Fisheries Innovation Scotland

FIS001 - A Review of Scotland's Marine Fisheries: Stock Status, Knowledge Gaps, Research Requirements and Stakeholder Engagement

A REPORT COMMISSIONED BY FIS
AND PREPARED BY

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A REVIEW OF SCOTLAND'S MARINE FISHERIES: STOCK STATUS, KNOWLEDGE GAPS, RESEARCH REQUIREMENTS AND STAKEHOLDER ENGAGEMENT



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Fisheries Innovation Scotland

Executive summary

Fishing is a significant industry for Scotland's rural communities. Scotland's marine fishing industry is the largest in the UK and the 4th largest in the European Union (EU). Over the past five years, Scotland's sea fish and shellfish landings have averaged around 370,000 t with a value of over £450 million p.a. The industry provides employment to almost 5000 fishermen, working on over 2000 vessels, most of whom are located in rural areas away from the major conurbations.

There are approximately 139 recognised stocks of marine fish and shellfish which account for 99% of total landings by Scottish vessels. Most of the stocks occurring within 12 nautical miles of the shore (inshore fisheries) are shellfish and are managed nationally. Fish stocks that occur beyond national jurisdictions are managed predominantly under the EU's Common Fisheries Policy (CFP) and bilateral arrangements with neighbouring coastal states such as Norway.

This document reports on the outcome of a review by members of the Marine Alliance for Science and Technology Scotland (MASTS) Fisheries Science Forum in response to a research call from Fisheries Innovation Scotland (FiS). Its purpose was to: (a) provide a summary of the status of Scotland's fish and shellfish stocks; (b) summarise previously funded research into a searchable database; (c) review the process of stakeholder engagement; and (d) identify relevant research requirements.

In 2013, of the 63 internationally managed stocks, 11 were sustainable, 4 were overfished, 5 were declining and 3 were recovering based on internationally agreed reference points. 40 stocks were undefined either due to lack of data or reference points. These unclassified stocks represented approximately 22% of the value of landings. Of the 76 nationally managed stocks, one quarter of these were overfished in excess of rates consistent with maximum sustainable yield (MSY). There are no estimates of the abundance of any of the crab and lobster stocks.

A database of relevant research projects carried out since 2005 was constructed. This has details of over 130 projects, funded by the European Commission, the Scottish government and other national funders. Details in the database include a project summary, contact details of project leaders, project websites, and locations of final reports. The database was built in Excel and is searchable using instructions contained therein. It is publicly available on the FiS website at www.fiscot.org.

A synthesis of management concerns associated with the various stocks considered is provided with a summary of key knowledge gaps. Additional consideration is given to the challenges which are common to many stocks. These are further summarised by listing over 40 research requirements to fill these gaps, ranked according to importance, impact and likely success. These requirements for further research were grouped into key topics which include: the landing obligation, inshore fisheries, climate change, stock status and MSY.

Finally, the role of stakeholders in the science and management of fisheries is examined. Stakeholder engagement is reviewed from examples throughout the world, including the EU, USA, Canada and Norway. A more detailed analysis was conducted of Scottish systems of stakeholder engagement. Generally, local bottom-up approaches were more effective than initiatives driven by larger institutions: results-based management (RBM) and participatory approaches are more likely to succeed.

List of abbreviations

AC	Advisory Council
ACOM	ICES Advisory Committee
CAFSAC	Canadian Atlantic Fisheries Scientific and Advisory Committee
CCTV	Closed circuit television
CFP	Common Fisheries Policy
COFASP	Cooperation in Fisheries, Aquaculture and Seafood Processing
CORDIS	Community Research and Development Information Service
CPUE	Catch per unit effort
Defra	Department for Environment, Food and Rural Affairs
DCF	Data collection framework
DFO	Department of Fisheries and Oceans
DoF	Directorate of Fisheries
ENGO	Environmental non-governmental organisation
EU	European Union
F	Fishing mortality
FAO	Food and Agriculture Organisation
FiS	Fisheries Innovation Scotland
FISA	Fisheries Industry Science Alliance
FMAC	Fisheries Management and Conservation Group
FOS	Friends Of the Sea
FQA	Fixed quota allocation
FRCC	Fishery Resource Conservation Council
FSP	Fisheries Science Partnership
FU	Functional management unit
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IFG	Inshore Fisheries Group
IFMAC	Inshore Fisheries Management and Conservation Group
IFMP	Integrated Fisheries Management Plan
IMR	Institute of Marine Research
LCA	Length cohort analysis
MASTS	Marine Alliance for Science and Technology Scotland
MEY	Maximum economic yield
MPA	Marine protected area
MSC	Marine Stewardship Council
MSF	Marine Strategy Forum
MSFD	Marine Strategy Framework Directive
MSS	Marine Scotland Science
MSY	Maximum sustainable yield
nmi	nautical mile
NERC	Natural Environment Research Council
RAC	Regional Advisory Council
RBM	Results-based management
RTC	Real-time closure
SCCS	Scottish Conservation Credit Scheme
SCICOM	ICES Science Committee
SDSG	Scottish Discarding Steering Group
SISP	Scottish Industry/Science Partnership
SSB	Spawning stock biomass
SSC	Science and Statistics Committee
SSMO	Shetland Shellfish Management Organisation
t	tonne
TAC	Total allowable catch
VMS	vessel monitoring system
VPA	virtual population analysis
WWF	World Wide Fund for Nature
y	year

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1. Introduction

Scotland has a long history of fishing at sea (SFM 2015). Its marine commercial fishing industry is the largest in the UK and the 4th largest in Europe. In 2013, Scotland landed a total of 367,000 t of marine finfish and shellfish, with a corresponding value of £430 million (Anon 2014): this accounts for approximately 60% of UK, and 8% of European Union (EU) landings by weight. In the same year, there were 2020 active marine fishing vessels in Scotland, employing a total of 4992 fishermen, just over 40% of the UK's total. The Scottish fishing ports of Peterhead, Lerwick and Fraserburgh, are the largest in the UK, together accounting for approximately 30% of UK landings. The sea fishing industry is, therefore, of much greater significance to Scotland than to the rest of the UK. Further information on catches, value and the structure of the Scottish marine fishing fleet is provided by Marine Scotland in the annual series of Scottish Sea Fisheries Statistics, e.g. Anon (2014), or in a UK context, in the series of similar publications by the Marine Management Organisation (Radford 2014).

As stated on their website: "Marine Scotland manages quota for fish stocks and all inshore fisheries within the 12 nautical mile territorial waters limit. It is also responsible for monitoring the activities of fishing vessels and fishing effort (i.e. days spent at sea) in the North Sea, west of Scotland and Faroese waters. To do this, Marine Scotland works with the UK Government in negotiating fishing opportunities through the EU and in other international organisations." Management arrangements are discussed below (see Section 2.2), but essentially there is a distinction between nationally managed stocks which occur within the 12 mile limit and international stocks which are shared resources and so are internationally managed under the EU's (CFP) and bilateral arrangements with other coastal states (i.e. Norway, the Faroe Islands, Iceland and Russia). Within the latter international arrangements, negotiations with the other coastal states can be more problematic than processes within the EU: this can sometimes leading to protracted disputes, for example, in the management of north east Atlantic mackerel (Hannesson 2013).

The definition of a fish stock can vary according to the information available. According to the Food and Agriculture Organisation (FAO), a fish stock is defined as "all the individuals of fish in an area, which are part of the same reproductive process" (FAO 2005). Hence, a fish stock is defined spatially and is independent of other stocks of the same species. For the purposes of fisheries management a "stock" is defined as a unit of fish made up of a single or multiple species. The International Council for the Exploration of the Sea (ICES) provides fisheries management advice for stocks by area of capture (see Figure 1).

In Scotland, the major provider of fisheries information and expertise to ICES is Marine Scotland Science (MSS). Based in the Marine Laboratory Aberdeen, MSS operates national fisheries monitoring programmes, with two ocean-going research vessels conducting surveys throughout the year, a team of observers on fishing vessels, and a team of biologists sampling fishing markets. The data are used to assess the status of stocks by a team of experienced analysts using a variety of mathematical models. MSS also conducts research to underpin the monitoring, assessment and advice programme. MSS, along with eleven Higher Education Institutions in Scotland and the Scottish Association of Marine Science (SAMS), are part of the Marine Alliance for Science and Technology Scotland (MASTS) pooling initiative. There are several scientists in these other institutions which also have fisheries research programmes: these are collected under the MASTS Fisheries Science Forum. Responding to an initiative of the Scottish Government, MASTS, along with key industry partners, developed Fisheries Innovation Scotland (FiS), an independent, non-profit-distributing organisation. FiS brings together government, scientists, industry and other key stakeholders to lead an on-going programme of research, knowledge exchange and education concerned with the management of Scotland's marine fisheries and related areas.

This document is the outcome of a review, commissioned by FiS in late 2014, and carried out by members of the MASTS Fisheries Science Forum. Its aims were to summarise the status of Scotland's capture fisheries, to review recent research and innovation projects and highlight key knowledge gaps and data resources, so that FiS can be better informed about future research calls. Specifically the objectives of the review were to:

1) Review available data on marine commercial capture fisheries in Scotland to provide a concise summary of their status with respect to stock management.
2) Identify, through a combination of review and consultation, research requirements relevant to selected Scottish inshore fisheries to inform future FiS activity in this area.
3) Compile a simple spreadsheet database of previously funded research (UK and EU) over the last decade, relevant to Scottish fisheries. The database will be designed to provide a basis for an online searchable resource available through the FiS website.
4) Review the process and practice of stakeholder engagement and influence in management of the Scottish fishing industry, with the objective of improvement and optimisation.

The report is structured around these objectives, dealing with each in successive chapters. A series of annexes detailing some of the findings by stock are appended.

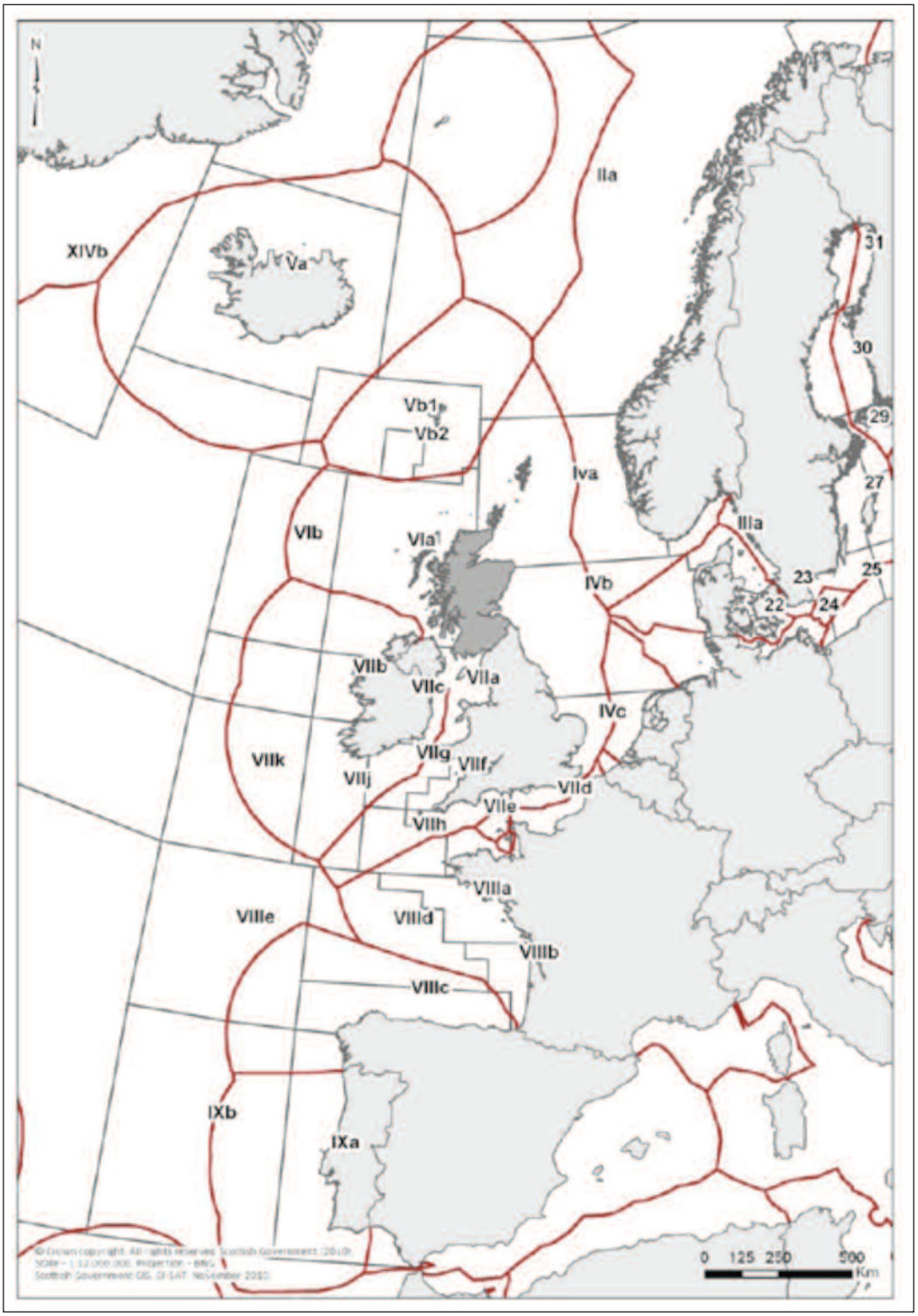


Figure 1 **Map of the north east Atlantic showing ICES divisions (roman numerals and letters) used for fish stock management. Red lines depict exclusive economic zone boundaries.**
Source: http://spoxy5.insipio.com/generator/sc/www.scotland.gov.uk/Publications/2010/11/22125407/4

[1] By comparison, in 2013 Spain landed 882,000 t, Denmark landed 668,000 t, France 529,000 t, Iceland 1,384,000 t and Norway 1,944,000 t: the EU-28 total landings were 4,806,000 t.

2. Stock status

2.1. Identification of key stocks

Fish stocks are defined according to the international convention of area of capture adopted by ICES within the northeast Atlantic (Figure 1). The main fishing areas around Scotland are identified as; North Sea (Sub-area IV); west of Scotland (Division VIa); Irish Sea (Division VIIa). Other areas of interest to Scottish fishermen mainly comprise ICES Divisions in Sub-area VII and Division IIa. "Widely distributed stocks" encompass multiple ICES Sub-areas that are occupied by species such as mackerel and hake.

2.2. International vs national stocks

Commercial fish stocks around the UK are managed either nationally or internationally. The EU is responsible for managing shared stocks within EU waters, while the UK has responsibility for the management of national stocks. In Scotland, fishery management is a devolved responsibility. European fish stocks are managed under the CFP using a combination of input controls (e.g. fishing licences, effort limits, and technical measures) and output controls (e.g. national quotas). Total allowable catch (TAC) limits are set annually for individual fish stocks fished by EU member states, limiting the weight of fish landed. The TAC is distributed to EU Member States utilising the principle of relative stability, based on each EU Member State's catching record during the reference period (1973-78). Scotland's share of TAC is distributed to individual Scottish fishing vessels as fishing quota allowance for individual stocks. The allocation of quota distinguishes international from nationally managed fish stocks. Stocks for which Scotland is allocated fishing quota are identified as international stocks. Nationally managed stocks are those stocks for which no quota is allocated. National stocks are often data limited and are managed on a different scale to international stocks. In Scotland, national stocks are regulated primarily through the Inshore Fishing (Scotland) Act 1984.

Selection of stocks for analysis

International and national stocks were identified using the FAO STATLANT database [2]. Fish landings data by Scottish registered fishing vessels in 2013 were extracted by species and ICES Sub-area of capture. The average price per species was applied to the landed weight to estimate the value of landings. Individual stocks were assigned an ICES stock name, where possible, according to these ICES Sub-areas. International fish stocks were identified as those managed under the CFP, for which quota is allocated. National fish stocks were identified as stocks which are not managed using quota and are outwith the CFP. International and national stocks landed by Scottish vessels were each ranked according to value of landings and the cumulative proportion of landed value estimated. "Key" international and national stocks were selected according to the top 99% of stocks landed by value (Table 1 and Table 2, respectively) into ICES Sub-areas (although information on the status of nationally managed stocks is available on a finer scale than ICES Sub-area – see Section 2.4.1 below). These international and national stocks make up the stocks identified for review in this project.

[2] The STATLANT database can be found at **http://www.nafo.int/data/statlant21/**

Table 1 **Landed value and top 99th percentile (n = 41) of landings of internationally managed stocks by Scottish fishing vessels, 2013. Source: FAO STATLANT database**

Stock name	Species common name	Landed value, £	Cumulative proportion landed value, £
Mackerel in the northeast Atlantic (combined Southern, Western, and North Sea spawning components)	Atlantic mackerel	126,136,721	0.355
Nephrops in Division VIa	Norway lobster	40,455,821	0.469
Haddock in Subarea IV and Divisions IIIa West and VIa (North Sea, Skagerrak, and West of Scotland)	Haddock	38,544,507	0.578
Nephrops in Subarea IV (North Sea)	Norway lobster	24,067,664	0.645
Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak)	Atlantic cod	21,112,961	0.705
Anglerfish *(Lophius piscatorius and L. budegassa)* in Division IIIa and Subareas IV and VI	Anglerfishes	20,434,415	0.762
Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)	Atlantic herring	15,367,999	0.806
Hake in Division IIIa, Subareas IV, VI, and VII, and Divisions VIIIa,b,d (Northern stock)	European hake	13,380,777	0.843
Whiting in Subarea IV (North Sea) and Division VIId (Eastern Channel)	Whiting	9,775,343	0.871
Saithe in Subarea IV (North Sea), Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall)	Saithe	9,093,100	0.896
Megrim *(Lepidorhombus spp.)* in Divisions IVa and Via (Northern North Sea, West of Scotland)	Megrims	5,253,852	0.911
Ling (Molva molva) in Divisions IIIa and IVa, and in Subareas VI, VII, VIII, IX, XII, and XIV (other areas)	Ling	4,774,317	0.925
Plaice in Subarea IV (North Sea)	European plaice	4,712,245	0.938
Herring in Division VIa (North)	Atlantic herring	4,018,519	0.949
Herring in Subareas I, II, and V, and in Divisions IVa and XIVa (Norwegian spring-spawning herring)	Atlantic herring	3,275,920	0.959
Lemon sole in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)	Lemon sole	2,348,676	0.965
Blue whiting in Subareas I–IX, XII, and XIV	Blue whiting	1,818,346	0.970
Nephrops in Subarea VII	Norway lobster	1,061,078	0.973
Turbot in Subarea IV (North Sea)	Turbot	763,469	0.975

Table 1 continued

Stock name	Species common name	Landed value, £	Cumulative proportion landed value, £
Pollack in Subarea IV (North Sea) and Division IIIa (Skagerrak–Kattegat)	Pollack	717,927	0.977
Boarfish in the northeast Atlantic	Boarfish	699,094	0.979
Witch in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)	Witch flounder	541,722	0.981
Sandeel in Subarea IV	Sandeels	457,426	0.982
Sole in Subarea IV (North Sea)	Common sole	397,526	0.983
Atlantic halibut in Subarea IV	Atlantic halibut	395,691	0.984
Greenland halibut in Subarea IV	Greenland halibut	375,310	0.985
Megrim *(Lepidorhombus whiffiagonis)* in Divisions VIIb–k and VIIIa, b, d (L. whiffiagonis and L. boscii)	Megrims	375,275	0.987
Horse mackerel *(Trachurus trachurus)* in Divisions IIa, IVa, Vb, VIa, VIIa–c, e–k, and VIIIa–e (Western stock)	Jack and horse mackerels	334,937	0.987
Blue ling *(Molva dypterygia)* in Division Vb and Subareas VI and VII	Blue ling	291,665	0.988
Albacore tuna in Subarea VII	Albacore	283,737	0.989
Cod in Division VIa (West of Scotland)	Atlantic cod	275,300	0.990
Golden redfish *(Sebastes norvegicus)* in Subareas I and II and Beaked redfish (Sebastes mentella) in Subareas I and II	Atlantic redfishes	272,164	0.991
Greater forkbeard *(Phycis blennoides)* in the Northeast Atlantic	Greater forkbeard	255,842	0.991
Sprat in Subarea VI and Divisions VIIa–c and f–k (Celtic Sea and West of Scotland)	European sprat	225,315	0.992
Redfish in Subarea IV (North Sea)	Atlantic redfishes	206,185	0.993
Greenland halibut in Subareas V, VI, XII, and XIV	Greenland halibut	204,910	0.993
Greenland halibut in Subareas I and II	Greenland halibut	161,771	0.994
Albacore tuna in Subarea X	Albacore	153,069	0.994
Haddock in Divisions VIIb–k	Haddock	149,905	0.994
Whiting in Division VIIa (Irish Sea)	Whiting	131,314	0.995
Whiting in Division VIa (West of Scotland)	Whiting	117,280	0.995

Table 2 Landed value and top 99th percentile (n = 37) of landings of nationally managed stocks by Scottish fishing vessels, 2013. Source: FAO STATLANT database http://www.nafo.int/data/statlant21/

Stock name	Species common name	Landed value, £	Cumulative proportion landed value, £
Great Atlantic scallop in Subarea IV	Great Atlantic scallop	13,299,010	0.175
Great Atlantic scallop in Subarea VII	Great Atlantic scallop	12,266,701	0.336
European lobster in Subarea IV	European lobster	7,812,052	0.439
Great Atlantic scallop in Subarea VI	Great Atlantic scallop	7,659,126	0.540
Edible crab in Subarea VI	Edible crab	6,493,118	0.625
Edible crab in Subarea IV	Edible crab	5,293,303	0.695
Queen scallop in Subarea VII	Queen scallop	5,124,139	0.762
Velvet swimming crab in Subarea IV	Velvet swimming crab	2,461,734	0.794
Common squids in Subarea IV	Common squids	2,412,723	0.826
European lobster in Subarea VI	European lobster	2,271,662	0.856
Solen razor clams in Subarea VI	Solen razor clams	2,200,146	0.885
Common squids in Subarea VI	Common squids	1,774,168	0.908
Velvet swimming crab in Subarea VI	Velvet swimming crab	1,517,056	0.928
Common squids in Subarea VII	Common squids	605,902	0.936
Queen scallop in Subarea VI	Queen scallop	548,455	0.943
Solen razor clams in Subarea IV	Solen razor clams	444,895	0.949
European lobster in Subarea VII	European lobster	431,719	0.955
Wolffishes in Subarea IV	Wolffishes	374,601	0.960
Cuttlefish, bobtail squids in Subarea VII	Cuttlefish, bobtail squids	348,633	0.964
Solen razor clams in Subarea VII	Solen razor clams	326,720	0.969
Whelk in Subarea VII	Whelk	288,474	0.973
Whelk in Subarea IV	Whelk	245,631	0.976
European seabass in Subarea VII	European seabass	201,796	0.978
Palinurid spiny lobsters in Subarea VI	Palinurid spiny lobsters	127,326	0.980
John dory in Subarea VI	John dory	123,342	0.982
Periwinkles in Subarea IV	Periwinkles	119,619	0.983
John dory in Subarea VII	John dory	119,089	0.985
Green crab in Subarea IV	Green crab	107,453	0.986
Palinurid spiny lobsters in Subarea IV	Palinurid spiny lobsters	101,861	0.988
Blue mussel in Subarea IV	Blue mussel	97,893	0.989
Whelk in Subarea VI	Whelk	97,824	0.990
Sand gaper in Subarea IV	Sand gaper	85,396	0.991
Green crab in Subarea VI	Green crab	67,560	0.992
Gurnards, in Subarea IV	Gurnards,	59,600	0.993
Grey gurnard in Subarea IV	Grey gurnard	55,037	0.994
Red gurnard in Subarea VI	Red gurnard	45,083	0.994
Gurnards, in Subarea VI	Gurnards	36,379	0.995

In 2013, the total value of internationally and nationally managed stocks landed by Scottish registered vessels was £353,419,094 and £75,645,229, respectively. The North Sea (Subarea IV) and west of Scotland (VIa) were the two main areas in which Scottish vessels fished.

A total of 41 internationally managed stocks were identified in the top 99th percentile of landings (Table 1). Three international stocks (northeast Atlantic Mackerel, Nephrops in division VIa and Haddock in Subarea IV) accounted for over half (58%) of the landed value of internationally managed stocks by Scottish vessels. Of the internationally managed stocks, *Nephrops* and sandeel are sub-divided into smaller functional management units (FUs). As a result there are 63 internationally managed stock units.

A total of 37 nationally managed stocks were identified in the top 99th percentile of landings (Table 2). Four nationally managed stocks (great Atlantic scallop in Subarea IV, great Atlantic scallop in Subarea VII, European lobster in Subarea IV and great Atlantic Scallop in Subarea VI) accounted for 54% of the landed value of nationally managed stocks by Scottish vessels. Of the nationally managed stocks, European lobster, edible crab, velvet crab, great Atlantic scallop, queen scallop, whelk and green crab are broken down into smaller FUs. As a result there are 116 nationally managed stock units.

2.3. Internationally managed stocks

2.3.1. Stock and status

To evaluate stock status the results of the assessments conducted by ICES were examined. ICES classifies stock status according to estimates of current spawning stock biomass (SSB) and fishing mortality (F) relative to biological reference points (ICES 2014). The most consistent recent information at the time of writing was available from assessments conducted in 2014 (unless otherwise indicated): these are based on estimates of SSB at 1 January 2014, and the mean F over the year 2013. The information on these assessments is summarised in the ICES advice sheets which can be searched by region or species at http://www.ices.dk/community/advisory-process/Pages/Latest-Advice.aspx. These sheets indicate which expert group compiled the information: more detailed information of the assessments is available from the appropriate expert group report, searchable at http://www.ices.dk/community/groups/Pages/default.aspx.

ICES integrates the precautionary approach, maximum sustainable yield (MSY) and an ecosystem approach into its advisory framework. Here we adopt a simpler approach, determining current stock status relative to ICES MSY reference points, FMSY and BTRIGGER (ICES 2014), defined in Table 3.

Table 3 ICES MSY reference points defined

Reference point	Explanation
F_{MSY}	F consistent with achieving MSY.
MSY $B_{TRIGGER}$	SSB reference point that triggers a cautious management response within the ICES MSY framework: it is considered the lower bound of fluctuation around B_{MSY} which is the average biomass expected if the stock is exploited at F_{MSY}.

After reviewing various status classifications systems in the literature, we used the definition of stock status used by Australia (Flood et al. 2014) and adapted it to incorporate a knife-edge assessment of F and SSB relative to ICES MSY biological reference points. Since we consider two reference points there are four possible stock states depending on whether the reference point is exceeded or not: these are "sustainable", "recovering", "declining", "overfished"; and an "undefined" state (see Table 4 for definitions). Table 5 lists the status of each internationally managed stock in relation to this definition of stock status.

