate classification to reflect the broad substrate types used in seabed habitat classifications: Rock, Coarse sediment, mixed sediment, sand and muddy sand and, mud and sandy mud. The four sediment types in this classification are based on the British Geological Survey (BGS) Folk Sediment Trigon. Five datasets were used in the construction of the UKSeaMap 2010 substrate layer. BGS were contracted to produce a substrate layer for the project area from these datasets: DigSBS250; the Defra data contract MB0103 hard substrate layer (Gafeira et al. 2010); the Water Framework Directive (WFD) typology layer (Rogers et al. 2003). Minor gaps between the substrate layer and the mean low water mark were subsequently filled using data from Marine Nature Conservation Review (MNCR) surveys.

Sediment classifications according to UKSeaMap are shown below (Figure 3).

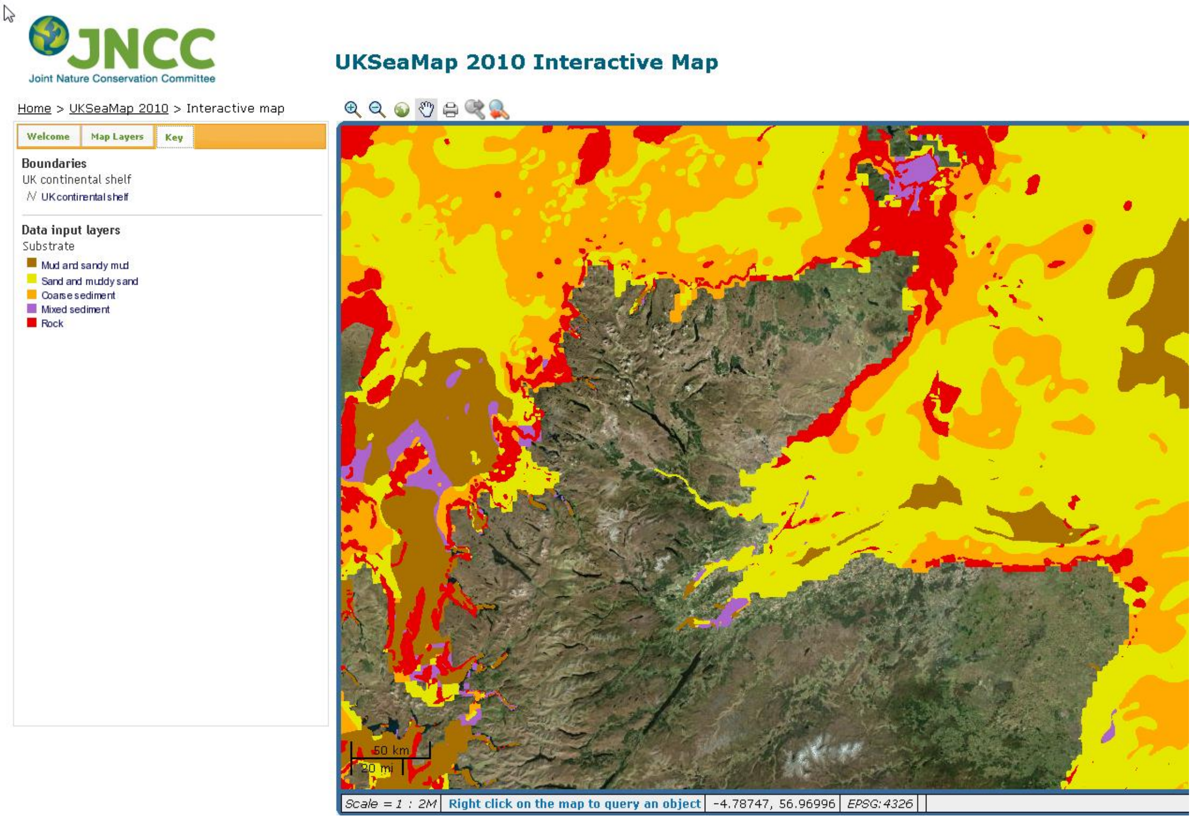


Figure 3: Sediment map for Moray Firth region

Further improvements in sediment mapping should be possible utilising additional information e.g. backscatter signal (Diesing et al. 2014), from the fine-scale bathymetry being collected under MAREMAP and associated programs (Howe et al., unpublished data). However, it is important to remember that results from a survey conducted primarily for improving bathymetry may not be optimal for evaluating sediment or habitat type (Diesing et al. 2014). In addition, sediments can be mobile, especially in tidally energetic parts of the Firth, so maps may become out of date quite rapidly.

Benthic habitats

The distribution of benthic habitats is of interest for inshore fisheries management because it is one of the main factors affecting the distribution of fish and the types of fishing which can be undertaken. Furthermore the health of certain benthic habitats will influence the degree to which they can act as nursery grounds for young fish. The quality of some benthic habitats may be adversely affected by some types of fishing and the occurrence of certain benthic habitats is a major reason for designation of areas as marine protected areas. Designation as a marine protected area may affect the types of or intensity of fishing activity which are permitted within such areas.

Early investigations in the Moray Firth using a Petersen grab were reported by Stephen (1928). The broad distribution of benthic habitats was linked with sediment type which in turn was described by Bowman (1928e). The species described are much as one would expect although some changes in biota may have occurred since then due to disturbance. In contrast to some of the other Scottish Firths, Stephen (1928) considered the fauna to be a continuation of that found further offshore and that distinctly estuarine biota were only found in the extreme inner parts of the Moray Firth. Despite the Firth supporting significant bottom fish populations, Stephen (1928) suggested that the average density of invertebrates was lower compared with other east coast locations. An updated general description of the benthic habitats in the Moray Firth can be found in Eleftheriou et al. (2004).

Since then the benthic habitats for the shallow sub-tidal parts of the Firth, mainly inshore, have been mapped by Scottish Natural Heritage (SNH) as part of a project investigating the Moray Firth SAC (Foster-Smith et al. 2009). Those surveys were conducted using a combination of acoustic discrimination (Roxann) and grab sampling. The benthic habitat of some of the offshore parts of the Firth has also been investigated in some detail in relation to various developments in the region. In particular, the Beatrice Oil and Gas Field (Hartley & Bishop 1986), and proposed windfarm sites (Beatrice Demonstrator and Smith Bank) have been surveyed using video plus physical sampling (Moray Offshore Renewables Ltd. 2012b). Several studies have been conducted around the Beatrice Field on the impacts of drilling muds on the benthos (Addy et al. 1984, Kingston 1992). Some additional work would be required to bring these data into any visualisation system and it is not known if the actual data are readily available.

Marine habitats are often patchy so an obvious question which arises is what is an adequate spatial resolution for sampling and monitoring? The costs of conducting habitat surveys are particularly relevant in relation to monitoring because it is not just a one-off survey which is required, but regular repeats (Frost et al. 2013). Even though large amounts of video-based observations can often be collected relatively cheaply, the costs of analysing these data are often quite high. Whether non-scientific stakeholders could be involved in collecting and analysing such data should be explored further (citizen science). Within shallow habitats use of ‘amateur’ divers has proven useful in this regard (for example the Sea-Search program www.seasearch.org.uk). The key point is that adequate training and quality control is essential so that the data are reliable (SeaSearch data are lodged on the National Biodiversity Network site). In deeper waters a similar approach, but using new relatively cheap video cameras and streaming data over the internet to analysts, might be feasible.

The increasing availability of fine resolution bathymetry derived from multi-beam acoustics described previously can also improve habitat maps, especially for deeper areas. Habitat type can, to some extent, be derived from multi-beam data although the survey may need to be optimised for back-scatter detection. It is important to remember therefore that results from a survey designed for improving bathymetry may not be optimal for evaluating sediment or habitat type (Diesing et al. 2014).

Physical Oceanography

Physical oceanography is the study of the processes giving rise to the properties of seawater. Typical measurements made include seawater temperature, salinity and currents but can also include chemical parameters, such as the concentrations of various nutrients and gases. Although the temperature and salinity of seawater are largely determined by physical processes, biological processes strongly affect other properties, such as the concentrations of nutrients and oxygen. This is because the organisms living in the water and seabed both consume and produce these chemicals and so alter their concentration in the water and sediment. Because the abundance and productivity of marine organisms varies both spatially and during the year these physical and biological interactions give rise to gradients in sea water properties. Although the collection and interpretation of the full range of oceanographic data tends to be a specialised task, the availability of relatively cheap instruments capable of accurately recording at least some oceanographic parameters (temperature at depth for example) means that useful data can now be collected by suitably trained non-scientists. Because fishing vessels spend large amounts of time at sea they could provide ideal platforms for the collection of oceanographic data (World Ocean Council 2011). However, to be of value instruments would need to be well maintained and calibrated.

The general hydrography of the Moray Firth was reviewed by Tait (1928) as part of the ICES investigation into the trawling ban. By that time it was understood that Atlantic origin water flowed across the Wyville-Thompson ridge into the Norwegian Sea and that offshoots of that flow entered the northern North Sea. The broad seasonal variation in the inflow was understood as being strongest in late spring but that there could be substantial inter-annual variability. Less saline coastal water had also been observed along the Scottish coast. Tait reported that the Atlantic water did not penetrate far into the Moray Firth and that surface salinities did not vary greatly (33.5 to 34.95) but that lower salinities were recorded inshore due to the influence of freshwater run-off. The broad patterns in temperature were also described with warmer surface water offshore in late winter. Cooling and sinking of nearshore waters during the first two quarters of the year tended to drive a surface drift towards the coast. This pattern was reversed as the shallower inshore water warmed during early summer. Average coolest temperatures from 20 year of data were around 5^{o}C and warming to 12-15^{o}C in August-September. The main current flow into the Firth was described as coming from the north but that this divides forming an eddy coincident with where the main fishing for spawning plaice and cod occurred.

In terms of oceanographic models, the Moray Firth has often been excluded from courser scale models covering the North Sea because of its size. A finer-resolution hydrodynamic model covering the Moray Firth was developed in relation to the Moray Offshore Renewables proposals for windfarms in the outer Firth (Moray Offshore Renewables Ltd. 2012a). This model is not however in the public domain but such models can be used to study a range of processes, such as sediment transport, organism dispersal and biological connectivity. One significant issue though is that running and using the output from such models requires expertise and research level computing resources.

Water quality

Good water quality is clearly important for aquatic ecosystems to support living organisms. Water quality is assessed in terms of its Ecological (Biological, Physical, Chemical and Hydromorphological[7] elements) and Chemical status. Present status is assessed in relation to 'reference values' taken to be representative of minor alteration as a result of human disturbance (UKTAG 2007). Biological indicators are used because certain organisms are sensitive to poor water quality, whilst the presence of others may be indicative of poor conditions (UKTAG 2013). Phytoplankton are also monitored because changes in standing stocks and/or community composition can be indicative of problems with nutrient enrichment. Parameters typically monitored under the Physic and Chemical headings include temperature, oxygen and nutrient levels. Member states are also required to identify and monitor specific pollutants. All these factors will interact and if below optimal levels can negatively affect aquatic life. Water quality is also very important with regard to shellfish which can accumulate pollutants and biotoxins (e.g. from harmful algal blooms) if they are present.

Water quality as captured in the EU Water Framework Directive covers rivers, lakes, transitional (estuaries) and coastal waters. There are five classes for ecological status under the WFD; 'high', 'good', 'moderate', 'poor' and 'bad'. The Directive requires that the overall ecological status of a water body be determined by the results for the biological or physicochemical quality element with the worst class (UKTAG 2007).

Waters from which shellfish are harvested receive special attention under the Shellfish Growing Waters Directive (SGWD) but additional areas may also be included under the WFD for the protection of economically significant aquatic species.

In Scotland the body responsible for monitoring water quality for WFD and SGWD purposes is SEPA (Scottish Environmental Protection Agency) although Marine Scotland Science contributes monitoring data for intermediate and coastal waters. Management actions are co-ordinated through river basin management plans (http://www.sepa.org.uk/water/river_basin_planning/area_advisory_groups.aspx).

River basin management for the Moray Firth comes under two areas, Northeast Scotland and North Highland. In 2008 the ecological status of the waters was classed as 'high' or 'good' (Figure 4) with a single moderate zone off Fraserburgh (Rosehearty to Cairnbulg Point) which failed to reach good status due to diffuse source pollution from harbours and associated structures.

[7] Hydromorphology refers to the shape of the rivers and coastlines and implies that changes in water quality due to dredging or the construction of dams, ports, flood defences etc. must be taken into account.

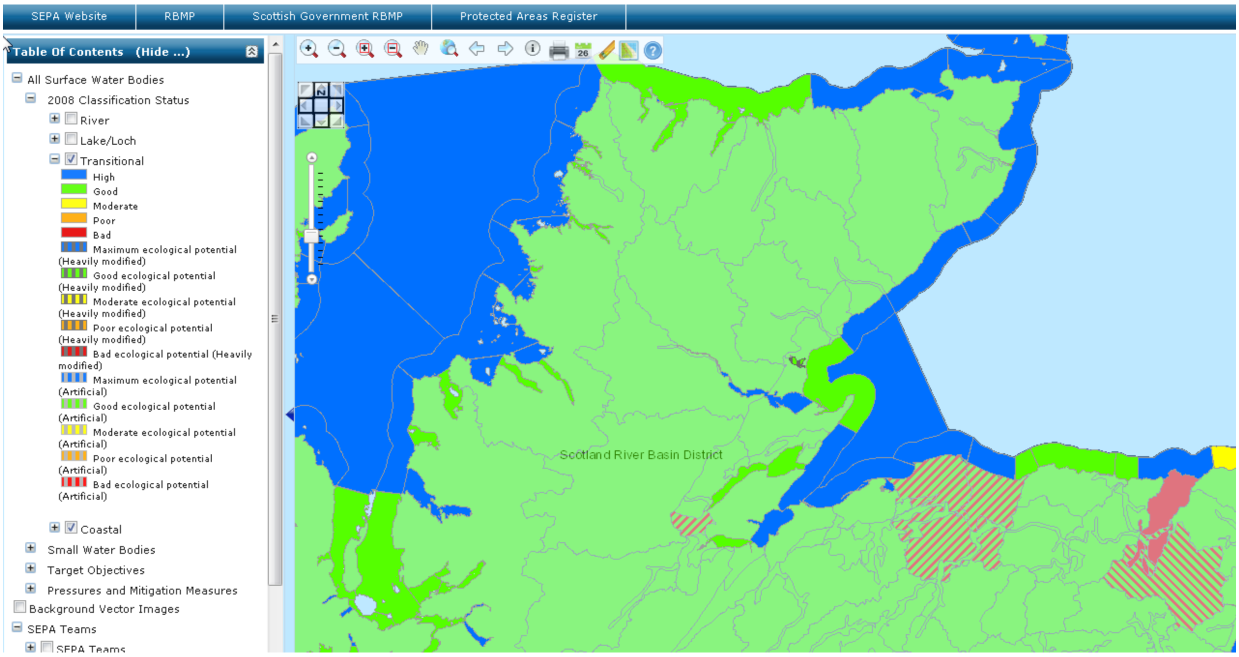


Figure 4: Classification of transitional and coastal waters in the Moray Firth region (2008)

The Moray Firth pilot region contains two areas designated as shellfish growing waters (Figure 5).

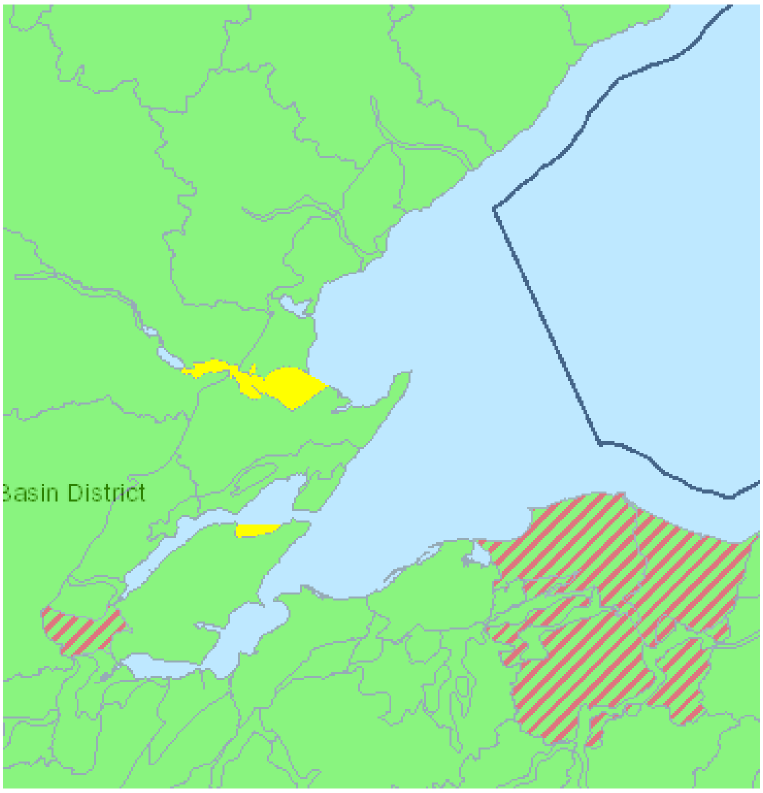


Figure 5: Locations of waters designated for the purpose of shellfish growing in the Moray Firth (shaded in yellow)

Nutrients

Because of its relatively open nature, nutrient enrichment is expected to be less of a problem in the Moray Firth apart from in some of the inner regions. Webster et al. (2007) reported on nutrient measurements of samples taken in the Moray Firth between 1999 and 2006 as part of a process of developing a national monitoring program. Stations 95 (Intermediate Moray Firth) and 105 (Offshore Moray Firth) are now sampled annually and form part of the UK Clean Seas Environment Monitoring Program (CSEMP).

Pollutants

Heavy metals and persistent organic pollutants

In advice in relation to the designation of the Moray Firth as an SAC (Special Area of Conservation), SNH noted that diffuse agricultural run-off had the potential to cause impairment of dolphin's reproductive or immune systems and could also cause smothering of organisms on sandbanks. Commercial effluent and chemical discharges from shipping, as well as sewage, could also lead to problems.

As well as nutrients, levels of pollutants are also measured at stations 95 and 105 of the UK CSEMP. Recent data can be accessed at the Marine Environment Monitoring and Assessment National database (MERMAN). The most recent assessment shows some elevated organic pollutant levels in samples from the Cromarty Firth in particular and elevation in some heavy metals at the offshore site. See also Baxter et al. (2011) for an overall summary.

Litter

Marine litter is acknowledged as a serious problem (Potts & Hastings 2012, Ivar do Sul & Costa 2014). Litter can endanger marine life, cause damage to shipping and other offshore industries but it also reduces the enjoyment people gain from living on or visiting the coast with consequent economic and social impacts. As well as visible litter there are increasing concerns about plastics which have become dispersed throughout the oceans eventually degrading into micro-particles and fibres (Woodall et al. 2014). The long-term impact of these fibres and particles on marine life is largely unknown but particles have been found in the guts of various marine organisms (Wright et al. 2013). Although most litter has terrestrial origins a significant percentage does derive from fisheries and takes the form of lost or discarded netting, rope, creels etc. Apart from the dangers to wildlife, the presence of such material on beaches gives a bad public perception of fisheries. For these reasons local management and stakeholders may wish to monitor this aspect. Litter indices will also be required to be reported under the EU Marine Strategy Framework Directive. However, marine litter is one area with relatively poor monitoring (Potts & Hastings 2012) although the Marine Conservation Society organises annual beach surveys and records regional trends in these data (Table 8).

Seabirds

Seabirds can be affected both directly and indirectly by fisheries. For example, direct interactions may include entanglement in gear and this is the primary reason behind management proposals for some Marine Protected Areas. Indirect effects include provision of additional food for seabirds via discards. Proposed changes in discarding under reform of the Common Fisheries Policy are likely to affect some seabirds and this has been examined using food-web models (Heath et al. 2014a). Another indirect effect which has received much attention is fisheries-induced reductions of prey, such as sandeels (Ammodytidae), impacting seabird feeding and breeding success. The general conclusion of such studies in the North Sea has been that changes in sandeel abundance and nutritional condition seem more related to changes in the environment than fisheries (Poloczanska et al. 2004, Heath et al. 2012). However, this does not mean that all other prey-related fisheries-seabird impacts can be dismissed and research would have to be conducted on a case-by-case basis.

The Moray Firth contains important permanent and transient populations of wading birds and wildfowl and a number of areas have been designated for their protection (Table 8). The East Caithness Cliffs have nesting colonies of Black Guillemot (*Cepphus grille*), Cormorant (*Phalacrocorax carbo*), Guillemot (*Uria aalge*), Herring gull (*Larus argentatus*), Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), Shag (*Phalacrocorax aristotelis*), Fulmar (*Fulmarus glacialis*) and Great black-backed gull (*Larus marinus*). The East Caithness MPA is extended out to sea for the protection of foraging Black Guillemot.

Colony count data for the Moray Firth can be found at the JNCC website and the National Biodiversity Network site (Table 6). Seabird counts are also recorded periodically at sea and overall summaries of these data can be found at http://seamap.env.duke.edu/. It is however difficult to interpret trend data from this website.

Marine mammals

As with seabirds, fisheries may interact with marine mammals in both a direct and indirect manner. Entanglement of mammals in certain fishing gears can occur whilst fisheries themselves can be affected by predation and gear damage due to mammals such as seals. Because marine mammals (excepting seals) do not breed on land it is more difficult to census their population sizes through direct observation although this can be done for some groups which tend to be more resident in inshore waters e.g. the Moray Firth dolphins. The Sea Mammal Research Unit based at University of St. Andrews produces regular reports on marine mammal populations around the UK. Annual reports are produced and available from their website which summarise recent population trends including those for seals. Major grey seal (*Halichoerus grypus*) breeding colonies are found in the inner and outer Hebrides. Harbour seal (*Phoca vitulina*) haul-out sites are found around the Scottish coast including in the Moray Firth although the Scottish West Coast supports a greater number of colonies (Special Committee on Seals 2014). Grey and harbour (common) seals can show differing population trends although fishers may not always distinguish between the two species Moore (2003).

The Moray Firth count of harbour seals declined by 50% up to 2005, then remained reasonably stable for 4 years, followed by an increase by 40% in 2010. Since then numbers have fluctuated (Special Committee on Seals 2014). The Special Committee on Seals

(SCOS) reports also contain summaries of recent investigations into issues such as the diet of different seal populations and interactions of seals with salmon netting.

A variety of other marine mammal species have been recorded within the Moray Firth including harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncates*), common dolphin (*Delphinus delphis*), white-beaked dolphin (*Lagenorhynchus albirostris*) and minke whale (*Balaenoptera acutorostrata*). Most of these species are not entirely resident year-round but move in and out of the area.

Compared to the Scottish west coast, there have been a relatively large number of studies of the marine mammals in the Moray Firth. However, different survey techniques have often been used which can make comparing results between studies, even those conducted in the same region, difficult. Relatively recent data on marine mammals in the Moray Firth have also been collected as part of the Environmental Impact Assessments being conducted with regard to proposals for a wind-farm on the Smith Bank area (Moray Offshore Renewables Ltd. 2012a).

Two SACs in the area are specifically related to marine mammals, namely the Moray Firth SAC for bottlenose dolphin and the Dornoch Firth and Morrich More SAC for harbour seal. Because of these designations the site conditions within the SACs must be monitored by Scottish Natural Heritage including a summary of recent population trends (Cheney et al. 2012, Cheney et al. 2014).

Marine Protected Areas

The UK and Scottish Governments are committed to establishing an ecologically-coherent network of Marine Protected Areas. The areas are designated under various legal frameworks which can be confusing. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) fall under European Directives. Across Europe such sites form part of a wider network called Natura 2000. The UK (and Scottish) government are obligated to maintain the quality of these sites and to report periodically on their condition to the European Commission.

In addition there are a variety of international and national frameworks, such as Ramsar Convention sites and Sites of Special Scientific Interest. These are mainly terrestrial but can include coastal and inter-tidal locations. Many of the sites in the Moray Firth in particular have multiple designations (Table 8) often reflecting the importance of the habitat for migratory and resident birds.

Additional marine protected areas are being established around the UK to supplement these existing networks. The high level policy aim is to protect rare, representative and productive species and habitats on the basis of sound science so that the rich diversity of life in the waters around Scotland and the benefits they bring can be enjoyed in the future. In Scotland the powers to designate these sites rest with the Cabinet Secretary for Rural Affairs, Food and Environment acting via powers granted under the Scottish Marine Act (2010). The collection of supporting scientific evidence is undertaken mainly by Scottish Natural Heritage for sites within the 12 nm limit. Advice on offshore sites comes from the Joint Nature Conservation Committee (JNCC). In addition, local communities can propose sites. At present management plans for these sites, including most Natura sites with marine components, are being developed by Marine Scotland. Some restrictions on fishing activities may therefore be put in place at some sites but the management plans will be put out to public consultation prior to adoption.

The Moray Firth contains numerous protected inter-tidal areas for wading birds and wildfowl (Table 8) but most of these will not be likely affected by fisheries apart from possible shellfish harvesting. There are important seabird breeding sites at East Caithness Cliffs and these are also protected. In this case the area of protection extends out to sea to cover foraging. The Firth also contains an important population of bottlenose dolphins for which an SAC is designated.

The proposed management measures for these MPAs are still under consultation and so, although the MPA boundaries (Table 8) are included in our web-viewer, associated information on possible restrictions to fisheries, and other activities in these areas are not shown (Marine Scotland 2014).

Other activities which may affect inshore fisheries

Inshore fishing can also be affected by a wide range of other human activities including shipping, port developments, offshore renewables, oil and gas extraction etc. Information on many of the existing activities in the Moray Firth is being collated under the remit of Marine Planning and much of this is already available on NMPI. As stated in the work-package objectives, the aim was not to re-collate all available data for the Moray Firth, but rather to consider how different datatypes, which may be of specific interest to inshore fisheries managers, might be visualised. It is for these reasons that the visual data explorer accompanying this report only includes a selection of the many possible data-layers available.

Data characteristics

A summary of the characteristics of the different datatypes discussed above is provided in Table 6. Metadata for the high resolution bathymetry datasets available for the Moray Firth are shown in Table 7. Metadata for the Marine Protected Areas in the Moray Firth are shown in Table 8. A number of these datasets are included as layers in the demonstration web-based data viewer developed as part of the overall Work Package. Further discussion of the web-based data viewer can be found in Parts 3 and 4 of this report.

Table 6: Summary of data characteristics for information relevant to inshore fisheries management for the Moray Firth pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Fish and shellfish	Stock assessments	ICES, Marine Scotland Science 2015, Dobby et al. 2012	Reports	Some on-line	Varies with species	Unknown	Referred to in the report text
	General changes in fish community	Literature	Time-series	Published or available on request	Periodically	< 1kB	Reviewed
	Spawning grounds	Literature	Limited map data	Published	No recent updates	< 1kB	Reviewed – insufficient data for mapping
	Nursery areas	Literature	Limited map data	Published	No recent updates	<1kB	Reviewed – insufficient data for mapping
	Diseases	FSA Scotland	Levels of biotoxins and potentially harmful bacteria in harvested shellfish	http://www.foodstandards.gov.scot/shellfish-monitoring-180815	Weekly	< 200 kB	Weekly reports can be easily downloaded but timeseries of results would need to be requested
	Ecosystem indicators	Generally only calculated for larger ecoregions e.g. www.indiseas.org. Calculation of indicators for smaller regions is possible providing underlying data are available but interpretation of results can be complex. Ecosystem indicators are still in development and there is little agreement on which of the large number of proposed indicators are appropriate. Suites of proposed indicators to date normally include consideration of the status of commercial and non-commercial fish and shellfish, but will also include indicators for a wide range of other environmental and human-based factors.						

Table 6: Summary of data characteristics for information relevant to inshore fisheries management for the Moray Firth pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Fisheries	Location of <10 m vessels	SuccorFish or similar vessel position recording system	Time-series	Variable - dependent on confidentiality agreements with vessel owners	Daily though receiver coverage can lead to data delays depending on data transmission method used	< 1kB upwards	Demo data were included in web-viewer demo
	VMS > 10 m vessels	Statutory vessel monitoring system	Time-series	Needs data access agreements	Seasonal updates although data delivered to MS more frequently		Not included in web-viewer demo – access to underlying data restricted due to confidentiality agreements
	Spatial distribution of fishing	ScotMap	Snapshot	On-line	One off exercise	< 1kB	Included in web-viewer demo – already in NMPI
	Reported landings	http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/RectangleData	Tabulated data by ICES rectangle but further processing needed to adjust to IFG boundaries	On-line	Annual but lag due to data collation and processing	< 2 kB	Summarised

Table 6: Summary of data characteristics for information relevant to inshore fisheries management for the Moray Firth pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Base maps	Admiralty charts	www.seazone.com	Hydroview geoTiff	Licenced product	Infrequent	< 10MB	Included in web-viewer demo but not for public release
	Single and multibeam acoustics	UKHO-INSPIRE	Bathymetry	Public (https://www.nationalarchives.gov.uk/doc/open-government-licence/version/2/)		kB to Gb depending on area and survey type	Latest data downloaded and incorporated into web-viewer demo (Table 7). Data tiles can be incorporated into NMPI
Base maps con/td	Single and multibeam acoustics con/td	Olex	Bathymetry	http://www.olex.no/index_e.html	On-going	> 1 MB	Not included at this time
	ICES Statistical rectangles and sub-rectangles	ICES	GIS	Public	Never	< 1 kB	Customised grids can be incorporated into web viewer
Sediments	Gridded sediment maps	JNCC		Public (http://jncc.defra.gov.uk/page-2117)			Static data layer could be incorporated into web viewer as for bathymetry.
Oceanography	Sea temperature	Hadley ISST http://www.metoffice.gov.uk/hadobs/hadisst/	netCDF	Public non-commercial use but requires specialist analysis	Annual	< 1 Mb yr^{-1}	Historical data described in this report

Table 6: Summary of data characteristics for information relevant to inshore fisheries management for the Moray Firth pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Water quality	Water Framework Directive Ecological Status assessments	http://gis.sepa.org.uk/rbmp	Text summaries	Summaries are public	Infrequent	kB	Website consulted
Water quality con/td	Contaminants in sediments and fish samples	http://www.bodc.ac.uk/projects/uk/merman/	Graphic summaries	Summaries are public but underlying data require data request	Annual	< 1kB	Website consulted
Litter	Trends	www.mcs.org	Graphic summaries	Underlying data require data request	Annual	< 1MB	Consulted
Seabirds	Count data	http://jncc.defra.gov.uk/page-1550 and https://data.nbn.org.uk/ and http://seamap.env.duke.edu/	Graphic and numeric summaries	On-line	Variable	< 1MB	Websites consulted – data for specific sites available but production of trends requires further extraction and compilation
Marine mammals	Population trends	(Special Committee on Seals 2014)	Summaries	Public	Annual	< 1kB	Current status described in this report

Table 6: Summary of data characteristics for information relevant to inshore fisheries management for the Moray Firth pilot region

Category	Aspect	Source	Type	Availability	Updated	Dataset size (approx.)	Status in this project
Marine Protected Areas	Designated	(Scottish Natural Heritage 2013)	Report	Public	Irregularly	< 1kB	Current status described in this report; available in NMPI

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1975 K7508 Moray Firth Tarbat Ness to Burghead Blk2	19750731	19750418	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Echo	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008673
Downloaded 18 Aug 2014	1976 K7508 Moray Firth Tarbat Ness to Burghead Blk1	19750731	19750418	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Echo	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008672
Downloaded 18 Aug 2014	1975 K7428 Moray Firth Fort George to Karakan Hill	19750726	19750421	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Enterprise	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008693

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 26	19861013	19860117	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008608
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 27	19860905	19860117	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008609
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 29	19860302	19860117	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008611

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 17	19861205	19860121	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Beagle	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008604
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 18	19861205	19860121	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Beagle	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008605
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Sheet 24	19861001	19860512	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Bulldog	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008607

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Area 20	19860813	19860723	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Fox	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008591
Downloaded 18 Aug 2014	1986 HI246 Scotland East Coast Moray Firth Area 23	19860904	19860814	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Fox	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008592
Downloaded 18 Aug 2014	1986 HI246 Moray Firth Area 21	19861018	19860905	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	HMS Fox	Echosounder - single beam	Unknown	Maritime and Coastguard Agency	2008580

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded 18 Aug 2014	2000 HI874 Cromarty Firth HMS Natal	20000723	20000717	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMS Roebuck	Echosounder - single beam	DGPS	Ministry of Defence	2005887
Downloaded 18 Aug 2014	2000 HI875 Cromarty Deep Water Anchorage	20000725	20000719	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.001"], EXTENSION["Source","CARIS"]]	HMS Roebuck	Echosounder - single beam	DGPS	Ministry of Defence	2005888

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 18 Aug 2014, converted to .csv in CARIS	2006 HI 1150 Tarbat Ness to Sarclet Head 4m SB	20060822	20060531	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008784

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 18 Aug 2014, converted to .csv in CARIS	2006 HI1150 Tarbat Ness to Sarclet Head 2m SB	20060822	20060531	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008783

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 19 Aug 2014, converted to .csv in CARIS	2009 HI1155 Todhead Point to Bosies Bank Blk4 4m SB	20090625	20090305	PROJCS["BAG Coord System", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Unknown	Echosounder - multibeam	Unknown	Maritime and Coastguard Agency	2007608

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 19 Aug 2014, converted to .csv in CARIS	2009 HI1155 Todhead Point to Bosies Bank Blk6 8m SB	20090625	20090305	PROJCS["BAG Coord System", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Unknown	Echosounder - multibeam	Unknown	Maritime and Coastguard Agency	2007609
Downloaded as .bag 19 Aug 2014, converted to .csv in CARIS	2010 HI1336 Riff Bank 2m SB	20100620	20100528	GEOGCS["WG84", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572201434276], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.0000001,0.0000001,0.0001"], EXTENSION["Source","CARIS"]]	Unknown	Echosounder - multibeam	Unknown	Maritime and Coastguard Agency	2007051

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 19 Aug 2014, converted to .csv in CARIS	2012 HI1372 Moray Firth Block1 2m SB	20120704	20120207	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008045

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 19 Aug 2014, converted to .csv in CARIS	2012 HI1372 Moray Firth Block2 2m SB	20120704	20120207	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008046

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 22 Aug 2014, converted to .csv in CARIS	2012 HI1372 Moray Firth Block4 2m SB	20120704	20120207	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008048

Table 7: Metadata for Moray Firth bathymetry

STATUS	OBJNAM	Survey end date	Survey start date	Hcosys	Platform	Sensor	Positioning System	IPRHolder	sourceBOID
Downloaded as .bag 22 Aug 2014, converted to .csv in CARIS	2012 HI1372 Moray Firth Block6 2m SB	20120704	20120207	PROJCS["UTM Zone 30, Northern Hemisphere", GEOGCS["unnamed", DATUM["WGS_1984", SPHEROID["WGS_1984",6378137,298.2572235629972], TOWGS84[0,0,0,0,0,0,0]], PRIMEM["Greenwich",0], UNIT["degree",0.0174532925199433], EXTENSION["Scaler","0,0,0,0.01,0.01,0.0001"], EXTENSION["Source","CARIS"]], PROJECTION["Transverse_Mercator"], PARAMETER["latitude_of_origin",0], PARAMETER["central_meridian",-3], PARAMETER["scale_factor",0.9996], PARAMETER["false_easting",500000], PARAMETER["false_northing",0], UNIT["Meter",1]]	Other - inform Database Manager	Echosounder - multibeam	DGPS	Maritime and Coastguard Agency	2008050

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

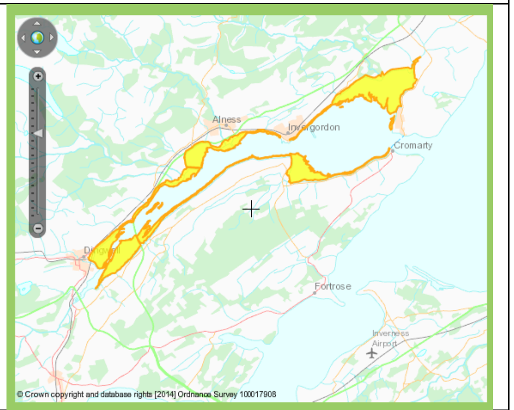
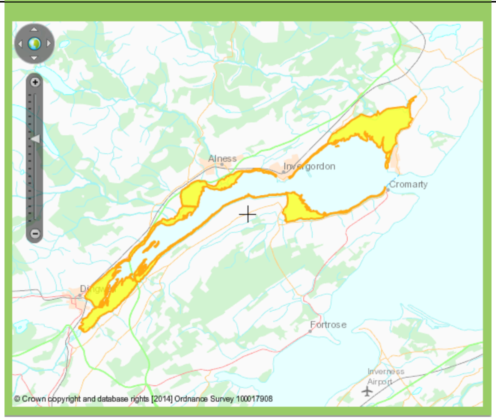
Site	Description and features	Map
Cromarty Firth, SSSI	Area designated as Site of Special Scientific Interest. Bar-tailed godwit (*Limosa lapponica*), Redshank (*Tringa totanus*), Wigeon (*Anas penelope*), Whooper swan (*Cygnus cygnus*), Red-breasted merganser (*Mergus serrator*). Saltmarsh, Mudflats, Sandflats.	
Cromarty Firth, Ramsar	Area designated as an internationally important wetland habitat. Greylag goose (*Anser anser*), Bar-tailed godwit (*Limosa lapponica*). Intertidal mudflats and sandflats.	