Table 4 Definition of internationally managed fish stock

Stock status	Status indicator	Explanation	Definition
Sustainable stock		Stock for which SSB (or a biomass proxy) is at or above MSY $B_{TRIGGER}$ and F is at or below F_{MSY}. The stock is at a level sufficient to ensure that, on average, the MSY can be obtained from the stock and for which fishing pressure is adequately controlled to avoid the stock becoming overfished. The appropriate management is in place.	SSB/ MSY $B_{TRIGGER} \geq 1$ and $F/F_{MSY} \leq 1$
Recovering stock		Biomass is below the level required to derive the MSY (SSB < MSY $B_{TRIGGER}$) but F is at or below F_{MSY}, so the appropriate management is in place, and the stock biomass is expected to recover.	SSB/ MSY $B_{TRIGGER} < 1$ and $F/F_{MSY} \leq 1$
Declining stock		Biomass is above level required to derive the MSY (SSB ≥ MSY $B_{TRIGGER}$), but fishing pressure is too high (F > F_{MSY}) and moving the stock in the direction of becoming overfished. Management is needed to reduce F to ensure that biomass does not decline to an overfished state.	SSB/ MSY $B_{TRIGGER} \geq 1$ and $F/ F_{MSY} > 1$
Overfished stock		SSB is below level required to derive the MSY (MSY $B_{TRIGGER}$) and F is above F_{MSY}. The stock has been reduced by fishing, so that average recruitment levels are significantly reduced. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements. Management is needed to recover the stock.	SSB/MSY $B_{TRIGGER} < 1$ and $F/ F_{MSY} > 1$
Undefined		Insufficient quantitative information exists to determine stock status. This could either be due to lack of data, lack of an agreed assessment, or a lack of one or more reference points.	Data to assess the stock status is required

Table 5 The status of internationally managed stocks, including year of stock assessment and accompanying notes

Stock	Stock status	Year of assessment	Stock assessment notes
Mackerel in the northeast Atlantic (combined Southern, Western, and North Sea spawning components)		2014	Substantial revision of stock status (SSB x 2) based on new assessment in 2014: model is now a state-space assessment model with catch, tagging, and 3 survey indices.
Nephrops in Division VIa			
Nephrops in Division Via - North Minch (FU 11)		2014	TV Survey. Small areas of sea lochs not presently included. Fishing effort declining. Medium density population.
Nephrops in Division Via - South Minch (FU 12)		2014	TV Survey. Area of mud uncertain, especially in sea lochs - relatively high variance on TV estimates. Fishing effort declining, low exploitation rate. Medium density population.
Nephrops in Division Via - Firth of Clyde (FU 13)		2014	TV Survey. Fishing effort stable. High effort per unit area of ground. High density population
Nephrops in Division Via - Sound of Jura (FU 13)		2014	TV Survey - intermittent. MSY $B_{TRIGGER}$ undefined owing to limited survey series. V low harvest rate. High density population. Sampling limited to other WC stocks
Haddock in Subarea IV and Divisions IIIa West and VIa (North Sea, Skagerrak, and West of Scotland)		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 2-4 for 2013. Following EU request for advice on F_{MSY} ranges based on multispecies modelling, ICES advised that a plausible value F_{MSY} is 0.37.
Nephrops in Subarea IV (North Sea)			
Nephrops in Division IVb, c - Botney gut - Silver Pit (FU 5)		2014	Data limited stock - advice provided on basis of ICES 'Nephrops' data limited approach
Nephrops in Division IVb - Farn Deeps (FU 6)		2014	TV Survey. 2014 data. Issues with sampling of 'tailed Nephrops'. Frequently fished well above F_{MSY} harvest rate. Stock below MSY $B_{TRIGGER}$. F_{MSY} influenced by reduced male population
Nephrops in Division IVa - Fladen Ground (FU 7)		2014	TV Survey. V large area to survey. Some patches to N not surveyed. V low harvest rate. Generally low density population
Nephrops in Division IVa - Firth of Forth (FU 8)		2014	TV Survey. High effort per unit area of ground. Relatively high harvest rate (frequently above F_{MSY}). High density population
Nephrops in Division IVa - Moray Firth (FU 9)		2014	TV Survey. Moderate harvest rate. Moderate density population
Nephrops in Division IVa - Noup (FU 10)		2014	Data limited stock - Limited \TV survey information - advice provided on basis of ICES 'Nephrops' data limited approach

Table 5 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Nephrops in Division IVa - Norwegian Deep (FU32)		2014	Data limited stock - advice provided on basis of ICES 'Nephrops' data limited approach
Nephrops in Division IVa - Off Horn's Reef (FU 33)		2014	Data limited stock - advice provided on basis of ICES 'Nephrops' data limited approach
Nephrops in Division IVb - Devil's Hole (FU 34)		2014	Data limited stock - Limited TV Survey information. advice provided on basis of ICES 'Nephrops' data limited approach
Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak)		2014	SSB is estimate for 2014, F is given as Fbar 2-4 for 2013. Following EU request for advice on FMSY ranges based on multi-species modelling, ICES advised that a plausible value for FMSY of 0.22 (slightly different from value given in 2014 advice which is described as an FMSY proxy based on FMAX 2010 but remains in place until planned bench-marking in 2015).
Anglerfish (Lophius piscatorius and L. budegassa) in Division IIIa and Subareas IV and VI		2014	There is no analytical stock assessment for this stock. ICES consider this as a Category 3 data-limited stock.
Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)		2014	No MSY BTRIGGER defined. BPA used as MSY BTRIGGER reference value.
Hake in Division IIIa, Subareas IV, VI, and VII, and Divisions VIIIa,b,d (Northern stock)		2014	Assessment model is length based (SS3). M is constant at 0.4. Discards in the assessment are "partial" with high uncertainty: likely large quantities. Ages not validated. Assessment has retrospective pattern.
Whiting in Subarea IV (North Sea) and Division VIId (Eastern Channel)		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 2-6 for 2013.
Saithe in Subarea IV (North Sea), Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall)			SSB is estimate for 1 Jan 2014, F shown as Fbar 3-6 for 2013. Following EU request for advice on FMSY ranges based on multi-species modelling, ICES advised that a plausible value for FMSY is 0.32.
Megrim (Lepidorhombus spp.) in Divisions IVa and VIa		2014	BMSY is shown as the estimate for 2013, FMSY shown as estimate for 2013 to be consistent with estimates of stock biomass and F ratios. The stock assessment uses a Bayesian state-space biomass dynamics model so the absolute estimates of the biological reference points change with re-assessment.
Ling (Molva molva) in Divisions IIIa and IVa, and in Subareas VI, VII, VIII, IX, XII, and XIV (other areas)		2014	Data limited stock

Table 5 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Plaice in Subarea IV (North Sea)		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 2-6 for 2013. Following EU request for advice on F_{MSY} ranges based on multi-species modelling, ICES advised that a plausible value for F_{MSY} is 0.19, lower than the estimate from single-species assessment.
Herring in Division VIa (North)		2014	No MSY $B_{TRIGGER}$ or B_{PA} defined. B_{LIM} is given as 50,000t.
Herring in Subareas I, II, and V, and in Divisions IVa and XIVa (Norwegian spring-spawning herring)		2014	
Lemon sole in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)		2014	Data limited stock.
Blue whiting in Subareas I–IX, XII, and XIV		2014	F and SSB are below/above all ref points. Managed on basis of management plan. On the advice sheet, the outlook for 2015 table is based on a catch constraint of 1200 t (TAC) which gives an F in 2014 of 0.27; then it states the basis for 1.5*F(2014)=1*F(2013)=0.41, but F(2013)=0.16?
Nephrops in Subarea VII			
Nephrops in division VIIa - Irish Sea East (FU 14)		2014	TV Survey. (England) MSY $B_{TRIGGER}$ undefined owing to limited survey series
Nephrops in Subarea VIIa - Irish Sea West (FU15)		2014	TV Survey. Ireland and NI)
Nephrops in Subarea VIIb, c, j, k - Porcupine Bank (FU 16)		2014	MSY $B_{TRIGGER}$ undefined owing to limited TV survey series
Nephrops in Subarea VIIb - Aran Grounds (FU 17)		2014	TV Survey
Nephrops in Subarea VIIg, h - Celtic Sea - Labadie (FU 20-21)		2014	TV Survey
Nephrops in Subarea VIIg, f - Celtic Sea - The Smalls (FU 22)		2014	TV Survey
Turbot in Subarea IV (North Sea)		2014	ICES advice is based on data limited stock. F_{MSY} 2-6 is a precautionary proxy based on F0.1 relative to the average of the time series.
Pollack in Subarea IV (North Sea) and Division IIIa (Skagerrak–Kattegat)		2014	ICES advice is based on data limited stock but catches cannot be quantified due to unknown amounts of discarding.

Table 5 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Boarfish in the northeast Atlantic		2014	The stock status is currently unknown. Survey indices indicate that the stock is declining. F is low.
Witch in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)		2014	ICES advice is based on data limited stock but catches cannot be quantified due to unknown amounts of discarding.
Sandeel in Subarea IV			
Sandeel in Subarea IV SA1 Dogger		2014	MSY $B_{TRIGGER}$ is the escapement biomass.
Sandeel in Subarea IV SA2 Southeast		2014	
Sandeel in Subarea IV SA3 Central east		2014	
Sandeel in Subarea IV SA4 Central west		2014	
Sandeel in Subarea IV SA5 Viking Bergen Bank		2014	
Sandeel in Subarea IV SA7 Shetland		2014	
Sole in Subarea IV (North Sea)		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 2-6 for 2013. Following EU request for advice on F_{MSY} ranges based on multi-species modelling, ICES advised that a plausible value for F_{MSY} is 0.20 and MSY $B_{TRIGGER}$ was estimated at 37,000 t. These values are somewhat different to estimates from the single-species basis.
Atlantic halibut in Subarea IV		2014	There are no assessments or advice for Atlantic halibut in sub-area IV. This is confirmed by information from the report FCI (2013), which looked at which stocks of importance to the inshore fisheries in England might achieve Marine Stewardship Council (MSC) certification.
Greenland halibut in Subarea IV		2014	There are no stock assessments or advice for this stock in subarea IV.
Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d (*L. whiffiagonis and L. boscii*)		2014	ICES advices on basis for data-limited stocks but cannot quantify the resulting catches due to unknown levels of discards (and other data issues).
Horse mackerel (*Trachurus trachurus*) in Divisions IIa, IVa, Vb, VIa, VIIa–c, e–k, and VIIIa–e (Western stock)		2014	Assessment model is Linked Seperable Adapt virtual population analysis (VPA) with single survey index every three years.

Table 5 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Blue ling (Molva dypterygia) in Division Vb and Subareas VI and VII		2014	SSB increasing since 2004, although no SSB reference point
Albacore tuna in Subarea VII			
Albacore tuna in the North Atlantic		2013	There is substantial uncertainty on current stock status.
Cod in Division VIa (West of Scotland)		2014	SSB is estimate for 1 Jan 2014, F is given as Fbar 2-5 for 2013. MSY BTRIGGER is set equal to Bpa; FMSY is a proxy by analogy with the North Sea.
Redfish in Subarea II			
Golden redfish (Sebastes norvegicus) in Subareas I and II		2013	Status 'declining stock' based on ICES advice but unsupported by any reference points. Renamed from Sebastes marinus to Sebastes norvegicus in 2014. No biomass or F data are given in the 2014 or 2013 Advice Books. SSB in 2013 and F in 2012 taken from the 2015 Working Group Report. No formal biomass of fishing reference points available.
Beaked redfish (Sebastes mentella) in Subareas I and II		2014	Status 'declining stock' based on ICES advice but unsupported by any reference points SSB in 2014 and F in 2013 taken from the 2014 ICES Advice Book. No formal biomass of fishing reference points available.
Greater forkbeard (Phycis blennoides) in the northeast Atlantic		2013	No biomass estimate nor F, but a combined abundance index indicates a substantial increase since 2009. Discards are considered high.
Sprat in Subarea VI and Divisions VIIa–c and f–k (Celtic Sea and West of Scotland)		2014	This is not a single stock. It relates to a species in a wider region where data are available.
Redfish in Subarea IV		-	There are no stock assessments or advice for this stock in Subarea IV.
Greenland halibut in Subareas V, VI, XII, and XIV		2014	There are problems regarding recommendations from the 2013 bench-mark to base advice on a Bayesian surplus-production model. Problems with the model led to NWWG rejecting the bench-mark recommendation and advice was produced on a data-limited stock approach. BMSY and FMSY are implicitly estimated from the surplus production model.
Greenland halibut in Subareas I and II		2014	Advice is based on survey-trends based assessment.
Albacore tuna in Subarea X			

Table 5 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Albacore tuna in the North Atlantic		2013	There is substantial uncertainty on current stock status.
Haddock in Divisions VIIb–k		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 3-5 for 2013.
Whiting in Division VIIa (Irish Sea)		2014	Assessment is analytical survey-based but is considered to be indicative of trends only. Although MSY reference levels remain undefined WGCSE suggest it is likely that F is above FMSY.
Whiting in Division VIa (West of Scotland)		2014	SSB is estimate for 1 Jan 2014, F shown as Fbar 2-4 for 2013.

2.3.2. Phase plots

The stock status is summarised in Figure 2 in the form of a phase or Kobe plot. This is a graphical representation of the status of a fish stock with respect to F and SSB reference points. Each quadrant of the phase plot indicates stock status (described in Table 4) showing whether it exceeds one or both of the reference point criteria. The green quadrant shows that both criteria are satisfied, while the red quadrant shows that both criteria are violated. Remaining quadrants correspond to either the SSB (yellow) or F (orange) reference point being violated.

The phase plot (Fig.2) was constructed for the internationally managed species where sufficient quantitative information (F/F_{MSY} and SSB/MSY $B_{TRIGGER}$) existed to determine stock status in the most recent year of assessment (2014 in most cases). Of the 63 internationally managed stocks 4 were overfished, 5 declining, 3 recovering, 11 sustainable and 40 undefined. Although these stocks represent a subset of all stocks considered, they represent all the most valuable species in the Scottish fishery as measured by 99th percentile value of landings at first sale.

The single largest group of stocks are in the "sustainable" zone. Of the two cod stocks that are in the red zone, the status of cod in the North Sea has been reassessed in the latest ICES advice (http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2015/2015/cod-347d.pdf). Although the state of the stock is much improved it remains in the "red" zone but is closer to MSY reference points.

An analysis of stocks assessed by ICES in the northeast Atlantic (Fernandes and Cook 2013) showed that the current status of stocks as illustrated in Figure 2 represents a general improvement on status compared with the situation in 2002 and suggests that management in recent years has been more successful.

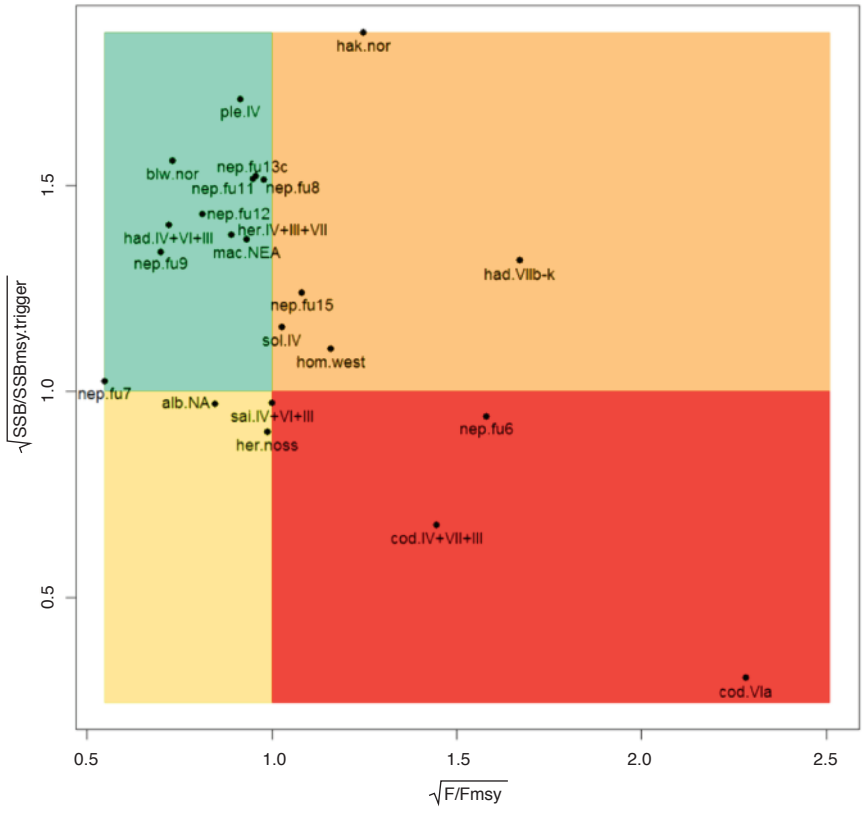


Figure 2 The status of internationally managed stocks of interest to Scotland. Status is expressed as the ratio of the current F and current SSB to their respective MSY values. For F ratios greater than 1 current F is too high. For SSB ratios less than 1, SSB is too low. Stocks in the green zone satisfy both MSY criteria while those in the red zone fail on both criteria. Stocks in the orange region have a satisfactory SSB but are being fished too heavily while stocks in the yellow region have a satisfactory exploitation rate but the SSB is too low. The axes have been rescaled using square root transformation for clarity of presentation. Stock codes are defined in Table 6.

Table 6 Stock code and name of internationally managed stocks

Stock code	Internationally managed stock
mac.NEA	Mackerel in the northeast Atlantic (combined Southern, Western, and North Sea spawning components)
had.IV+VI+III	Haddock in Subarea IV and Divisions IIIa West and VIa (North Sea, Skagerrak, and West of Scotland)
cod.IV+VII+III	Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak)
ang.III+IV+VI	Anglerfish (*Lophius piscatorius* and L. *budegassa*) in Division IIIa and Subareas IV and VI
her.IV+III+VII	Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)
hak.nor	Hake in Division IIIa, Subareas IV, VI, and VII, and Divisions VIIIa, b, d (Northern stock)
whi.IV+VII	Whiting in Subarea IV (North Sea) and Division VIId (Eastern Channel)
sai.IV+VI+III	Saithe in Subarea IV (North Sea), Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall)
meg.IV+VI	Megrim (*Lepidorhombus* spp.) in Divisions IVa and Via
lin.nor	Ling (*Molva molva*) in Divisions IIIa and IVa, and in Subareas VI, VII, VIII, IX, XII, and XIV (other areas)
ple.IV	Plaice in Subarea IV (North Sea)
her.VIn	Herring in Division VIa (North)
her.noss	Herring in Subareas I, II, and V, and in Divisions IVa and XIVa (Norwegian spring-spawning herring)
so.IV+III+VII	Lemon sole in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)
blw.nor	Blue whiting in Subareas I–IX, XII, and XIV
tur.IV	Turbot in Subarea IV (North Sea)
pol.IV+III	Pollack in Subarea IV (North Sea) and Division IIIa (Skagerrak–Kattegat)
boa.NEA	Boarfish in the northeast Atlantic
wit.IV+III+VII	Witch in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)
sol.IV	Sole in Subarea IV (North Sea)
hal.IV	Atlantic halibut in Subarea IV
ghl.IV	Greenland halibut in Subarea IV
meg.VII+VIII	Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb–k and VIIIa,b,d
hom.west	Horse mackerel (*Trachurus trachurus*) in Divisions IIa, IVa, Vb, VIa, VIIa–c, e–k, and VIIIa–e (Western stock)
bln.V+VI+VII	Blue ling (*Molva dypterygia*) in Division Vb and Subareas VI and VII
alb.NA	Albacore tuna in the North Atlantic
cod.Via	Cod in Division VIa (West of Scotland)

Stock code	Internationally managed stock
gfb.NEA	Greater forkbeard (*Phycis blennoides*) in the northeast Atlantic
spr.VI+VII	Sprat in Subarea VI and Divisions VIIa–c and f–k (Celtic Sea and West of Scotland)
red.IV	Redfish in Subarea IV (North Sea)
ghl.V+VI+XII+XIV	Greenland halibut in Subareas V, VI, XII, and XIV
ghl.I+II	Greenland halibut in Subareas I and II
had.VIIb-k	Haddock in Divisions VIIb–k
whi.VIIa	Whiting in Division VIIa (Irish Sea)
nep.fu11	*Nephrops* in Division Via - North Minch (FU 11)
nep.fu12	*Nephrops* in Division Via - South Minch (FU 12)
nep.fu13c	*Nephrops* in Division Via - Firth of Clyde (FU 13)
nep.fu13j	*Nephrops* in Division Via - Sound of Jura (FU 13)
nep.fu5	*Nephrops* in Division IVb, c - Botney gut - Silver Pit (FU 5)
nep.fu6	*Nephrops* in Division IVb - Farn Deeps (FU 6)
nep.fu7	*Nephrops* in Division IVa - Fladen Ground (FU 7)
nep.fu8	*Nephrops* in Division IVa - Firth of Forth (FU 8)
nep.fu9	*Nephrops* in Division IVa - Moray Firth (FU 9)
nep.fu10	*Nephrops* in Division IVa - Noup (FU 10)
nep.fu32	*Nephrops* in Division IVa - Norwegian Deep (FU32)
nep.fu33	*Nephrops* in Division IVa - Off Horn's Reef (FU 33)
nep.fu34	*Nephrops* in Division IVb - Devil's Hole (FU 34)
nep.fu14	*Nephrops* in division VIIa - Irish Sea East (FU 14)
nep.fu15	*Nephrops* in Subarea VIIa - Irish Sea West (FU15)
nep.fu16	*Nephrops* in Subarea VIIb, c, j, k - Porcupine Bank (FU 16)
nep.fu17	*Nephrops* in Subarea VIIb - Aran Grounds (FU 17)
nep.fu20-21	*Nephrops* in Subarea VIIg, h - Celtic Sea - Labadie (FU 20-21)
nep.fu22	*Nephrops* in Subarea VIIg, f - Celtic Sea - The Smalls (FU 22)
san.dog	Sandeel in Subarea IV SA1 Dogger
san.SE	Sandeel in Subarea IV SA2 Southeast
san.cE	Sandeel in Subarea IV SA3 Central east
san.cW	Sandeel in Subarea IV SA4 Central west
san.vik	Sandeel in Subarea IV SA5 Viking Bergen Bank
san.she	Sandeel in Subarea IV SA7 Shetland
gre.I+II	Golden redfish (*Sebastes norvegicus*) in Subareas I and II
bre.I+II	Beaked redfish (*Sebastes mentella*) in Subareas I and II

2.4. Nationally managed stocks

2.4.1. Stock and status

The stocks identified as Scottish "nationally" managed stocks comprise mainly of shellfish species, along with a few finfish species which are of limited commercial significance ("other international" stocks). Although these stocks are listed in Table 2 by ICES Subarea, they are not assessed at this scale. For the purposes of this report the assessment units used by Marine Scotland (as in Mesquita et al. 2015) have been used to define stock areas (Figure 3). For shellfish species the status of stocks has been compiled using assessment outputs produced by both MSS on data from 2009 – 2012 and the NAFC Marine Centre in Shetland, using data from 2000 – 2014 (Table 7). For crustaceans Length Cohort Analysis (LCA) is used in the stock assessment process and this is carried out for males and females separately because they often have different growth rates and may have different susceptibility to fishing gears. LCA does not provide any information on recruitment and the effects of fishing effort on recruitment. It should be noted that the input data and period of assessment differ between the MSS and NAFC assessments and they are not, therefore, directly comparable within the context of this report.

Shellfish stock assessments are based on LCA and do not produce the same reference points as indicated in Table 4. However for crustaceans F_{MAX} is used as a proxy for FMSY, an approach which has been used by ICES (ICES 2010). F_{MAX} is a measure of the rate of fishing which optimises the growth potential of the stocks and differs from F_{MSY} which also takes recruitment into account. Fishing above F_{MAX} is referred to as "growth overfishing". Stocks were colour coded red if the F rate was more than 10% above F_{MSY} and green if below this value (Table 7). There is no agreed biomass or F reference points for Scottish scallop stocks and management advice has been provided using recent estimates of F, recruitment and biomass in relation to historical values. The lack of any clear stock-recruitment relationship for scallops means that reference points relating to MSY cannot be calculated (Dobby *et al.*, 2012). For this reason the stock status of scallops has been classified as undefined (Table 7).

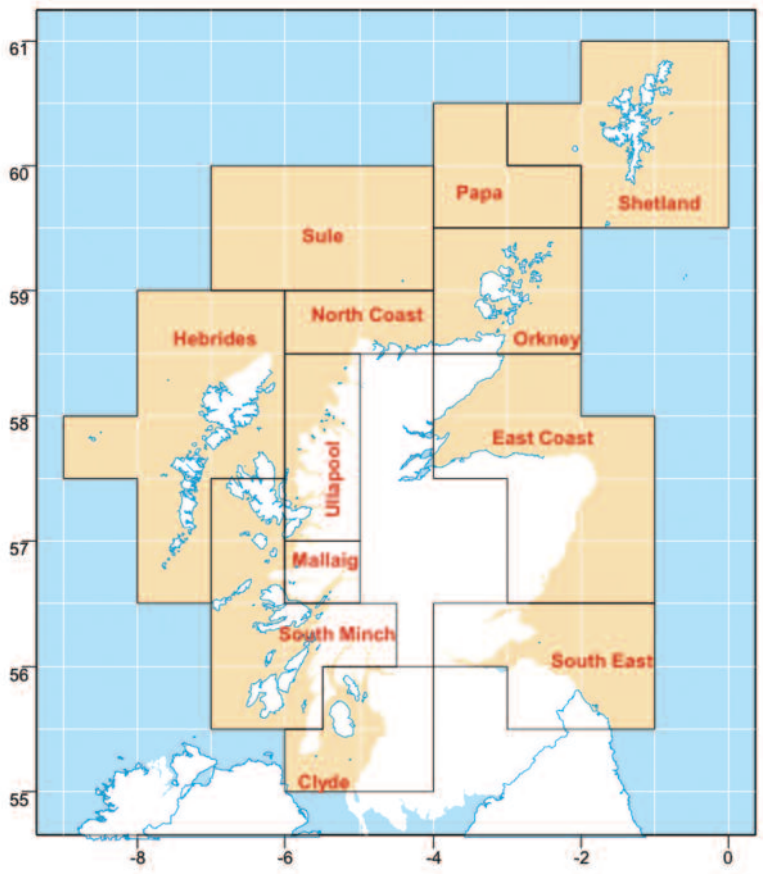


Figure 3 Map of Scotland showing the 12 management units used for crab and lobster assessments, based on the landings reporting system used by Marine Scotland.

Table 7 The status of nationally managed stocks, including year of stock assessment and accompanying notes

Stock	Stock status	Year of assessment	Stock assessment notes
Great Atlantic scallop in Subarea IV			
Scallop -North East	Stable - but below long term means	2011	There is no clear relationship between stock size and recruitment at age three for this stock. There are no formal reference points for this stock.
Scallop - Shetland (MSS)	Stable - above long term average	2011	Assessment carried out using time series analysis. There are no formal reference points for this stock.
Scallop - Shetland (NAFC)	Declining	2015	Assessment is carried out using VPA. LPUE trends data is also available for the period 2000 - 2014. Biological reference points are being developed but there are no formal reference points available for this stock.
Scallop - East Coast	Undefined	2011	No Assessment
Scallop - Orkney	Undefined	2011	No Assessment
Great Atlantic scallop in Subarea VII			
Scallop - Irish Sea	Undefined	2011	No Assessment
European lobster in Subarea IV			
Lobster - Papa - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Papa - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Shetland (MSS) - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Shetland (MSS) - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Shetland (NAFC) - Male	Undefined, but below F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends, data on undersized individuals and moult stage. Data in assessment covers the period 2000 - 2014.
Lobster - Shetland (NAFC) - Female	Undefined, but below F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends, data on undersized individuals and moult stage. Data in assessment covers the period 2000 - 2014.