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

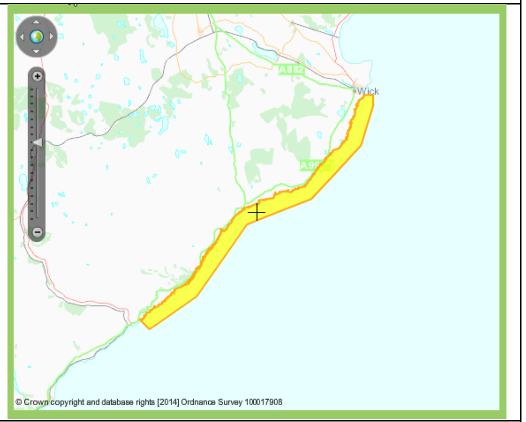
Site	Description and features	Map
Cromarty Firth, SPA	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Common tern (*Sterna hirundo*), Osprey (*Pandion haliaetus*), Curlew (*Numenius arquata*), Dunlin (*Calidris alpina alpina*), Greylag goose (*Anser anser*), Pintail (*Anas acuta*), Red-breasted merganser (*Mergus serrator*), Whooper swan (*Cygnus cygnus*), Bar-tailed godwit (*Limosa lapponica*).	As above
East Caithness Cliffs SPA EU code UK 9001182	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Cormorant (*Phalacrocorax carbo*), Guillemot (*Uria aalge*), Herring gull (*Larus argentatus*), Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), Shag (*Phalacrocorax aristotelis*), Fulmar (*Fulmarus glacialis*), Peregrine (*Falco peregrinus*), Great black-backed gull (*Larus marinus*).	
East Caithness Cliffs MPA	Designated to protected black guillemots and their nearshore feeding grounds, this MPA extends 2 km out to sea and stretches up Scotland's north-east coast from Helmsdale to Wick. Black Guillemot (*Cepphus grille*).	As above

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

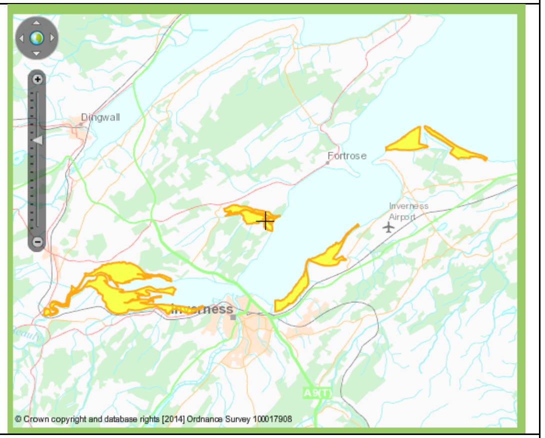
Site	Description and features	Map
Inner Moray Firth, Ramsar	Area designated as an internationally important wetland habitat. Bar-tailed godwit (*Limosa lapponica*), Redshank (*Tringa totanus*), Greylag goose (*Anser anser*), Red-breasted merganser (*Mergus serrator*). Saltmarsh, Intertidal mudflats and sandflats.	
Inner Moray Firth, SPA EU code UK 9001624	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Common tern (*Sterna hirundo*), Osprey (*Pandion haliaetus*), Bar-tailed godwit (*Limosa lapponica*), Curlew (*Numenius arquata*), Goldeneye (*Bucephala clangula*), Greylag goose (*Anser anser*), Redshank (*Tringa totanus*), Wigeon (*Anas penelope*), Goosander (*Mergus merganser*), Teal (*Anas crecca*).	As above

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

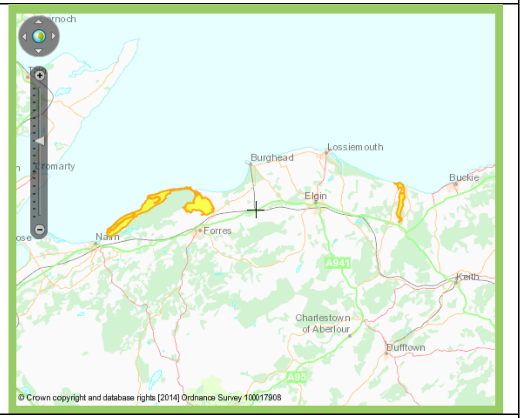
Site	Description and features	Map
Moray and Nairn Coast, Ramsar	Area designated as an internationally important wetland habitat. Pink-footed goose (*Anser brachyrhynchus*), Greylag goose (*Anser anser*), Redshank (*Tringa totanus*). Saltmarsh, Intertidal mudflats and sandflats.	
Moray and Nairn Coast, SPA EU code	Designated Special Protection Area for Birds under the EU Birds Directive (79/409/EEC amended as Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds). Osprey (*Pandion haliaetus*), Common scoter (*Melanitta nigra*), Long-tailed duck (*Clangula hyemalis*), Oystercatcher (*Haematopus ostralegus*), Bar-tailed godwit (*Limosa lapponica*), Wigeon (*Anas penelope*), Pink-footed goose (*Anser brachyrhynchus*), Red-breasted merganser (*Mergus serrator*), Redshank (*Tringa totanus*), Velvet scoter (*Melanitta fusca*).	As above

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

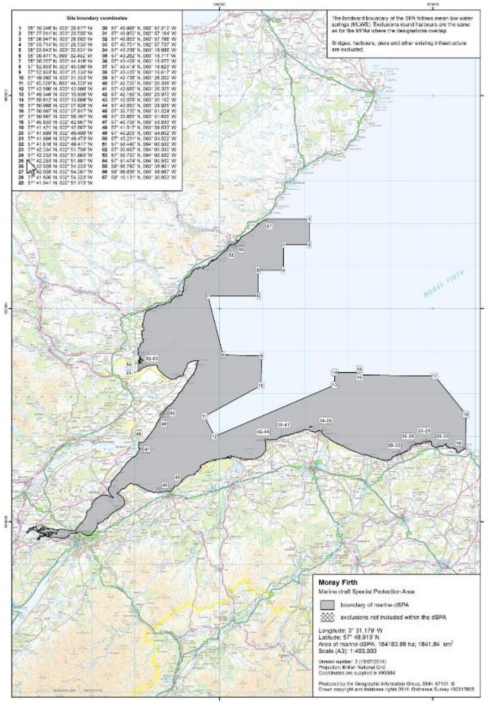
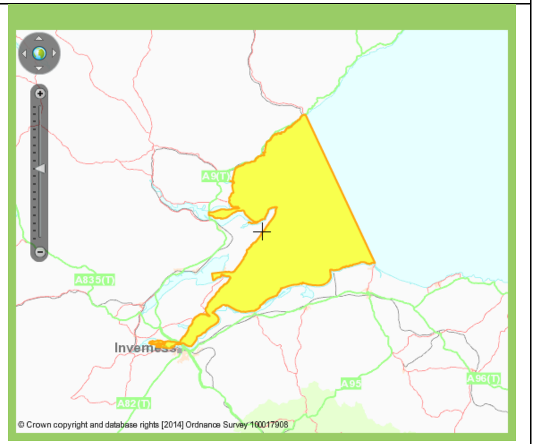
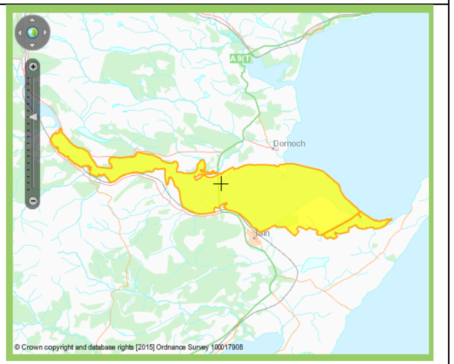
Site	Description and features	Map
Moray Firth, draft SPA	The UK government has committed to identifying a network of SPAs in the marine environment, and having them substantially classified, by the end of 2015. A suite of marine dSPAs in Scottish waters is hereby provided for the information of stakeholders. It is designed to alert stakeholders to additional marine sites that are likely to be considered by the Scottish Government over the next few months. Its public release does not constitute a consultation at this stage but aims to provide early information on the process of developing a network of marine SPAs in Scotland. Qualifying bird species in the Moray Firth marine dSPA Annex 1 species: Great northern diver (*Gavia immer*); Red-throated diver (*Gavia stellate*); Slavonian grebe (*Podiceps auritus*); Migratory species: Scaup (*Aythya marila*); Common eider (*Somateria mollissima*); Long-tailed duck (*Clangula hyemalis*); Common scoter (*Melanitta nigra*); Velvet scoter (*Melanitta fusca*); Common goldeneye (*Bucephala clangula*); Red-breasted merganser (*Mergus serrator*); European shag (*Phalacrocorax aristotelis*)	

Table 8: Metadata for Moray Firth Protected Areas

Data source for all these PAs http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/mpas/ and http://gateway.snh.gov.uk/sitelink/index.jsp

Site	Description and features	Map
Moray Firth, SAC	Designated as Special Area of Conservation under the EU Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). Subtidal sandbanks; Bottlenose dolphin (*Tursiops truncates*).	
Dornoch Firth and Morrich More, SAC	Designated as Special Area of Conservation under the EU Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). Estuaries, mudflats and sandflats; Harbour seal (*Phoca vitulina*)	

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Part 3: The potential utility of different types of biological and physical data for inshore fisheries management

Contents

Introduction

As part of Work Package 4 we undertook a number of meetings with the Inshore Fisheries Management Groups and with the Planning Partnerships for the Clyde and Moray Firth. We also attended a number of related workshops and events (Table 1).

Table 1: Meetings attended as part of, or related to, this project

Date	Meeting	Outcome
17 Jul 2014	Project meeting - Edinburgh	Project start-up meeting
21 Jul 2014	Meeting with regional facilitators - SAMS	Initial general discussion
21 Aug 2014	Project progress meeting - Edinburgh	
24 Sep 2014	Project meeting - Edinburgh	Kick-off meeting for overall project
6 Oct 2014	SW IFG advisory group - Glasgow	Discussed overall aims of project in relation to issues in the Clyde – discussion of types of information which would be useful to the wider IFG Advisory group
9 Oct 2014	Videoconference	NMPi integration investigation with Marine Scotland
17 Nov 2014	Clyde 2020 workshop	Improved understanding of issues around Clyde
2 Dec 2014	SW IFG Exec. Committee meeting - Glasgow	NMPi integration investigation with Marine Scotland and Atkins
11 Dec 2014	Moray Firth IFG – Elgin Council Offices	Improved understanding of issues around the Moray Firth
19 Dec 2014	Videoconference	
3 Feb 2015	Project meeting - Edinburgh	Improved understanding of how different project elements interact
28/29 Apr 2015	North-west MPA workshop	Improved understanding of MPA issues around Moray Firth
18 May 2015	Moray Firth Marine Planning meeting	Introduction to issues around Marine Planning for Moray Firth

The first set of meetings with the Clyde and Moray Firth groups allowed an exchange of ideas about how Work Package 4 should be developed, including some initial discussion around data layers which might be included (Table 2). Based on these discussions we selected an example from each of the different types of data to be included in the demonstration web-based data explorer (Table 3). Again it is important to emphasise that our goal was not to include every possible data source available, but to focus on those data types which may be of value to inshore fisheries management. We also wanted to include a range of data types with varying characteristics in terms of their frequency of updating, overall size, and difficulty of processing and potential level of user interaction[1].

[1] A much broader range of data are needed for marine planning and this is covered by the NMPI project although NMPI at present only includes static data layers.

Table 2: Initial evaluation of the potential value of datasets for inshore fisheries management based on discussions with the Clyde and Moray Firth IFGs and their Advisory Groups

The datasets included here are not the full range needed for marine planning but are those which were considered to be most relevant to inshore fisheries management. At this stage in the discussions the level of detail was kept deliberately quite open so as not to constrain discussions about how such data could be used.

Several potential levels of users were identified: IFAs Inshore fisheries advisors providing scientific support (the source for such support is left open but could include Marine Scotland Science, Universities, fisheries consultancies etc.); IFGs Inshore Fisheries Groups delivering local management; The IFAs together with the IFGs would probably comprise the full IFG Advisory bodies, although the exact future structure of inshore fisheries management bodies in Scotland is unclear at this time; MPPs Marine Planning Partnerships are likely to be charged with delivering wider marine planning incorporating, but not limited to, fisheries aspects.

Category	Aspect	Level of use	Usefulness	Justification
Fish and fisheries	Stock assessments	IFAs, IFGs	High	Provides data on changes in stock status over time, depending on type of assessment can also provide estimates of fishing mortality.
	General changes in fish community	IFAs, IFGs, MPPs	High	Provides historical baselines against which present state and desired outcomes may be evaluated.
	Changes in commercial fishing patterns	IFAs, IFGs, MPPs	High	Changes in fishing patterns may necessitate changes to management measures e.g. development of new fisheries may require new measures.
	Changes in recreational fisheries	IFAs, IFGs, MPPs	Medium	Perhaps of more interest to marine planning in terms of facilities required but some overlap with commercial fishing especially if vessels switch to recreational charters.
	Spawning grounds	IFAs, IFGs, MPPs	Medium	In some cases spawning grounds may require special protection measures.
	Nursery areas	IFAs, IFGs, MPPs	Medium	In some cases spawning grounds may require special protection measures.
	Stock discreteness	IFAs, IFGs	Medium	May provide insight into how self-sustaining inshore stocks are. However, interpretation of genetics data is complex so stakeholders will probably be more interested in interpreted results from research programs.

Category	Aspect	Level of use	Usefulness	Justification
Fish and fisheries	Fish health – Pollutants and disease	IFAs, IFGs, MPPs	Medium	Stakeholders may wish to check updates from fish health monitoring programs but unless there is a major pollution incident the information is not likely to be very useful. Fish health data could be of value for marketing local products by demonstrating that the fish are caught from a clean and healthy environment. Harvested shellfish must be tested regularly for toxins which is co-ordinated through the Food Standards Agency. Marine and terrestrial planning may be able to mitigate fish health problems caused by human activities e.g. problems due to sewage run-off.
	Location of <10 m vessels	IFAs, IFGs, MPPs	High	Indicative of use of inshore areas, allows tracking changes in use over time. However, raw location data require filtering to indicate possible fishing activity as opposed to steaming or other vessel movements. Issues around data confidentiality.
	Vessel monitoring systems > 10 m vessels	IFAs, IFGs, MPPs	High	Larger vessels will fish in areas such as the Clyde and Moray Firth and data on their amount of use of the inshore areas needs to be taken into account in management. Issues around data confidentiality.
	Spatial distribution of effort	IFAs, IFGs, MPPs	High	Indicates where different activities take place and importantly whether they are shifting over time. Issues around data confidentiality.
	Total catch	IFAs, IFGs	High	Changes in total catch may trigger warnings that need to be examined more closely – changes in total catch can have several underlying causes such as changes in stocks, fishing effort or fishing conditions.
	Catch per unit effort by species	IFAs, IFGs	High	Trends in CPUE may give a better indication of underlying changes in stocks because they standardise for shifts in fishing effort. However, obtaining accurate effort data for many fisheries is challenging e.g. catchability varies with creel soak times in a non-linear manner and changes in gear and fishing practice can affect the measure.