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Lobster - East Coast - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - East Coast - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Orkney - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Orkney - Female	Undefined, but at F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - South East - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - South East - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Great Atlantic scallop in Subarea VI			
Scallop - West of Kintyre	Very reduced level	2011	Assessment carried out using time series analysis. There is no clear relationship between stock size (SSB) and recruitment to the fishery for this stock. There are no formal reference points for this stock
Scallop - Clyde	Undefined	2011	No Assessment
Scallop - North West	Low stock levels	2011	Assessment carried out using time series analysis. No formal reference points available for this stock.
Edible crab in Subarea VI			
Brown Crab - Clyde - Male	Undefined	2015	No Assessment
Brown Crab - Clyde - Female	Undefined	2015	No Assessment
Brown Crab - Hebrides - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Hebrides - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - North Coast - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - North Coast - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Sule - Male	Undefined, but at F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Brown Crab - Sule - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Mallaig - Male	Undefined	2015	No Assessment
Brown Crab - Mallaig - Female	Undefined	2015	No Assessment
Brown Crab - South Minch - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - South Minch - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - Ullapool - Male	Undefined	2015	No Assessment
Brown crab - Ullapool - Female	Undefined	2015	No Assessment
Edible crab in Subarea IV			
Brown crab - Papa - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - Papa - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Shetland (MSS) - Male	Undefined, but at F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Shetland (MSS) - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Shetland (NAFC) - Male	Undefined, but below F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends, data on undersized individuals and moult stage
Brown Crab - Shetland (NAFC) - Female	Undefined, but below F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends, data on undersized individuals and moult stage
Brown Crab - East Coast - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - East Coast - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown Crab - Orkney - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Brown Crab - Orkney - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - South East - Male	Undefined, but above FMSY	2015	The assessment is carried out on length data from 2009 - 2012.
Brown crab - South East - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Queen scallop in Subarea VII			
Queen Scallop - Scotland	Undefined	-	No Assessment
Velvet swimming crab in Subarea IV			
Velvet Crab - Papa - Male	Undefined	2015	No Assessment
Velvet Crab - Papa - Female	Undefined	2015	No Assessment
Velvet Crab - Shetland (MSS) - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Shetland (MSS) - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Shetland (NAFC) - Male	Undefined, but above F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends (2000 - 2014), data on undersized individuals and moult stage
Velvet Crab - Shetland (NAFC) - Female	Undefined, but above F_{MSY}	2015	In addition to the LCA outputs other available data include, effort, LPUE trends (2000 - 2014), data on undersized individuals and moult stage
Velvet Crab - East Coast - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - East Coast - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Orkney - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Orkney - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - South East - Male	Undefined	2015	No Assessment

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Velvet Crab - South East - Female	Undefined	2015	No Assessment
Common squids in Subarea IV	Undefined	-	No Assessment. ICES has a cephalopod study group and periodically does developmental work on assessing the various species. Length data are sometimes available from IBTS surveys.
European lobster in Subarea VI			
Lobster - Clyde - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Clyde - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Hebrides - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Hebrides - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - North Coast - Male	Undefined	2015	No Assessment
Lobster - North Coast - Female	Undefined	2015	No Assessment
Lobster - Sule - Male	Undefined	2015	No Assessment
Lobster - Sule - Female	Undefined	2015	No Assessment
Lobster - Mallaig - Male	Undefined	2015	No Assessment
Lobster - Mallaig - Female	Undefined	2015	No Assessment
Lobster - South Minch - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - South Minch - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Lobster - Ullapool - Male	Undefined	2015	No Assessment - future assessments where available will be carried out using time series analysis
Lobster - Ullapool - Female	Undefined	2015	No Assessment - future assessments where available will be carried out using time series analysis
Solen razor clams in Subarea VI	Undefined	-	No assessment

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Common squids in Subarea VI	Undefined	-	No Assessment. ICES has a cephalopod study group and periodically does developmental work on assessing the various species. Length data are sometimes available from IBTS surveys.
Velvet swimming crab in Subarea VI			
Velvet Crab - Clyde - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Clyde - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Hebrides - Male	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - Hebrides - Female	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - North Coast - Male	Undefined	2015	No Assessment
Velvet Crab - North Coast - Female	Undefined	2015	No Assessment
Velvet Crab - Sule - Male	Undefined	2015	No Assessment
Velvet Crab - Sule - Female	Undefined	2015	No Assessment
Velvet Crab - Mallaig - Male	Undefined	2015	No Assessment
Velvet Crab - Mallaig - Female	Undefined	2015	No Assessment
Velvet Crab - South Minch - Male	Undefined, but above F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab - South Minch - Female	Undefined, but below F_{MSY}	2015	The assessment is carried out on length data from 2009 - 2012.
Velvet Crab Ullapool - Male	Undefined	2015	No Assessment
Velvet Crab - Ullapool - Female	Undefined	2015	No Assessment
Common squids in Subarea VII	Undefined	-	No Assessment. ICES has a cephalopod study group and periodically does developmental work on assessing the various species. Length data are sometimes available from IBTS surveys.

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Queen scallop in Subarea VI			
Queen Scallop - Scotland	Undefined	-	No Assessment
Solen razor clams in Subarea IV	Undefined	-	No Assessment
European lobster in Subarea VII	Undefined		
Wolffishes in Subarea IV	Undefined	-	No assessments. IBTS survey data? landings
Cuttlefish, bobtail squids in Subarea VII	Undefined	-	No Assessment
Solen razor clams in Subarea VII	Undefined	-	No Assessment
Whelk in Subarea VII			
Whelk - Scotland	Undefined	-	No Assessment
Whelk in Subarea IV		-	
Whelk - Shetland	Undefined	-	Trends in LPUE data are available for 2000 - 2014
European seabass in Subarea VII			
seabass IVbc, VIIa, and VIId-h	Undefined	-	ICES 2014. Proxy F_{MSY} F35% SPR F_{MSY} advice. F exceeds F_{MSY} proxy. MSY $B_{TRIGGER}$ not defined. Biomass declining after series of lower recruitments but remains above BLIM
seabass - VIa, VIIb and VIIj	Undefined	-	ICES 2014. Data limited stock. Landings information only
Palinurid spiny lobsters in Subarea VI	Undefined	-	No assessment
John dory in Subarea VI	Undefined	-	No assessments. IBTS survey data? Landings?
Periwinkles in Subarea IV	Undefined	-	No assessment
John dory in Subarea VII	Undefined	-	No assessments. IBTS survey data? Landings?

Table 7 cont

Stock	Stock status	Year of assessment	Stock assessment notes
Green crab in Subarea IV			
Green Crab - Shetland	Undefined	-	Trends in LPUE data are available for 2000 - 2014
Palinurid spiny lobsters in Subarea IV	Undefined	-	No Assessment
Blue mussel in Subarea IV	Undefined	-	No Assessment
Whelk in Subarea VI			
Whelk - Scotland	Undefined	-	No Assessment
Sand gaper in Subarea IV	Undefined	-	No Assessment
Green crab in Subarea VI			
Green Crab - Scotland	Undefined	-	No Assessment
Gurnards, searobins in Subarea IV	Undefined	-	No Assessment
Grey gurnard IV and VIId and IIIa	Undefined	-	ICES 2014. Data limited stock. Survey - 2013 data didn't change perception of stock - no change in advice for 2015 and 2016. Unreliable catch information
Grey gurnard VI VIIa, c, e-K	Undefined	-	No ICES or other assessments. IBTS survey data, landings and catch information unreliable
Red gurnard - widely distributed	Undefined	-	No ICES or other assessments. IBTS survey data, landings and catch information unreliable

2.4.2. Phase plots

Analysis of the stock assessment outputs is shown Figures 4 and 5. These figures represent the ratio of current F to F^{max} as derived from the assessments as outlined above. It can be seen from Figure 4 that around one quarter of the stocks currently assessed would not meet the Fmax criterion, with velvet crab and lobster fisheries showing the highest values. When looking at these results by area (Figure 5) it can be seen that the North Coast, Shetland (where there is local management) and Papa have the highest proportion of stocks where fishing effort was considered to be at a level which would not result in growth overfishing. For almost all of the other stocks in each of the other areas, current F is considered to be too high.

The assessment outputs for the Shetland area show some differences between the MSS and NAFC (Table 7, Figure 5), these are due in part to the difference in the area covered by the management units. The Shetland Shellfish Management Organisation (SSMO) manages the 0-6 nmi area based on NAFC assessments, whereas the MSS Assessments are based on the ICES statistical rectangles in the Shetland area, which cover a larger area, and waters beyond the 6 nmi limit. Other differences in the assessments can be explained by differences in time periods selected for the input data.

Figure 4 The status of stocks managed by Scotland. Status is expressed as the ratio of the current F to F_{max} values where Fmax is a proxy for F_{MSY}. For F ratios greater than 1 current F is too high. Stocks coloured green satisfy the F_{MSY} criterion while those in the red fail.

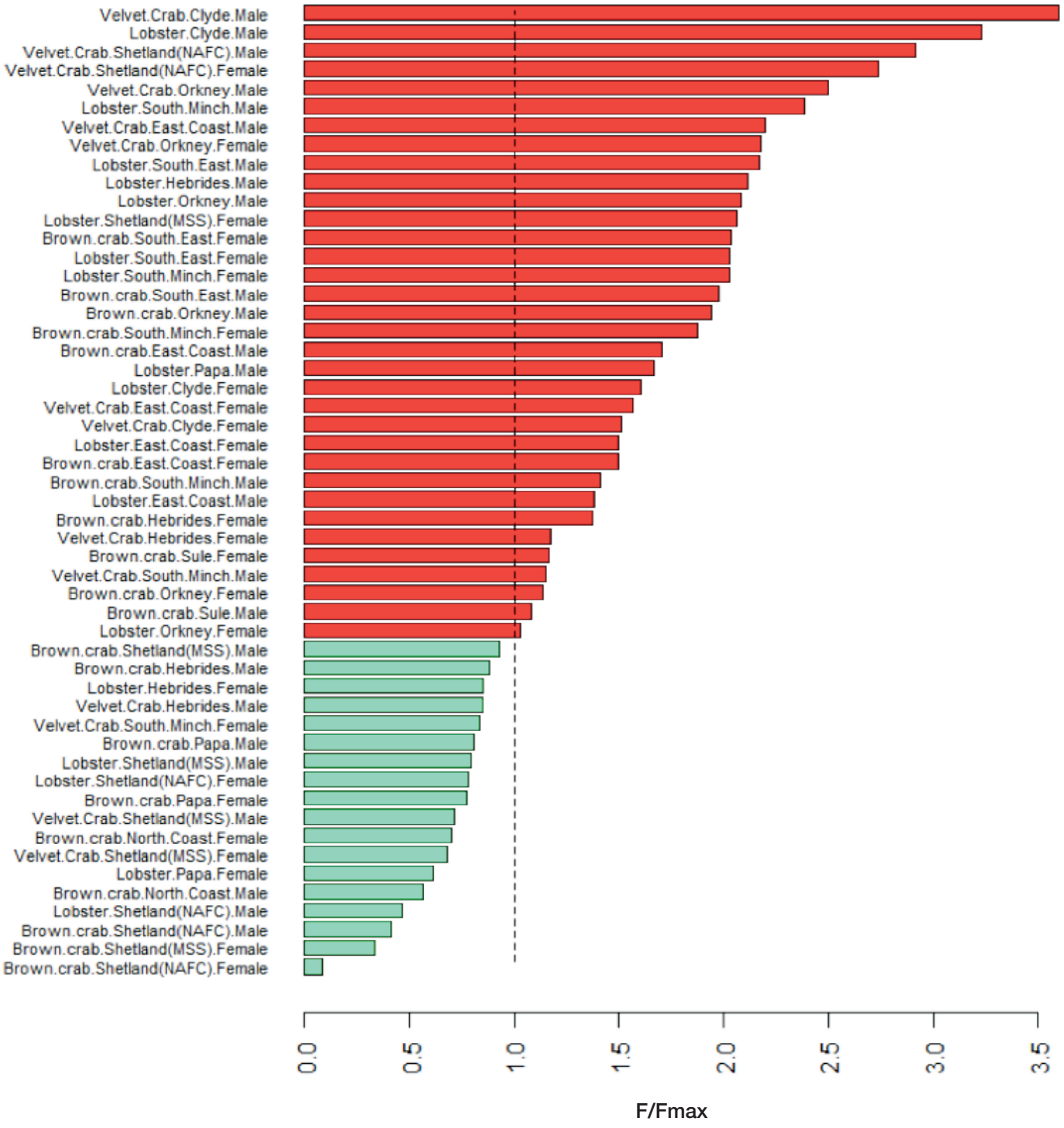
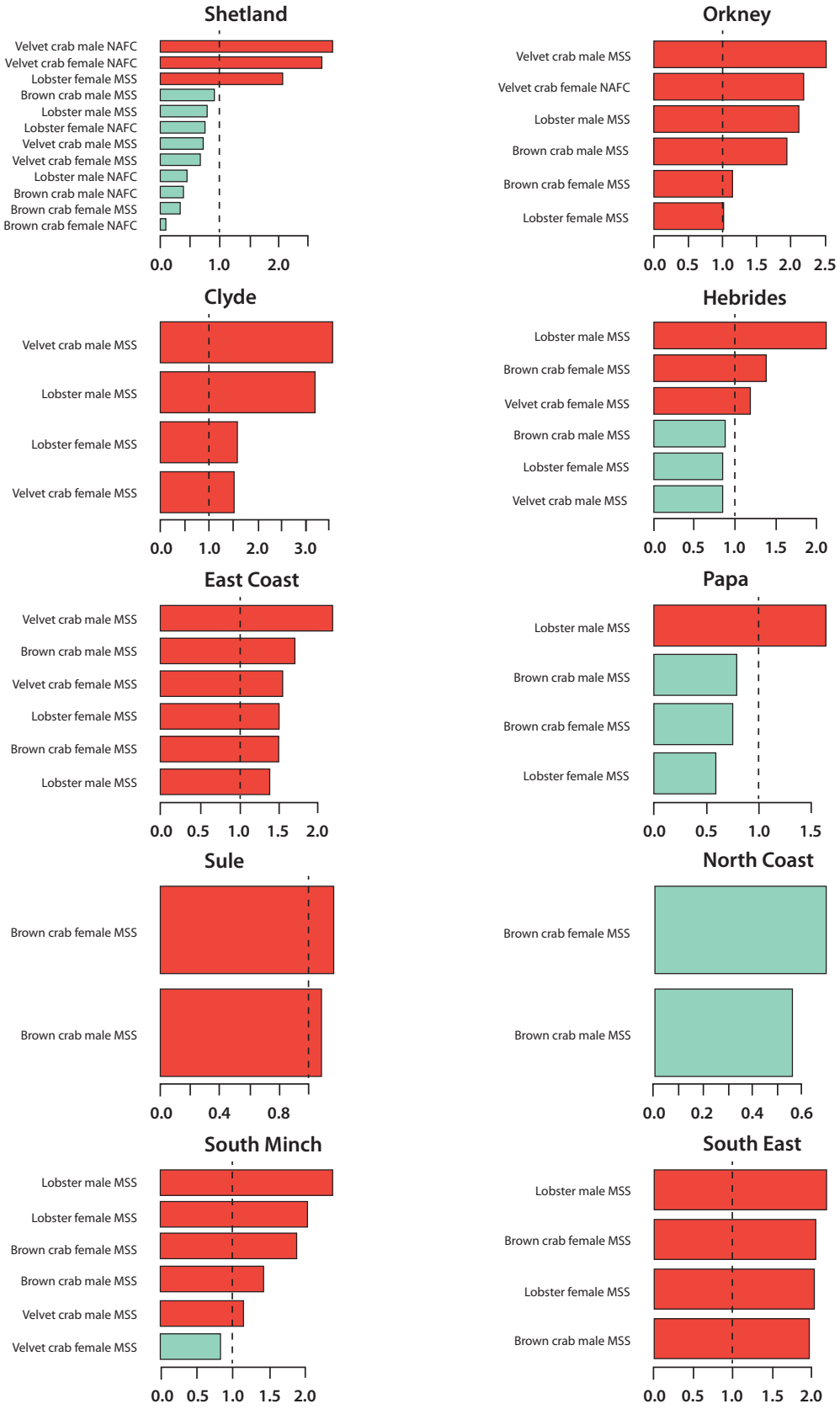


Figure 5 Status of stocks by area managed by Scotland. Status is expressed as the ratio of the current F to F_{max} values where Fmax is a proxy for F_{MSY}. For F ratios greater than 1 current F is too high. Stocks coloured green satisfy the F_{MSY} criterion while those in the red fail. MSS and NAFC refer to stocks assessed by MSS, Aberdeen and NAFC assessed by NAFC Marine Centre, Shetland respectively.



3. Fisheries research database

3.1. Summary of previous research

The database was designed to collate information on research relevant to Scottish commercial marine fisheries undertaken in the last 10 years. A scoping study was undertaken to determine the format of a fisheries research database. A spreadsheet was deemed appropriate given available time and resources. The database was designed as a simple tool to assist stakeholders, and was compiled based on publicly available research information.

Research projects running from 2005 were included in the database to provide an overview of past and current fisheries research. The main sources of publicly available information used to populate the database are described in Table 8. It was not always possible to fully populate the database as project dates and cost information were particularly difficult to obtain. Sources of publicly available information overlap, for example Marine Knowledge Gate 2.0 (http://www.kg.eurocean.org/) and Community Research and Development Information Service (CORDIS) (http://cordis.europa.eu/projects/home_en.html) both include European funded fisheries research (i.e. FP6, FP7 and Horizon 2020). Gateway To Research (http://gtr.rcuk.ac.uk/) is an inventory of UK Research Council funded projects including; Biotechnology and Biological Sciences Research Council; Economic and Social Research Council; and Natural Environment Research Council (NERC). Often it is not explicit from project information available whether research is of relevance to Scotland, as opposed to the UK as a whole.

Table 8 Main publicly available online databases of fisheries research project information

Name of public online database	Source of funding	Year information recorded from [year website last updated]	Number of records (results filtered by)	URL	Notes
Gateway to Research	Research Councils, UK	2006-2015 [June 2015]	~150 (UK, "fisheries")	http://gtr.rcuk.ac.uk/	Database is searchable by keyword, funder, project status, region and start year. The database is not updated regularly. Gateway to Research publishes information from a variety of sources.
Department for Environment, Food and Rural Affairs (Defra)	Defra, UK	1988-2015 [2015]	~280 (UK, "marine fisheries" theme)	http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=Detail&Completed=0&FOSID=17	Defra commissioned research projects only. The database is searchable by themes, and project title, cost, contractor, duration, description, and reports.
Marine Knowledge Gate 2.0	European and national	1960-present	~1190 (UK, 2005-present)	http://www.kg.eurocean.org/	Database of European and nationally funded marine science and technology research. The database is searchable by keyword, country and programme of funding. The database is hosted and maintained by EurOcean.
Community Research and Development Information Service (CORDIS)	European Commission (FP5, FP6, FP7, Horizon2020)	1990-present	~3700 (UK, "Resources of the sea and fisheries" theme)	http://cordis.europa.eu/projects/home_en.html	Database is searchable by keyword, project acronym and project results or report summaries
Cooperation in Fisheries, Aquaculture and Seafood Processing (COFASP) Database	European and national	1974-2015 [January 2015]	~23 (UK, "fisheries")	http://cofasp.eurocean.org/index.jsp	Fisheries aquaculture and seafood under FP7
EThOS: UK E-Theses Online Service	The British Library, UK	-	Over 340,000 records of PhD theses	http://www.bl.uk/reshelp/findhelprestype/theses/ethos/	Keyword search

The database captured over 130 records of projects categorised according to the species, area and keywords. The database records information relating to each project. Table 9 describes each field of the database.

Table 9 Description of the fields within the fisheries research database

Database field	Description of field
Origin of funding	Country of origin of funding
Project reference	Project reference number
Project Title	Title of project
Start Date	Start date of project
End Date	End date of project
Cost To Funder	Cost of project to main funder
Total Cost £	Total cost of project in pounds sterling
Total Cost Euro	Total cost of project in Euros
Project Summary	Abstract or summary of the project
Species keyword	Common name of the species that the project involved
Area keyword	Name of the area that the project covered (i.e. ICES areas - North Sea, West of Scotland, Irish Sea, and Celtic Sea etc.)
Keyword 1	Keyword associated with research
Keyword 2	Keyword associated with research
Any stakeholder engagement?	Was there any stakeholder engagement? (i.e. yes or no)
Main Funder	The name of the main funder
Other funders	Names of other funders
Main Funder contact Name	Contact name of the main funder
Funder Contact Email	Email of main funder
Main project coordinator institute	Name of the main coordinating institute
Project leader/coordinator	Name of main project leader/coordinator
Project leader/coordinator email	Email of main project leader/coordinator
Project website	URL of project website
Final report / deliverables / report summaries	URL to final report, deliverables or report summaries
Notes	Additional notes relating to the project

Research categories such as bycatch/discarding/gear selectivity, ecosystem approach to fisheries management, stock distribution/dynamics have received the most attention from the fisheries research community over the last decade, in terms of value of research funded. The majority of funding has been allocated to government, universities or agency laboratories. Economic and social science research has attracted the least funding, probably reflected by the fact that the database has captured more research projects encompassing biological research relative to economic and social research, which may present a somewhat misleading representation of research.

Of the research expenditure since 2005 captured in the database, over £70 million, the largest 23 projects (each of value over £1 million) are worth over £62 million, i.e. 87% of the total value recorded. Of these projects, research is focussed on ecosystem modelling, stock or population dynamics and some bio-economic modelling of socio-economic impacts of fisheries management. European funding (including the EU Framework Programmes FP5, FP6, FP7 and Horizon2020) account for the highest proportion (85%) of research in terms of value (£61 million) of research funded.

Relevance to the Scottish fishing industry

The fishing industry is of importance to Scotland. Hence, there is increasing interest in funding research in support of the Scottish fishing industry. Most funding is likely to come from public sources through a number of different bodies such as the European Commission, Research Councils and the Scottish Government for example. Currently the EU is investing its allocation of research funding under the Horizon 2020 programme.

The European nature of the database, in terms of where research is undertaken and sources of funding, was considered in the context of the Scottish fishing industry. The database suggests there is an increasing interest in funding fisheries research relevant to the Scottish fishing industry, although the direct relevance to the Scottish fishing industry is difficult to quantify. Publicly available information, in some cases, is not explicit to what degree the project is directly relevant to the Scottish fishing industry because there is no reference to Scotland or a Scottish case study. Hence, the database comes with the caveats because there are various degrees of application to the Scottish fishing industry.

When research was not of a direct commercial relevance, the motivation was often weighted towards academic measures of performance and impact. Therefore, there is a requirement for research that translates directly to the importance and value of the sustainability of the Scottish fishing industry. Non-academic research impact is of growing importance for the University research sector (see Section 5.9.3).

A low proportion of research projects are funded by the fishing industry. While the industry have invested in research they mostly give their time and use of vessel or participate in stakeholder engagement as opposed to direct funding. The level of fishing industry investment in research is difficult to quantify because this information is often not publicly available. In the UK, in common with many European countries, the cost of basic data collection and stock assessment is met by public funds whereas in New Zealand, for example, these costs are recovered from the industry.

Limitations to database

The database represents Scottish fisheries research project information, capturing a significant proportion of publicly funded research in this area with the UK and EU Framework Programmes. Therefore, the database does not cover research funded by countries outside of the UK or EU. The database also only captures publicly funded, not privately funded research, which might also might be of interest to the Scottish fishing industry. Given funding constraints it is important that lessons are learned from publicly funded research. Users of this database should note that while the database is built on a review of research information, it is not a complete record of all fisheries research relevant to the Scottish fishing industry nor does it encompass all fisheries research completed in the last 10 years. Hence, users of the database should note the database comes with some limitations.

Operationalising the database

The most recent version of the database can be downloaded from the FiS website at http://www.fiscot.org/.

Recommendations

The principal recipients of fisheries research funds are Scottish universities and European research institutes. From a strategic research perspective, for Scotland to maximise the potential of research funding to support the fishing industry requires a co-ordinate research agenda. The research database assisted in the identification of knowledge gaps to facilitate the allocation of funding and focus of research in the future in a more directed and co-ordinated manner. There is a responsibility on those allocating funds to distribute resources to support research addressing knowledge gaps. A review of potential research areas and topics is given in Section 6 as a conclusion to this report, whilst knowledge gaps are addressed in the following Section 4.

4. Synthesis of management concerns & research requirements/knowledge gaps

4.1. By stock

In this section, common knowledge gaps associated with many stocks are highlighted along with the major gaps associated with some of the more significant stocks. Specific management concerns and knowledge gaps for each of the international and national stocks are reported in Annex 9.1 and 9.2, respectively. Common management challenges and concerns are discussed in Section 4.2 below.

One of the most significant common knowledge gaps concerns the information on abundance of Scotland's major nationally managed shellfish stocks of lobsters and brown crabs. Current assessments (Table 7) are based on catch-at-length models and can only assess the current F in relation to sustainable limits that avoid growth overfishing (when fish are caught before they reach their optimum size). Without knowledge of abundance, it is not possible to know whether stocks are at a level that can replace themselves in the long term.

Methods to determine the abundance of mobile shellfish, such as lobsters and crabs, are notoriously difficult, because these animals live in rocky crevices which are difficult to sample. Potential techniques include capture-mark-recapture methods and visual surveys, but innovative solutions to this problem should be encouraged. Proxies for abundance, such as catch per unit of effort may also shed some light on relative abundance, but measures of effort by the shellfish fisheries must be made first. Allied to this is the need to develop means of determining the age of shellfish which shed their exoskeletons and make tagging experiments difficult. Currently, age is inferred from length using parameters from a growth model. These growth rate parameters may show local variability and should be determined more precisely. There is also a desire to determine the size of *Nephrops* during TV surveys.

In terms of assessment methods, for certain species, such as ling, lemon sole, turbot and boarfish, there is a need for further development using existing data. Survey-based assessment methods may be appropriate for species such as anglerfish and megrim but these should be improved upon, as existing time series of good quality survey data are available. Extensions to this work would include management strategy evaluations. A number of other species still require basic fishery dependent catch at length or age data to determine their status (halibut, forkbeard, west of Scotland sprat, and certain sandeel stocks, beyond the southern North Sea); while others would benefit from additional, more accurate fishery independent data (mackerel, horse mackerel, albacore). Although understanding and quantifying recreational fisheries (pollack) may be of low priority at the moment, it may be locally important (e.g. west of Scotland sealochs or the Clyde).

Where discarding is high, better and/or alternative estimates of discard quantities are required. This includes cod, hake, saithe and whiting in the North Sea; and cod, juvenile haddock, juvenile whiting and saithe on the west coast. Estimates should be disaggregated by fishery where possible at least to the whitefish fleet (TR1) and *Nephrops* fleet (TR2) designations specified in the cod recovery plan. Studies of discard survival rates, mitigation measures and selectivity (e.g. Drewery *et al.* 2010), are also required ahead of the forthcoming landing obligation (but see management concerns research priorities in Section 4.2.1). In a similar vein, studies to determine slippage in the pelagic sector and its mitigation are required.

Understanding recruitment processes, particularly where they are either very variable (haddock) or in long term decline (herring, whiting), would help to provide supplementary supporting information to stakeholders which would help to explain the need for certain management measures. Knowledge of stock structure in North Sea whiting, North Sea cod, west of Scotland herring, blue whiting, witch, Greenland halibut and scallops would be helpful in the assessment and management of these stocks. There may also be some stocks where species identification at sea or on markets is difficult to determine and so there is a need for efficient methods to determine species and/or stocks and their traceability (e.g. redfish, and anglerfish, the fisheries of which consist of two species).

Understanding demersal mixed fishery interactions is key to setting appropriate harvest limits and the development of new fisheries management plans. This can be developed with the application of multispecies models, ecosystem models and other process driven or empirical approaches. From these, and/or with additional studies, such as stomach content sampling schemes, better estimates of natural mortality for a range of stocks would benefit their assessments. Part of this natural mortality is driven by top predators of fish (e.g. seals on west of Scotland cod, porpoises on North Sea cod) so incorporation of these into models and further understanding of their dynamics will help to understand better the balance between natural and F. An understanding of new catching methods being applied in some fisheries would be of benefit to estimate fishing selectivity, environmental impact and incidental or bycatch mortality (e.g. pulse trawl, electrofishing, and sumWing - an alternative to a beam in beam trawling).

The long term effects of climate change on fish distribution, particularly for those species at the edges of the range (cod to the south, hake to the north) will be important in the medium to long term. Allied to this is the requirement to develop methods to determine zonal attachment for certain stocks in anticipation of future changes under climate change or where recent changes have led to allocation disputes (e.g. mackerel, hake). Knowledge of stock structure in North Sea whiting, North Sea cod, west of Scotland herring, blue whiting, witch, Greenland halibut and scallops would be helpful in assessment and management of these stocks.

Collection of fishing effort in the inshore shellfish fisheries, for vessels of 10 m or less (not subject to vessel monitoring system (VMS) monitoring) would be useful to determine fishing patterns to inform fisheries management and also to develop indices of catch per unit effort (CPUE) which may aid in stock assessments. It should be noted however that this proxy for abundance has limitations and should be considered inferior to fishery independent methods of determining abundance. In a meta-analysis of various types of finfish fisheries Harley et al. (2001) found that CPUE was most likely to remain high while abundance declines (hyperstability), due to behaviour of both fish (range contraction) and fishermen (improved efficiency and enhanced communication): the extent to which this applies in shellfish fisheries is unknown.

Research into ageing methods is needed for certain species (hake, anglerfish, *Nephrops* and other shellfish) so that cohort-based analytical techniques can be applied to determine their status. Such methods are considered preferable to length based approaches. Whilst the latter are still in use, there is a need to determine stock specific growth rates for shellfish, to better inform current and future length-based assessments of status. These are particularly important for *Nephrops* stocks at the FU level.

4.2. By management challenge

4.2.1. Landing obligation

The reformed CFP contains a number of new policies including an obligation to land all catches – frequently referred to as the 'discard ban'. This policy represents one of the most significant challenges for fisheries in the last 40 years and raises a number of management and operational issues. The policy is being introduced gradually from 2015 to 2019 and will cover species of fish managed by TACs.

Mixed fishery quota issues

With the exception of the fisheries for pelagic fish (mainly mackerel and herring), most of Scotland's key stocks are caught in mixed fisheries where catches comprise several species. The mix of species and the quantities taken during fishing operations are not always predictable so that quotas for the different stocks are often used up at different rates. Under existing arrangements, when the quota for a species is used up vessels may then discard that species in order to continue fishing for other species for which catching opportunities remain. Similarly, by-catches of species for which quota is not available are also presently discarded. Discarding can also take place for other reasons (see Fernandes et al 2011). Under the landing obligation the requirement not to discard has led to the concept of 'choke' species – the first species for which quota runs out leading to the termination of fishing (Russel et al. 2005, Baudron and Fernandes 2014). Clearly, a management mechanism which increases flexibility in quota availability would help alleviate these problems and a number of options may play a part.