Category	Aspect	Level of use	Usefulness	Justification
Fish and fisheries	Ecosystem indicators	IFAs, IFGs, MPPs	Low at present, may become more important over time	Users may wish to track the general health of their ecosystem but research experience to date suggests that existing ecosystem indicators can be difficult to interpret. In addition, many indicators require expertise in their calculation. Under the Marine Strategy Framework Directive, member states will have to report a range of indicators for Good Environmental Status, but these will be aggregated at large spatial-scales. At river basin scales a different set of indicators are already reported on under the Water Framework Directive.
Base maps	ICES Statistical rectangles and sub-rectangles	IFAs, IFGs, MPPs	High	Provides base gridded reference system for spatial aspects of management. Inshore fisheries data may need to be gridded to finer spatial scales.
	Admiralty charts	IFAs, IFGs	Medium	Perhaps of lower interest to IFAs and IFGs who have this information available from other sources.
		MPPs	High	Provides a lot of base detail information for spatial aspects of management, particularly in relation to navigation channels, marks and hazards.
	Bathymetry - Single and multibeam acoustics	IFAs, IFGs	Low - Medium	Provides base information for spatial aspects of management. Information on sediment types might be very useful but most high resolution acoustic data at present is just bathymetry.
		MPPs	Medium	Very useful for public dissemination of marine plans as provides a very strong visual impression of the underwater topography.
	Sediment maps	IFAs, IFGs, MPPs	Medium	Basic sediment mapping is based on interpolation from data on Admiralty charts. Newer maps are based on a combination of modelling from acoustics data and sampling (grabs and cores) or historical data. At present only available at high spatial resolution for small areas. Provides base information for spatial aspects of management but required levels of spatial resolution need to be determined and data improved.
	Predicted habitat maps	IFAs, IFGs, MPPs	Medium	Often based on models which combine bathymetry (depth, angle, rugosity), hydrodynamics (bed stress) and usually ground-truthed with sampling (often limited). Provides base information for spatial aspects of management but

Category	Aspect	Level of use	Usefulness	Justification
				required levels of spatial resolution need to be determined. Fishers in particular were rather sceptical about the accuracy of existing available habitat maps.
Oceanography	Observations	IFAs	High	Important for research into links between fisheries productivity and environment and for calibrating and testing hydrodynamic models. However, requires expertise to process and interpret raw observational data.
		IFGs	Medium	Interpreted observations e.g. summaries of trends in factors such as sea temperatures might be helpful in interpreting changes in fisheries data. However, care would need to be taken with making simplistic assumptions regarding links between environment and fish population/fisheries responses.
		MPPs	Medium	Interpreted observations e.g. trend summaries could be helpful in tracking issues such as changes in water quality – such interpreted trends are likely to be provided via organisations such as SEPA or from dedicated research projects.
	Hydrodynamic models	IFAs	High	Essential tools for research into habitat connectivity, pollutant dispersal, flood risk, sea level rise etc. However, requires expertise to process and interpret model outputs.
		IFGs	Low - medium	Interpreted outputs could be of potential use for understanding issues around connectivity of habitats. Also with regard to sediment transport and changes in the seabed in some areas.
		MPPs	Medium	Interpreted output will be of potential use for strategic planning with regard to flood risk, coastal defence, sediment transport, protection of spawning and nursery habitats etc.
Water quality	Water Framework Directive Ecological Status assessments	IFGs	Low - medium	Useful in relation to any problems with Shellfish Growing Waters. However, the WFD assessments themselves seem updated too infrequently for operational use by IFGs.
Marine Protected Areas	Defined	IFAs, IFGs, MPPs	High	Fishers will need to be aware of restrictions in protected areas which may affect their activities. IFAs will need to provide advice on fisheries aspects within MPAs.
	Proposed	IFAs, IFGs, MPPs	High	Fishers will need to be aware of potential future restrictions in protected areas which may affect their activities. IFAs will need to provide advice on fisheries aspects within MPAs.

Table 3: Data layers selected to be included in the Demonstration web-based Data Explorer

Data	Layer type	Update frequency
Coastline	Static, low memory demand	Infrequent
Admiralty charts for Clyde and Moray Firth	Static, low memory demand	Occasional - updated via Notices to Mariners
High resolution bathymetry (where available)	Static, high memory demand and pre-processing required	Infrequent but additional surveyed areas will become available over time
Nature conservation MPA boundaries	Static, low memory demand	Infrequent but restrictions on activities within MPAs may be updated periodically in line with management plans
Fishing vessel locations (fishing)	Dynamic, high memory demands, on-fly or pre-processing required	Frequent – in operational mode data would be updated at least monthly, possibly more frequently
Fisheries catch records	Dynamic, medium memory demands, on-fly or pre-processing required	Frequent – in operational mode would be updated at least monthly depending on methods used to collect and compile data from vessels
Fisheries catch-per-unit-effort records	Dynamic, medium memory demands, on-fly or pre-processing required	Frequent – in operational mode would probably be updated at least monthly depending on methods used to collect and compile data from vessels

Originally a further set of meetings had been planned with the IFGs, to take place during spring 2015, to demonstrate the data explorer and get feed-back from potential users. However, because of difficulties with setting convenient dates it was decided that evaluation of the web-based data explorer could be more efficiently undertaken using the internet.

A short video was therefore produced and uploaded to YouTube demonstrating the web-based explorer (https://www.youtube.com/watch?v=vFoSySbCClk) and this was linked to a feedback survey hosted on SurveyMonkey. A range of stakeholders, principally for the two pilot regions - Clyde and Moray Firth, selected in consultation with the project co-ordinators Kyla Orr and Ali McKnight, were invited by email to view the video, try the web-demo and give feedback via the survey.

Following the analysis of the survey results the findings were summarised in terms of how useful different the different data sources and visual representations might be for future inshore fisheries management.

Survey results

Overall 23 survey responses have been received. Although this is a low number in terms of conducting rigorous statistical analysis, the results received were quite informative.

The survey results are set out graphically in Table 4.

A summary of the responses is given below:-

1. The first set of questions (Q1 to 4) was designed to evaluate the respondees' interests, level of knowledge and to obtain general feedback on the approach we took to disseminating the demonstration web-viewer.
    - Overall there was a reasonable level of interest in the work package across a wide range of stakeholders, although no responses from NGOs were received. However, NGO respondees may have categorised themselves as members of another group e.g. a Marine Planning Partnership. Note here that no individual identifiers were collected due to the additional issues around Data Protection that this would have caused.
    - The majority of respondees classed themselves as being very experienced (>10 years) in the fields of inshore fisheries or marine planning.
    - Most users were able to access the data explorer website without problems but a minority of users did experience issues. We did ask for additional feedback on specific problems and one respondee indicated their system was slow, but did not provide further details (slow internet, slow PC or other issue). Feedback was received by email from one person who was unable to access any of the web resources for an un-specified reason. If the system were to be developed further then clearly additional user-testing would be required to investigate access problems across a range of platforms and internet connection speeds.
    - Over three-quarters of users found the video demonstration on YouTube helpful suggesting that this is quite an effective method for disseminating such information. One particular advantage over a Webinar is that the resources could be accessed at any time, rather than requiring users to log in at a specific date and time. Around one-fifth of respondees did not watch the video to the end, although no additional feedback comments were provided to explain why.

2. The second set of questions (Q5 to 9) was designed to obtain feedback on how useful users thought the specific static data layers we added to the demonstration web-viewer would be for inshore fisheries management.
    - In relation to the Marine Protected Areas layer in the demonstration, all respondees felt that this layer would be useful for fisheries management. Specific comments included that :-
        - It will be critical for fishers to be up to date and aware of where these emerging areas are located if they wish to actively demonstrate

responsible fishing practice. A tool such as this being easy to access and use would remove many of the obstacles to this.

- All Proposals (commercial, leisure & environmental) for use of the marine environment should be mapped so possible spatial conflict issues can be identified early and negotiations with the specific fishermen liable to be disrupted and displaced can be entered in to. Accurate and complete historical fishing data is also required to achieve this. On-going tracking will be useful for other purposes as stated in the video. This is an interesting point in that it refers to Proposals rather than just existing activities.
- One user commented that overlaying vessel activity data on an MPA layer could be counter-productive if you have no means of determining whether a vessel is fishing or not, how they are fishing, and for what species.

Perhaps the last comment was made before the respondee had examined the dynamic fishing activity filtering layer where this issue was explicitly dealt with.

- In relation to the Admiralty charts layer, respondees were less convinced of its importance for fisheries management but specific comments were divided. One respondee felt it would be an essential layer in relation to marine planning.
- In relation to the high resolution bathymetry, around a quarter of respondees did not feel (or were unsure) that this layer would be useful for fisheries management. However, another respondee pointed out that this layer provides valuable information on substrate type and topography which can often provide an indication of why, particularly static gear fishers, may target certain areas.
- In relation to the ScotMap layer, around a third of respondees thought it is essential. Specific comments included :-
    - Particularly for overfishing creels but need to include un-licenced fishermen during summer months.
    - While ScotMap provides information on fishing activity, it is merely a discrete snapshot, as fisheries are dynamic entities such data is less relevant than current/regularly updated data sets.

However, many of the comments pointed out deficiencies with ScotMap such as :-

- It is inaccurate, incomplete and out of date. That particular respondee, presumably representing an association proposed gathering plotter data from all of our members to provide accurate and complete historical data to prevent any more user licences being granted for areas where there will be disruption and displacement without proper consultation, mitigation, compensation etc. being agreed prior to consent.
- That the ScotMap data is shown at too large a scale (5 nm squares) and for some areas too incomplete and perhaps out of date to be really useful in local management issues, but is the best we have pending more data gathering.

- It is very broad scale, although not as bad as ICES squares, and does not cover all of Scotland. However, if you do not have real time vessel activity information (e.g. Succorfish units) then it is essential.

These comments do indicate an appreciation that ScotMap data are an intermediate step which needs improvement but that the layer will probably need to continue to be used until better data can be collected.

- The majority (around 80%) of testers felt that the ability to change the opacity of layers to allow blending was essential or useful. One respondee commented that it was particularly useful when trying to compare bathymetry with vessel tracks to check for patterns. One respondee pointed out that mixing some layers was easier than others e.g. enabling ScotMap and bathymetry at the same time; it is hard to make out which part refers to which setting. One respondee felt that it could be useful but it was not clear (from the demonstration?) in my mind why.

3. The third set of questions (Q10 to 14) was designed to obtain feedback in relation to the dynamic layers i.e. where the user was provided with tools allowing some control over which sub-sets of the data are displayed. The dynamic data layers we included in the demonstration were for data which might be collected from fishing vessels so a question about data sharing and confidentiality was also included (Q14).
   - Regarding the ability for users to filter dynamic data, around 80% of respondees felt it would be an essential or useful feature. Positive comments included :-
     - Particularly regarding gear conflict.
     - I imagine the majority of users will have requirement to tailor the data displayed, usually temporally.
     - One needs to know what gears are involved and where.
     - Suggest that the speed options should be set to e.g. stationary (0-0.5 knots); trawling (2-3 knots or whatever); steaming (>5 knots). May have to be specific to particular type of activity.
     - The more ways you can view the facts the better for informed decision making.
   - However, around 20% of respondees were not so convinced of the utility of this feature. Comments included :-
     - I think you will need more filters possibly. Also, why would you filter for speed to see fishing activity when you can simply use catch? Maybe I've missed the point here.
     - It all depends how many data are required for various types of gear etc. and how near 'real time' data are really required. I think the jury is still out on that. Surely it is more important to know aggregated data of recent years rather than real time for fisheries management? Real time data are more about enforcement / compliance with rules than stock management.

   The last comment illustrates some confusion which we may have created by using the term 'real-time data' – in fact the data displayed are aggregated over time but the time-period can be controlled by the user. If the system were to be developed further this is an area which would require more development attention and work with potential users.

- With regard to vessel track data, there was a little more uncertainty about how useful it would be. Around a third of respondees felt it would be either not be useful or were unsure. However, the additional comments do not provide much insight into why respondees felt it would not be useful information. Most comments supported its utility providing all vessels were providing data :-
    - Particularly useful regarding gear conflict.
    - Very useful as an indicator of fishing effort.
    - For future planning and management considerations is should be useful but I couldn't yet say how.
    - I also think it is essential for fisheries managers to have access to the raw vessel ping data. Without this, how do managers know if a vessel has breached a closed area while fishing or which vessels will be directly impacted by development applications? Knowing how many vessels, as well as pings, would also be beneficial on the current gridded map.

  The last comment is relevant, but only if bodies such as the IFGs were also to become responsible for enforcement.

- With regard to the total catch data layer, around 80% of respondees thought it would be useful or essential. Positive comments included :-
    - Very useful when used in conjunction with the vessel tracks layer.
    - Provided the data are displayed in appropriate layers e.g. for gear type, fish type / season etc. and at a reasonable resolution, which may be a challenge.
    - It will be needed when considering sustainable fishing matters including no-catch zones, diversity, re-stocking, nurseries etc.

  However, 20% felt it would not be useful. Possible reasons for the negative response included :-

    - It is not clear to me whether you really mean catch, or if you mean landings that were caught in that area, i.e. catch minus discards.
    - CPUE is more important.
    - It needs to be linked with vessel activity though.
    - This information is available to Marine Scotland already.

  The last comment is interesting in that it does demonstrate a misunderstanding of the spatial scales this information is presently collected at. Most persons this was discussed with felt that data for inshore fisheries management would need to be gathered at finer spatial scales compared with the spatial scales which catch data is presently collected at.

- With regard to the CPUE data layer, a slightly higher percentage (around 30%) of respondees were either unsure or felt this information would not be useful. Some of the comments indicate that CPUE is not well understood as a concept outside of fisheries management specialists :-

- Sorry, I'm not familiar with this term and would need to have it defined first to be able to offer a considered response.

Other respondees did feel measures of CPUE would be valuable :-

- Will be valuable in indicating areas where stocks may be being depleted, and therefore requiring constraints on fishing.
- This would be very useful information but requires more explanation. Especially whether your data in fact shows landings per unit of effort rather than catch per unit of effort. More easy-to-find specification of the unit of measurement would be useful.

- With regards to the issue of data sharing, around two-thirds of respondees felt that summary data should be publically available but that viewing access to the underlying individual vessel data should be restricted. However, around 20% of respondees felt that even summary data should only be visible to restricted groups, such as the IFGs. This question attracted a large number of comments including :-
  - My experience of fishermen is that they are wary of allowing traceability of data, and many will struggle to agree to make any data available about the areas they find most productive
  - I think all data should be freely available but not to the extent where it may impinge on an individual's right to privacy.
  - I think it is unrealistic to expect that making data available online to a broad group will lead to that data never being seen by people outside that group. If you make it available to a broad group then it should be considered public.
  - I think you really cannot make individual vessel data publicly available. This question requires detailed consideration and discussion with vessel owners and operators, allowing them to see examples of what different levels would mean in practice.
  - commercial confidentiality must be observed to avoid giving away someone's specific fishing position linked to catch data
  - It's a public resource, so the public should know.
  - What's the sense in all this when MS ignore the fishing and do what the quangos like SNH and the greens dictate to them.
  - This level of data will be essential but should only be available to genuine fishery managers, e.g. IFG's (or future equivalent) and Marine Scotland who would then decide what to share with other stakeholders. This tool will be invaluable in policing MPA's for example.
  - When discussing offering up our plotter data, our members will not do it if their proprietary data is made openly available. If investor owned vessels and pirates from outwith our fishery can identify where we are being most successful, they'll come in and plunder stocks. We self-police conservation and nobody is allowed to over fish an area. Given the current membership of the East Coast IFG, we would only allow Marine

Scotland to use our data to cause rival marine users to enter in to negotiations with the fishermen affected to mitigate spatial conflict.
  - I found the wording of this question difficult to answer re what is "Non publically" available and knowing who the user group will be.
  - Not sure who would be controlling and using the background data? Fishermen could presumably ask for their own data, but not sure if all CPUE/Catch data per vessel should be publicly accessible.
  - How is this data resource expected to tie into NMPi? I presume this will go to a smaller scale and have more spatial detail than NMPi
  - It should be the top option (all publically available) but I don't think you will get buy-in from fishers with that. The middle option is what is currently available through Marine Spatial Planning and VMS.

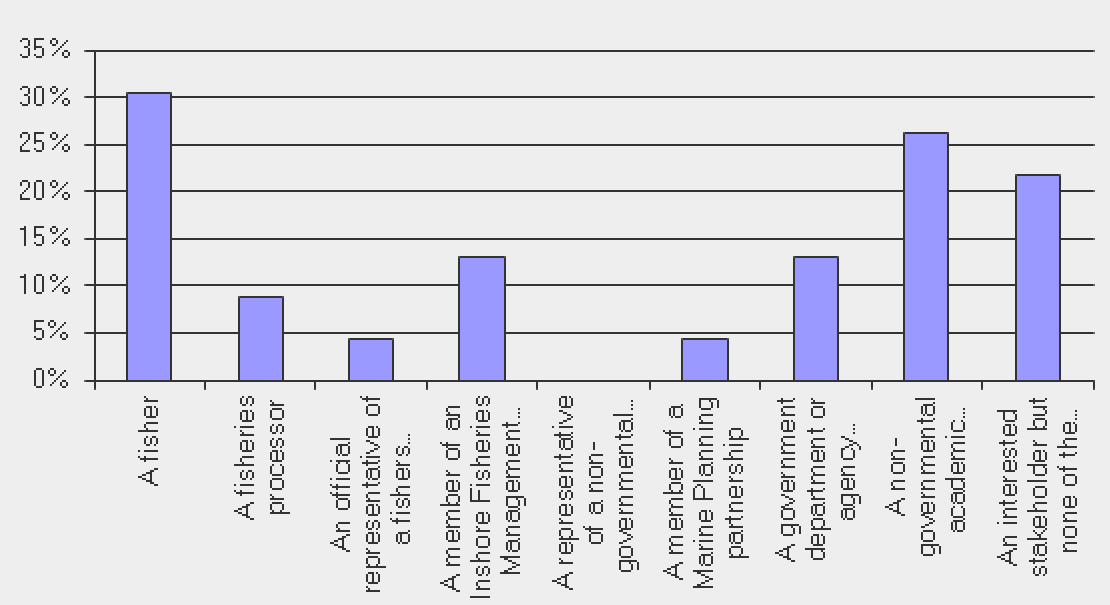
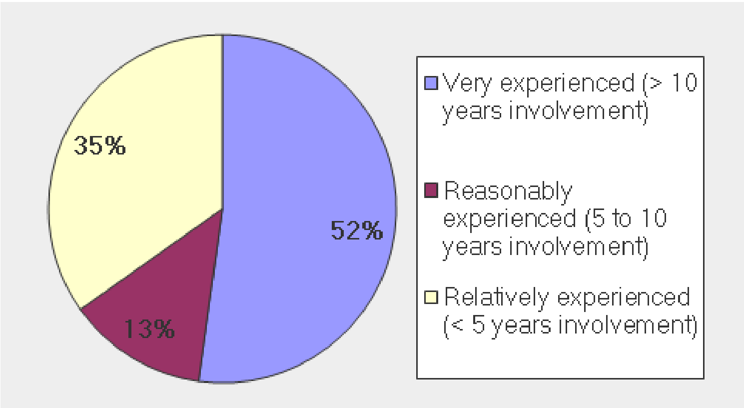
As anticipated this proved to be a contentious issue and is clearly one which would require careful attention if an operational system were to be developed for inshore fisheries management.