There is an urgent need to investigate how the current TAC share out at the International level (enshrined in Relative Stability) adequately reflects the distributions of fish and fishing activity and the extent to which it confounds the implementation of the landing obligation. Improved data exist on fish and effort distributions but evaluation and impact assessment of adopting different options is lacking. The current TAC shares were established some decades ago and it is perhaps time to examine the evidence for a change or perhaps the adoption of a new, more adaptable approach reviewed on a more frequent basis. Equally, there is a need to consider the tools available for increased flexibility in international, national and vessel to vessel quota swapping. Similarly, some economic analysis of the benefits of new arrangements within Scotland (for example the adoption of 'quota pools') would be very worthwhile.

Adaptation of fishing operations

Adjustments to fishing operations provide another way reducing discards. A variety of options are available including changes in fishing gear and alteration of fishing strategy through seasonal, temporal and spatial means. Fishing gear options continue to be explored as ways to improve selectivity and, in the context of the landing obligation, both species and size selection is important. Trials exploring conventional (e.g. mesh change) or novel approaches (fish response to light, more dynamic 'opening/closing nets' etc.) are underway but will continue to need to be supported. In order to improve acceptance of new measures it will be necessary to demonstrate the impact on business of any new development. This requires economic modelling to provide both short and medium term analysis. Spatial and temporal options (moving fishing operations to avoid certain species or sizes of fish) merit investigation. While closed area management has

been around for a long time, the more dynamic RTC (real-time closure) approach is relatively new. For the implementation of the landing obligation, new more flexible approaches are needed which provide easily accessible tools for fishermen to use - interactive fish abundance maps are one. Such developments will require investment in data portals and interfacing facilities accessible at sea. There also needs to be work with fishermen to investigate the economic balance between sharing information (to help avoid landing obligation induced interruption to fishing) and not sharing. Since the landing obligation will be around for some time it is unlikely that arrangements to solve current problems will always be relevant. An important new area of research is likely to be the improvement of forward forecasts to include not only estimates of total catches but of the composition in terms of size and distribution. This would enable advance planning and preparation of mitigation measures. Without such developments the process of dealing with the landing obligation will remain a reactive one.

Dealing with unwanted catches

Inevitably some catch will still be unwanted but will have to be landed and there is a relative shortage of knowledge on how best to deal with this. On board vessels the issue is one of storage space and of recording the catch. Onshore the issues include storage, transport, alternative uses and cost of disposal. Fish under the MCRS (minimum conservation reference size) cannot be sold for human consumption or find outlet markets that encourage their exploitation. Alongside traditional outlets (e.g. bait for creeling) there is a challenge for chemists, engineers etc. to develop uses for variable quantity, variable composition products which might supplement other 'waste' products. Bioenergy production is an obvious area for exploration and other specialist uses might also be identified. The scale of the issue is difficult to judge – if the industry response is to move swiftly to more selective gears, then the scale of investment in onshore facilities will likely be smaller. An informed exploration of options would, however, be beneficial and this necessarily requires input from a range of disciplines and industries beyond fishing alone.

Exemptions and provisions – survival and flexibility

Within the landing obligation various provisions exist to help mitigate the difficulties associated with the land-all policy. Of these, two of the provisions require some advances in knowledge. An exemption is available for species which show 'high-survival' following the fishing and discarding process – what constitutes high survival is not defined and is unlikely to be in the future. In some fisheries, for example involving creeling for crustaceans, anecdotal evidence suggests that survival can be high. In trawl fisheries the survival rates are much less clear. For many fish species, ICES assessments assume 100% discard mortality although emerging evidence suggests that some fish do survive. The process of establishing rates of survival, and whether this is short term or longer term (to allow the animal to reproduce for example), attracts considerable debate. Experiments to measure survival are difficult and potentially expensive. Research on best approaches which offer cost effective but robust results are required. At present, application for the exemption is rather ad hoc and the analysis and judgement of survivability somewhat subjective – an improved framework would be beneficial.

Another provision allows end year and inter-species quota flexibility. The latter is of particular concern since it essentially allows one species of fish to be regarded as 'equivalent' to another using conversion factors. Certain safeguards limit the proportions of quota that can be converted and prevent transfers involving stocks outside safe biological limits. There is however, a need to better understand the implications of quota transfers of this type and presently analysis would rely on the tools used within the ICES prediction process. An improved suite of analysis tools would help inform the process and would lead to decisions being based on stronger evidence.

Monitoring and enforcement

Critical to the successful implementation of the landing obligation will be the monitoring of catches and efforts to generate compliance with the rules (e.g. through a combination of incentives and enforcement). The ability to demonstrate benefits (economic and otherwise) arising from the landing obligation would encourage compliance. At present, large scale, longer term benefits and their translation to the individual fishing businesses is difficult to demonstrate but would be helped by informed socio/economic analyses.

Failure to adequately account for all fish caught will undermine the scientific stock assessment process and compromise future catching opportunities. At this stage it is difficult to judge the extent to which the quality of catch data will change and it will be sometime before the effects are manifest in fisheries advice. It is, however, important that the potential implications of bias in catch data (whether increased or decreased) are explained to stakeholders from an early stage in order to encourage compliance from the outset. A FiS programme of 'information and training events' would aid in raising awareness.

There are major questions remaining about the approaches that will be used to monitor catch. Up to now, the monitoring of landings onshore has been supplemented by scientific observers on board vessels providing information on discards. Under the landing obligation it is unclear the extent to observers will be

able to operate using present arrangements. Observers currently have no compliance role but may be perceived or be required to have one in the future. It is doubtful that resources will allow for observers on every vessel so considerable reliance may be placed on skippers to supply accurate records of any fish discarded (under the legitimate exemptions) and landed in the ports. In recent years there has been investment in the use of remote electronic monitoring (REM, closed circuit television (CCTV) for images of operations and sensors of winch activity etc.). These technologies offer new approaches for monitoring and, coupled with image analysis and structured sampling schemes, could provide cost effective, efficient methods to augment the reporting process described above. Further research on image analysis and exploration of sampling strategies that meet the needs of science and compliance are urgently required. In the end, these will ensure continuity in catching opportunities.

4.2.2. Maximum sustainable yield

International commitments that are incorporated into the CFP require stocks in Europe to be fished at levels consistent with MSY. Most stocks jointly managed with third parties also make the same commitment. The implementation of MSY generally means estimating F rates corresponding to MSY (FMSY) and the SSB resulting from fishing at this level (BMSY). Estimation of these values is apparently straightforward for single stocks but there are uncertainties that prevent or undermine such calculations. These include lack of knowledge about the relationship between stock size and subsequent recruitment, how growth and maturity change in response to the environment and stock size, and predatory interactions between species that affect mortality rates. These weaknesses can be addressed directly through research, or circumvented by defining so-called "proxies" that approximate the desired MSY level. Where MSY cannot be explicitly calculated research on appropriate proxies is desirable.

While estimation of MSY, or a proxy, is usually feasible for individual stocks, complications arise where a fishery exploits a mixture species and the individual species FMSY values differ significantly. In such "mixed fisheries" it may be impossible to identify an overall exploitation rate that is consistent with all the individual species in the fishery. This is a major area for new research to establish credible fishery exploitation rates that recognise biological differences between species but are consistent with the concept of MSY.

An additional important area of concern is the meaning of MSY when there are biological interactions between species. It is well known that where species prey on each other assumptions of constancy of biological inputs to the calculation of MSY are no longer valid. The violation of these assumptions may have a profound effect on the estimation of MSY to the extent that is has little meaning in terms of maximising yield on a stock by stock basis. Work is required on appropriate ways of accounting for biological interactions in order to estimate F rates consistent with the concept of MSY. At least one approach is to develop ecosystem models that consider the essential elements of the ecosystem as applied to fisheries.

4.2.3. Economic performance

Fisheries policy in Scotland also aims to deliver a sustainable and profitable industry. The economic performance of the Scottish fishing fleet is estimated annually by Seafish and figures for gross value added, operating profit and net profit are included for each of 33 fleet segments in the UK. Scotland-only figures are supplied regularly to the Scottish Government. Seafish also provides required estimates to the European Commission under Commission Regulation (EC) No. 665/2008 of the 14 July 2008 which establishes the Data Collection Framework (DCF), a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the CFP.

The concept of profitability implies a comparison of actual amount of profit in relation to the money or value invested in the businesses that generate that profit. Therefore, an absolute amount of annual profit of, say, £10,000, cannot be assessed as being acceptable or not unless we know how much capital was invested in order to generate that profit.

The right to fish is represented in several instruments including vessel licences, shellfish entitlements and Fixed Quota Allocation (FQA) units. These instruments are bought and sold (whether officially or otherwise) and FQA units are leased out for one year periods. Therefore, the value of fishing rights should be included in the balance sheet of a fishing business, along with tangible fixed assets such as the fishing boat, as it is a necessary investment to permit the generation of fishing revenues.

For the DCF data submission, Seafish estimates the value of fishing rights and return on investment, or a proxy, return on fixed tangible assets for the designated fleet segments. These two measures are at present particularly difficult to estimate robustly for several reasons. First, the value of fishing rights, assuming that they were not all available for sale at the same time, could be estimated based on recent trading prices. However, trading in fishing rights (specifically in Scotland, FQAs and shellfish entitlements, among others) is not transparent and

prices are not publicly available. Therefore, in order to estimate the value of all rights based on recent trades, a sample of trade prices has to be obtained for all quota species. This is a difficult process, complicated greatly by the fact that FQAs are often (probably usually) sold in mixed stock packages. FQAs for less desirable species have been included in packages with units for the truly desired species, making it impossible to estimate a price per unit for the different species in the package. Hypothetically, the value could be based on the entire national expected fishing revenues and profits over a period of years and an assumed discount rate to reflect the risk of the investment. This is the approach taken by Seafish in recent years and this approach has been endorsed in a review of DCF economic variable estimations.

In order to make a genuine estimate of profit in relation to capital invested, we would ideally have a much more robust estimate of the value of fishing rights. This could possibly be achieved by having a transparent market for quota trading and the sale and purchase of licences and entitlements, as exists in some European countries such as Iceland and Denmark. However, the implementation of the landing obligation will further complicate the value of fishing rights if a choke species quota prevents the catching and sale of other stocks once choke stock quota has been fully caught. It is unlikely that a robust estimate of the value of fishing rights will be obtainable until after the landing obligation has been fully implemented and a transparent market for quota units is available.

Until there is a robust estimate of the value of fishing rights, there cannot be a true estimate of return on investment, and we must continue to rely on estimates of return on fixed assets to compare the performance of the fishing sector to other primary production sectors, and to compare performance of various fleet segments with each other.

Management objectives based on maximum economic yield (MEY) seek to maximise the long-term profitability of the fishing industry, rather than the long term biomass of fish landed (based on F_{MSY}). The rationale behind MEY is to create the largest difference between the total revenues and the total costs of fishing (including capital, labour, and fuel costs). Although not currently part of the CFP, the MEY concept is currently being implemented for federally managed fisheries in Australia which have formally adopted B_{MEY} as the target biomass (Harley *et al.* 2001). In contrast to B_{MSY}, which depends on biological considerations only, B_{MEY}depends on assumptions regarding fishery dynamics and values for economic quantities such as fish prices and input costs (Harley *et al.* 2001). Uncertainty about these quantities makes estimation of F_{MEY} and B_{MEY} even more challenging than estimating F_{MSY} and B_{MSY}. Generally F is lower under MEY than MSY, resulting in larger unfished stock sizes and a reduced environmental impact. When stock sizes are larger, fish are easier to catch (thereby reducing fuel costs) and generally larger in size which increases their market value. For these reasons MEY strategies are often regarded as benefitting both industry and conservation. However, implementing F_{MEY} may not be that straightforward as costs and prices vary considerably over time making F_{MEY} a moving target. Furthermore, fishing to MEY may require reductions in fleet sizes and employment related to the fishing industry, which could potentially produce a net economic loss despite increased profits for the fishery.

4.2.4. Marine Strategy Framework Directive

Biodiversity

The requirement to meet biodiversity indicators defined under the Marine Strategy Framework Directive (MSFD) presents some challenges for fisheries management in regions where it has been shown that there is an association between the decline of fish stocks due to exploitation, and depletion of species richness or changes in the dominance of species in the fish communities. A particular case in point is the Firth of Clyde (Heath et al 2011), where demersal fish species evenness has declined to extremely low values (community almost entirely dominated by whiting) in concert with decline in demersal community biomass and finfish landings, and expansion of Nephrops landings. Similar trends (decline in demersal finfish landings, rise in Nephrops landings) are evident in data collected throughout Scottish inshore waters, though the association with demersal fish species evenness is less well established.

MSFD indicators are not confined to commercial species but potentially span the entire range of fauna and flora. Hence, impacts of fishing activity on non-commercial species will be a sensitive issue for fisheries management. These include loss of benthos diversity as a result of the cumulative effects of trawling, and especially physical damage to sensitive seabed communities such as those associated with sea pens, deep water corals and maerl beds. Finally, fisheries effects on the species diversity of top predators are perceived to be a potential issue, for example as a result of the promotion of scavenging and opportunistic seabird species by the long-term practice of discarding at sea. The consequences for seabird species diversity of the implementation of the landing obligation are unknown.

Non-indigenous species

Challenges to fisheries management arising from non-indigenous species are perceived to be low, other than possible bio-security issues associated with vessels

returning to operate in Scottish waters after distant-waters operations.

Commercial species
MSFD targets for commercial species are convergent with CFP goals on harvesting at MSY and hence present no particular additional challenges to fisheries management. Nevertheless, the issues associated with achieving MSY harvesting across all commercial species should not be under-estimated (see section 4.2.2).

Food webs
Indicators and targets on food webs remain the least well defined of all aspects of the MSFD. Nevertheless, they are also potentially the most challenging for fisheries management. There is no doubt that the most significant cumulative effect of fisheries harvesting has been the depletion of top-predatory taxa at the apex of marine food webs and the driving down of mean trophic levels in shelf sea food webs worldwide. Restoration of marine food webs to anything resembling an unfished state could take many decades, even if it is possible at all on any meaningful time scale. The eventual setting of food web targets represents a serious potential challenge for fisheries management which could require extensive reduction of commercial harvesting operations.

Eutrophication
Eutrophication indicators and targets under the MSFD (and the Water Framework Directive) are not likely to cause a challenge for fisheries management, except in the cases of shallow inshore trawl fisheries where seabed sediment disturbance by towed gears accounts for a significant fraction of the nutrient flux into the water column. Instances of eutrophication enhancement by this means have been recorded e.g. in some inshore Danish waters, but should not be an issue in Scotland. Algal blooms, which are a consequence of eutrophication, may have some impacts on fisheries, particularly when caused by toxic species. In the past, incidences of paralytic, diarrheic and amnesic shellfish poisoning by toxic algae have led to the closure of scallop and other bivalve fisheries in Scottish waters, and are a frequent problem in other regions of the world.

Seafloor integrity
Limitations on the extent of damage to the seafloor under the MSFD pose some challenges to fisheries management in relation to the physical impacts of towed seabed-contact gears. The existence and extent of 'trawl-scars' on the seabed is well known, and the continued use of gears which cause such damage could be constrained under MSFD legislation. Research would be needed to identify gear modifications to alleviate the physical impacts of towed gear on the seabed.

Hydrographic conditions
Expectations that human activity shall not lead to significant alteration of hydrographic conditions are not expected to pose any challenges to fisheries management.

Contaminants
MSFD targets on environmental contaminants are not likely to pose a challenge for fisheries management.

Contaminants in seafood
Contaminants in seafood are already an issue for the sale and marketing of fish from some regions. Dioxin levels in northeast Atlantic fish are higher than in the southern Pacific for example, making Pacific fish cheaper to process to acceptable contaminant standards for fish meal and oil for aquaculture feed purposes. Mercury levels in some deep water fish species in the northeast Atlantic (e.g. Black scabbard fish) are considered to be high by some food standards limits. If the MSFD leads to more exacting contaminant standards then this could become a challenge for fisheries management.

Marine Litter
A high proportion of marine litter represents the cumulative result of many decades of loss or abandonment of fishing gear and related equipment, especially static gear in some regions such as isolated regions of the Hebrides. This, and accumulated non-fishing related litter in the marine environment is the most significant marine environmental issue of concern to many of the general public. Cleansing the seas of litter is a major problem, especially where the material has already broken down into micro-particles which evidence shows are now interfering with the food web. Reducing new littering in Scottish fishing fleets to zero is likely to become a requirement under the MSFD. Resources are available to enable fishing vessels to gather and retain litter captured during routine fishing operations and bring ashore for disposal in facilities provided by port authorities. Demonstrating that Scottish fisheries comply with zero littering standards could become a challenge for management.

Underwater noise
Noise generated by some forms of towed seabed-contact gears forms a significant fraction of the noise emissions from commercial fishing operations, and may become come an issue in some instances under MSFD noise limitation targets. However, there is relatively little information on this issue, or on whether the frequencies and intensities involved pose a threat sensitive marine fauna.

4.2.5. Marine planning

Marine Renewables
The Scottish Government is committed to the expansion of the marine renewable energy industry. Generating power at sea involves installing structures that have the potential to:

1. Modify or change habitats,
2. Deny fish access to feeding, nursery or spawning grounds
3. Change local hydrographic conditions
4. Act as barriers to fish migration routes
5. Generate noise that interferes with normal behaviour
6. Act as refuges resulting in local enhancement of fish populations

At present the scientific assessment of environmental impacts tends to be done on a case-by-case basis. Perhaps what is overlooked is the total effect of the anticipated marine renewable development on fisheries in Scottish waters. A study that looked at this question would need to evaluate both the ecological and economic consequences of expanded marine development at a regional sea scale.

Oil and gas platform decommissioning
The offshore oil and gas industry has reached a stage where some major infrastructure is no longer required and will be decommissioned. While there are commitments to remove structures there are likely to be pressures to re-use them to avoid the costs of decommissioning. Alternative uses and their implications will need to be evaluated. This includes their use as refuges for fish and as potential sites for offshore aquaculture.

Mariculture
Scottish waters have long been used for aquaculture, most notably for salmon. This is restricted primarily to sheltered coastal waters. There is likely to be further expansion of the industry to include new species and offshore production facilities. The effect of these developments will need to be investigated and will need to include not just the environmental impact but also genetic aspects resulting from escapes and the potential for disease transmission to wild fish.

Marine protected areas
The establishment of marine protected areas (MPAs) is a commitment both at European and national level. While the value of MPAs for sessile or sedentary species can be relatively straightforward to assess, it is much more difficult to evaluate the effects on mobile species that are not permanent residents of the site. Research is required on methods to assess MPAs and their effect on fish populations that are only temporary residents of the area. Proposals have been made for a network of MPAs that would collectively act as a way of protecting and enhancing fish (and other) populations. Research to evaluate these ideas is needed to examine both the biological and economic consequences.

4.2.6. Climate

Observations show that levels of carbon dioxide (CO2) in the atmosphere have been increasing since industrialisation . It is widely accepted that this is leading to a period of rapid environmental change relative to historical baselines. Around the UK, annual mean sea temperatures have shown warming over the last few decades, although there are quite large regional variations. For example, annual warming in surface and bottom temperatures in the North Sea has been around 0.4oC per decade (Rutterford *et al.* 2015) but offshore waters to the west of Scotland have shown slightly slower warming rates (Hughes and Turrell 2011). According to the Intergovernmental Panel on Climate Change there is high confidence that warming will continue at a global scale in the coming decades. Warming trends are also likely to continue around the UK (Marine Climate Change Impacts Partnership 2013).

Changes in the fish species recorded in UK waters have already been noted and linked with increasing temperatures (Montero-Serra *et al.* 2015). There are also less obvious effects since a wide range of important biological processes, such as growth, maturation and survival rates of eggs and larvae are affected by temperature (Heath *et al.* 2012). There may be possible changes in diseases and parasites affecting wild-stocks although more is known in relation to cultivated species and very little research has been conducted on wild-stocks (Callaway *et al.* 2012).

The dissolution of CO2 from the atmosphere in seawater is also leading to a gradual reduction in the pH of seawater, a process commonly called "ocean acidification" . Direct detrimental effects on marine organisms have been observed in other locations e.g. on survival of larval oysters reared in up-welled water on the eastern coast of the USA (Waldbusser et al. 2015). Such impacts may however only become

[3] Data on atmospheric CO2 levels can be found at https://scripps.ucsd.edu/programs/keelingcurve/

[4] The term 'ocean acidification' can be confusing - seawater is moderately alkaline (pH>7.0) and ocean acidification is causing the pH to drop, but it will not actually lead to seawater becoming acidic (pH<7.0). However, such apparently small declines in pH are associated with decreased carbonate ion content which can be sufficient to affect the physiological processes of marine organisms which rely on the formation of calcium carbonate based shells. Such organisms include coccolithophores, corals, pteropods and shellfish.

apparent in UK waters over the longer-term because the pH of coastal waters varies naturally (Blackford and Gilbert 2007). Climate change is also predicted to lead to sea level rise as well as changes in precipitation and storminess, all of which may affect inter-tidal and shallow sub-tidal habitats in particular (Marine Climate Change Impacts Partnership 2013).

The main climate-change related issues which fisheries managers will have to deal with in the short to medium-term (present to plus 20 y) are likely to be changes in fish distribution and productivity. For established commercial species the biological data used in stock assessments and reference points may need to be revised more frequently. A good example is the 2015 bench-mark assessment for North Sea cod (ICES 2015) where changing from a fixed maturity ogive to a varying maturity ogive has resulted in a large change in the estimated amount of mature fish in the stock . As well as changes to established commercial stocks, the appearance of warmer water species in our waters may lead to quite rapid development of new fisheries e.g. red mullet in the North Sea. The main problem this generates is the lack of historical time-series on which harvest reference values are usually based (ICES 2015).

In the medium to longer-term (present to plus 50 y), modelling studies suggest that overall productivity of fish stocks may become lower due to warming (Cheung et al. 2013). This is a consequence of the energetic demands on organisms under warmer temperatures and there is some evidence for such an effect in a number of North Sea fish stocks over the last 40 years (Baudron *et al.* 2014). However, there is considerable uncertainty about how fish and shellfish communities will respond to warming (and ocean acidification), because many of the effects may be indirect, as a result of accumulated impacts throughout the food-web. In the longer-term we should expect to see large changes in the abundance of some stocks which presently form the main commercial species as their capacity for behavioural adaption e.g. by seeking cooler, deeper waters, reaches its limits (Rutterford *et al.* 2015). Furthermore, although adult fish may be able to respond behaviourally, this flexibility may not apply to all life stages. Spawning grounds for many important species, including plaice and cod, appear to be relatively fixed spatially and so their early life stages may be more susceptible to changing conditions, compared with the more mobile adults (Hufnagl *et al.* 2013, Fox *et al.* 2008).

Despite all the uncertainties, the main conclusion is that fish and shellfish are showing responses to climate change and that the direction of change is expected to continue over the coming decades. Fisheries management will need to be aware of and adaptable to such changes. Further research and modelling will be able to provide more detailed projections of likely changes, although, because of the complexities described above, these will likely continue to have medium levels of confidence (Marine Climate Change Impacts Partnership 2013). Continued research is required at all levels from how individual species respond to changing conditions right up to whole ecosystem effects. Research will also be required into trade-offs in yield and economic returns resulting from reviewing reference points, and relative stability, at more frequent intervals.

Finally it should be noted that many of the consequences of our changing ocean climate are likely to be indirect and inter-acting and so will remain difficult to predict. As a consequence, managers, policy-makers and fisheries policy will probably need to become more responsive to changes in the marine environment (Montero-Serra *et al.* 2015, Gattuso *et al.* 2015).

4.2.7. Fishery certification

Sustainability certification has an important and increasing contribution to developing sustainable industries. The basic concept is that buyers can be assured that certified products have been produced to specified standards. Across the whole range of consumer products there is a wide variety of certification schemes relating to quality, materials sourcing, manufacturing standards and ethics of production. Certification schemes are run by a wide variety of organisations but usually the actual certification process is handled by separate auditing companies with expertise in evaluating whether a production system reaches the required standard. Certified products may sometimes carry a price premium, but this is not universal. Particularly in fisheries, many processors are beginning to focus on certified products because the system helps ensure quality or continuity of supply.

For capture fisheries the two main certification schemes are run by the Marine Stewardship Council (MSC) and Friends of the Sea (FOS). Although fisheries management does not necessarily interact directly with

[5] There has been a trend for cod in the North Sea to mature at younger ages over time. This may be partly related to changes in the environment but could also be an adaptive response to fishing. Allowing for this change in maturation has resulted in an increase in the estimated amount of mature fish in the stock. However, the working group cautioned that this ignores any effects of younger maturation on egg production (in terms of quantity or quality), and so may give an overly optimistic impression of the reproductive capacity of the stock in recent years.

[6] The MSC scheme does include a risk-based framework which could be applied to stocks lacking assessments but it has not been widely used.

these schemes, the fact that increasing numbers of fisheries are going forward with certification places certain additional pressures on managers. Both schemes place a strong emphasis on the status of the stocks, both the directly targeted stock and any which contribute non-target catch by the fishery. Certification is only likely to be successful when stocks have robust stock assessments and reference points . Other issues which are considered during certification include the wider habitat and ecosystem impacts of the fishery, including discarding, and the legal framework within which the fishery operates. At present neither the MSC nor FOS schemes specifically evaluate issues such as carbon footprint or social considerations, although such areas might be added in future.

A key feature of the MSC scheme in particular is that it allows for a fishery to improve over time in order to reach the required standard. On the one hand this has been criticised because fisheries which have short-comings can be certified as sustainable (Christian et al. 2013), but on the other hand it can act as a mechanism to drive positive change.

Significant criticisms of the wider state of fisheries eco-labelling relate to the plethora of labels which are being used, including super-market chain's own designs, leading to public confusion about what the labels really mean (Gutierrez and Thornton 2014). The costs of MSC certification have also been criticised and do seem to discourage smaller fisheries, particularly in developing countries, from taking part (Pérez-Ramírez et al. 2012). In addition, there have been some problems with deliberate or accidental mis-labelling, although a subsequent wider survey of products commissioned by the MSC did not find any large-scale issues with fraud (Marko et al. 2011).

The 2013 CFP reforms include a much stronger commitment to providing consumers with accurate information for seafood products. New labelling requirements have been introduced to cover species, fishing method and area landed and this improved traceability is likely to require research to provide better and cheaper tools for product testing in order to detect fraud (Nielsen et al. 2012).

For UK and Scottish fisheries management, the main issue which certification raises is likely to be an increased demand on science support from the industry. This relates not only to stock assessments, but in terms of providing supporting evidence on wider habitat and ecosystem impacts. Although individual fisheries can be expected to have the resources to commission limited pieces of research on areas such as the impacts of their gear, monitoring ecosystem health is of such scale that only national and international administrations will have the resources to undertake such work. If significant progress can be made in achieving Good Environmental Status for European waters under the MSFD, then that will help address this knowledge gap and aid the industry in getting more fisheries certified as sustainable.

4.2.8. Inshore fisheries management

As indicated in preceding sections (Section 4.2), the sea space in Scotland's inshore sector is becoming increasingly busy with competition from fisheries, aquaculture, nature conservation, marine renewables, tourism and other users of the marine environment. The challenges facing inshore fisheries managers within this context centre around a lack of available data, both fisheries and biological, with which to quantify fishing activity and its spatial distribution, carry out stock assessments, and effectively manage fisheries.

There are currently insufficient resources to carry out data collection and assessment programmes that would be analogous to those implemented for finfish fisheries (international stocks). Specific issues relating to stock assessment arise from the fact that ageing of many shellfish species is not possible. The outputs of length based assessments can vary significantly depending on the input data and may be influenced by changes in the fishery during the assessment period. For scallop stocks, where aging is possible and there is a greater confidence in the assessment methods, there are no formal reference points for the stocks. Nor is there an approach available to provide information on suitable stock levels for each of the fishery management areas. For some species, such as brown crab, there is also uncertainty with regards to the extent of individual stocks from which exploitation in different assessment areas takes place.

There is limited information on fishing effort and the spatial distribution of fishing activity within the inshore sector. Collection and analysis of this data would be extremely useful in describing the fishery and would supplement the current assessment methods, for example to provide an index of abundance. This type of data is also required to ensure that fisheries can be adequately represented within marine spatial planning frameworks as they are implemented, as has been carried out in Shetland, and also to feed into spatial management measures which may arise through nature conservation, for example through the introduction of MPAs.