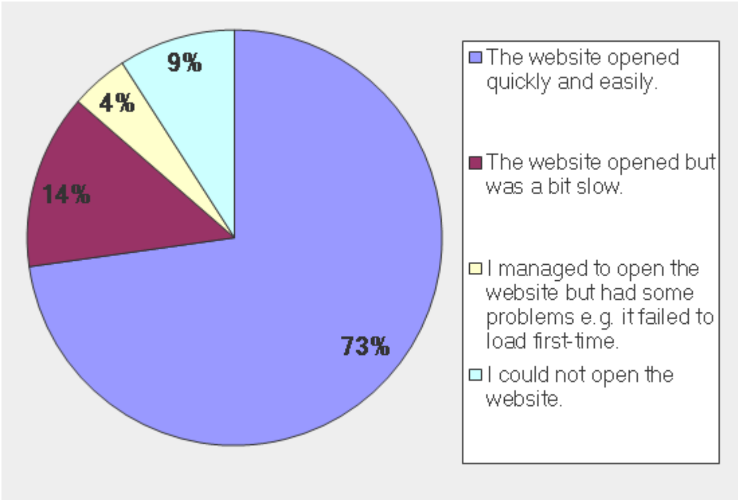
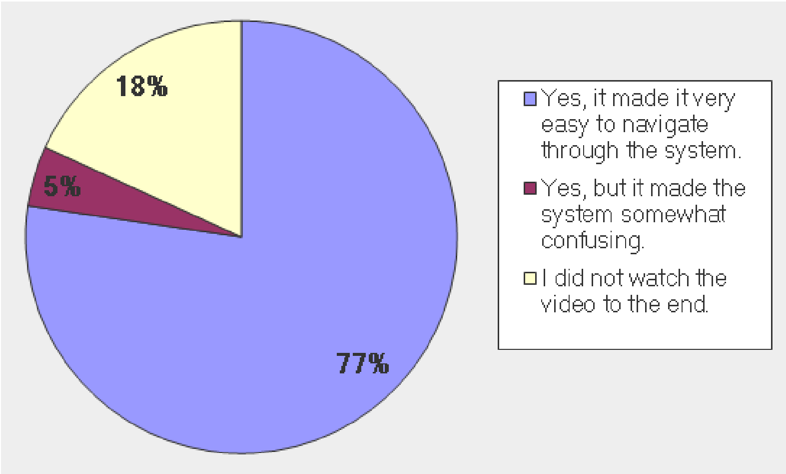
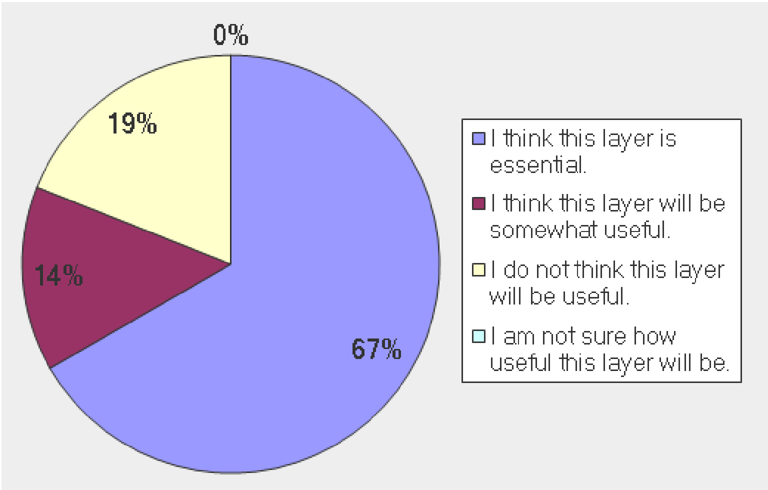
4. The last set of questions (Q15-19) was designed to seek feedback on possible future developments for data visualisation, including links with NMPI.
   - Only around half of testers completed the ranking of future features question (email feedback indicated some testers had problems with getting this particular question's style to work). However, based on limited feedback received, respondees felt that additional data displays relating to how fish catches change over time and mapping of sensitive habitats would be most useful.
   - Additional comments from respondees included :-
     - It may well be that future effort may well have to be devoted to getting all the fishermen and their representatives on board rather than to further refinements.
     - An indicator of average sea state for the period of reference as this could potentially have a major impact on fishing effort.
     - Ability to see tracks of vessels from various home ports. Ability to filter the vessels by size. Where you have type I think you mean type of gear at present.
     - Links to relevant documentation and reports perhaps for localised areas.
     - Currents
     - People
     - Seasonal/timing closure data - would be clearer if vessels were potentially using areas outside agreed times.
     - From experience, habitat types are rarely correct although they can point you in the right direction with regards sensitive habitats.
     - It would be of even more value if it could link to the literature database by clicking in a position and it bringing up the relevant recent publications.

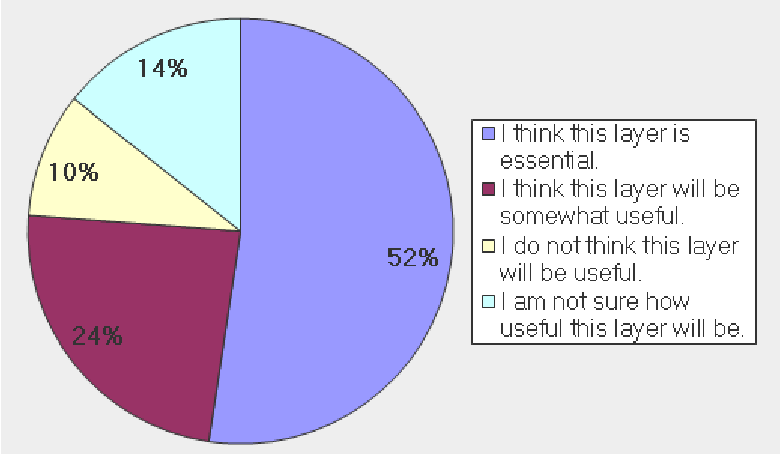
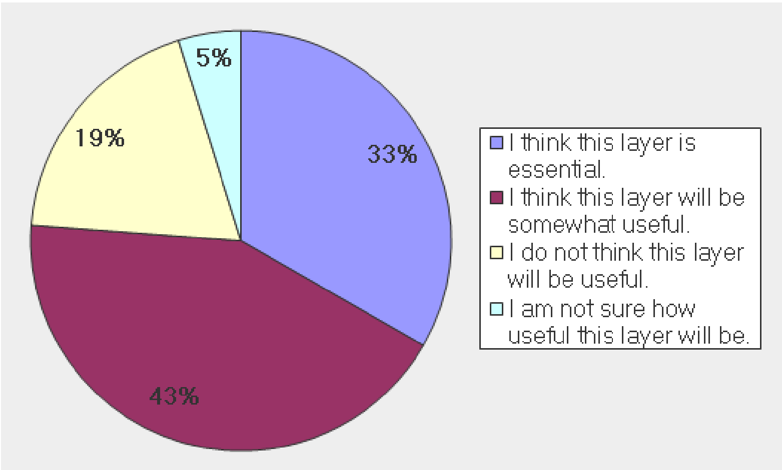
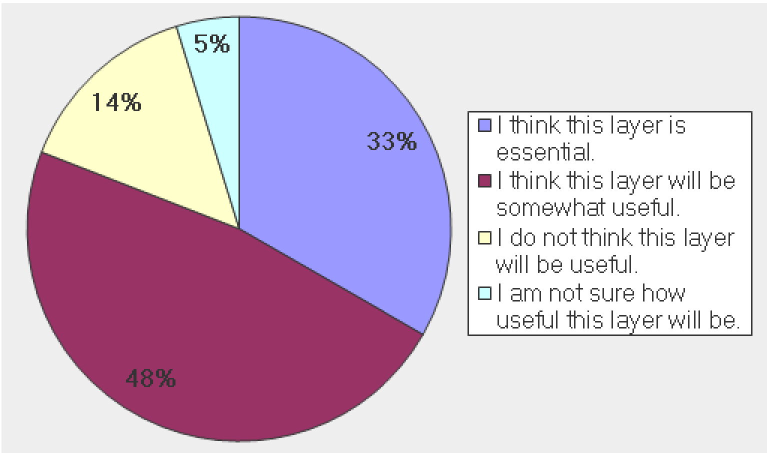
   - The last few questions were designed to get feedback from respondees regarding NMPI and whether they felt the Inshore Fisheries Data Explorer should be incorporated, in some way, into that system.

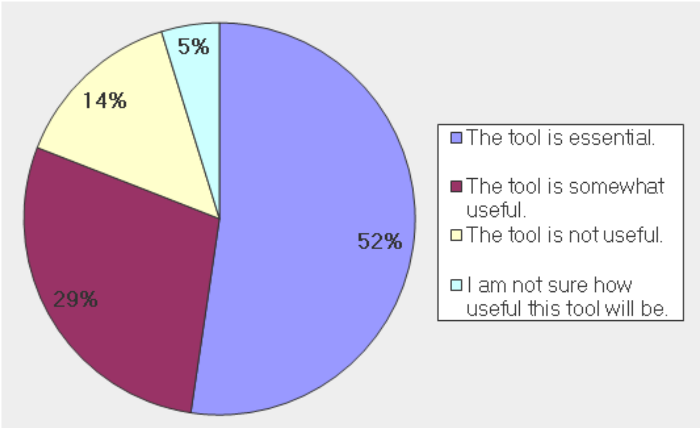
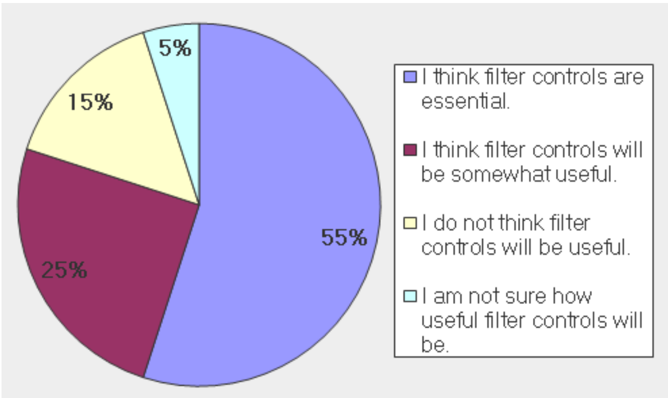
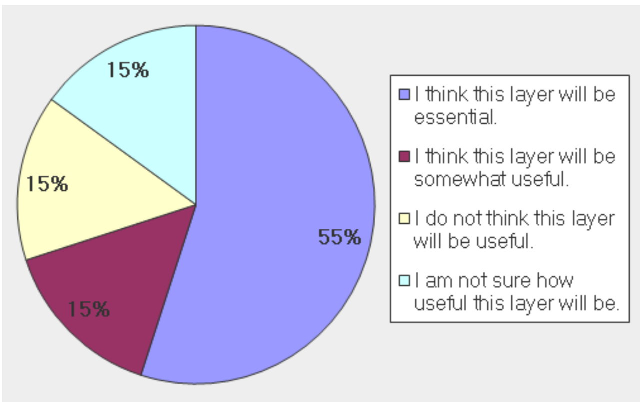
- Around 60% of respondees were familiar with NMPI but around 30% had not heard about it at all.
- When asked if it would be useful to incorporate Dynamic layers, as demonstrated in the Inshore Fisheries Data Explorer, into NMPI, around 80% of respondees felt it would be quite useful. However, only 11% felt it was essential. This may reflect a potentially slightly different user group for NMPI, which is really aimed at marine planning, as compared with the Inshore Fisheries Groups. The issue of whether NMPI could provide a 'one-stop shop' for the data required for both marine planning and inshore fisheries management clearly requires more exploration.

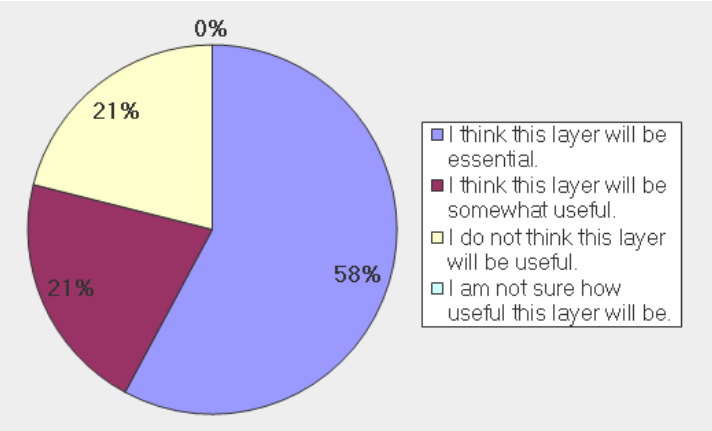
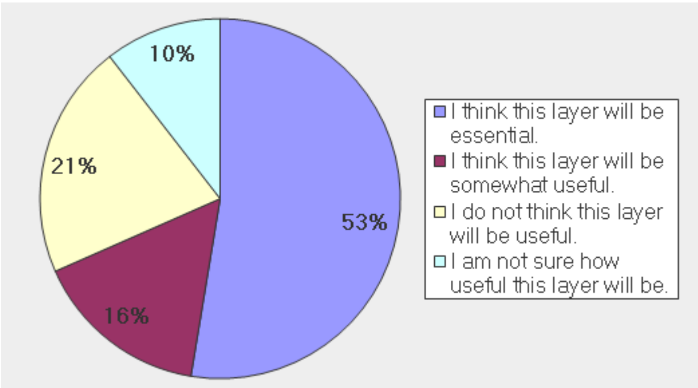
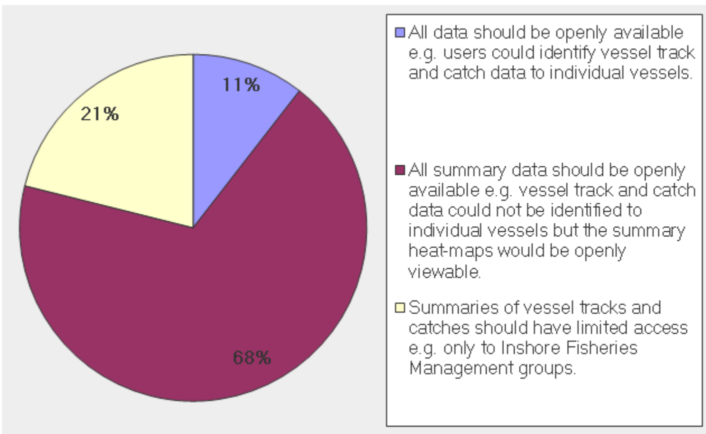
Table 4: Summary of the responses to the survey on user experience with the inshore fisheries data explorer

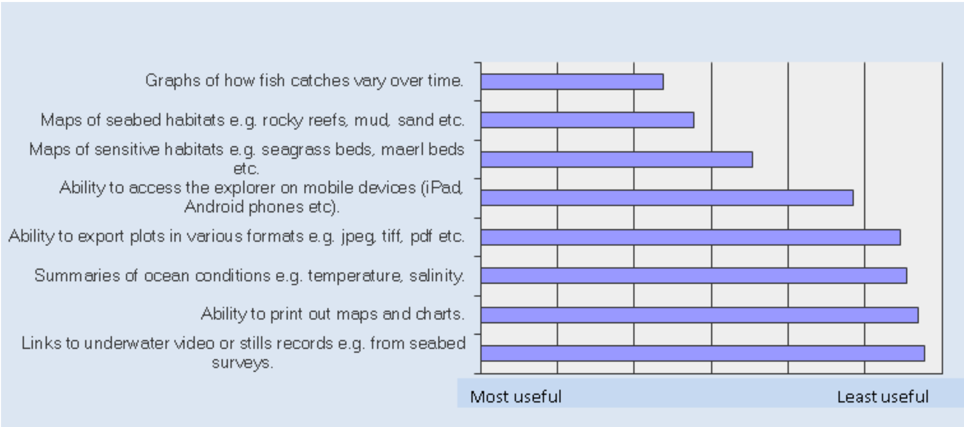
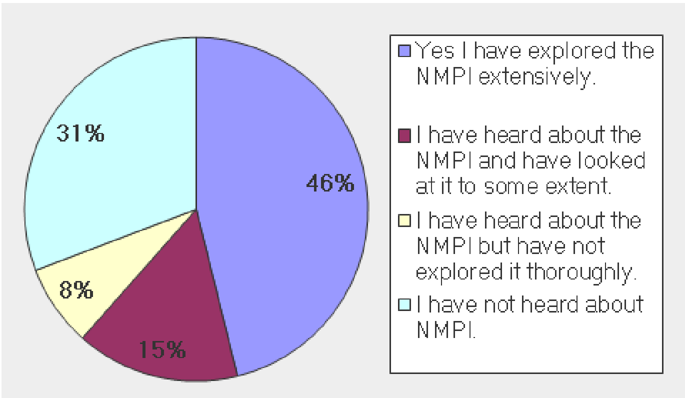
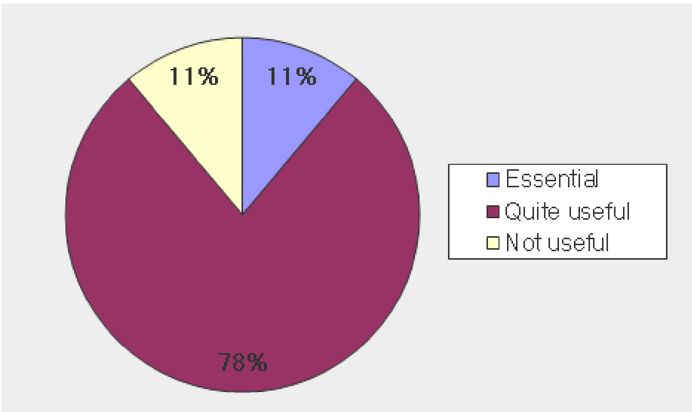
Question set 1 – General information	
Q1: I am responding as 	
Q 2: Please give a rough estimate of your level of experience in inshore fisheries or marine planning	

Q3: Did you find it easy to open the inshore fisheries data explorer?	
Q4: Did you find the video demonstration useful?	
Question set 2 – Static data layers	
Q5: Do you think that the marine protected areas map layer will be useful for inshore fisheries management?	

Q6: Do you think that the Admiralty charts layer will be useful for inshore fisheries management?	
Q7: Do you think that the high resolution bathymetry layer will be useful for inshore fisheries management?	
Q8: Do you think that the ScotMap layer will be useful for inshore fisheries management?	

Q9: How useful did you find the blending layers tool (opacity sliders)?	
Question set 3 – Dynamic data layers	
Q10: Thinking about the dynamic layers (vessel tracks and catch data), how useful do you think the ability for users to filter the data for viewing will be for inshore fisheries management?	
Q11: How useful do you think the vessel tracks layer will be for inshore fisheries management?	

Q12: How useful do you think the total catch layer will be for inshore fisheries management?	
Q13: How useful do you think the catch per unit effort layer will be for inshore fisheries management?	
Q14: In terms of what non-publically available data a user can view, do you think it is important for effective fisheries management that	

Question set 4 – Future developments	
Q15: Testers were asked to rank a number of potential future features	
Q16: Are you familiar with NMPI?	
Q17: National Marine Planning Interactive - NMPI presently displays static layers such as Marine Protected Areas but how useful for inshore fisheries management do you think it would be if NMPI could display dynamic data such as vessel tracks?	

Conclusions

- Based on survey feedback, the inshore fisheries data explorer was successful in terms of engaging the Clyde and Moray Firth IFGs and wider Advisory Groups with the range of data which might be needed to underpin Inshore Fisheries Management.
- Based on survey feedback, the work package was also successful in prompting the Clyde and Moray Firth IFGs to begin thinking about the types of data which they will need to operationalise inshore fisheries management in their areas.
- The concept that IFGs and MPPs could be actively involved in working with inshore fisheries data, through an interactive visualisation tool, seemed to be attractive to them.
- As expected, issues around the confidentiality of fisheries data were quite contentious. This had been anticipated in this work package and the web-based data explorer included log-in access control capabilities, although these were disabled in the demonstration for ease of use.
- Dummy fishing vessel location and catch data were used in this work package as real data from Work packages 1 and 3 were not available in time. Incorporating real data into the underlying database used in the Fisheries Data Explorer should be relatively straight-forward but might lead to further technical issues (see Part 4 of this report for details). In particular, the robustness and speed of the Data Explorer would need thorough testing when challenged with very large datasets. Internet users are generally intolerant of slow screen load times and thorough testing across a range of platforms and connection speeds would be required. This is especially relevant for remote rural locations where high-speed internet access may not be available. Further IT development work would be required to achieve acceptable delivery speeds for data visualisations, particularly across slower networks.
- If an operational system were to be developed, further work would be required to optimise the data streams and required pre-processing. Further work would also be required to optimise the user-experience. Based on survey feedback, potential users saw value in additional visualisations of some types of data as time-series graphs in particular. Issues around data confidentiality would need to be resolved and a robust control system for data security implemented. An iterative development cycle involving close consultation and testing with both data suppliers, software engineers and proposed user groups, as adopted in this Work Package, is recommended.
- Users saw some benefit in incorporating the dynamic-data tools demonstrated in this work package into the Scottish Government's marine planning visualisation system, NMPI. However, the spread of survey feedback suggested that testers were not entirely convinced that a 'one-shop stop' for both inshore fisheries management and marine planning would be an effective solution.
- The main challenge to further development of this form of interactive data management and visualisation for inshore fisheries is that it is presently unclear exactly how Inshore Fisheries Management will be delivered within Scotland.

Part 4: A demonstration web-viewer for data of potential interest to inshore fisheries management

Contents

Versions

Date	Version	Name	Description
28-01-2015	0.1	Lovro	Document created
01-04-2015	0.2	Lovro	Document framework created
14-04-2015	0.3	Lovro	Introduction and code sections created
21-04-2015	0.4	Lovro	Admiralty charts and Bathymetry layer write-up
29-04-2015	0.5	Lovro	Protected areas write-up
30-04-2015	0.6	Lovro	Vessel data write-up
31-04-2015	0.7	Lovro	Catch data write-up
19-06-2015	0.8	Lovro	Web and file section write-up
23-06-2015	1.0	Lovro	Code section updates

Introduction

This document describes the process of taking the raw data from this project and turning them into layers on the Data Explorer web app. Each section consists of the description of the raw data (see full report for more details and metadata), the processing that was needed to prepare the raw data for our web app, as well as the technique needed to display the data in the web app.

Protected Areas

Source data

Source data for this layer was provided in ASCII text-file format of marine protected area boundary co-ordinates (list of lat, lng pairs).

Processing

Input data files were processed and combined into one JSON dictionary and prepared for rendering as polygons on the map. In addition to the boundary data, each protected area in this JSON dictionary was also described with a name and a description field.

PROTECTED AREAS: JSON DATA FORMAT


```
{
    "1": {
        "group": "pa",
        "description":  "<p><b>Area  designated  as  Site  of  Special  Scientific
Interest.<\/b><\/p><p><b>Bar-tailed godwit<\/b> (Limosa lapponica), <b>Redshan
k<\/b>  (Tringa  totanus),  <b>Wigeon<\/b>  (Anas  penelope),  <b>Whooper  swan<\/b>  (Cygnus
cygnus), <b>Red-breasted merganser<\/b> (Mergus serrator).<br><b>Saltmarsh, Mudfla
ts, Sandflats<\/b>.<\/p>",
        "title": "Cromarty Firth, SSSI",
        "color": "#7FC23B",
        "line": "solid",
        "polygons": [
            {
                "color": "#7FC23B",
                "line": "solid",
                "poly": [
                    [
                        [
                            "-4.399732017",
                            "57.595516828"
                        ],
                        [
                            "-4.399698805",
                            "57.595517459"
                        ],
                        [
                            "-4.399633354",
                            "57.595533458"
                        ],
                        [
                            "-4.399552134",
                            "57.595585187"
                        ],
 END SO ON...
```


Display

In order to display the protected area polygons with their name labels and descriptions, AJAX is used to load JSON data from previous step into JavaScript objects. Polygons, labels and info window objects are used to render the protected area layer to the map.

PROTECTED AREAS: JSON TO MAP

```
/* Generate Protected Area Polygons */

        function setProtecedArea(id, area_data) {
```

```
  var info_window = new google.maps.InfoWindow({content: ''});

  var bermudaTriangle = null;

  var mapLabel = null;

                var linePath = [];

  var len1 = 0;

  var tmpobj2 = [];

                var bounds1 = new google.maps.LatLngBounds();

  var area_title = area_data["title"];
  var area_description  = area_data["description"];
  var len2 = 0;
                                var area_color = null;
                                var area2_paths = null;
                                var area2_path = null;
                                var linePaths = null;
                                var len1 = null;

  $.each(area_data["polygons"], function( j, area2 ) {
        area_color = area2["color"];
        area2_paths = area2["poly"];
        linePaths = [];
        len1 = area2_paths.length;

        bounds1 = new google.maps.LatLngBounds();

                                        for (j = 0; j < len1; j++) {

                                        linePath = [];
                                        area2_path = area2_paths[j];
                                        len2 = area2_path.length;

                                            if(j == 0) {
                                                for (i = 0; i < len2; i++) {
                                                                linePath.push(
                                                                        new
google.maps.LatLng(area2_path[i][1],area2_path[i][0])
                                                                );
                                                                bounds1.extend(new
google.maps.LatLng(area2_path[i][1],area2_path[i][0]));
                                                }
                                            } else {
                                                /*for (i = (len2-1); i >= 0; i--) {*/
      for (i = 0; i < len2; i++) {
                                                                linePath.push(
                                                                        new
google.maps.LatLng(area2_path[i][1],area2_path[i][0])
                                                                );
                                                }
                                            }
                                            linePaths.push(linePath);
                                        }


        ProtectedAreasOpacityBorder = (ProtectedAreasOpacity + 0.2);
        if(ProtectedAreasOpacityBorder > 1) ProtectedAreasOpacityBorder = 1;

        var center = bounds1.getCenter();
        area_color = "#EE2F24";
        // Construct the polygon.
        bermudaTriangle = new google.maps.Polygon({
          paths: linePaths,
          strokeColor: area_color,
          strokeOpacity: ProtectedAreasOpacityBorder,
          strokeWeight: 1,
          fillColor: area_color,
          fillOpacity: ProtectedAreasOpacity
        });
```

```
        bermudaTriangle.setMap(map);

        try {

   mapLabel = new MapLabel({
        text: area_title,
        position: center,
        map: map,
        fontSize: 9,
        minZoom: 10,
        align: 'center'
   });
   mapLabel.set('position', center);
        } catch(err) {
   document.getElementById("demo").innerHTML = err.message;
        }
        tmpobj2.push([bermudaTriangle, mapLabel]);
        //map.fitBounds(bounds1);

        bindPolyInfoWindow(bermudaTriangle,      map,      info_window,      area_title,
area_description);

        /*google.maps.event.addListener(bermudaTriangle, 'click', function(event) {
      placeInfoW(event.latLng);
      map.set('disableDoubleClickZoom', false);
        });*/

  });

        ActiveProtectedAreas[id] = tmpobj2;

 }

 /* Show/Hide/Call Generate Protected Area Polygons  */
 function buildProtectedAreas() {

        if($.map(ActiveProtectedAreas, function(n, i) { return i; }).length > 0) {
  $.each(ActiveProtectedAreas, function(ai, polyobjects ) {
        $.each(polyobjects, function(aij, polyji ) {
   polyji[0].setMap(map);
   polyji[1].set('minZoom', 10);
        });
  });
        } else {

  $.each(ProtectedAreas, function( area_id, area ) {
        setProtecedArea(area_id, area);
  });
        }

 }

 /* Load Protected Areas JSON Data from file */
 function loadProtectedAreas($do_build) {


        if($do_build == null) $do_build = true;

        if(ProtectedAreas != null && $do_build == true) {

  buildProtectedAreas();

        } else {
  url = "views/pa2.php";
        $.ajax({
        type: 'GET',
        url: url,
        data: {},
        dataType: 'json',
        timeout: 152000,
        success: function(objdata){

        ProtectedAreas = objdata;
```

```
        activateProtectedAreaPolySlider();
        if($do_build == true) { buildProtectedAreas(); }
        else { enableDisableProtectedAreasControlles(); }

        },
        error: function(xhr, type){

        },
        beforeSend: function(xhr, type){
        if($do_build == true) { $("#ajax-process").show(); }
        else {

$("#protected_area_poly_info").html("<br>      loading...");
        }
        },
        complete: function(xhr, type){
        if($do_build == true) { $("#ajax-process").hide(); }
        else {
      $("#protected_area_poly_info").html("");
        }
        }

        });
        }
 }
```

Admiralty Charts

Source data

Admiralty charts were provided as large geoTIFF raster image files.

Processing

Source images were first re-projected from WGS84 World Mercator (EPSG:3395) to WGS84 Web Mercator (EPSG:3857).

Since the resulting images were too large to load directly into the web app interface, they were tiled for map display purposes. During this process, a set of 256x256 pixel images (tiles) were made for each zoom level of the web map, using the following tools: Gdal and Gdal2tiles.

Sample code to re-project and convert raster file **2724-0_W.tif** to a set of tiles is listed below.

ADMIRALTY: RASTER TO TILES

```
gdal_translate -of vrt -expand rgba 2724-0_W.tif 2724-0_W_1.vrt

gdalwarp  -s_srs "EPSG:3395" -t_srs "EPSG:3857" 2724-0_W_1.vrt 2724-0_W_2.tif

gdal2tiles.py -z 1-13 --resume 2724-0_W_2.tif
```

Display

The resulting set of image tiles is loaded into Google Maps using the following JavaScript code.

ADMIRALTY: TILES TO MAP

```
     /* Config Array */
     var OverlaysConfig = {
            'hydro':{'name':'Hydro     Layer','source':'views/hydro_layer','opacity':0.6,
'level':'0','coordinate':'google', colorbar:{}},
            'hydro2':{'name':'Hydro Layer 2','source':'views/hydro_layer2','opacity':0.6,
'level':'1','coordinate':'google', colorbar:{}}
  };

        /* Define map colorbar element holder */
        function defineMapLegend() {
            var map_legend = $('#map_legend');
            var legend = document.getElementById('map_legend');

            if(map_legend.css('display') != 'none') {

            } else {
                map.controls[google.maps.ControlPosition.LEFT_BOTTOM].push(legend);
                map_legend.css({'bottom':'45px','display':'block'});
            }
        }


        /* Create layer colorbar */
       function setLayerColorbar($overlayid, $visible) {

            var $ovcfg = OverlaysConfig[$overlayid];
            var colorbar_cfg =  $ovcfg['colorbar'];
```

```
            if(Object.keys(colorbar_cfg).length <= 0) return;

        defineMapLegend();

            if(!OverlaysElements[$overlayid]) {

                var   $colorbar1   =   "<div   id='"   +   $overlayid   +"_colorbar'
style='padding:2px  4px  2px  4px;'><img  width='300'  src='"  +  $ovcfg['source']  +  "/"  +
colorbar_cfg['img'] + "' border='0' /></div>";
                $("#map_legend").append($colorbar1);
                OverlaysElements[$overlayid] = $("#" + $overlayid + "_colorbar");

            } else {
                if($visible == false) {
                   OverlaysElements[$overlayid].hide();
                } else {
                   OverlaysElements[$overlayid].show();
                }
            }


        }

        /* Link tiles to Google Map */
        function generateOverlayObject($overlaycfg) {

            globalfoovar = new google.maps.ImageMapType({
               getTileUrl: function(tile, zoom) {
                   if($overlaycfg["coordinate"]    &&    $overlaycfg["coordinate"]    ==
"openlayer") {
                       y2 = (Math.pow(2,zoom)-tile.y-1)
                   } else {
                       y2 = tile.y;
                   }
                   return $overlaycfg["source"] + "/" + zoom + "/" + tile.x + "/" + y2
+".png";
               },
               tileSize: new google.maps.Size(256, 256),
               opacity:$overlaycfg["opacity"],
               isPng: true
           });

           //map.overlayMapTypes.push(null);
           return globalfoovar;

        }

        /* Show/Hide Layer Tiles on map */
        function setOverlayObject($overlayid, $visible) {

          var $ovcfg = OverlaysConfig[$overlayid];


          if(!Overlays[$overlayid]) {
              Overlays[$overlayid] = generateOverlayObject($ovcfg);
          }

          if($visible == true) {
            map.overlayMapTypes.setAt($ovcfg["level"],Overlays[$overlayid]);
          } else {
            map.overlayMapTypes.setAt($ovcfg["level"],null);
          }

          setLayerColorbar($overlayid, $visible);

        }
```

Bathymetry

Source data

Data was provided as a set of ASCII data files containing the following fields: Latitude, Longitude, Depth.

Processing

Input vector data files were processed into a 2D raster surface using Python programing language, using the following libraries: Matplotlib, Basemap, and Numpy.

Each point on the map was rendered using the scatter plot method, resulting in a raster image file, using the following code:

BATHYMETRY: VECTOR TO RASTER CONVERSION

```
#!/usr/bin/python
# -*- coding: utf-8 -*-

import MySQLdb
import os
import sys
import time
import commands
import math
from decimal import *
from datetime import datetime, timedelta
import datetime
from mpl_toolkits.basemap import Basemap
import numpy as np
import matplotlib.pyplot as plt

#script start
db_name = "bathymetry"
tbl_name = "clyde2"

#plot section
section = {  'ul':[-4.9, 55.99],
             'll':[-4.9, 55.95],
             'ur':[-4.8, 55.99],
             'lr':[-4.7, 55.95]};

#width and height of image
dimension = [2000,1000];

#image dpi
my_dpi = 300

db = MySQLdb.connect(host="localhost",
                     user="root",
                      passwd="root",
                      db=db_name)

cur = db.cursor()
try:
       sql_str = "SELECT * FROM " +  tbl_name +" WHERE lat>=" + str(section["lr"][1]) +" AND lat<=" + str(section["ul"][1]) +" AND lng>=" + str(section["ul"][0]) +" AND lng<=" + str(section["lr"][0]) + " ORDER BY lat ASC, lng ASC";
       cur.execute(sql_str)
except MySQLdb.Error, e:
    try:
        print "MySQL Error [%d]: %s" % (e.args[0], e.args[1])
    except IndexError:
        print "MySQL Error: %s" % str(e)
       pass

cm = plt.cm.get_cmap('spectral')
```

```
fig = plt.figure(figsize=(dimension[0]/my_dpi, dimension[1]/my_dpi), dpi=my_dpi)

x = [];
y = [];
z = [];

for row in cur.fetchall():

        lat1 = float(row[0])
        lng1 = float(row[1])
        x.append(lng1)
        y.append(lat1)
        z.append(float(row[2]))


xmin,xmax = min(x), max(x)
ymin,ymax = min(y), max(y)

image_section = {
 'ul':[xmin,ymax],
 'll':[xmin,ymin],
 'ur':[xmax,ymax],
 'lr':[xmax,ymin]
 }

llcrnrlat1 = image_section["ll"][1]
llcrnrlon1 = image_section["ll"][0]
urcrnrlat1 = image_section["ur"][1]
urcrnrlon1 = image_section["ur"][0]

#define basemap area
m         =         Basemap(projection='merc',lat_ts=0,resolution='f',llcrnrlat=llcrnrlat1,
llcrnrlon=llcrnrlon1, urcrnrlat=urcrnrlat1, urcrnrlon=urcrnrlon1)

#plot data set
x1, y1 = m(x, y)
m.scatter(x1, y1, marker=',', c=z, s=1, alpha=1, edgecolors='None', cmap=cm)

#save plot as png image
plt.savefig(tbl_name    +'_dpi'    +         str(my_dpi)    +'.png',    transparent=True,
bbox_inches='tight', pad_inches=0, dpi=my_dpi)

print image_section

db.close()
```

Display

Since the resulting surface raster image was too large to load directly into the web map interface, the resulting image was tiled for map display purposes. During this process, a set of 256x256 pixel images (tiles) were made for each zoom level of the web map, using the following tools: Gdal and Gdal2tiles.