The mechanisms by which stock assessment outputs and fisheries data are used in fisheries management are less clear to stakeholders (see Section 5.7). Better integration of their data within the management process, for example developing biologically relevant

reference points, would permit more effective management plans to be drawn up. The collection and maintenance of adequate fisheries data sets would permit the implementation of more informed inshore fisheries management measures and a fuller understanding of the potential implications of such measures. Current issues, for example, include gear conflict and the potential impact of recreational fishers on the stocks. Without understanding the effort and distribution (both spatial and temporal) of current commercial fishing activity it is extremely difficult for fisheries managers to address either of these concerns.

There is increasing interest in proving sustainability through accreditation schemes (see Section 4.2.7), with commitments from some supermarket chains to have all produce sourced from accredited fisheries by 2020. Without sufficient data to carry out assessments and management processes based on such data, inshore fisheries in Scotland may struggle to attain accreditation and the access to markets this may facilitate.

Some current research programmes have been devised to start investigating the use of technology such as VMS and camera systems to obtain fisheries data and also additional data submission by fishermen at a finer spatial scale. The outcomes of these projects will further inform the way forward.

The mechanisms by which data are integrated in fisheries management are unclear. Better integration of data within the management process would permit more effective management plans to be drawn up. The collection and maintenance of adequate fisheries data sets would permit the implementation of more informed inshore fisheries management measures and a fuller understanding of the potential implications of such measures. Current issues, for example, include gear conflict and the potential impact of hobby fishers on the stocks. Without understanding the effort and distribution (both spatial and temporal) of current commercial fishing activity it is extremely difficult for fisheries managers to address either of these concerns.

There is increasing interest in proving sustainability through accreditation schemes, as mentioned in section c vii, with commitments from some supermarket chains to have all produce sourced from accredited fisheries by 2020. Without sufficient data to carry out assessments and management processes based on such data, inshore fisheries in Scotland may struggle to attain accreditation and the access to markets this may facilitate.

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5. Stakeholder engagement

5.1. Background

Stakeholder engagement is the generic term used to refer to initiatives or systems through which managers and members of diverse interest groups, known as stakeholders, can enter dialogues whereby the expert knowledge and opinions of stakeholders is sought, shared, or summarised. Effective stakeholder engagement builds trust, fosters openness and transparency and, in some cases, develops consensus about management objectives (Mackinson et al. 2011). In fisheries, stakeholders normally fall into one of two broad categories. Fisheries stakeholders include management agencies, fishermen and crew, shore-side businesses and employees, and fishery-dependent families and communities. The second category includes all other special interest groups concerned with the marine environment such as environmental non-governmental organisations (ENGOs). The shift in Europe and elsewhere towards ecosystem-based management, an integrated approach to management that considers entire ecosystems, including humans, has greatly increased the importance of stakeholder engagement (Mackinson et al. 2011).

Stakeholder engagement relevant to fisheries issues can take a wide variety of forms. For the purposes of this study, we consider there to be three general categories of stakeholder engagement (Garrett et al. 2012). The first are fisheries-science partnerships, which commission and undertake research to support stock assessment, investigate operational aspects of fishing (e.g., gear) or collect tactical data on emergent issues (Armstrong et al. 2013). A second category of stakeholder engagement is initiatives promoting interactive governance. This broad category is exemplified by regional advisory councils and advisory groups and the provision of formal or "ad hoc" consultative opportunities for stakeholders. The third category is results-based management (RBM) which are management systems whereby the governing authority sets management and operational objectives and establishes a framework with stakeholders assuming responsibility for delivering these objectives (Santiago et al. 2015).

There are many reasons and objectives for undertaking stakeholder engagement in fisheries-related issues. The expanded opportunities for dialogue and research can give industry members a greater understanding of relevant natural and social science and improve scientists' understanding of industry and management. When effective, stakeholder engagement gives participating interest groups a greater sense of ownership of the management process and, therefore, a stronger commitment to the regulatory framework and developing consensus. Results-based management has the additional benefit of alleviating the responsibility for micromanaging complex fisheries from government agencies.

This section reviews a range of recent and current stakeholder engagement systems relevant to Scottish fisheries. These are then evaluated using a semi-quantitative evaluation of the relative strength of stakeholder engagements. The results of a short questionnaire of Scottish stakeholders are presented. International examples of best practice are briefly summarised followed by a summary of emergent trends in stakeholder engagement. Lastly, challenges for the future are identified.

5.2. Stakeholder engagement at EU Level

Regional Advisory Councils (RACs) were established by enabling legislation in 2004 as part of the 2002 CFP reform. As well as being consulted by the Commission, the RACs could make suggestions or recommendations on any aspect of the CFP. The seven stakeholder-led RACs covered five distinct maritime areas surrounding Europe as well as the pelagic sector and long-distance fleets. Three RACs were relevant to Scottish fisheries: the North Sea (http://www.nsrac.org/), North-Western Waters (http://www.nwwac.org/), and Pelagic (http://www.pelagic-ac.org/) RACs. Following the 2013 CFP reform, these RACs were renamed Advisory Councils (ACs). ACs are consulted on the design and implementation of crucial fisheries management tools, such as discard reduction plans. They are intended to achieve greater regionalisation and more extensive stakeholder consultation. Each year the AC members agree a work plan which is approved by the European Commission. The plan identifies work that will be addressed over the year and sets a meeting schedule for the year. The work of the ACs is normally delivered by Working Groups which typically meet several times a year to consider and discuss current and emerging topics and to develop advice and policy on behalf of the AC membership. Advice developed by the Working Groups is presented to the Executive Committee for approval. A Working Group can be supported by a number of Focus Groups, which are smaller groups set up to develop advice on a specific topic. Focus Groups are flexible in their approach, drawing in representatives and experts from a number of sources including scientists, fishers, environmental specialists, economists and others.

5.3. Stakeholder engagement in ICES

Interested stakeholders are permitted to participate in a range of ICES science activities either as observers or full participants. For example, meetings of the ICES Scientific Committee (SCICOM), expert groups, and science workshops are all open to participants. The decision to accept a participant is made by the chair of the meeting in consultation with the Secretariat or by the national delegate to ICES from the country of residence of the applicant. Advice Drafting Groups, as well as Advisory Committee (ACOM) meetings, which are a component of ICES, are also open to observers from governmental, intergovernmental, and non-governmental organizations and individuals, after application for observer status has been approved by ICES. There is a code of conduct for such observers. All data workshops, including Benchmark and Data compilation workshops, are open and can be attended by anyone provided they have relevant expertise to the process.

ICES Annual Science Conferences are open to the public. They are attended primarily by scientists, many of whom are members of ICES expert groups, SCICOM and ACOM and (or) affiliated with universities and marine research institutes. ICES Symposia are intended to broaden the diversity of scientists who participate in ICES activities and are often structured around topics that are relevant to science-based stakeholders (http://www.ices.dk/news-and-vents/symposia/Pages/default.aspx). For example, symposium topics in 2015 and 2016 are "Targets and Limits for Long-term Fisheries Management" and "Understanding marine socio-ecological systems: including the human dimension in Integrated Ecosystem Assessments", respectively. Recently, ICES has sponsored conferences that were relevant to fisheries industry stakeholders including two recent conferences on using fishery-dependent information in management (held in 2010 in Galway, Ireland and in 2014 in Rome). Lastly, ICES also offers a wide range of specialized training courses (see http://www.ices.dk/news-and-events/Training/Pages/Previous-reports.aspx) that are relevant to science-based stakeholders.

5.4. Stakeholder engagement in Scotland

5.4.1. Marine Strategy Forum

The Marine Strategy Forum (MSF) has been in existence since 2009 and provides a cooperative base for developing an integrated strategic approach to the management, use and protection of Scotland's seas and coasts by using cross-sector awareness and collaboration on marine issues. The remit is to "provide advice to Scottish Ministers on Marine Scotland's priorities, contribute to key strategic policies and framework documentation to balance competing marine interests, to advise on Scottish input to significant policies affecting Scotland's seas, being taken forward at a UK or international level, and to provide strategic advice on enhanced stakeholder engagement". The MSF meets three times a year and has a standing membership that is drawn from a diverse range of stakeholders; government, industry (fishing and non-fishing), ENGOs, science, (see http://www.gov.scot/Topics/marine/seamanagement/forum/Membership).

5.4.2. Fisheries Management and Conservation Group

Responding to the need for greater stakeholder involvement in marine affairs, in 2011 the Scottish Cabinet Secretary for Rural Affairs and the Environment announced a refreshed stakeholder engagement plan covering both fisheries management and seafood. Two new advisory bodies were created. The Fisheries Management and Conservation Group (FMAC) replaced the Scottish Fisheries Council, incorporating aspects of the Conservation Credits Steering Group, and was intended to cover all aspects of inshore and offshore sea fisheries. The Scottish Seafood Partnership replaced the Scottish Fisheries Council and is made up of the key players from processors, retailers and Producer Organisations. Since the introduction of FMAC in 2011, responsibilities for inshore fisheries and discarding have been devolved to three newly created Advisory Groups: Inshore Fisheries Groups (IFGs), Inshore Fisheries Management and Conservation Group (IFMAC) and The Scottish Discard Steering Group. The stakeholders engaging in activities of each of these engagement systems are reviewed below in Section 5.4.3 and 5.4.4 respectively.

FMAC has a remit to take decisions and, on request, make recommendations to the Cabinet Secretary for Rural Affairs and the Environment on matters connected to: the development of national policies and legislation about the management and conservation of sea and inshore fisheries, and impacts on the marine environment so as to ensure a viable Scottish fishing industry and the maintenance of sustainable fishing communities; the allocation and management of fishing opportunities available to vessels managed by the Scottish Government, seeking where possible, to align management measures with economic objectives identified by the Scottish Seafood Partnership; the development of measures designed to better conserve and sustainably exploit stocks of sea fish (recognising that maximum effect will be gained through international cooperation), and to enable fishermen and other persons with an interest to contribute to such

development; and the development of objectives for and approaches to international negotiations across a range of fisheries, seeking improved international partnership arrangements. Membership is weighted towards fisheries stakeholders although there are some ENGOs represented including the World Wide Fund for Nature (WWF). Marine Scotland chairs the group, determines initial membership and provides a secretary. Membership is restricted to representatives of defined stakeholder groups and changes to membership are made with the agreement of the group. Members may nominate a substitute but may not invite additional attendees, although the group may agree to invite individuals to present on specific topics.

5.4.3. Scottish Inshore Fisheries Working Groups

The Scottish IFGs (http://ifgs.org.uk/) are non-statutory bodies that aim to improve the management of Scotland's inshore fisheries out to six nautical miles, and give commercial inshore fishermen a consolidated voice in wider marine management developments. There are currently six IFGs responsible for different sea areas: East Coast, Moray Firth & North Coast, North West, Orkney, Outer Hebrides, and South West. Additionally, there is a group responsible for the management of shellfish around Shetland (http://ssmo.co.uk/). Marine Scotland provides chairs for the Groups and administrative support services and IFG members normally represent relevant fishermen's associations. Individuals may also be members, to represent groups of non-affiliated fishermen. Members are expected to represent the views of, and report back to, the associations that they represent.

A recent review of the IFGs has resulted in a proposed change to the management structure with a proposed reduction in the overall number of IFGs around the mainland coast. The maintenance of local aspects of management would be achieved through the development of local sub-groups. It is proposed that the IFGs are to be supported by two outreach officers.

5.4.4. Inshore Fisheries Management and Conservation Group

The IFMAC complements the IFG network by focusing on national, as opposed to local, inshore issues and covering inshore sea areas not covered by IFGs (e.g. 6–12 nmi). Its remit is similar in scope to FMAC. IFMAC takes decisions and, on request, can make recommendations to the Cabinet Secretary for Rural Affairs and the Environment on matters connected to: the development of national inshore fishing policies and legislation relating to the management and conservation of the sea in the 0-12 nmi zone, and effects on the marine environment so as to ensure a viable Scottish fishing industry and the maintenance of sustainable fishing communities; the allocation and management of inshore fishing opportunities available to vessels managed by the Scottish Government, seeking, where possible, to align management measures with economic objectives identified by the Scottish Seafood Partnership, and the development of national measures designed to better conserve and sustainably exploit stocks of sea fish and shellfish, and to enable fishermen and other persons with an interest to contribute to such development. Marine Scotland chairs the Group meetings, provides administrative support and determines initial membership. Similar to FMAC, changes to membership are made with the agreement of the group and is subject to periodic review. Members may nominate a substitute but may not invite additional attendees, although the group may agree to invite individuals to present on specific topics. Recent changes to the structure of IFMAC will see two meetings of the full membership, one of which will be at the annual Inshore Fisheries Conference, with specialist sub-groups taking forward specific issues.

5.4.5. Scottish Discarding Steering Group

The remit of the Scottish Discarding Steering Group (SDSG) is to advise the Scottish Government on developing policies relevant to the implementation of the landing obligation. The SDSG is predicated on the assumption that successful implementation of the landing obligation rests on a shared partnership-based approach between stakeholders and government. Unlike the three other advisory groups (IFG, IFMAC, FMAC), membership is broadly based including representatives of Marine Scotland, The Scottish Fishermen's Federation, The Scottish Pelagic Fishermen's Association, the Scottish Whitefish Producers' Organisation, the Shetland Fishermen's Association, the Scottish Association of Fisheries Producers' Organisations, the Scottish Fishermen's Organisation, the Scottish Seafood Association, the Fishermen's Association Ltd, WWF and The Royal Society for the Protection of Birds. The Group meets several times a year and reviews progress on a wide range of research initiatives.

5.4.6. Scottish Seafood Partnership

The Scottish Seafood Partnership provides strategic advice to a range of bodies including Scottish Ministers, the seafood industry, Seafish (in Scotland) and Seafood Scotland. The remit of the Partnership is to provide advice on ways to add value to all seafood and aquaculture products from net to plate and to promote the sustainable profitability of the seafood and aquaculture sectors. Membership includes groups representing the supply chain of both seafood and aquaculture sectors, industry partners, Scottish Government, industry bodies, the MSC, retail and

consumer bodies. In contrast to FMAC, the members of the partnership participate as individuals rather than as representatives of their parent organisations. The partnership meets on a quarterly basis.

A Fishing Focus Group existed for a limited period (2010-2013) with a remit to provide a strategic and co-operative forum to ensure commercial fishing interests are considered in the development of Marine Scotland policy in relation to marine planning, marine renewables and marine conservation and to provide for an integrated approach to information dissemination and discussion.

5.5. Other systems for stakeholder engagement in Scotland

The advisory groups described above normally have restricted membership. However, there have also been opportunities for broader stakeholder engagement in the form of public meetings that are coordinated by Marine Scotland. Quayside Conversations were held regularly through 2012 to 2013 and then were superseded by Regional Fishing Industry Assemblies in 2014. The aims of the Regional Fishing Industry Assemblies were two-fold: to seek views on issues that will have a major influence on the future prosperity of the Scottish seafood sector, in particular (the CFP and implementation of the landing obligation, access to quota for active fishermen, encouraging new entrants into the industry, and fishing and the shared marine environment); and to report back on the actions being taken to address some of the key points raised during the earlier Quayside Conversations events. In 2014 seven assemblies were held around the Scottish coast attracting local skippers and other interested parties.

5.6. Evaluating Scottish stakeholder engagement systems

Marine ecosystems are highly complex with several distinct knowledge systems that often need to be reconciled during processes of stakeholder engagement. Garrett et al. (2012) developed a framework for evaluating the relative strength of different systems of stakeholder engagement that was based on learning theory. Three stages in an interactive learning cycle were identified: reflection, dialogue and interaction, and action. Reflection is the inward process of observation, sense making and analysis. Action is the outward process of goal setting, planning and implementation. Dialogue and interaction is the means of stimulating and uniting these two distinct processes across different stakeholder groups. All three in combination can be considered as constituting stakeholder engagement. The desired outcome is "better decision making and well informed actions resulting from a thorough and balanced assessment of all relevant issues" (Garrett et al. 2012). They evaluated contrasting systems of stakeholder engagement by applying this interactive learning framework to four case studies relevant to UK fisheries. Table 10 below shows and defines characteristics of three key processes in the learning cycle, Reflection, Dialogue and interaction, and Action, used by Garrett et al. (2012).

Table 10 Characteristics of key processes in the learning cycle; reflection, dialogue and interaction, and action. (Garrett et al. 2012)

Reflection	Issue	Complexity and severity of the issue(s)
	Exploration	Scope and thoroughness of knowledge and information gathering
Dialogue and interaction	Dialogue	Frequency of meetings (single workshop or series)
	Stakeholder mix	Range and diversity of stakeholders involved
	Engagement of fishermen	Extent to which working fishermen are involved
Action	Feedback	Detailed feedback of outcomes communicated to stakeholders
	Common Understanding	Achievement of common understanding or shared vision amongst stakeholders
	Practical Action	Extent to which substantive action resulted from agreed stakeholder initiatives

These evaluation criteria were applied to 24 recent and current systems of stakeholder engagement (Table 11), either Scottish or including Scotland, summarised in Section 5.4. Each system for stakeholder engagement was assessed, on a rather broad brush basis, as strong (✓✓✓), moderate (✓✓) or weak (✓) against the criteria (Table 12). The scores were determined by a group of natural and social scientists with experience of the different systems. This is not meant to be an exhaustive or indeed representative survey but rather an illustrative sketch of one way to compare different systems that have been used in Scotland.

Taking the approach of Garrett et al. further, the scores for each of the eight characteristics were summed and the sum assumed to reflect, in a rather imprecise way, the relative strength of the stakeholder engagement (Table 12). The scoring system used allocates a score of zero to an assessment of "weak" in order that an engagement system assessed as "weak" in all categories would score zero overall. One point is allocated for an assessment of "moderate" and two points for "strong". It is important to note that this assessment framework has been applied retrospectively on a number of systems that had substantially different aims, scopes and available resources: some were not designed as stakeholder engagement systems, but have opportunities to be so hence their inclusion. The assessment should not be taken to imply anything about the extent to which these engagement systems achieved their own initial aims.

Table 11 Stakeholder engagement systems relevant to Scottish fisheries

Level	Stakeholder engagement system	Type	Dates	Comments
European Commission / EU	RACS / Advisory Councils	Interactive Governance	2004 to present	RACs superceded by ACs in 2014.
	DG visits various ports, one off visits	Interactive Governance	Recent years	"Fact-finding" / PR missions to ports
	STEFC Expert Working Groups	Interactive Governance	2006 - present	Industry observers can attend EWGs and contribute when invited by Chair
ICES	Advisory Process	Interactive Governance	To present	Stakeholders can be observers
	Training Courses	Fisheries-science partnerships	To present	Stakeholders attend to learn about stock assessment
	Annual Science Conferences	Fisheries-science partnerships	Finished	Places for fishermen at ICES conference
Scottish Government	Shetland Shellfish Management Organisation	Interactive Governance	1999 - present	Regulated Fishery Order grants legal right to manage shellfish commercial fisheries. Promoted stock recovery and business sustainability. Vessel owners are licences and contribute to design of management rules.
	Conservation Credit Steering Group	Interactive Governance	2009 - 2013	Government meeting with industry to get their input in how to administer the days at sea regime for vessels in the Cod Recovery Zone (CRZ).
	Scottish Industry Science Partnership / Fishing Industry Science Alliance	Fisheries-science partnerships	FISP: 2006 - 2011 FISA: 2012 - present	Government funded research, industry-led ideas, to enhance cooperation between fishing and science providers; create more sustainable, effective fisheries.
	Shetland Marine Spatial Planning	Interactive Governance	2008 - present	Fishing industry interests are considered in marine spatial planning, with specific engagements on MPAs. SSMO is on advisory group
	Inshore Fisheries Groups	Interactive Governance	2009 - present	Six non-statutory bodies, aim to improve management of inshore fisheries to 6 nm.

Table 11 cont

Level	Stakeholder engagement system	Type	Dates	Comments
	Scottish Discard Steering Group	Interactive Governance	October 2013 - present	To advise SG on developing policy re implementing the landing obligation of the reformed CFP. Industry and Government bodies plus ENGOs.
	Fisheries Management and Conservation group	Interactive Governance	2011 - present	Initiated and chaired by government, fisheries co-management group, replaced Scottish Fisheries Council. Builds on CCSG. Decision-making body & discussion forum. Industry, policy, science and ENGOs.
	Inshore Fisheries Management and Conservation Group	Interactive Governance	2013 - present	New version of FMAC for inshore, also covers 6 - 12 nm. IFMAC takes decisions and on request makes recommendations to Cabinet Secretary. Members are fishermen's associations / federations.
	Regional Fishing Industry Assemblies	Interactive Governance	2014	Follow on from Quayside Conversations. 7 one-off assemblies held around Scottish coast. Feedback on actions to address issues raised in QC, sought views on 4 issues: CFP LO; access to quota for active fishers; new entrants to industry; fishing & shared seas.
	Inshore Fisheries Conference (annual)		since 2013	annual conference
	Involvement in international negotiations EU / Norway, December Council	Interactive Governance	To present	Marine Scotland invite input from industry before negotiations
	Quayside Conversations	Interactive Governance	Oct 2012 - April 2013	Cabinet Secretary & civil servants in series of public meetings. 18 conversations held.
Other	Fishing into the Future	Interactive Governance	2013 to present	UK-wide industry led initiative, facilitated by the ISU and Seafish. Aims include sustainability training and fishermen's contribution to science.
	Seafish annual fleet economic surveys	Interactive Governance	2006 to present	Seafish researchers interview 600 - 700 vessel owners each summer on vessel performance and fisheries management issues.
	Seafish Issues Groups	Interactive Governance	2006 to present	Raft of UK-wide open discussion forums tackling most important issues facing industry. Stakeholders of various sectors contribute.
	Clyde 20 20	Fisheries-science partnerships	2014 to present	Initiative to improve marine ecosystem of the Clyde sea. Scientific research and practical measures. Series of workshops.
	Profitable Futures	Interactive Governance	2009	Commissioned by Marine Scotland. Consultant-led day long workshops with break out groups per fleet sector.
	MASTS Fisheries Science Forum - Nephrops discards workshop	Fisheries-science partnerships	2014	One off workshop with scientists and industry, to consider how the LO would affect Scottish nephrops fisheries and identify knowledge gaps.

Table 12 Evaluation of stakeholder engagement systems following Garrett et al. (2012). N.b. ✓= weak, ✓✓ = moderate and ✓✓✓ = strong. Scores are 0 for weak, 1 for moderate and 2 for strong. Thus max score per system is 16 and max per characteristic is 48

			Reflection		Dialogue and interaction				Action		
Level	Stakeholder engagement system	Type	Issue	Exploration	Dialogue	Stakeholder mix	Engagement of fishermen	Feedback	Common understanding	Practical action	Overall score
European Commission / EU	RACS / Advisory Councils	Interactive Governance	✓✓✓	✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓	✓✓	10
	DG visits various ports, one off visits	Interactive Governance	✓✓✓	✓	✓	✓	✓✓	✓	✓	✓	3
	STEFC Expert Working Groups	Interactive Governance	✓✓✓	✓✓	✓	✓	✓	✓	✓	✓	3
ICES	Advisory Process	Interactive Governance	✓✓	✓✓✓	✓✓	✓	✓	✓✓	✓	✓	5
	Training Courses	Fisheries-science partnerships	✓	✓✓	✓	✓✓	✓	n/a	✓✓	✓✓	4
	Annual Science Conferences	Fisheries-science partnerships	✓	✓✓	✓✓	✓✓	✓	✓	✓	✓	3
Scottish Government	Shetland Shellfish Management Organisation	Interactive Governance	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	15
	Conservation Credit Steering Group	Interactive Governance	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓✓	13
	Scottish Industry Science Partnership / Fishing Industry Science Alliance	Fisheries-science partnerships	✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓	12
	Shetland Marine Spatial Planning	Interactive Governance	✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	12
	Inshore Fisheries Groups	Interactive Governance	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓to ✓✓✓	✓	✓to ✓✓✓	8 to 12
	Scottish Discard Steering Group	Interactive Governance	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	9
	Fisheries Management and Conservation group	Interactive Governance	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓	✓	✓✓	9
	Inshore Fisheries Management and Conservation Group	Interactive Governance	✓✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓	✓	✓	8
	Regional Fishing Industry Assemblies	Interactive Governance	✓✓✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	7

Table 12 Evaluation of stakeholder engagement systems following Garrett et al. (2012). N.b. ✓= weak, ✓✓ = moderate and ✓✓✓ = strong. Scores are 0 for weak, 1 for moderate and 2 for strong. Thus max score per system is 16 and max per characteristic is 48

			Reflection		Dialogue and interaction			Action			
Level	Stakeholder engagement system	Type	Issue	Exploration	Dialogue	Stakeholder mix	Engagement of fishermen	Feedback	Common understanding	Practical action	Overall score
	Inshore Fisheries Conference (annual)	Interactive Governance	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓	✓	✓	7
	Involvement in international negotiations EU / Norway, December Council	Interactive Governance	✓✓✓	✓✓✓	✓✓	✓	✓	✓✓	✓	✓	7
	Quayside Conversations	Interactive Governance	✓✓✓	✓	✓	✓✓	✓✓	✓	✓	✓	6
Other	Fishing into the Future	Interactive Governance	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	12
	Seafish annual fleet economic surveys	Interactive Governance	✓✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓✓	✓✓	✓	10
	Seafish Issues Groups	Interactive Governance	✓✓✓	✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓	✓	9
	Clyde 20 20	Fisheries-science partnerships	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓	✓	✓	8
	Profitable Futures	Interactive Governance	✓✓	✓✓	✓	✓✓	✓✓✓	✓	✓	✓	5
	MASTS Fisheries Science Forum - Nephrops discards workshop	Fisheries-science partnerships	✓✓	✓✓	✓	✓	✓	✓	✓	✓	2
			38	27	24	27	21	21	14	14	

5.6.1. Comparison of stakeholder engagement systems

Scores for strong (2 points), medium (1 point) and weak (0 points) assessments for each criteria were summed for each engagement system in Table 12, in order to indicate the strongest and weakest systems according to the assessment criteria used in Garrett *et al.* 2012. Among the overall highest scoring engagement systems considered in this exercise is the SSMO, the Shetland Marine Spatial Planning programme, the Fishing Industry Science Alliance, Fishing into the Future and IFGs (which were not scored separately for each IFG). These examples were not assessed as weak in any of the criteria.

Under the Reflection category, the two assessment criteria were Issue: the complexity and severity of issue(s) discussed and Exploration: Scope and thoroughness of knowledge and information gathering. Most stakeholder engagements were assessed as Strong against Issue, due to the inherent complexity of fisheries management. Against Exploration, only six of the 24 systems assessed were rated as Strong. The highest scoring systems under Reflection include the Conservation Credit Steering Group, SSMO, industry input before international negotiations and Seafish annual fleet economic surveys.

Under the Dialogue and Interaction category, there were three assessment criteria: Dialogue: frequency of meetings (single workshop or series); Stakeholder mix: range and diversity of stakeholders involved; and Engagement of fishermen: Extent to which working fishermen are involved. There were some engagement systems where the depth of exploration was naturally curtailed by having a broader mix and diversity of stakeholders involved or vice versa. Indeed, only two of the 24 systems compared scored Strong for both of these criteria. Only six of the systems were rated Strong against Engagement of fishermen, which reflects the extent to which fishermen are often represented by professional officers of associations and federations, since they themselves have businesses to run and have limited time for the wide raft of engagement opportunities that exist. The highest scoring systems under Dialogue and Interaction included Fishing into the Future, IFGs, SSMO and Clyde 2020.

Under the Action category, the criteria are Feedback: Detailed feedback of outcomes to stakeholders; Common understanding: Achievement of common understanding and share vision amongst stakeholders; and Practical action: Extent to which substantive action flows from agreed stakeholder initiatives. Scores for these three categories were the weakest of the eight categories. Only four systems were rated Strong for Feedback, three systems were rated Strong for Common Understanding and three were rated Strong for Practical Action.

Overall scores for each category suggest that these systems have been much better at exploring complex issues than they are (or have been) at reaching common understanding and taking practical action. Of course, other people might score or assess these engagement systems differently if they have a different degree of knowledge than the experts involved. Nevertheless, this assessment process has resulted in a story that would likely be recognisable to the participants.

The characteristics of the standout examples included in this assessment, such as the SSMO, could be considered in any future design or reviews of stakeholder engagements. The criteria used for assessment in Garrett *et al.* (2012) could be used or adapted to help participants be clear about what is hoped for from new or ongoing engagement systems and to help achieve the aims.

5.7. Fisheries stakeholder survey

Engaging stakeholders in fisheries management is important for fisheries governance (Coffey 2005). Insufficient engagement in the decision-making process can lead to limited acceptance of fisheries management with negative impacts on environmental, economic and social sustainability (Pita *et al.* 2012). Therefore, understanding stakeholders' perception of the fisheries management process is important. Stakeholder surveys have been implemented in a number of fishery case studies to understand stakeholders' perception and attitude towards fisheries management.

A fisheries stakeholder survey was developed to assess stakeholders' perception of their engagement in the fisheries management and science process (See Annex 9.3). Statements on perception elicited responses that indicated degrees of agreement or disagreement. Stakeholders were asked to respond to statements using a seven-point Likert scale ranging from "strongly disagree" to "strongly agree" (Likert 1932). Likert scales have been used to estimate fishers' attitude and perception to fisheries management and policy (Pita *et al.* 2010, Marshall 2007, Richardson et al. 2005, Gelcich *et al.* 2008, Mangi and Austen 2008). In addition, an open-ended question asked stakeholders what single change they would like to see to improve stakeholder engagement in fisheries management. The survey also collected information on the stakeholders' role in the fishing industry. A total of 150 surveys were distributed in stakeholders' delegate packs at the FIS conference in July 2015. The survey took 10 minutes to complete but the response rate was very low (7%).

The survey was distributed to fisheries stakeholders attending FIS's 2015 Fisheries Annual Scottish Fishing Conference held in St. Andrews. A diversity of stakeholders attended the conference to discuss the implications of the landing obligation, including fishers, processors, retailers, scientists, regulator and government advisor, technical specialists and conservationists.

The stakeholder survey was completed by consultants, researchers, fishers, government advisors and regulators. Histograms represent the distribution of responses to the 9 statements in the stakeholder survey (Figure 6 - Figure 14). Most responses showed a central tendency (Likert scale number 3, 4 and 5) regarding their agreement with a number of statements. This central tendency is particularly evident in response to statement A1 (Figure 6), A2 (Figure 7), A3 (Figure 8), A8 (Figure 13), and A9 (Figure 14).

Stakeholders elicited stronger more skewed attitude towards a few statements. Statements A4 and A5 elicited a tendency towards strongly agree and disagree, respectively. These results suggest stakeholders would like more responsibility for taking fishery management decisions and the provision of scientific advice within Scotland is not perceived as adequate.

The greatest variation in attitude scale related to the statement regarding stakeholders contributing more to the cost of fishery management or scientific advice (A7). Fishing skippers showed a central tendency with this statement and did not strongly agree or disagree that they should contribute. A researcher and consultant more strongly disagreed that stakeholders should contribute more to the cost of the provision of management or scientific advice.

The histograms reveal a consistency across a number of the stakeholders' responses. The stakeholders had a tendency to disagree that the provision of scientific advice is adequate (A5) and that stakeholder knowledge is fully considered in the assessment of stocks and scientific advice (A6). Furthermore, most stakeholders neither agreed nor disagreed that there were too many meetings which to contribute to (A8). There was also a central tendency of stakeholders' perception regarding the right balance of stakeholder groups involved in fishery management (A9). While only a small sample of responses was collected the consistency in responses is reassuring and are in line with what one might expect. However, limited conclusions can be drawn from a sample of 11 responses. Often there is a feeling of disconnect between management and stakeholders, consequently management decisions are not fully informed. Therefore, it is important to give stakeholders a greater sense of ownership in the management process which may lead to a stronger commitment to comply with the regulatory framework (Garrett *et al.* 2012).

Figure 6 **Histogram summarising responses to statement A1 (Fisheries in Scotland are effectively managed).**

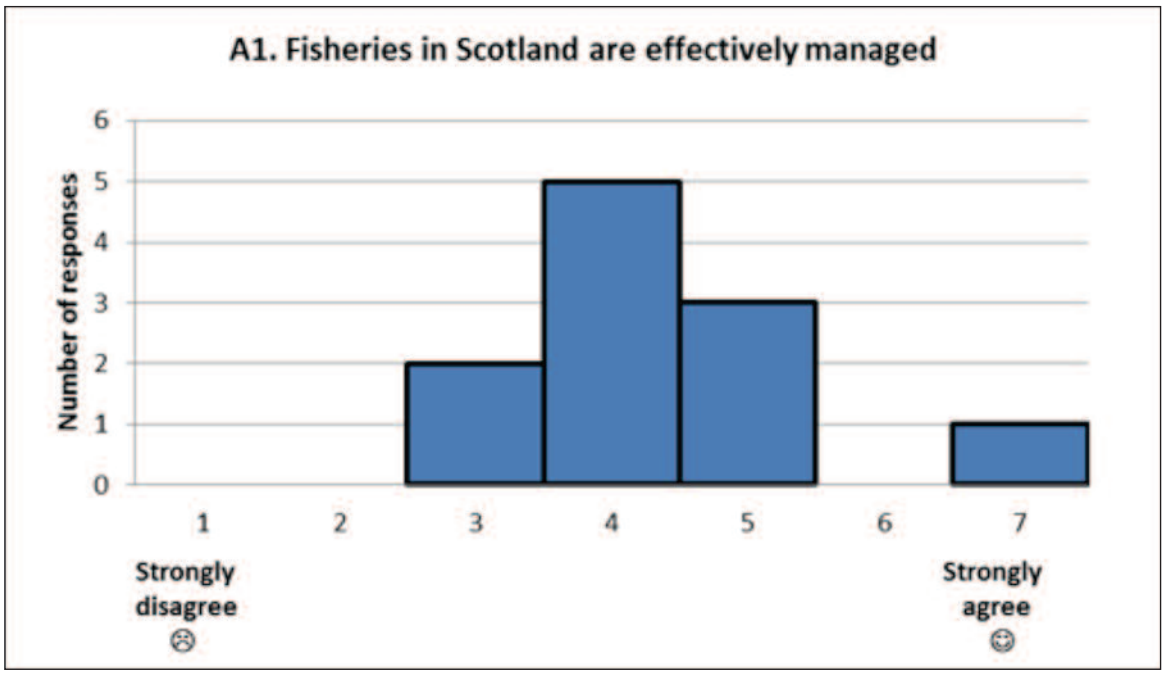


Figure 7 Histogram summarising responses to statement A2 (The decision-making process in fishery management is open and transparent).

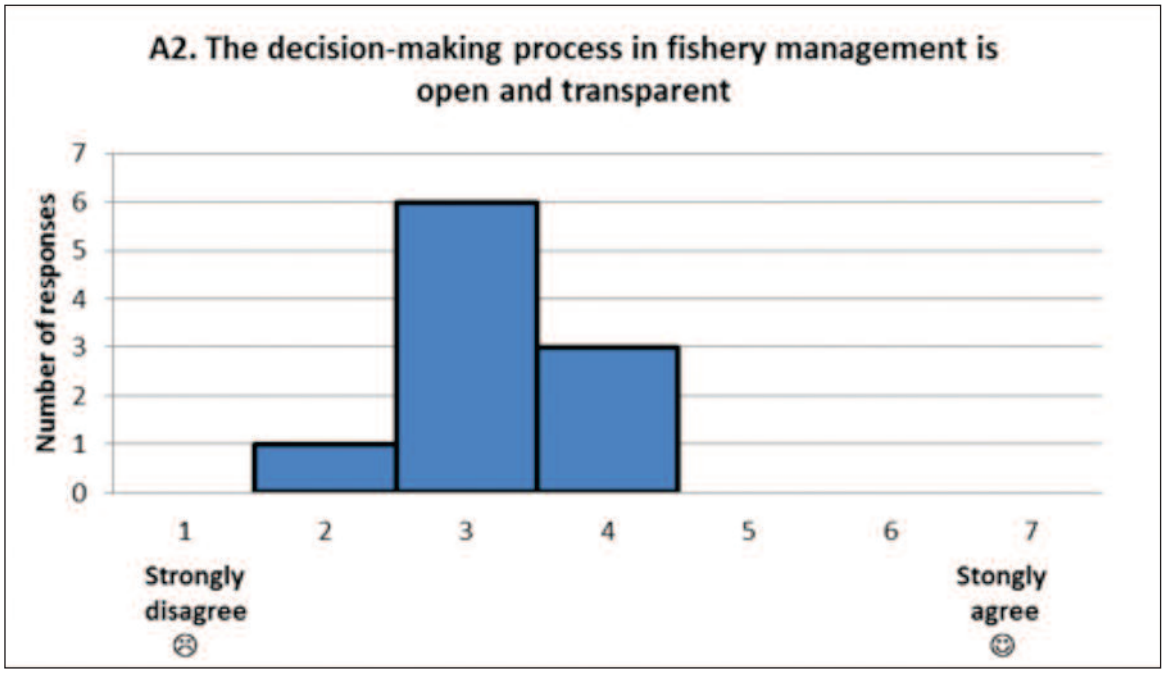


Figure 8 Histogram summarising responses to statement A3 (Stakeholders are able to influence decision-making at all levels in the management process).

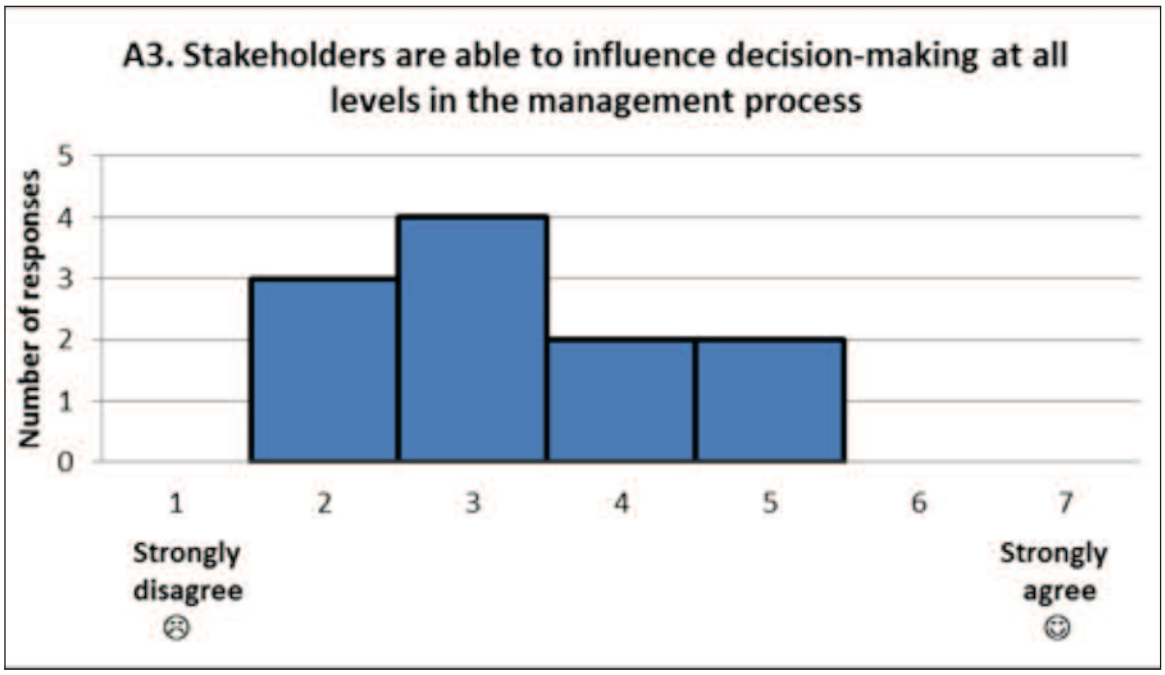


Figure 9 Histogram summarising responses to statement A4 (Stakeholders would like to bear more responsibility for taking fishery management decisions).

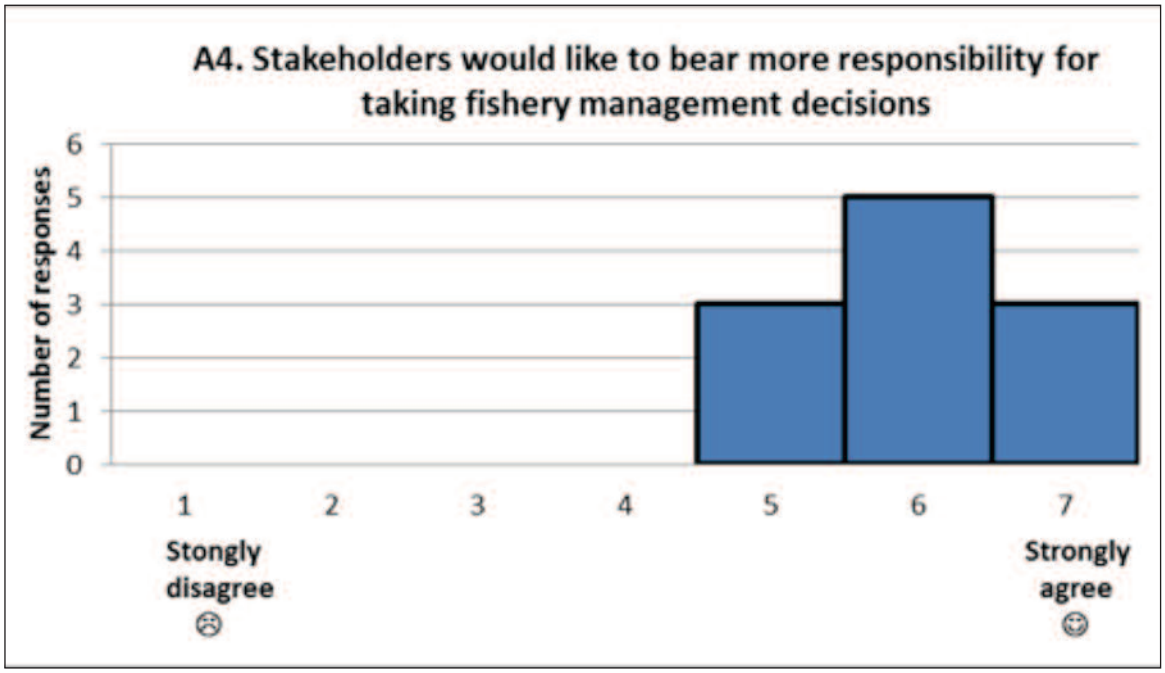


Figure 10 Histogram summarising responses to statement A5 (The provision of scientific advice relating to commercial fisheries within Scotland is adequate).

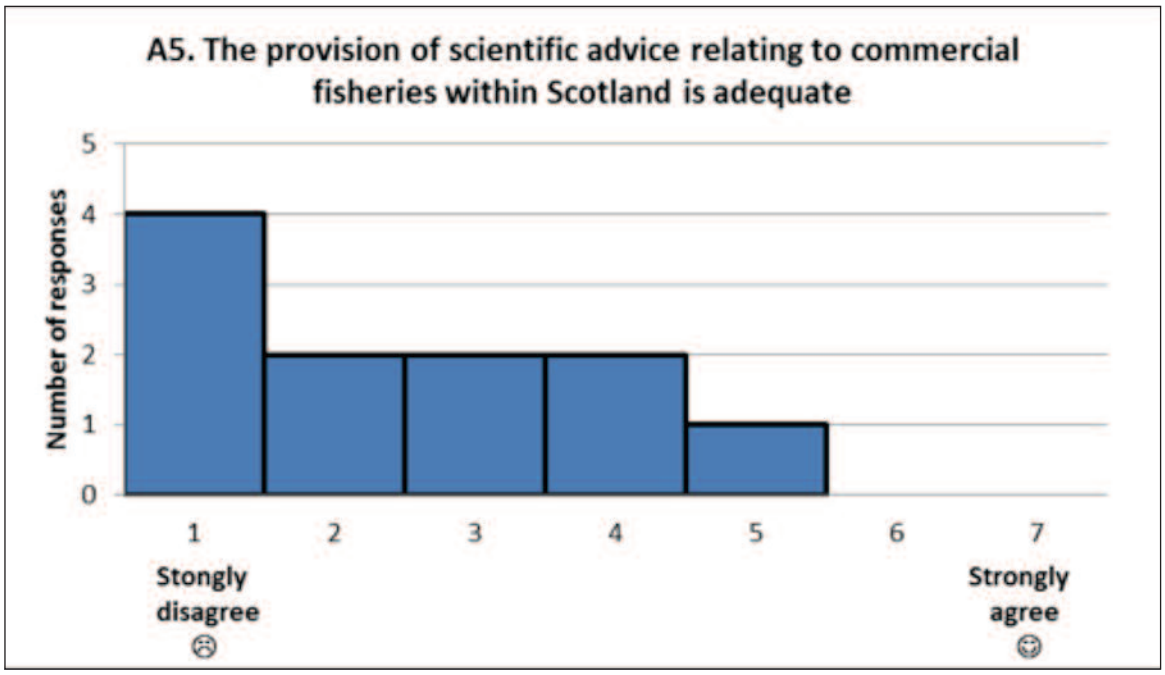


Figure 11 Histogram summarising responses to statement A6 (Stakeholder knowledge is fully considered in the assessment of stocks and scientific advice).

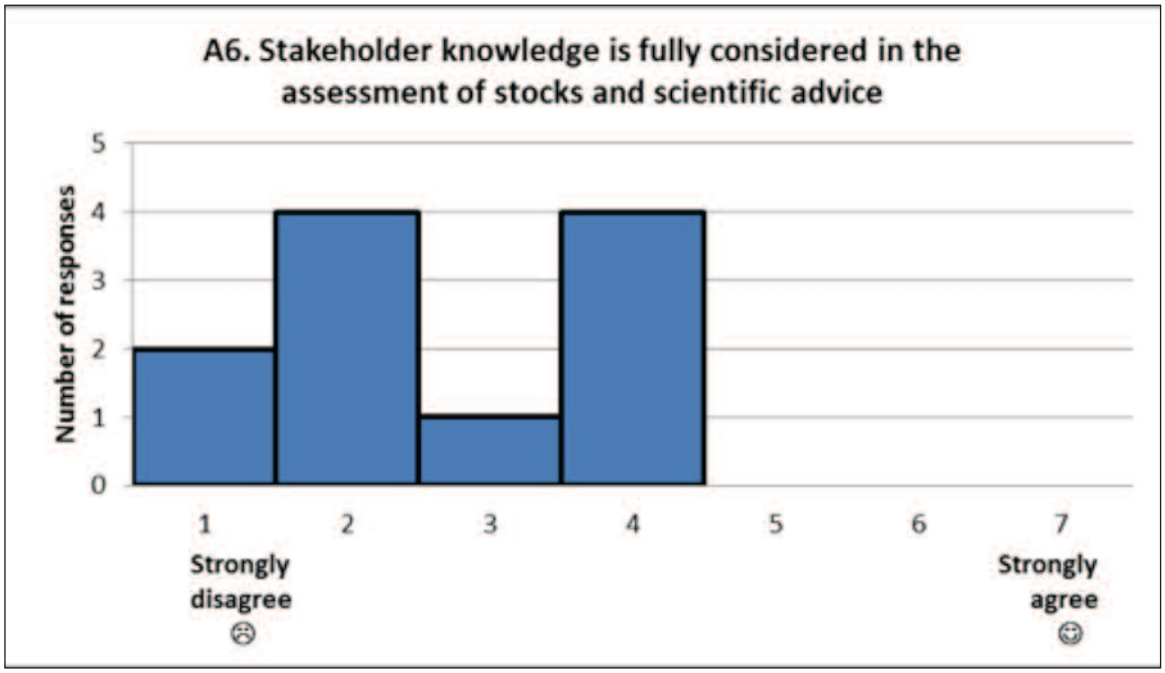


Figure 12 Histogram summarising responses to statement A7 (Stakeholders should contribute more to the cost of providing fishery management or scientific advice).

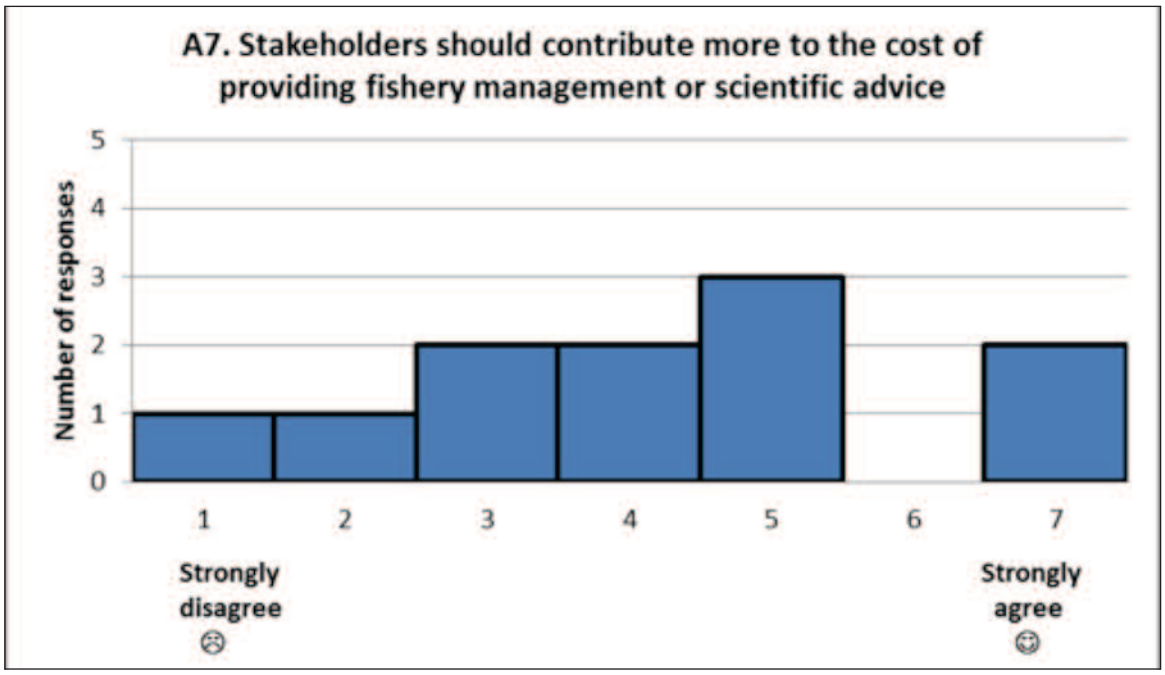
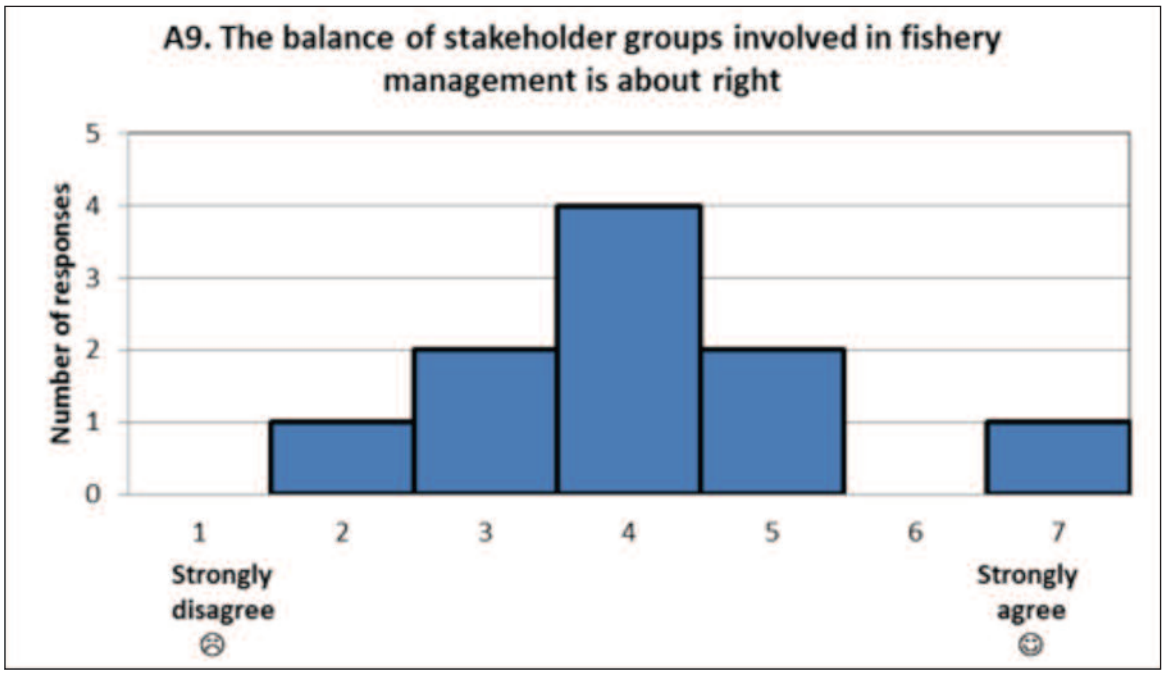


Figure 13 Histogram summarising responses to statement A8 (There are too many meetings stakeholders are expected to contribute to).

Figure 14 Histogram summarising responses to statement A9 (The balance of stakeholder groups involved in fishery management is about right).



5.8. Stakeholder engagement in other fishing nations – Case studies

5.8.1. US

In the USA, fishery management is implemented through regional Fishery Management Councils. These Councils develop and implement fishery management plans that conform to Federal law, as overseen by the Department of Commerce. The Councils have responsibility for fisheries in Federal waters (i.e. beyond 3 miles). Members of the Councils are appointed based on lists of candidates that comprise any person knowledgeable in some aspect of the fisheries. Typically, the Council members will be fishermen, fish processors, representatives of state fishery and wildlife interests and representatives of the National Marine Fishery Service. Since the Councils have decision making powers, stakeholders are directly involved in the process as voting members of the Council. This differs significantly from ACs in Europe that have no decision making powers and may only offer advice to the European Commission.

The Management Councils are informed by a fish stock data and assessment process overseen by a Science and Statistics Committee (SSC). The SSC comprises scientific experts from a wide range of disciplines including both the natural and social sciences. Their meetings are open to the public who may submit comments on agenda items. Technical data, assessment and scientific peer review meetings that provide the evidence base for advice provided by the SSC are open to the public. It is commonplace for stakeholders to participate in data workshops and stock assessment workshops where they actively contribute to the work and technical decisions. This contrasts with the ICES process in Europe where stakeholders are not eligible to observe or participate in the assessments, though they may participate in data workshops and observe the review and advisory meetings.

5.8.2. Canada

Like the US, Canadian fisheries management emphasizes regionalisation and an adaptive approach to management. For each commercial fishery the regional offices of the Department of Fisheries and Oceans (DFO) are responsible for developing an Integrated Fisheries Management Plan (IFMP) which is the principal document for the management of a specific stock. There are currently approximately 175 IFMPs in place nationally. These documents follow a fixed format serving two purposes. Firstly, they synthesise the is¬sues, objectives and management measures designed to ensure an orderly, economically viable, socially/culturally beneficial and sustainable fishery; and secondly, they disseminate information to all stakeholders by being publically available. Long-term objectives are specified in relation to five distinct aspects of a fishery: stock conservation, ecosystem, stewardship, social, cultural, and economic (i.e., commercial, recreational, Aboriginal), and compliance. Any shared stewardship arrangements that are put in place to meet these objectives, including shared decision-making responsibilities, are specified. IFMPs may last one year or be multi-an¬nual. They are normally prepared following several rounds of formal consultation, often with advisory groups working together with the DFO staff. Advisory groups may include scientists, fisheries industry representatives, ENGOs as well as community and aboriginal representatives. There is considerable variation between re¬gions and stocks regarding the nature of stakeholder groups that participate, consequently, representation is considered as 'ad hoc'. Aside from the spe¬cial constitutional status of Aboriginal peoples that affects their rights in using fish resources, stakehold¬ers are involved in consultation processes but not in deci¬sion-making. Consequently, while the consultation embedded in the IFMP for each fishery can be considered as a highly developed form of interactive governance, it cannot be considered as true RBM.

Canada has had a distinctive example of stakeholder engagement in place for several decades. In the wake of the collapse of several cod stocks on the east coast of Canada in 1992/1993, DFO introduced a fisheries-science partnership termed sentinel surveys. The aim of the sentinel fishery program was to develop time series of abundance indices which could be used in the assessment of cod stocks. During the surveys, fishers are required to keep a log describing the gear used, fishing effort, fishing site and total weight of each species caught and measure the size of all the cod caught. The northern Gulf of St. Lawrence sentinel fishery program was the first to incorporate abundance indices into stock assessment. Since 1998, four of the five abundance indices used to calibrate the assessment of this cod stock have come from the sentinel fisheries. Data from the surveys can be downloaded (http://slgo.ca/en/sentinel/data/fixed.html) making them readily accessible to non-DFO scientists and industry.