Sample code to convert raster file **clyde_section_dpi300.png** to a set of tiles is listed below. Output is a set of folders with a set of tiles for each zoom level.

BATHYMETRY: RASTER TO TILES

```
gdal_translate -of VRT -a_srs EPSG:4326 -gcp 0 0 -4.899997471 55.989938135 -gcp 1800 0 -
4.725686  55.989938135  -gcp  1800  736  -4.725686  55.950012746  clyde_section_dpi300.png
clyde_section_dpi300_t1.vrt

gdalwarp -of VRT -t_srs EPSG:4326 clyde_section_dpi300_t1.vrt clyde_section_dpi300_t2.vrt

gdalwarp   -of   VRT   -s_srs   EPSG:4326   -t_srs   EPSG:3857   clyde_section_dpi300_t2.vrt
```

```
clyde_section_dpi300_t3.vrt

gdal2tiles.py -p mercator -z 1-13 clyde_section_dpi300_t3.vrt
```

The resulting set of image tiles is loaded into our web app using the following JavaScript code snippet.

BATHYMETRY: TILES TO MAP

```
     /* Config Array */
      var OverlaysConfig = {
            'clyde_surface':{'name':'Clyde                                        Surface
Layer','source':'views/clyde_surface','opacity':1.0,
'level':'4','coordinate':'openlayer',
           colorbar:{'width':400,'height':84,'img':'colorbar.png','offset':10}},
            'moray_surface':{'name':'Moray                                        Surface
Layer','source':'views/moray_surface','opacity':1.0,
'level':'5','coordinate':'openlayer',
          colorbar:{'width':400,'height':76,'img':'colorbar.png','offset':94}}

 };


        /* Define map colorbar element holder */
        function defineMapLegend() {
            var map_legend = $('#map_legend');
            var legend = document.getElementById('map_legend');

            if(map_legend.css('display') != 'none') {

            } else {
                map.controls[google.maps.ControlPosition.LEFT_BOTTOM].push(legend);
                map_legend.css({'bottom':'45px','display':'block'});
            }
        }


        /* Create layer colorbar */
        function setLayerColorbar($overlayid, $visible) {

            var $ovcfg = OverlaysConfig[$overlayid];
            var colorbar_cfg =  $ovcfg['colorbar'];

            if(Object.keys(colorbar_cfg).length <= 0) return;

        defineMapLegend();

            if(!OverlaysElements[$overlayid]) {

                 var    $colorbar1    =    "<div    id='"    +    $overlayid    +"_colorbar'
style='padding:2px  4px  2px  4px;'><img  width='300'  src='" + $ovcfg['source'] + "/" +
colorbar_cfg['img'] + "' border='0' /></div>";
                 $("#map_legend").append($colorbar1);
                 OverlaysElements[$overlayid] = $("#" + $overlayid + "_colorbar");

            } else {
                if($visible == false) {
                   OverlaysElements[$overlayid].hide();
                } else {
                   OverlaysElements[$overlayid].show();
                }
            }


        }

        /* Link tiles to Google Map */
        function generateOverlayObject($overlaycfg) {
```

```
            globalfoovar = new google.maps.ImageMapType({
               getTileUrl: function(tile, zoom) {
                   if($overlaycfg["coordinate"]     &&     $overlaycfg["coordinate"]     ==
"openlayer") {
                       y2 = (Math.pow(2,zoom)-tile.y-1)
                   } else {
                       y2 = tile.y;
                   }
                   return $overlaycfg["source"] + "/" + zoom + "/" + tile.x + "/" + y2
+".png";
               },
               tileSize: new google.maps.Size(256, 256),
               opacity:$overlaycfg["opacity"],
               isPng: true
           });

           //map.overlayMapTypes.push(null);
           return globalfoovar;

        }

        /* Show/Hide Layer Tiles on map */
        function setOverlayObject($overlayid, $visible) {

          var $ovcfg = OverlaysConfig[$overlayid];


          if(!Overlays[$overlayid]) {
              Overlays[$overlayid] = generateOverlayObject($ovcfg);
          }

          if($visible == true) {
            map.overlayMapTypes.setAt($ovcfg["level"],Overlays[$overlayid]);
          } else {
            map.overlayMapTypes.setAt($ovcfg["level"],null);
          }

          setLayerColorbar($overlayid, $visible);

        }
```

ScotMap data

Source data

Source data was provided in TIFF format.

Processing

Source raster data files were of relatively low resolution (as compared to other raster datasets in this project). They were manually cropped and geo-referenced using raster image editor (Gimp) before they could be placed on the map.

Display

Due to their small size, these images were directly placed on the map as image overlays.

SCOTMAP: RASTER TO MAP

```
function lydenephropstrawlOverlays() {


        var clydenephropstrawlBounds = new google.maps.LatLngBounds(
         new   google.maps.LatLng(54.845571817,   -6.239355321),   //South   West   coordinates
(down,left)
                                           new   google.maps.LatLng(56.403647262,   -4.090970281)
//North East coordinates (up,right)
                                   );

        var moraynephropstrawlBounds = new google.maps.LatLngBounds(
         new google.maps.LatLng(57.276498661, -4.085574737), //South West coordinates
                                           new   google.maps.LatLng(59.224092968,   -1.400086693)
//North East coordinates
                                   );

                var clydenephropstrawlImage = "views/overlay/ClydeNephropsTrawlNumber.png";
                var moraynephropstrawlImage = "views/overlay/MorayNephropsTrawlNumber.png";

        var                           clydenephropstrawlColorbar                               =
"views/overlay/ClydeNephropsTrawlNumber_colorbar.png";

        Overlays['clydenephropstrawl'] = new google.maps.GroundOverlay(
                clydenephropstrawlImage,
                clydenephropstrawlBounds
                );

        Overlays['moraynephropstrawl'] = new google.maps.GroundOverlay(
                                                    moraynephropstrawlImage,
                                                  moraynephropstrawlBounds
                );

        Overlays['clydenephropstrawl'].setOpacity(0.8);
        Overlays['moraynephropstrawl'].setOpacity(0.8);

        google.maps.event.addListener(Overlays['clydenephropstrawl'],             'mousemove',
function(event) {
         google.maps.event.trigger(map, 'mousemove', event);
        });

        google.maps.event.addListener(Overlays['clydenephropstrawl'],              'mouseout',
function(event) {
         google.maps.event.trigger(map, 'mouseout', event);
        });

        google.maps.event.addListener(Overlays['moraynephropstrawl'],             'mousemove',
function(event) {
         google.maps.event.trigger(map, 'mousemove', event);
        });
```

```
        google.maps.event.addListener(Overlays['moraynephropstrawl'],              'mouseout',
function(event) {
        google.maps.event.trigger(map, 'mouseout', event);
        });

        google.maps.event.addListener(Overlays['clydenephropstrawl'],                 'click',
function(event) {
        google.maps.event.trigger(map, 'click', event);
        });

        google.maps.event.addListener(Overlays['moraynephropstrawl'],                 'click',
function(event) {
        google.maps.event.trigger(map, 'click', event);
        });



                        if($("#clydenephropstrawl_layer").length > 0) {

google.maps.event.addDomListener(document.getElementById('clydenephropstrawl_layer'),'click'
, function()
                            {
        if (document.getElementById('clydenephropstrawl_layer').checked) {

               Overlays['clydenephropstrawl'].setMap(map);
               Overlays['moraynephropstrawl'].setMap(map);
               setCustomLayerColorbar("clydenephropstrawl",       clydenephropstrawlColorbar,
true);


        } else {
               Overlays['clydenephropstrawl'].setMap(null);
               Overlays['moraynephropstrawl'].setMap(null);
               setCustomLayerColorbar("clydenephropstrawl",       clydenephropstrawlColorbar,
false);
        }
                            });
                        }

  }
```

Vessel tracks

Source data

Since the intended dataset was not available within the framework of this project, a mock dataset was created for demonstration purposes. The mock dataset was designed to resemble the expected data set, consisting of the following data fields:

Id, asset_id, asset_name, asset_type, generated_date, gps_lon,gps_lat,speed,course, over_sat, received_date

Processing

All mock data were stored into a database data table to speed up raw and filtered data requests. Data table was configured as follows:

Field	Type
id	bigint(20)
asset_id	bigint(20)
asset_name	varchar(220)
asset_type	varchar(100)
generated_date	datetime
gps_lon	decimal(15,9)
gps_lat	decimal(15,9)
speed	float(10,4)
course	float(10,4)
over_sat	tinyint(4)
received_date	datetime

Display

This dynamic layer extracts only the relevant data from the database data table, aggregates the data according to applied filters and renders the data using the pre-defined color map.

Query to extract all the data from the data table for the current viewport (viewable map area) and user-defined filters.

VESSELS: DATABASE TO MAP: QUERY

```
/* VIEWPORT PARAMS */
$point1[0] = $_GET["x1"];
$point1[1] = $_GET["y1"];

$point2[0] = $_GET["x2"];
$point2[1] = $_GET["y2"];

$stepx = $_GET["stepx"];  // zoom x
$stepy = $_GET["stepy"];  // zoom y


/*FILTER PARAMS */
$date_now_sql = date('Y-m-d H:i:s', time());
$date_one_day_sql  =  date('Y-m-d  H:i:s',  (strtotime($date_now_sql)   -  (60  *  60  *  24  *
30)));
```

```
$date_start = ($_GET["date_start"] != "") ? $_GET["date_start"] : $date_one_day_sql;
$date_end = ($_GET["date_end"] != "") ? $_GET["date_end"] : $date_now_sql;
$speed_min = ($_GET["speed_min"] != "") ? $_GET["speed_min"] : null;
$speed_max = ($_GET["speed_max"] != "") ? $_GET["speed_max"] : null;
$asset_type = ($_GET["asset_type"] != "") ? $_GET["asset_type"] : null;

$sql_clouses = "";

if($date_start != null) {
        $sql_clouses .= "AND datetime>='" . $date_start."' ";
}
if($date_end != null) {
        $sql_clouses .= "AND datetime<='" . $date_end."' ";
}

if($speed_min != null) {
        $sql_clouses .= "AND speed>=" . $speed_min ." ";
}

if($speed_max != null) {
        $sql_clouses .= "AND speed<=" . $speed_max ." ";
}

if($asset_type != null) {
        $sql_clouses .= "AND asset_type='" . $asset_type . "' ";
}


//----------------------------------------------

$decimals_max = (($decimals - 1) >= 0) ? ($decimals - 1) : 0;


/*Retrive records from DB */

$sql = "SELECT SUM(number_of_boats) as number_of_boats, gps_lon, gps_lat FROM
boatlog_daily_log ";
$sql .= " WHERE gps_lon >= " . $point1[0]." AND gps_lon <= " . $point2[0]. " ";
$sql .= " AND gps_lat <= " . $point1[1]." AND gps_lat >= " . $point2[1]. " ";
$sql .= " " . $sql_clouses;
$sql .= " GROUP BY gps_lon, gps_lat ORDER BY gps_lon ASC, gps_lat ASC";

$boats = getQueryResult($sql, $link, true, true);
$boats_number = count($boats);
```

Once all the data is extracted, the data is grouped depending on the map zoom level and processed into a JSON dictionary.

VESSELS: DATABASE TO MAP: JSON DICTIONARY

```
//-----------------------------------------
// Group by GPS decimal places
$decimals = getNumberOfDecimalPlaces($stepx);


//Loop records and group by GPS position
foreach($boats as $n=>$v) {

        $xi = $v["gps_lon"];
        $yi = $v["gps_lat"];

        $xi_f = null;
        $yi_f = null;

        //if(!$input2["$xi"]) $input2["$xi"] = array();
        //$input2["$xi"]["$yi"] = $v["number_of_boats"];
```

```
        if($stepx != $zero_step) {
                $xdelta = getPositionMatch($point1[0], $stepx, $xi);
                if($xdelta != 0) {
                        $xi_f = $xi - $xdelta;
                }
        }

        if($stepy != $zero_step) {
                $ydelta = getPositionMatch($point1[1], $stepy, $yi);
                if($ydelta != 0) {
                        $yi_f = $yi - $ydelta;
                }
        }

        if($xi_f != null ||$yi_f != null) {

                if($xi_f == null) { $xi_f = $xi; }
                if($yi_f == null) { $yi_f = $yi; }

                if(!$input["$xi_f"]) { $input["$xi_f"] = array(); }
                if(!$input["$xi_f"]["$yi_f"]) { $input["$xi_f"]["$yi_f"] = 0; }

                $input["$xi_f"]["$yi_f"] += $v["number_of_boats"];

        } else {

                if(!$input["$xi"]) $input["$xi"] = array();
                $input["$xi"]["$yi"] = $v["number_of_boats"];

        }

}


//generate JSON output
echo json_encode($input);
END
//-------------------------------------


/* Match GPS position group */
function getPositionMatch($x0, $step, $x1) {
        $number_of_rep = abs($x1 - $x0) / $step;
        $remains = $number_of_rep - floor($number_of_rep);
        $delta = round($remains * $step, 4);
        return $delta;
}
```

JSON Dictionary is then rendered to map as Rectangles.

VESSELS: DATABASE TO MAP: JSON TO MAP

```
/*Init Vessel function on Viewport change */
        function drawRects () {

                if($("#boatlayer").prop("checked") != true) { return; }

                var current_zoom = map.getZoom();
                var rect_size = 100000;

                 var NE=map.getBounds().getNorthEast()
                 var SW=map.getBounds().getSouthWest()

                 var lng_diff = Math.abs(NE.lng() - SW.lng());
                 var lat_diff = Math.abs(NE.lat() - SW.lat());

                 var number_of_cells_lat = 2 * current_zoom;
                 var number_of_cells_lng = 4 * current_zoom;
```

```
                var lng_step = 0;
                var lat_step = 0;


               if(current_zoom <= 6) {

                lng_step = 0.2;
                lat_step = 0.1;
                number_of_decimals = 1;

               } else if(current_zoom >= 7 && current_zoom <= 8) {

                lng_step = 0.04;
                lat_step = 0.02;
                number_of_decimals = 2;

               } else if(current_zoom >= 9 && current_zoom <= 10) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 2;

               } else if(current_zoom == 11) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 2;

               } else if(current_zoom >= 12) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 2;

               }


               var upper_left_lng = Math.floor(SW.lng());
               var lower_right_lng = Math.ceil(NE.lng());
               var upper_left_lat = Math.ceil(NE.lat());
               var lower_right_lat = Math.floor(SW.lat());



        retriveBoatLayerHeatMap(upper_left_lat,upper_left_lng,lower_right_lat,lower_right_lng
,lat_step,lng_step);


        }

        /* Retrive JSON data with filter options */
        function
retriveBoatLayerHeatMap(upper_left_lat,upper_left_lng,lower_right_lat,lower_right_lng,lat_st
ep,lng_step) {




                       data = {
                               'x1':upper_left_lng,'y1':upper_left_lat,
                               'x2':lower_right_lng,'y2':lower_right_lat,
                               'stepx':lng_step,'stepy':lat_step,
                               'asset_type': $("#boat_type").val(),
                               'speed_min': $("#speed_min").val(),
                               'speed_max': $("#speed_max").val(),
                               'date_start': $("#date_start").val(),
                               'date_end': $("#date_end").val()

                       };

                       //console.log(data);

                       var url = "views/boats_heatmap.php";
```

```
                                                    $.ajax({
                                                                   type: 'GET',
                                                                   url: url,
                                                                   data: data,
                                                                   dataType: 'json',
                                                                   timeout: 852000,
                                                                   success:
function(objdata){

        removeRects();

        drawRects2(objdata, lng_step, lat_step);

                                                                   },
                                                                   error:      function(xhr,
type){

                                                                   },
                                                                   beforeSend: function(xhr,
type){
                                                                                  $("#ajax-
process").show();
                                                                   },
                                                                   complete:   function(xhr,
type){
                                                                                  $("#ajax-
process").hide();
                                                                   }

                                                    });



        }

        /* Draw Vessel Heatmap on Google Map */
        function drawRects2(response, stepx, stepy) {

        max_value = parseFloat(response["max"]);

        BoatsLimits['speed_min'] = parseFloat(response["speed_min"]);
        BoatsLimits['speed_max'] = parseFloat(response["speed_max"]);
        BoatsLimits['date_start'] = response["datetime_min"];
        BoatsLimits['date_end'] = response["datetime_max"];

        $("#speed_min").val(BoatsLimits['speed_min']);
        $("#speed_max").val(BoatsLimits['speed_max']);
        $("#date_start").val(BoatsLimits['date_start']);
        $("#date_end").val(BoatsLimits['date_end']);
        $("#map-title").html("<h3>" + response["title"] + "</h3>");

        rects = response["data"];

                       for (i in rects) {

                                              point = rects[i];


                                              var cc = boatColorScheme(point[2], max_value);

                                              var lng_left = parseFloat(point[0]);
                                              var lng_right = parseFloat(point[0]) + stepx;

                                              var lat_top = parseFloat(point[1]);
                                              var lat_bottom = parseFloat(point[1]) - stepy;

                                              var          SW_point          =          new
google.maps.LatLng(lat_bottom, lng_left);
                                              var  NE_point  =  new  google.maps.LatLng(lat_top,
lng_right);


                                              var rectangle = new google.maps.Rectangle();
```

```
                                              var rectOptions = {
                                              number_of_boats: point[2],
                                              strokeColor: "#EEECCC",
                                              strokeOpacity: 0.0,
                                              strokeWeight: 0,
                                              fillColor: cc,
                                              fillOpacity: BoatOpacity,
                                              map: map,
                                              bounds:                                            new
google.maps.LatLngBounds(SW_point,NE_point)
                                              };

                                              rectangle.setOptions(rectOptions);


                                              google.maps.event.addListener(rectangle,
'mousemove', function(event) {
                                                     google.maps.event.trigger(map,
'mousemove', event);
                                              });

                                              google.maps.event.addListener(rectangle,
'mouseover', function(event) {
                                                     $("#boat_legend").html("<span>Ping
count: " + this.number_of_boats + "</span>")
                                                     .css({'display':'block',
'left':mouse['x'], 'top':(mouse['y']-20)});
                                              });

                                              google.maps.event.addListener(rectangle,
'mouseout', function(event) {
       $("#boat_legend").html("").css({'display':'none'});
                                                     google.maps.event.trigger(map,
'mouseout', event);
                                              });


                                              BoatRectArr.push(rectangle);
                      }
       }
```

The colour code for each rectangle is defined by the boatColorScheme function.

VESSELS: RECTANGLE COLOUR CODE

```
function boatColorScheme(current_value, max_value) {

                      var                                 scheme                                 =
["#46EFFF","#45F5FF","#44FBFF","#43FFFD","#42FFF7","#40FFF0","#3FFFEA","#3EFFE3","#3DFFDD","
#3CFFD6","#3BFFD0","#3AFFC9",

       "#38FFC2","#37FFBB","#36FFB4","#35FFAD","#34FFA6","#33FF9F","#32FF97","#30FF90","#2FF
F89","#2EFF81","#2DFF7A","#2CFF72",

       "#2BFF6A","#29FF62","#28FF5A","#27FF52","#26FF4A","#25FF42","#24FF3A","#23FF32","#21F
F29","#20FF21","#26FF1F","#2CFF1E",

       "#32FF1D","#39FF1C","#3FFF1A","#46FF19","#4CFF18","#53FF17","#5AFF16","#61FF15","#68F
F14","#6FFF12","#76FF11","#7DFF10",

       "#84FF0F","#8CFF0E","#93FF0D","#9BFF0C","#A2FF0A","#AAFF09","#B2FF08","#B9FF07","#C1F
F06","#C9FF05","#D1FF03","#D9FF02",

       "#E1FF01","#EAFF00","#F1FE00","#F8FD00","#FCF800","#FAEE00","#F9E500","#F8DC00","#F7D
300","#F6CA00","#F5C100","#F3B800",

       "#F2AF00","#F1A600","#F09E00","#EF9500","#EE8D00","#ED8400","#EB7C00","#EA7300","#E96
```

```
B00","#E86300","#E75B00","#E65300",

        "#E54B00","#E34300","#E23B00","#E13400","#E02C00","#DF2500","#DE1D00","#DC1600","#DB0
E00","#DA0700","#D90000"
                                             ];

                       var sch_length = scheme.length;
                       var step = Number(max_value / sch_length);
                       var position = Math.floor(current_value / step);
                       if(position < 0) position = 0;


                       return scheme[position];
        }
```

Catch data

Source data

Since the intended dataset was not available within the framework of this project, a mock dataset was created for demonstration purposes. The mock dataset was designed to resemble the expected data set, consisting of the following data fields:

Id, asset_id, asset_name, asset_type, generated_date, gps_lon, gps_lat, speed, heading, received_date, Species, NumberCreels, SoakTime, TowDuration, Catch, CatchPerUnitEffort

Processing

All mock data were stored into a database data table to speed up raw and filtered data requests. Data table was configured as follows:

Field	Type
id	bigint(20)
asset_id	bigint(20)
asset_name	varchar(220)
asset_type	varchar(100)
generated_date	datetime
gps_lon	decimal(15,9)
gps_lat	decimal(15,9)
speed	float(10,4)
heading	float(10,4)
received_date	datetime
Species	varchar(200)
NumberCreels	int(11)
SoakTime	int(11)
TowDuration	int(11)
Catch	int(11)
CatchPerUnitEffort	decimal(14,12)

Display

This dynamic layer extracts only the relevant data from the database data table, aggregates the data according to applied filters and renders the data using the pre-defined color map.

Query to extract all the data from the data table for the current viewport (viewable map area) and user-defined filters.

CATCH: DATABASE TO MAP: QUERY

```
//Viewport params

$point1[0] = $_GET["x1"];
$point1[1] = $_GET["y1"];

$point2[0] = $_GET["x2"];
$point2[1] = $_GET["y2"];
```

```
$stepx = $_GET["stepx"];
$stepy = $_GET["stepy"];


//FILTER params

$date_start = ($_GET["date_start"] != "") ? $_GET["date_start"] : null;
$date_end = ($_GET["date_end"] != "") ? $_GET["date_end"] : null;
//$speed_min = ($_GET["speed_min"] != "") ? $_GET["speed_min"] : null;
//$speed_max = ($_GET["speed_max"] != "") ? $_GET["speed_max"] : null;
$asset_type = ($_GET["asset_type"] != "") ? $_GET["asset_type"] : null;
$species = ($_GET["species"] != "") ? $_GET["species"] : null;
$count_column = ($_GET["count_column"] != "") ? $_GET["count_column"] : "Catch";

$sql_clouses = "";

if($date_start != null) {
        $sql_clouses .= "AND datetime>='" . $date_start."' ";
}
if($date_end != null) {
        $sql_clouses .= "AND datetime<='" . $date_end."' ";
}

if($asset_type != null) {
        $sql_clouses .= "AND asset_type='" . $asset_type . "' ";
}

if($species != null) {
        $sql_clouses .= "AND species='" . $species . "' ";
}
//----------------------------------------------
$time_start = microtime(true);

$decimals_max = (($decimals - 1) >= 0) ? ($decimals - 1) : 0;


if($count_column == "Catch") {
                $column_math_operand = "SUM";
} else {
                $column_math_operand = "AVG";
}

$sql = "SELECT SUM(number_of_boats) as number_of_boats, ";
$sql .= " SUM(Catch) as Catch, AVG(CatchPerUnitEffort) as CatchPerUnitEffort, ";
$sql .= " gps_lon, gps_lat FROM catchlog_daily_log ";
$sql .= " WHERE gps_lon >= " . $point1[0]." AND gps_lon <= " . $point2[0]. " ";
$sql .= " AND gps_lat <= " . $point1[1]." AND gps_lat >= " . $point2[1]. " ";
$sql .= " " . $sql_clouses;
$sql .= " GROUP BY gps_lon, gps_lat ORDER BY gps_lon ASC, gps_lat ASC";

$boats = getQueryResult($sql, $link, true, true);
$boats_number = count($boats);
```

Once all the data is extracted, the data is grouped depending on the map zoom level and processed into a JSON dictionary.

CATCH: DATABASE TO MAP: JSON DICTIONARY

```
//Loop and group by zoom level

$zero_step = 1 / pow(10, $decimals);


//--------------------------------------------
if(count($boats) > 0) {
        foreach($boats as $n=>$v) {

                $xi = $v["gps_lon"];
```

```
                $yi = $v["gps_lat"];

                $xi_f = null;
                $yi_f = null;

                //if(!$input2["$xi"]) $input2["$xi"] = array();
                //$input2["$xi"]["$yi"] = $v["number_of_boats"];

                if($stepx != $zero_step) {
                        $xdelta = getPositionMatch($point1[0], $stepx, $xi);
                        if($xdelta != 0) {
                                $xi_f = $xi - $xdelta;
                        }
                }

                if($stepy != $zero_step) {
                        $ydelta = getPositionMatch($point1[1], $stepy, $yi);
                        if($ydelta != 0) {
                                $yi_f = $yi - $ydelta;
                        }
                }

                if($xi_f != null ||$yi_f != null) {

                        if($xi_f == null) { $xi_f = $xi; }
                        if($yi_f == null) { $yi_f = $yi; }

                        if(!$input["$xi_f"]) { $input["$xi_f"] = array(); }
                        if(!$input["$xi_f"]["$yi_f"]) { $input["$xi_f"]["$yi_f"] = 0; }

                        if($column_math_operand == "AVG") {
                                $input["$xi_f"]["$yi_f"]   =   ($input["$xi_f"]["$yi_f"]   +
$v[$count_column])/2;
                        } else {
                                $input["$xi_f"]["$yi_f"] += $v[$count_column];
                        }

                } else {

                        if(!$input["$xi"]) $input["$xi"] = array();
                        $input["$xi"]["$yi"] = $v[$count_column];

                }

        }
}


//JSON output
echo json_encode($input);
```

JSON Dictionary is then rendered to map as Rectangles.

CATCH: DATABASE TO MAP: JSON TO MAP

```
/* Init Catch Data function */
        function drawCatchRects () {

                if($("#catchlayer").prop("checked") != true) { return; }

                var current_zoom = map.getZoom();
                var rect_size = 100000;

                 var NE=map.getBounds().getNorthEast()
                 var SW=map.getBounds().getSouthWest()

                 var lng_diff = Math.abs(NE.lng() - SW.lng());
```

```
                var lat_diff = Math.abs(NE.lat() - SW.lat());

                var number_of_cells_lat = 2 * current_zoom;
                var number_of_cells_lng = 4 * current_zoom;


                var lng_step = 0;
                var lat_step = 0;


               if(current_zoom <= 6) {

                lng_step = 0.2;
                lat_step = 0.1;
                number_of_decimals = 0;

               } else if(current_zoom >= 7 && current_zoom <= 8) {

                lng_step = 0.04;
                lat_step = 0.02;
                number_of_decimals = 0;

               } else if(current_zoom >= 9 && current_zoom <= 10) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 0;

               } else if(current_zoom == 11) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 0;

               } else if(current_zoom >= 12) {

                lng_step = 0.02;
                lat_step = 0.01;
                number_of_decimals = 0;

               }

               var upper_left_lng = Math.floor(SW.lng());
               var lower_right_lng = Math.ceil(NE.lng());
               var upper_left_lat = Math.ceil(NE.lat());
               var lower_right_lat = Math.floor(SW.lat());



        retriveCatchLayerHeatMap(upper_left_lat,upper_left_lng,lower_right_lat,lower_right_ln
g,lat_step,lng_step);


        }

        /*Retrice Catch data from JSON file with filter data*/
        function
retriveCatchLayerHeatMap(upper_left_lat,upper_left_lng,lower_right_lat,lower_right_lng,lat_s
tep,lng_step) {




                       data = {
                               'x1':upper_left_lng,'y1':upper_left_lat,
                               'x2':lower_right_lng,'y2':lower_right_lat,
                               'stepx':lng_step,'stepy':lat_step,
                               'asset_type': $("#catch_type").val(),
                               'species': $("#catch_species").val(),
                               'count_column': $("#count_column").val(),
                               'date_start': $("#date_start").val(),
                               'date_end': $("#date_end").val()

                       };
```

```
                        //console.log(data);

                        var url = "views/catch_heatmap.php";
                                                              $.ajax({
                                                                             type: 'GET',
                                                                             url: url,
                                                                             data: data,
                                                                             dataType: 'json',
                                                                             timeout: 852000,
                                                                             success:
function(objdata){


        removeCatchRects();

        drawCatchRects2(objdata, lng_step, lat_step);

                                                                             },
                                                                             error:      function(xhr,
type){

                                                                             },
                                                                             beforeSend: function(xhr,
type){
                                                                                            $("#ajax-
process").show();
                                                                             },
                                                                             complete:   function(xhr,
type){
                                                                                            $("#ajax-
process").hide();
                                                                             }

                                                              });



        }

        /*Draw Catch data on Google Map */
        function drawCatchRects2(response, stepx, stepy) {

        max_value = parseFloat(response["max"]);

        /*CatchLimits['speed_min'] = parseFloat(response["speed_min"]);
        CatchLimits['speed_max'] = parseFloat(response["speed_max"]);*/

        CatchLimits['date_start'] = response["datetime_min"];
        CatchLimits['date_end'] = response["datetime_max"];

        /*$("#speed_min").val(CatchLimits['speed_min']);
        $("#speed_max").val(CatchLimits['speed_max']);*/
        $("#date_start").val(CatchLimits['date_start']);
        $("#date_end").val(CatchLimits['date_end']);

        $("#map-title").html("<h3>" + response["title"] + "</h3>");

        rects = response["data"];

                        for (i in rects) {

                                             point = rects[i];


                                             var cc = boatColorScheme(point[2], max_value);

                                             var lng_left = parseFloat(point[0]);
                                             var lng_right = parseFloat(point[0]) + stepx;

                                             var lat_top = parseFloat(point[1]);
                                             var lat_bottom = parseFloat(point[1]) - stepy;

                                             var          SW_point          =          new
```

```
google.maps.LatLng(lat_bottom, lng_left);
                                                var  NE_point  =  new  google.maps.LatLng(lat_top,
lng_right);

                                                var rectangle = new google.maps.Rectangle();

                                                var rectOptions = {
                                                number_of_boats: point[2],
                                                strokeColor: "#EEECCC",
                                                strokeOpacity: 0.0,
                                                strokeWeight: 0,
                                                fillColor: cc,
                                                fillOpacity: CatchOpacity,
                                                map: map,
                                                bounds:                                     new
google.maps.LatLngBounds(SW_point,NE_point)
                                                };

                                                rectangle.setOptions(rectOptions);


                                                google.maps.event.addListener(rectangle,
'mousemove', function(event) {
                                                        google.maps.event.trigger(map,
'mousemove', event);
                                                });

                                                google.maps.event.addListener(rectangle,
'mouseover', function(event) {
                                                        $("#boat_legend").html("<span>"        +
this.number_of_boats + "</span>")
                                                        .css({'display':'block',
'left':mouse['x'], 'top':(mouse['y']-20)});
                                                });

                                                google.maps.event.addListener(rectangle,
'mouseout', function(event) {

        $("#boat_legend").html("").css({'display':'none'});
                                                        google.maps.event.trigger(map,
'mouseout', event);
                                                });


                                                CatchRectArr.push(rectangle);
                        }
        }
```

The colour code for each rectangle is defined by the catchColorScheme function.

CATCH: RECTANGLE COLOUR CODE

```
function catchColorScheme(current_value, max_value) {

                        var                                 scheme                              =
["#46EFFF","#45F5FF","#44FBFF","#43FFFD","#42FFF7","#40FFF0","#3FFFEA","#3EFFE3","#3DFFDD","
#3CFFD6","#3BFFD0","#3AFFC9",

        "#38FFC2","#37FFBB","#36FFB4","#35FFAD","#34FFA6","#33FF9F","#32FF97","#30FF90","#2FF
F89","#2EFF81","#2DFF7A","#2CFF72",

        "#2BFF6A","#29FF62","#28FF5A","#27FF52","#26FF4A","#25FF42","#24FF3A","#23FF32","#21F
F29","#20FF21","#26FF1F","#2CFF1E",

        "#32FF1D","#39FF1C","#3FFF1A","#46FF19","#4CFF18","#53FF17","#5AFF16","#61FF15","#68F
F14","#6FFF12","#76FF11","#7DFF10",

        "#84FF0F","#8CFF0E","#93FF0D","#9BFF0C","#A2FF0A","#AAFF09","#B2FF08","#B9FF07","#C1F
```

```
F06","#C9FF05","#D1FF03","#D9FF02",

        "#E1FF01","#EAFF00","#F1FE00","#F8FD00","#FCF800","#FAEE00","#F9E500","#F8DC00","#F7D
300","#F6CA00","#F5C100","#F3B800",

        "#F2AF00","#F1A600","#F09E00","#EF9500","#EE8D00","#ED8400","#EB7C00","#EA7300","#E96
B00","#E86300","#E75B00","#E65300",

        "#E54B00","#E34300","#E23B00","#E13400","#E02C00","#DF2500","#DE1D00","#DC1600","#DB0
E00","#DA0700","#D90000"
                                             ];

                      var sch_length = scheme.length;
                      var step = Number(max_value / sch_length);
                      var position = Math.floor(current_value / step);
                      if(position < 0) position = 0;


                      return scheme[position];
        }
```

Web App Components

Framework

The web app was built with standard HTML and CSS components. Server side scripts are running in PHP. Server side database is MySQL. Client-side scripts are running in JavaScript and JQuery.

All data in this app was rendered using Google Maps JavaScript API v3.

Opacity Slider

A standard JavaScript slider was used as the individual layer opacity slider. The slider was modified to call the Google Mpas API setOpacity() function for each layer.

WEB: OPACITY SLIDER

```
/*Slider Init function */

$('#bathymetry_layer_slider').noUiSlider({
                      start: 0.5,
                      connect: "lower",
                      range: {
                              'min': 0,
                              'max': 1
                              }
});


/*Slider handler function*/

$('#bathymetry_layer_slider').on('slide', function() {
               if(Overlays['moray_surface']) {
                      Overlays['moray_surface'].setOpacity(parseFloat($(this).val()));
               }
               if(Overlays['clyde_surface']) {
                      Overlays['clyde_surface'].setOpacity(parseFloat($(this).val()));
               }
});
```

Key files

List of key web app files and scripts with their relative paths.

app/

This is the root folder for the web app. This folder contains all the images, files, and scripts needed to render the web app on a web server.

app/index.php

This file contains the complete web framework for the web app, the Map Toolbox, and the placeholders for the top menu, the web map, and the footer.

app/menu.php

This file contains the web content for the top menu bar.

app/layer-info.php
This file contains the web content and info for individual layers which are available in the Map ToolBox.

app/ams.css
This file contains the complete web app style reference, regulating location and appearance of all web elements and fonts.

app/footer.php
This file contains the web content of the web app footer.

app/map.php
This file contains the web content of the web app map.

app/js/map.js
This file contains the scripts used to render and display the map.

app/js/slider
This folder contains the scripts used to display the opacity slider

app/img
This folder contains all the buttons and images used in the web app which are not related to the rendering of the data.

app/views
This folder contains all the prepared data layers as either tiles (Bathymetry and Admiralty Chart layers) or raster images (Scotmap layer).

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MASTS Company Number: SC485726; Charity Number: SC045259

ISBN 978-0-9934256-4-6

EFF: MI-NC-3-0093

This project was supported by a grant from the European Fisheries Fund