Canada has also implemented another form of fisheries-science partnership whereby industry co-funds the costs of fisheries management. Licence fees play a substantial role in funding management, including science. Annually, around CDN$40 million are collected from licence fees while the total cost of management has been esti¬mated to CDN$350 million. There is also industry funding of surveillance schemes such as extensive onboard observer coverage and cameras mounted on vessels. In some

fisheries, mainly those targeting high-value-species, the industry initiates and funds research projects. In addition, there are also collaborative research projects, including both scientists and fisher¬men, which are recognised as an efficient way to use resources and further, successfully build trust and increase mutual understanding.

5.8.3. Norway

The Ministry of Fisheries and Coastal Affairs is responsible for marine issues in Norway and the Directorate of Fisheries (DoF) is the Ministry´s advisory and executive body on matters related to fishing and aquaculture. Regulatory instruments, coupled with strict compliance measures, are used to ensure sustainable management of fish stocks while economic instruments are used to enhance efficiency and achieve structural policy targets. DoF purposely does not include non-scientific information when formulating fisheries advice because of the view that the impacts of fish¬eries management decisions should not be conflated with the provision of impartial advice on the status of stocks. There is a preference for stakeholders to negotiate their own decisions on non-sustainability issues which will then be implemented by the DoF/Ministry. For example, the allocation of quota between different fleet sectors is decided by negotiations within the Norwegian Fishermen's Association. The Ministry will normally follow these agreements. While there is frequent communication between the fishing industry and the DoF on a wide range of matters (i.e., dialogue meetings) there is not a tradition of regular meetings or advisory committees specifically intended to facilitate stakeholder engagement such as has been put in place in the US, Canada or Scotland. Often, informal communication occurs as two-sector conversations (e.g., industry-science) rather than more broadly based multi-sectorial discussions. Although the former can be effective in influencing policy the informal nature limits the transparency of decision making and, in some cases, may be closer to lobbying on single issues than to true stakeholder engagement. Assessment of the social and economic impacts of management decisions is being undertaken by the academic community in Norway (based at University of Bergen, Norwegian School of Economics, University of Tromsø, and the Norwegian University of Science and Technology) but systems to support stakeholder engagement are not yet formally embedded in fisheries management. The comparative underdevelopment of systems for stakeholder engagement means that the understanding of best practice of stakeholder engagement that is resulting from Norwegian researchers participating in national and EU research programmes cannot currently be integrated into fisheries management.

The most developed example of a fisheries-science partnership in Norway is the reference fleet of Norwegian fishing vessels that provides the Institute of Marine Research (IMR) with detailed information about fishing activity and catches. IMR established an offshore reference fleet in 2000 and a similar coastal reference fleet in 2005. The biological sampling and data management procedures are similar to the procedures used on board IMR's research vessel surveys. Data are used for management purposes including assessment of several pelagic and demersal stocks. Originally, the reference fleet was self-financed by the allocation of a minor part of the Norwegian fish quotas for research purposes. Since 2014, the reference fleet has been funded by the imposition of a research duty on sales of Norwegian fish. The reference fleet has also been included in recent funding applications to the Norwegian Research Council as the fleet provides economically efficient platform for collecting research data at sea.

5.8.4. How does Scotland compare to international examples?

Although stakeholder engagement systems were reviewed for three other countries only, it is still possible to draw some broad conclusions regarding how Scottish systems for stakeholder engagement compare. With respect to systems for interactive governance, it is clear that Scotland has a wide variety of opportunities for fisheries stakeholders and other interest groups to engage in dialogues on a regular basis. The majority of these were initiated and are supported by the Scottish Government via Marine Scotland. Documentation of the meetings is often very good with reports and minutes being made available on the web. Some of these systems, including the IFG, were scored as being relatively strong especially when compared to the comparatively remote European and ICES systems. These opportunities for interactive governance allow diverse range of viewpoints to be fed to relevant decision making authorities and ultimately the Cabinet Secretary. The decisions that are made can therefore be considered as being informed by stakeholder engagement.

Scottish systems differ from the systems for interactive governance in the three other countries considered here. Overall, the US and Canadian systems are far more open and transparent than the European system which necessarily includes Scotland. The stock assessment process in North America can benefit more directly from stakeholder knowledge, whereas in Europe ICES assessment working groups are only open to nominated scientists. Furthermore, the US and Canadian systems have genuine decision making power unlike European ACs. In the US, Fishery Management Councils are composed of a range of stakeholders all of

whom have a vote on decisions taken by the council. In Canada, the IFMP are clearly articulated, multi-sectorial management plans reflecting consensus about long-term management objectives which significantly influence decisions. In both countries decision making is of course limited by federal law but it does offer stakeholders a significant role in managing fishery resources. Interestingly, in Norway the government maintains clear decision making authority on the grounds that sustainability is separate from the interests of stakeholder groups. This could be regarded as being rather far from best practice when viewed in light of international experience.

Scotland has effective forms of fisheries-science partnership in various funding bodies that support this (Scottish Industry/Science Partnerships (SISP) followed by the Fishing Industry Science Alliance (FISA)), with funding largely provided by the Scottish Government. There has been some limited experience with industry-led surveys of specific resources. However, there is nothing which compares with the sentinel surveys of several fish stocks in Canada which are sufficiently long that they are used as tuning indices in stock assessments. The Norwegian reference fleet is proving scientifically valuable for collecting research data at sea. As industry data become increasingly available for scientists to analyse there are expanding opportunities for industry to both facilitate and participate in research. Such activities would be consistent with an evolution towards greater stakeholder engagement.

There is very little experience in Scotland with RBM, although it was noted above that the Scottish Conservation Credit Scheme (SCCS, Holmes et al. 2011) is regarded as being RBM-inspired (Section 5.9.2). There are few countries that have full RBM systems in place. The management of rock lobsters in New Zealand has been identified as a comprehensive RBM (Nielsen et al. 2015). Three pre-conditions were identified as facilitating the implementation of RBM for this fishery: property rights that create incentives for responsible management, contestable research contracts which allowed stakeholder organizations to bid for assessment-related research contracts with the government, and amendment of New Zealand's fishery act which created a legal basis for delegating responsibility. The pre-conditions do not exist in Europe currently.

One potential impediment to stakeholder engagement in fisheries issues in Scotland is that there is a relatively narrow base of academic or private sector expertise in the facilitation of stakeholder engagement systems. This is contrasts with Norway which has a well-developed academic base but limited opportunities to apply it. Fisheries-science partnerships could possibly serve as a means for fostering capacity in this area.

5.9. Emergent trends in stakeholder engagement

5.9.1. Crisis as a driver of change

There are many examples where improved opportunities for stakeholder engagement have resulted from a major fisheries crisis. In Canada, the collapse of Northern cod off the coast of Newfoundland and Labrador in the early 1980s initiated fundamental, permanent change in the approach to governance of fisheries. Prior to the collapse, stock assessment scientists worked in a series of sub-committees under the aegis of The Canadian Atlantic Fisheries Scientific and Advisory Committee (CAFSAC). These sub-committees met at least once annually to review complex and exclusively scientific stock assessments. Following the collapse of Northern cod, CAFSAC was terminated and the Minister of Fisheries set up a Fishery Resource Conservation Council (FRCC) to review the assessment process. Unlike CAFSAC, FRCC consisted of representatives from the fishing industry and scientists from various disciplines. The sentinel fishery programme was set up at the same time. Although FRCC was disbanded in 2011, the principle of stakeholder engagement is embedded in the IFMP that are now developed for each fishery. The cod crisis in Canada has, therefore, led to considerably improved systems for stakeholder engagement. In Scotland, the reduction in North Sea cod that occurred in the early 2000s was also a driver of change in the degree to which stakeholders became involved in fisheries management. The implementation of the Cod Recovery Programme in 2008 led directly to the SCCS which was noted as a form of "RBM inspired". The absence of a cod crisis might partly explain why stakeholder engagement systems in Norway, especially ones indicative of interactive governance, are comparatively underdeveloped.

5.9.2. Results-based management

RBM is the most highly developed type of stakeholder engagement. It is a goal-oriented management strategy that has been proposed as a means of overcoming the "micromanagement" (EU Commission) of European fisheries (Nielsen et al. 2015). RBM has three defining features: 1) public authorities define measurable requirements for resource users; 2) resource users (ideally, all stakeholders) have autonomy and flexibility in choosing how best to satisfy these requirements; and 3) independent auditors document the degree to which the resource users satisfy these requirements. A recent EU 7th-framework project (EcoFishMan www.ecofishman.com) identified several requirements for a fully developed RBM system (Nielsen et al. 2015): "First, an organisational environment that is conducive to active stakeholder participation and consolidated industry cooperation;

second, a political and legal framework that allows delegation of management responsibilities to industry partners; third, a strong commitment to the reversal of the burden of evidence, for instance in terms of cost recovery or industry-led data provision; fourth, secure entitlements for resource users, so that long-term gains form industry-led management improvements can be secured for those who make commitments with regard to their realisation."

Although these Utopian ideals seem far removed from current practice in Europe, the design of one Scottish stakeholder engagement system was highlighted as being "RBM-inspired" (Neilsen et al. 2014). Catch quota management involves the management and documentation of catches including discards as opposed to management and control of landings. Catch quota management was facilitated when European Member States were given responsibility for managing their own fishing effort schemes in 2007. Article 13 of the Cod Recovery Plan (European Commission 2008) permitted EU Member States to be credited with additional days-at-sea in exchange for adopting conservation-orientated fisheries management approaches (Little et al. 2014). Fishing vessels were granted extra days-at-sea to compensate for extra time spent searching for their target species when actively avoiding discarding of over-quota cod. Under the SCCS, Scotland became the first Member State to launch RTCs using Article 13 (Holmes et al. 2012). In 2008, under the SCCS, RTCs were introduced following joint discussions between the Scottish Government and fishing industry. The RTCs were partly based on the Norwegian system of RTCs, in operation in the Barents and Norwegian Seas. In 2009, RTCs subsequently became mandatory for the Scottish fishing fleet (Bailey et al. 2010). Thus, Scotland has initiated elements of RBM that are comparatively cutting-edge in the European context.

5.9.3. Participatory research

Participatory research is the term used for collaborative or cooperative research undertaken by stakeholders, often in the form of industry-science partnerships (Mackinson and Wilson 2014). Participatory research enables partners having different perspectives on fisheries issues to improve the knowledge base and quality of scientific information available for management. The knowledge generated through participatory research initiatives might be directly applicable to stock assessment, e.g. sentinel fisheries in Canada, or it might be relevant to issues of concern to a particular fleet, e.g. gear performance in relation to conservation objectives. In both cases the active cooperation between fishers and scientists to meet a shared research objective promotes relationships and potentially builds trust. EU projects such as GAP1 and GAP2 (www.gap2.eu) have developed best practice guidelines for participatory research that are useful for evaluating current programmes. EU projects are also actively developing theory related to how different types of knowledge can be combined (e.g., Experience-based knowledge and Research-based knowledge) so as to produce specific tools for fisheries management, e.g. long-term management plans (Stange et al. 2014).

In Scotland, funding for industry-science partnerships was provided by SISP from 2006 until 2011. Since 2012 FISA (http://www.gov.scot/Topics/marine/science/FISA) has allocated funding to a range of projects each year. FISA is overseen by FMAC and the call for proposals normally identifies priority areas for research. In England and Wales the Fisheries Science Partnership (FSP) is similar to FISA in supporting research in support of scientific or assessment issues, management or operational issues and new fisheries. The projects that were funded by FSP over a ten-year period were recently reviewed to determine whether the programme had been successful in engaging the fishing community in the science-management process (Armstrong et al. 2013). Overall, it was concluded that FSP fostered greater communication and trust among fishers, scientists and managers.

Traditionally UK research councils have funded blue skies research that is expected to generate publications in high impact journals. Increasingly, however, the calls for proposals (e.g., for PhD studentships) require an industrial partner. Industry placements may feature. A recent NERC call related to climate science research stated that the scope of work must begin with an assessment of the end-user needs particularly industry. Such calls afford researchers and industry opportunities to identify issues that are of mutual interest and work collaboratively to undertake research on strategic topics for industry.

5.9.4. Long-term management plans

Articles 9 and 10 of Regulation No 1380/2013 of the CFP requests the development of multiannual plans for European fisheries. Under the reformed CFP, these multiannual plans are required to set technically-based objectives related to levels of F and other conservation reference points and make provisions for implementing the landing obligation. There should be periodic evaluations of a multiannual plan based on updated scientific information. A multi-annual plan conforming to these requirements was recently proposed for Baltic fisheries but immediately encountered controversy particularly from ENGOs. This suggests there was a failure to appropriately engage with non-fisheries stakeholders which is inconsistent with aims of Ecosystem Approach to Fisheries Management.

The predominantly scientific approach to specifying long-term management plans taken by Europe contrasts sharply with the multi-annual forms of the IFMPs used in Canada which are designed to incorporate stakeholder concerns alongside science (see Section 5.8.2). Thus, over the medium term Europe looks set to fall short of the Utopian ideal of incorporating diverse types of stakeholder knowledge and building consensus into multi-annual management plans. However, examples of best practice for incorporating stakeholder knowledge in marine management are emerging globally (Daw et al. 2015) and nationally (Stange et al. 2014, Alexander et al. 2013) that are readily adaptable to the development of long-term management plans.

5.10. Challenges for future stakeholder engagement

Stakeholder engagement will only grow in importance. However, there are many practical challenges that need to be addressed. Trust is a prerequisite for effective interactions but it can be a difficult quality to manage. In this regard, industry-science partnerships provide excellent opportunities to build trust as they generally require close communication and collaboration over extended periods of time. Time scales for achieving consensus around a complex issue, e.g. developing a management plan, can be much longer than originally anticipated (Stange et al. 2015). Participation fatigue is a pervasive problem given that there are so many consultative processes occurring that many fishers (among those who are interested) participate in several processes. As a result of this, fisheries stakeholders participate in systems that are relevant to fisheries policy but hardly at all in systems that are related to the implementation of other policy, e.g. the MSFD (Ounanian et al. 2012). The "scale" of any given system for stakeholder engagement varies from Europe-wide to local meaning that there are variable degrees of separation between the stakeholder and the final decision-making authority. From the fisher's perspective, a system having many degrees of separation would make their contribution more remote from the decision-making process. In Europe, linguistic diversity poses real challenges for stakeholder engagement systems at regional scales. Technical meetings (e.g., stock assessments) are usually conducted in English, without interpretation, making it difficult for non-English speakers to participate or observe the proceedings.

6. Recommendations for future science

Following a review of the stock-by-stock knowledge gaps (Section 4.1) and a review of the key management challenges discussed in Section 4.2, a list of research topics was compiled that reflected the principal areas where science could contribute to improved management of Scottish fisheries. These topics reflect gaps in knowledge relating to the advice provided ICES, new policy instruments such as the revised CFP and MSFD, and environmental issues such as climate change. In order to arrive at a priority rank for each topic, seven experts were invited to score these according to three criteria. These were the importance of the topic in the context of managing Scottish fisheries, the impact the research would have if successful, and the probability of the research being successful. The criteria were scored on a scale of 1-5 and an average of the seven expert opinions was taken. Low scores meant lower importance/impact/success. An overall score for the topic was then taken as a simple sum of the criterion scores. The research requirements were ranked within topic areas according to the overall score.

Clearly the scoring procedure is subjective and the results needed to be treated with a degree of healthy scepticism. However, the values obtained do reflect a range of views and this will achieve a degree of balance representing one plausible view of priority. The simple aggregate score is also open to debate since different users may attach different weight to each criterion. Alternative weighting systems could be applied. Hence the reader should regard the priority score as representative of one particular exercise only and not as an exhaustive analysis.

The lists of priority research requirements are given in Table 13. Inshore fisheries are treated as a separate topic as they are generally managed nationally and typically outwith the CFP framework. However, other topics apply widely both to nationally and internationally shared fish stocks. The average aggregate priority scores is 9.7. Higher priority scores were generally associated with the landing obligation, inshore fisheries, climate change, advice on stock status and MSY.

Table 13 List of research requirements by topic

Climate change

Research requirement	Importance	Impact	Success	Total
Methods to determine zonal attachment for stocks such as mackerel and hake in anticipation of future changes under climate change.	3.7	4.0	2.9	10.6
Assess the effects of climate change on fish distribution and productivity for established commercial species. Effects on whole ecosystems will also be needed.	4.0	3.0	3.0	10.0
Assess the trade-offs in yield and economic returns resulting from reviewing reference points, and relative stability, at more frequent intervals due to the effects of climate change.	3.7	3.4	2.9	10.0

Economic performance

Research requirement	Importance	Impact	Success	Total
Investigate options for a transparent trading system for quota units and licences where prices are visible to others, as in the stock market.	3.5	3.3	2.8	9.7

Inshore fisheries

Research requirement	Importance	Impact	Success	Total
Collect fishing effort data for the inshore shellfish fisheries, for vessels of 10 m or less (not subject to VMS monitoring) to determine fishing patterns but also to develop indices of abundance to aid stock assessments.	4.6	3.6	3.4	11.6
Determine stock specific growth rates for shellfish to inform current and future length-based assessments of status. These are particularly important for Nephrops stocks at the FU level.	4.3	3.6	3.3	11.1
Develop innovative assessment methods, collect more data and identify appropriate management reference points for inshore fisheries.	4.1	3.6	3.0	10.7
Innovative methods are required to determine the absolute or relative abundance of crabs and lobsters.	3.7	3.4	2.6	9.7

Landings obligation

Research requirement	Importance	Impact	Success	Total
Short and medium term economic analysis to assess the effects of new technical and spatial measures intended to reduce discards. Spatial and temporal options (moving fishing operations to avoid certain species or sizes of fish) merit investigation.	4.4	3.9	2.7	11.0
Examine whether the current TAC allocation key adequately reflects the distributions of fish and fishing activity and the extent to which it confounds the implementation of the Landing Obligation.	3.9	4.1	2.9	10.9
Develop innovative technical (gear and fishing operation) solutions for avoidance of unwanted catches of certain species.	4.0	3.8	2.8	10.6
Exploration of options for the disposal of unwanted catch through a multidisciplinary approach.	3.9	3.9	2.6	10.3
Alternative or more cost effective ways of estimating discarded quantities where these are high. This includes cod, hake, saithe and whiting in the North Sea; and cod, juvenile haddock, juvenile whiting and saithe on the west coast. Estimates should be disaggregated by fishery where possible at least to the cod recovery designated TR1 and TR2 fleets.	3.9	3.1	3.3	10.3
Demonstrate the socio-economic effects of the Landing Obligation using multidisciplinary approaches in order to inform stakeholders and policy-makers.	3.9	3.4	3.0	10.3

Research requirement	Importance	Impact	Success	Total
Assess how different species survive the process of capture and subsequent discarding in order to identify which species are included in the Landing Obligation.	3.6	3.9	2.7	10.1
Develop tools for increased flexibility in international, national and vessel-to-vessel quota systems and assess the implications of quota flexibility across species and years. An economic analysis of the benefits of new arrangements within Scotland (for example the adoption of 'quota pools') is desirable.	3.9	3.7	2.4	10.0
Analyse the influence on price of fish size to model fleet profit under various management options. This would give vessel operators essential information to help inform their marketing strategies and tactics.	3.8	3.3	2.7	9.8
Studies to determine slippage in the pelagic sector and its mitigation.	3.4	2.9	3.0	9.3
Develop early warning system of high abundance areas of different species/sizes.	3.0	3.0	3.0	9.0
Research on the analysis of images from on-board CCTV and exploration of sampling strategies that provide estimates of discards are required to provide good quality data for scientific assessments and compliance purposes.	3.1	2.7	2.4	8.3

Marine planning

Research requirement	Importance	Impact	Success	Total
Evaluate the biological and economic value of a network of MPAs that would collectively act as a way of protecting and enhancing fish (and other) populations.	3.7	3.9	2.3	9.9
Assess the total effect of the anticipated marine renewable development on fisheries in Scottish waters to evaluate both the ecological and economic consequences of expanded marine development at a regional sea scale.	3.1	3.3	3.1	9.6
Evaluated alternative uses of redundant oil and gas structures and their implications. This includes their use as refuges for fish and as potential sites for offshore aquaculture.	2.7	3.4	3.1	9.3
Investigated the effect of expanded aquaculture into new areas and species to include not just the environmental impact but also genetic aspects resulting from escapes and the potential for disease transmission to wild fish.	3.0	3.1	3.0	9.1
Develop methods to assess MPAs and their effect on fish populations that are only temporary residents of the area.	3.1	2.9	2.6	8.6

Marine Strategy Framework Directive (MSFD)

Research requirement	Importance	Impact	Success	Total
Identify physical impacts of towed gear on the seabed and develop appropriate gear modifications to alleviate these.	3.9	3.6	2.7	10.1
Assess the effect of fishing on biodiversity indicators. This would include changes in abundance of targeted species and bycatch as well as through habitat modification resulting from physical disturbance.	3.7	3.3	2.9	9.9
Develop practical indicators and targets for food webs in order to operate the MSFD appropriately.	3.7	3.1	2.7	9.6
Develop an appropriate monitoring programme to assess litter produced by Scottish fisheries.	2.4	2.4	3.0	7.9
Consider the effects of noise and whether the frequencies involved pose a threat sensitive fish species in order to satisfy MSFD noise limitation targets.	2.4	2.7	2.3	7.4

Maximum Sustainable Yield (MSY)

Research requirement	Importance	Impact	Success	Total
Establish credible fishery exploitation rates in mixed fisheries that can be reconciled with the concept of single species MSY reference points.	4.9	4.1	4.0	13.0
Develop appropriate proxies for MSY for stocks where is cannot be explicitly calculated due to data or biological uncertainty.	3.9	3.9	2.9	10.6
Develop appropriate ways of accounting for biological interactions between fish species in order to estimate fishing mortality rates consistent with the concept of MSY.	3.7	3.5	2.5	9.7

Product labelling

Research requirement	Importance	Impact	Success	Total
Provide better and cheaper tools for product testing in order to detect fraud in order to more easily comply with new labelling requirements.	2.3	2.5	3.2	8.0

Stakeholder participation

Research requirement	Importance	Impact	Success	Total
Evaluate industry-science partnerships such as SISP, FISA and perhaps the Defra/CEFAS FSP, so that the potential for long term impacts of these partnerships can be assessed and help in the strategic direction of future work.	3.0	3.0	3.2	9.2

Advice on stock status

Research requirement	Importance	Impact	Success	Total
For certain species, ling, lemon sole, turbot and boarfish, there is a need for further development of assessment methods using existing catch and, where appropriate, survey data. For other species, survey-based assessment methods should be developed (anglerfish & megrim).	4.6	3.7	3.1	11.4
Review approaches to developing long term management plans with a view to implementation in Scotland.	3.7	3.7	3.7	11.1
Understand demersal mixed fishery interactions through the development of multispecies models, ecosystem models and other process driven or empirical approaches in order to inform new fisheries management plans.	4.0	3.7	3.3	11.0
Assess the effect of top predators of fish stocks (e.g. west of Scotland cod) to understand the balance between natural and fishing mortality.	3.6	3.9	3.1	10.6
Identify better estimates of natural mortality for a range of stocks assessments.	3.9	3.9	2.4	10.1
Collect basic data to determine stock status status of halibut, forkbeard, west of Scotland sprat, and certain sandeel stocks, beyond the southern North Sea. In some cases these might include fishery dependent catch at length or age data. Other species would benefit from additional, more accurate fishery independent data (mackerel, horse mackerel, albacore).	3.6	3.1	3.3	10.0
Understanding new catching methods (pulse trawl, electrofishing, sumWing),especially selectivity, incidental mortality and bycatch.	3.1	2.7	3.6	9.4
Methods to determine the size of Nephrops in TV surveys.	3.4	2.9	3.0	9.3
Improve knowledge, understanding and quantify recreational fisheries such as pollack.	2.7	2.6	3.0	8.3
Clarify stock structure of North Sea whiting, North Sea cod, west of Scotland herring, blue whiting, witch, Greenland halibut and scallops to improve assessment and management of these stocks.	3.0	3.3	2.0	8.3
Develop methods for identifying stocks to improve assessments and traceability where species identification is problematic (redfish, other?)	2.7	2.3	3.0	8.0

Research requirement	Importance	Impact	Success	Total
Develop ageing methods for hake, anglerfish, Nephrops and other shellfish so that cohort-based analytical techniques can be applied to determine their status.	3.1	3.1	1.6	7.9
Improve understanding of recruitment processes, particularly where they are either very variable (haddock) or in long term decline (herring, whiting), to provide supplementary supporting information to stakeholders which would help to make them understand management measures.	2.9	3.0	1.6	7.4

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9. Annexes

9.1. Stock status, management concern and knowledge gap of internationally managed stocks

Stock	Stock status	Management concern	Knowledge gap
Mackerel in the northeast Atlantic (combined Southern, Western, and North Sea spawning components)		In 2014, as in all years since 2008, a lack of agreement on the Management Plan has led to unilateral quotas being set which together are higher than the TAC indicated by the Management Plan. This disagreement is a result of substantial geographical expansion of the spawning distribution to the north and the northwest for the western component since 2007.	Total removals are expected to be underestimated because of incomplete discards data and unquantified slippage. Zonal attachment to determine appropriate catch shares.
Nephrops in Division VIa			
Nephrops in Division VIa - North Minch (FU 11)		*Nephrops* stock currently managed within global TAC but should be managed at FU level, to ensure appropriate outtake. Periodic occurrence of largerTR2 vessel effort transfer from N Sea. Bycatch issue - small haddock and whiting caught and discarded in fishery. *Nephrops* discards presently low.	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans
Nephrops in Division VIa - South Minch (FU 12)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Periodic occurrence of largerTR2 vessel effort transfer from N Sea and offshore west (Stanton bank). Bycatch issue - small haddock and whiting caught and discarded in fishery. *Nephrops* discards presently low).	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans. Uncertainty about the area of ground occupied by Nephrops in South Minch
Nephrops in Division VIa - Firth of Clyde (FU 13)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Periodic occurrence of effort transfer from other areas - especially large scale from Irish Sea. Bycatch issue - small gadoids caught and discarded in fishery and area is important cod spawning ground. Small size of *Nephrops* in S will cause difficulties with landing obligation. *Nephrops* discards presently quite high.	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - growth rate information over 20 years old - impairs length based approaches. Unable to age crustaceans. Local impact of *Nephrops* trawling on fish population (including cod) poorly understood.

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Nephrops in Division VIa - Sound of Jura (FU 13)		*Nephrops* stock currently managed under global TAC but should be managed at FU level to ensure appropriate outtake. Jura is a Subarea of Clyde - may need measures to ensure appropriate allocation of opportunities. Bycatch issue - small gadoids caught in fishery. Small size of *Nephrops* in S will cause difficulties with landing obligation.	Incomplete knowledge of distribution and abundance in Sound of Jura. No direct information on recruitment - development of TV survey required to provide size based information. Biological parameters poorly known - growth rate information over 20 years old - impairs length based approaches. Unable to age crustaceans. Limited knowledge of current population structure owing to limited sampling. Discards not known.
Haddock in Subarea IV and Divisions IIIa West and VIa (North Sea, Skagerrak, and West of Scotland)		Cod rebuilding measures such as CCTV on vessels may have led to increased targeting of haddock. Discard rates remain high in some fleets e.g. TR2 Nephrops and further improvements in gear selectivity would be highly beneficial. Mixed fishery considerations need to be taken into account although haddock is not considered the main limiting species.	Recruitment is characterised by sporadic large year-classes thought to be environmentally determined but where mechanisms are poorly understood.
Nephrops in Subarea IV (North Sea)			
Nephrops in Division IVb, c - Botney gut - Silver Pit (FU 5)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	No information on stock abundance. Lack of biological parameter data
Nephrops in Division IVb - Farn Deeps (FU 6)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Periodic occurrence of vessels from other areas leads to effort transfer at unsustainable levels. Concerns over reduced male population leading to sperm limitation and poor recruitment	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Nephrops in Division IVa - Fladen Ground (FU 7)		*Nephrops* stock currently managed with global TAC but should be managed at FU level. Advice implies increased opportunities at Fladen but catches have been declining so there is risk that effort and catches will shift to other FUs. Currently no discards and some concern that reduced catches of small *Nephrops* may indicate reduced recruitment. Whitefish bycatch important to fishery - difficult to reconcile selectivity between *Nephrops* and fish. Fish discards sometimes a problem- landing obligation a challenge.	No direct information on recruitment - development of TV survey required to provide size based information. Biological parameters poorly known particularly growth rate - impairs length based approaches. Unable to age crustaceans. Underlying economics of the mixed fishery in this area not clear and scope for different fishery strategies unknown (even though some technical solutions available)
Nephrops in Division IVa - Firth of Forth (FU 8)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Periodic occurrence of largerTR2 vessel effort transfer from Fladen and other offshore areas- small area so incoming effort potentially significant. Population composed of small individuals but minimum landing size at 25mm so *Nephrops* discards high creating landing obligation problems	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans. Survival of discarded Nephrops in this area unknown -
Nephrops in Division IVa - Moray Firth (FU 9)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Periodic occurrence of largerTR2 vessel effort transfer from Fladen and other offshore areas	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans.
Nephrops in Division IVa - Noup (FU 10)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	Incomplete information on abundance. TV survey only available for some years. Lack of biological data
Nephrops in Division IVa - Norwegian Deep (FU32)		Stock managed by Norway. No overall TAC - allocation to EU.	No abundance surveys. Incomplete biological data
Nephrops in Division IVa - Off Horn's Reef (FU 33)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	No information on stock abundance. Lack of biological parameter data

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Nephrops in Division IVb - Devil's Hole (FU 34)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	Incomplete information on abundance. TV survey only available for some years. Lack of biological data
Cod in Subarea IV (North Sea) and Divisions VIId (Eastern Channel) and IIIa West (Skagerrak)		Although the SSB is rebuilding estimated F remains above FMSY although multispecies modelling also indicates that natural mortality may have increased due to seals and harbour porpoise although natural mortality due to cannibalism is likely to be low because of the level of total stock biomass. Low levels of recruitment since 2000. Low average age of the stock perhaps leading to reduced recruitment success. Mixed fisheries issues.	There are uncertainties about how changes in climate and multispecies interactions will impact stock rebuilding. There is evidence that the stock is comprised of several different sub-stocks with differing dynamics. There is a possible need for management by sub-areas.
Anglerfish *(Lophius piscatorius and L. budegassa)* in Division IIIa and Subareas IV and VI		Biomass data from Scottish and Irish anglerfish and megrim industry/science surveys for the Northern Shelf are used as a stock size indicator. Stock size indicator has been fluctuating between 35 to 55,000 t since 2005. ICES advises on the basis of the data-limited approach but cannot quantify the resulting catches. The implied landings should be no more than 14,702 t.	There are uncertainties in the catchability in the survey gear - particularly of younger age classes. This affects the reliability of the survey based stock assessment. There are uncertainties in age determination for this stock - a survey catch-at-age model was presented at WKFLAT 2012 and WKROUND 2013 but has not yet been accepted due to concerns over age-reading.
Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)		ICES has indicated that offshore renewable energy activity may affect herring spawning grounds.	BMSY is undefined. Current survival rate of larvae appears to be low and further work is needed to understand this as it has implications for longer term recruitment. Mixing between different stocks is uncertain and may affect recruitment indices. There is lack of knowledge about unallocated catches.
Hake in Division IIIa, Subareas IV, VI, and VII, and Divisions VIIIa, b, d (Northern stock)		Catch is uncertain due to potentially high discards. Hake potentially the choke species in North Sea mixed demersal fishery.	Assessment is length based (ageing requires validation) and only has partial discards.

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Whiting in Subarea IV (North Sea) and Division VIId (Eastern Channel)		Addition of natural mortality due to harbour porpoise in 2011 key run multispecies model resulted in considerable revision of abundance and mortality for whiting. Stock assessment sensitive to discards which are very variable at fine spatial scales. By-catch in *Nephrops* trawl fisheries. WGMIXFISH consider that the present single-species current basis for whiting advice is not consistent with other single-stock management plans.	Population structuring of whiting is complex and WGROUND consider that stock identify is a priority which needs to be resolved for this species. Standard approaches for defining MSY reference values for North Sea whiting have not been successful and WGROUND suggest a meta-analytic approach may have to be used. Recent low recruitments considered to have multiple causes including low SSB and environmental factors which are poorly understood.
Saithe in Subarea IV (North Sea), Division IIIa (Skagerrak), and Subarea VI (West of Scotland and Rockall)		Incomplete data on discarding levels. Uncertainty about long-term performance of the management plan. Recent low recruitments may be linked to environment but in an unknown manner.	Levels of discarding. There is no reliable recruit estimate for this stock due to spatial changes between young age classes. Environmental impacts on saithe recruitment.
Megrim *(Lepidorhombus spp.)* in Divisions IVa and VIa		Imprecise and missing age data hampers ability of ICES to undertake age-based assessment for this stock.	Depth-dependent growth differences. Further work is planned to investigate utility of using survey data to provide an estimate of recruitment.
Ling *(Molva molva)* in Divisions IIIa and IVa, and in Subareas VI, VII, VIII, IX, XII, and XIV (other areas)		A GADGET assessment model has been developed for ling in Va but has not been tested in other areas. Commercial CPUEs indicate stable or increasing trend in recent years.	
Plaice in Subarea IV (North Sea)		Increased use of pulse fishing gear and SumWing may change catchability patterns. Plaice also considered in mixed-fisheries advice for the North Sea. Stock increases in flatfish, especially plaice, in North Sea may mean benthivore carrying capacities may be being approached - changes in growth rates may occur.	

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Herring in Division VIa (North)		ICES has indicated that offshore renewable energy activity may affect herring spawning grounds. Grey seals may also exert a high predation mortality.	BMSY is undefined. Seal predation mortality needs to be evaluated. Stock identity and mixing with adjacent stocks needs to be further evaluated.
Herring in Subareas I, II, and V, and in Divisions IVa and XIVa (Norwegian spring-spawning herring)		Lack of agreement between coastal states has inflated catches above recommended levels. Stock is experiencing a period of low recruitment which will keep the stock below MSY BTRIGGER.	The amount of slippage is unquantified and needs be accounted for in the assessment. Reasons for current poor recruitment is not understood.
Lemon sole in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)		Advice based on survey trends assessment. The advice notes that TACs may not be an appropriate tool for managing what is essentially a by-catch fishery. Discarding occurs but data are insufficient to estimate discard proportion, total catches cannot be calculated. Management under a combined quota with witch could potentially lead to over-exploitation of either species.	WG state that there is a great deal of data available on lemon sole, but that this needs to be analysed.
Blue whiting in Subareas I–IX, XII, and XIV		Assessed as a single stock despite evidence for a northern and southern component	There is evidence for two components (northern and southern), but the data are only reflective of the northern component and there is not enough information to conduct separate assessments. Stock is affected by recruitment fluctuations, and recruitment success may be influenced by position and strength of the North Atlantic sub polar gyre: however, the mechanisms are not understood and require further exploration. Qualitative information on recruitment is provided by 5 trawl indices.
Nephrops in Subarea VII			
Nephrops in division VIIa - Irish Sea East (FU 14)		*Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	Incomplete information on abundance. TV survey only available for some years. Lack of biological data

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Nephrops in Subarea VIIa - Irish Sea West (FU15)		NI and Ireland. *Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Bycatch issues with a range of gadoids - especially cod. Difficult to reconcile selectivity for fish and *Nephrops*	No direct information on recruitment - development of TV survey required to provide size based information. Some biological parameters poorly known - especially growth rate information - impairs length based approaches. Unable to age crustaceans.
Nephrops in Subarea VIIb, c, j, k - Porcupine Bank (FU 16)		Ireland (Scottish interest) *Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Evidence of sensitivity in stock (fishery closed area and 'of which TAC)	Incomplete information on abundance. TV survey only available for some years. Limited biological data
Nephrops in Subarea VIIb - Aran Grounds (FU 17)		Ireland - *Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake.	Incomplete information on abundance. TV survey only available for some years. Lack of biological data
Nephrops in Subarea VIIg, h - Celtic Sea - Labadie (FU 20-21)		France /Ireland. *Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Significant mixed fishery issues	Incomplete information on abundance. TV survey only available for some years. Lack of biological data
Nephrops in Subarea VIIg, f - Celtic Sea - The Smalls (FU 22)		France /Ireland. *Nephrops* stock currently managed with global TAC but should be managed at FU level to ensure appropriate outtake. Significant mixed fishery issues	Incomplete information on abundance. TV survey only available for some years. Lack of biological data
Turbot in Subarea IV (North Sea)		Mixed fisheries need to be taken into account for this species.	Rather limited age data available. No reliable fisheries independent index covering the entire range is available. Estimates of recent recruitment levels are very uncertain.
Pollack in Subarea IV (North Sea) and Division IIIa (Skagerrak–Kattegat)		Potential importance of recreational catches for this species. Pollack often associate with wrecks or other areas inaccessible to IBTS trawl survey.	Unquantified discards. Recreational catches. Limited age-length-maturity data available at present.
Boarfish in the northeast Atlantic		No specific management objectives are known to ICES. A management plan has been proposed by the Pelagic RAC but has not yet been evaluated by ICES.	The current assessment model is not regarded as adequate and ICES recommends further development. More information is required on the byctach of TAC species within the boarfish fishery.

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Witch in Subarea IV (North Sea) and Divisions IIIa (Skagerrak–Kattegat) and VIId (Eastern Channel)		Witch is mainly a by-catch species and TACs may not be an appropriate management tool. Management under a combined quota with lemon sole could potentially lead to over-exploitation of either species. Survey indices are uncertain due to survey not being designed to catch this species. Information on stock structure, biological data and catch at age would be needed to perform an analytical assessment.	There is a lack of data on many aspects including stock structure, growth rates and maturity. There is a lack of data on levels of discarding for this species.
Sandeel in Subarea IV			
Sandeel in Subarea IV SA1 Dogger		Need for a management plan.	
Sandeel in Subarea IV SA2 Southeast		Lack of management objectives	A longer time series of dredge survey indices will improve the assessment
Sandeel in Subarea IV SA3 Central east		The EU and Norwegian are managed under different plans and a joint plan is required to reduce the risk of over-fishing.	A northerly extension of the dredge survey area and coverage of the Skagerrak area would probably increase the quality of the survey results for assessment purposes
Sandeel in Subarea IV SA4 Central west		Fishing is heavily restricted to protect breeding kittiwakes	Very limited data to assess the stock. Survey coverage is incomplete.
Sandeel in Subarea IV SA5 Viking Bergen Bank		The stock is small and very little fishing takes place	There is very little data to assess the stock
Sandeel in Subarea IV SA7 Shetland		The available information is inadequate to evaluate stock status or trends and the state of the stock is therefore unknown.	Need for data to assess the stock
Sole in Subarea IV (North Sea)		Mixed fisheries need to be taken into account for this species - high discard rates of plaice.	Periodic large recruitments appear to have an environmental link particularly with cold winters although the mechanisms involved are not well understood. Ecosystem and catchability effects of introducing novel gears such as Pulse trawls and SumWing.

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Atlantic halibut in Subarea IV		ICES have previously recommended that there should be no directed fishery for Atlantic halibut in the northeast Atlantic and there have been no further updates, advice or research to suggest otherwise.	Targeted fisheries in the waters around Greenland but the species is only landed as bycatch in other trawl, gill net and demersal long line fisheries. General lack of data for this species.
Greenland halibut in Subarea IV		Unknown	There are knowledge gaps around most aspects for this species.
Megrim *(Lepidorhombus whiffiagonis)* in Divisions VIIb–k and VIIIa, b, d		Issues with the quality of the assessment model when bench-marked in 2012.	Unknown levels of discarding by French vessels.
Horse mackerel *(Trachurus trachurus)* in Divisions IIa, IVa, Vb, VIa, VIIa–c, e–k, and VIIIa–e (Western stock)		No management plan. SSB declining.	Assessment heavily dependent on triennial egg surveys and very uncertain. Countries with major landings do not provide samples.
Blue ling *(Molva dypterygia)* in Division Vb and Subareas VI and VII		Deep-water bottom trawls impact the seabed, causing potential damage to deep-water coral communities. Part of a mixed fishery so effort on blue ling also impacts other deep water species.	No biomass reference point.
Albacore tuna in Subarea VII			
Albacore tuna in the North Atlantic		No specific concerns expressed by International Commission for the Conservation of Atlantic Tunas (ICCAT)	ICCAT does not identify any knowledge gaps. However, stock status is uncertain and CPUE series are not consistent indicating the need for research in this area.
Cod in Division VIa (West of Scotland)		Noisy estimates of mortality from discards dominated fishery. Lack of larger older fish in the stock. Surveys indicate unaccounted removals. Uncertainty about mortality rates due to seals.	There are uncertainties around the impacts of climate and predation changes on stock rebuilding rates.
Redfish in Subarea II			

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Golden redfish (Sebastes norvegicus) in Subareas I and II		No formal biomass or F reference points are available for this stock. SSB lowest on record. F estimated to be increasing and around ~6x natural mortality. Modelling simulations suggest that at current recruitment levels, a sustainable FMSY may lie around F = 0.08. Recommend no directed fishery. Reduction in bycatch in other fisheries would also be required to reduce F to sustainable levels. It is imperative to minimize catch on the remaining mature fish and to protect the recent recruitment until these fish become old enough to breed.	Catch data are in most cases reported as "redfish", without distinction between Sebastes mentella and S. norvegicus. Allocation of catch to golden redfish is done a posteriori with unquantified uncertainty. Discards are believed to be low, so catch is assumed to equate to landings.
Beaked redfish (Sebastes mentella) in Subareas I and II		No formal biomass or F reference points are available for this stock. However, MSY BTRIGGER of 600,000 t, and FTARGET 0.039 are considered a good starting point for management. ICES advises on the basis of precautionary considerations that an annual catch in 2015, 2016, and 2017 should be set at no more than 30 000 t, and that the measures currently in place to protect juveniles should be maintained.	Catch data are in most cases reported as "redfish", without distinction between Sebastes mentella and S. norvegicus. Allocation of catch to beaked redfish is done a posteriori with unquantified uncertainty. In 2012 and 2013 there was no age reading from the pelagic fishery, and numbers-at-age had to be derived from past age distributions and total catch numbers. Discards are believed to be low, so catch is assumed to equate to landings.
Greater forkbeard *(Phycis blennoides)* in the northeast Atlantic		Deep-water trawls impact the seabed, causing potential damage to deep-water coral communities. As this is a subject of mixed fisheries, effort on greater forkbeard also impacts on other deep-water species, although life history traits are in line with other gadoids which means it is less vulnerable to fishing than other deep-water species.	No biomass estimate, nor F estimate, nor any reference points
Sprat in Subarea VI and Divisions VIIa–c and f–k (Celtic Sea and West of Scotland)		ICES does not necessarily advocate that Subarea VI and Divisions VIIa–c, f–k constitute a management unit for sprat	No data to assess the stocks in this area. The relationship with sprat in Divisions VIId,e is also unknown
Redfish in Subarea IV		No assessment or management of catching of redfish in the North Sea	None specified. Unknown connection between North Sea redfish and open ocean stocks

Table 9.1. cont

Stock	Stock status	Management concern	Knowledge gap
Greenland halibut in Subareas V, VI, XII, and XIV		Implementation of 2012 Management Plan. Large uncertainty in estimates of F. Debate within NWWG regarding appropriate basis for providing advice - Bayesian surplus-production versus data-limited approach.	Currently assessed as one stock but the precise population stock definitions are unknown. There is a gap in knowledge about many aspects of the biology of this species e.g. location of nursery grounds is unknown.
Greenland halibut in Subareas I and II		No analytical stock assessment, on-going bench mark work in 2015 is designed to rectify this.	There is uncertainty about growth rates linked with changes in age reading methodology.
Albacore tuna in Subarea X			
Albacore tuna in the North Atlantic		No specific concerns expressed by ICCAT	ICCAT does not identify any knowledge gaps. However, stock status is uncertain and CPUE series are not consistent indicating the need for research in this area.
Haddock in Divisions VIIb–k		The 2013 year-class was strong and heavy discarding was anticipated for 2014-2015. Changes in discarding rules (selectivity panels, landing obligation etc.) may lead to shifts in discarding patterns which may impact the assessment model.	Stock is assumed contiguous with west Scotland and northern North Sea but there is some uncertainty about this. Recruitment is characterised by sporadic large year-classes which are thought to be environmentally determined but where mechanisms are poorly understood.
Whiting in Division VIIa (Irish Sea)		High levels of discarding since early 2000s.	Technical measures appropriate for Irish Sea fisheries which could reduce discarding of whiting.
Whiting in Division VIa (West of Scotland)		Levels of discarding in *Nephrops* TR2 fleet remain high despite use of square-mesh panels. Mis-reporting of landings between 1995 and 2005 impacts the perception of the stock status. Use of Time series analysis is designed to overcome this in the stock assessment. Changes in survey catchability may have occurred. Whiting caught almost exclusively as by-catch making direct management difficult.	Technical measures appropriate for west coast fisheries which could reduce discarding of small (1 and 2 year olds) whiting in particular.

9.2. Stock status, management concern and knowledge gap of nationally managed stocks

Stock	Stock status	Management concern	Knowledge gap
Great Atlantic scallop in Subarea IV			
Scallop -North East	Stable - but below long term means	F has been above the long term average	Population structure
Scallop - Shetland (MSS)	Stable - above long term average	NA - management is carried out at the local level	Population structure
Scallop - Shetland (NAFC)	Declining	Reduction in VPA predicted biomass and landings	Biomass estimates - being addressed by new survey design
Scallop - East Coast	Undefined	potential impact of falling sampling levels on assessment outputs	Population structure
Scallop - Orkney	Undefined	-	Population structure
Great Atlantic scallop in Subarea VII			
Scallop - Irish Sea	Undefined	potential impact of falling sampling levels on assessment outputs	Population structure
European lobster in Subarea IV	Undefined		
Lobster - Papa - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Papa - Female	Undefined, but below F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Shetland (MSS) - Male	Undefined, but below F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Shetland (MSS) - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Shetland (NAFC) - Male	Undefined, but below F_{MSY}	Lack of information on recruitment	Abundance information

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Lobster - Shetland (NAFC) - Female	Undefined, but below F_{MSY}	Lack of information on recruitment	Abundance information
Lobster - East Coast - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - East Coast - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Orkney - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Orkney - Female	Undefined, but at F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - South East - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - South East - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Great Atlantic scallop in Subarea VI			
Scallop - West of Kintyre	Very reduced level	SSB has declined markedly in the last 10 years and recent estimates of F are high.	Population structure
Scallop - Clyde	Undefined	potential impact of falling sampling levels on assessment outputs	Population structure
Scallop - North West	low stock levels	SSB, recruitment and catch have all declined markedly in the last 10 years.	Population structure
Edible crab in Subarea VI			
Brown Crab - Clyde - Male	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Brown Crab - Clyde - Female	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Hebrides - Male	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Hebrides - Female	Undefined, but above F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - North Coast - Male	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - North Coast - Female	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Sule - Male	Undefined, but at F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Sule - Female	Undefined, but above F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Mallaig - Male	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Mallaig - Female	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Brown Crab - South Minch - Male	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - South Minch - Female	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - Ullapool - Male	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - Ullapool - Female	Undefined	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Edible crab in Subarea IV			
Brown crab - Papa - Male	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - Papa - Female	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Shetland (MSS) - Male	Undefined, but at F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Shetland (MSS) - Female	Undefined, but below F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Shetland (NAFC) - Male	Undefined, but below F_{MSY}	-	Stock definition, abundance information
Brown Crab - Shetland (NAFC) - Female	Undefined, but below F_{MSY}	-	Stock definition, abundance information

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Brown Crab - East Coast - Male	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - East Coast - Female	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Orkney - Male	Undefined, but above F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown Crab - Orkney - Female	Undefined, but above F_{MSY}	-	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - South East - Male	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Brown crab - South East - Female	Undefined, but above F_{MSY}	recent substantial increases in F	stock definition, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Queen scallop in Subarea VII			
Queen Scallop - Scotland	Undefined	-	Abundance information stock distribution, population structure, fisheries dependent data (effort, spatial distribution of fishing effort)
Velvet swimcrab in Subarea IV			
Velvet Crab - Papa - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Velvet Crab - Papa - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Shetland (MSS) - Male	Undefined, but below F_{MSY}	uncertainty around LCA input parameters	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Shetland (MSS) - Female	Undefined, but below F_{MSY}	uncertainty around LCA input parameters	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Shetland (NAFC) - Male	Undefined, but above F_{MSY}	Reduced mean size of males (fisheries reference point), Reduced proportion of males in the population (reference point), uncertainty around LCA input parameters, setting harvest control rules based on reference points	Recruitment information
Velvet Crab - Shetland (NAFC) - Female	Undefined, but above F_{MSY}	uncertainty around LCA input parameters, setting of Harvest control rules based on reference points	-
Velvet Crab - East Coast - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - East Coast - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Orkney - Male	Undefined, but above FMSY	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Orkney - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - South East - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Velvet Crab - South East - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Common squids in Subarea IV	Undefined	There are not the resources to support depletion stock assessment methods, used in the Falklands, because such methods are very data intensive requiring data every couple of days. Instead management is by a 'proportional escapement approach'.	-
European lobster in Subarea VI			
Lobster - Clyde - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Clyde - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Hebrides - Male	Undefined, but above F_{MSY}	marked decline in mean size of larger animals	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Hebrides - Female	Undefined, but below F_{MSY}	marked decline in mean size of larger animals	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - North Coast - Male	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - North Coast - Female	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Sule - Male	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Lobster - Sule - Female	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Mallaig - Male	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Mallaig - Female	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - South Minch - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - South Minch - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Ullapool - Male	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Lobster - Ullapool - Female	Undefined	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Solen razor clams in Subarea VI	Undefined	Illegal electric fishing methods are a concern for this stock	Landings data but there are no stock assessments, the development of direct stock assessment methods would be appropriate. Surveys required to ensure sustainable fishing (based on knowledge of resource size and suitable harvest rate) of this valuable stock.
Common squids in Subarea VI	Undefined	There are not the resources to support depletion stock assessment methods, used in the Falklands, because such methods are very data intensive requiring data every couple of days. Instead management is by a 'proportional escapement approach'.	

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Velvet swimcrab in Subarea VI			
Velvet Crab - Clyde - Male	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Clyde - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Hebrides - Male	Undefined, but below F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Hebrides - Female	Undefined, but above F_{MSY}	-	Abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - North Coast - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - North Coast - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Sule - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Sule - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Mallaig - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Velvet Crab - Mallaig - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - South Minch - Male	Undefined, but above F_{MSY}	Lower data collection than expected (particularly Inner Hebrides)	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - South Minch - Female	Undefined, but below F_{MSY}	Lower data collection than expected (particularly Inner Hebrides)	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet - Crab Ullapool - Male	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Velvet Crab - Ullapool - Female	Undefined	-	Sampling data, abundance information, fisheries dependent data (effort, spatial distribution of fishing activity)
Common squids in Subarea VII	Undefined	There are not the resources to support depletion stock assessment methods, used in the Falklands, because such methods are very data intensive requiring data every couple of days. Instead management is by a 'proportional escapement approach'.	
Queen scallop in Subarea VI			
Queen Scallop - Scotland	Undefined	-	Abundance information stock distribution, population structure, fisheries dependent data (effort, spatial distribution of fishing effort)

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Solen razor clams in Subarea IV	Undefined	Illegal electric fishing methods are a concern for this stock	Landings data but there are no stock assessments, the development of direct stock assessment methods would be appropriate. Surveys required to ensure sustainable fishing (based on knowledge of resource size and suitable harvest rate) of this valuable stock.
European lobster in Subarea VII	Undefined		
Wolffishes in Subarea IV	Undefined	Not known, if any	No assessments available. IBTS may have relevant information. Literature search etc. required to establish extent of general knowledge.
Cuttlefish, bobtail squids in Subarea VII	Undefined	-	-
Solen razor clams in Subarea VII	Undefined	Illegal electric fishing methods are a concern for this stock	Landings data but there are no stock assessments, the development of direct stock assessment methods would be appropriate. Surveys required to ensure sustainable fishing (based on knowledge of resource size and suitable harvest rate) of this valuable stock.
Whelk in Subarea VII			
Whelk - Scotland	Undefined	-	Abundance information, stock distribution, population structure, fisheries dependent data (effort, spatial distribution of fishing effort)
Whelk in Subarea IV			
Whelk - Shetland	Undefined	-	Abundance information
European seabass in Subarea VII			

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Seabass IVbc, VIIa, and VIId-h	Undefined	Management plan urgently required to develop measures to reduce F. Features of biology render seabass vulnerable to overexploitation. Discarding a problem, selectivity need to improve to reduce catches of small fish.	No MSY BTRIGGER reference point. Unclear if seabass in these areas constitutes a separate unit from other areas. Absence of recreational landings and biological data from some fleet catches (FR) are a problem.
Seabass - VIa, VIIb and VIIj	Undefined	Landings relatively small. Unclear whether this stock is a significant issue for managers	Complete lack of information other than official landings. Unclear whether this represents a separate management unit. If management measures required, ICES advises that time series of relative abundance indices for adults and juveniles required
Palinurid spiny lobsters in Subarea VI	Undefined	-	-
John dory in Subarea VI	Undefined	Not known, if any	No assessments available. IBTS may have relevant information. Literature search etc. required to establish extent of general knowledge.
Periwinkles in Subarea IV	Undefined	-	-
John dory in Subarea VII	Undefined	Not known, if any	No assessments available. IBTS may have relevant information. Literature search etc. required to establish extent of general knowledge.
Green crab in Subarea IV			
Green Crab - Shetland	Undefined	-	Abundance information, population structure
Palinurid spiny lobsters in Subarea IV	Undefined	-	-

Table 9.2. cont

Stock	Stock status	Management concern	Knowledge gap
Blue mussel in Subarea IV	Undefined	The stock is not monitored or assessed. However, the Dornoch Firth fishery was locally managed by the Highland Council and local assessments were performed and a crude harvest strategy applied.	-
Whelk in Subarea VI			
Whelk - Scotland	Undefined	-	Abundance information, stock distribution, population structure, fisheries dependent data (effort, spatial distribution of fishing effort)
Sand gaper in Subarea IV	Undefined	-	-
Green crab in Subarea VI			
Green Crab - Scotland	Undefined	-	Abundance information, stock distribution, population structure, fisheries dependent data (effort, spatial distribution of fishing effort)
Gurnards, searobins in Subarea IV	Undefined	-	-
Grey gurnard IV and VIId and IIIa	Undefined	Discards considered to be high. Gurnard considered a predator of important demersal stocks - scale of mortality attributable to the species is significant.	Lack of information on relevant stock units. SPP ID a major problem in estimating landings. Status within the ecosystem and impact needs to be confirmed.
Grey gurnardVI VIIa c e-K	Undefined	-	Lack of information on relevant stock units. SPP ID a major problem in estimating landings.
Red gurnard - widely distributed	Undefined	Not known, if any	Lack of information on relevant stock units. SPP ID a major problem in estimating landings. General lack of information

9.3. Fisheries stakeholder survey

FISHERIES STAKEHOLDER SURVEY

As part of a contract to Fisheries Innovation Scotland (FIS) a group of scientists are reviewing the status of Scotland's commercial fisheries, fisheries research and stakeholder engagement. We would be interested to know your views on several aspects and would appreciate your input through this survey.

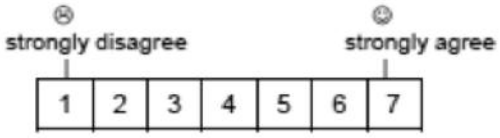
The survey is in two parts. Part A) asks you to indicate levels of agreement or disagreement with fisheries management and science topics. Part B) asks you information about your role in the fishing industry. There is also an opportunity to add additional comments.

We hope you will take the time to complete this confidential survey which we believe will lead to a better understanding of how we can most effectively meet your needs. The survey takes about 10 minutes to complete.

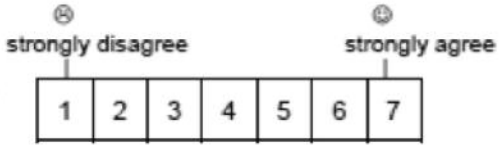
A) How much do you agree/disagree with the following statements?

Using the scale of 1 (strongly disagree) to 7 (strongly agree) please circle a score for the following. Responses should be based on your perceptions.

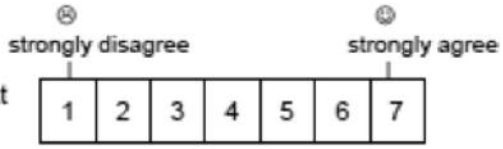
1. Fisheries in Scotland are effectively managed



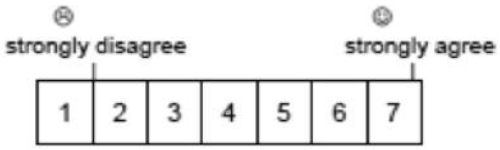
2. The decision-making process in fishery management is open and transparent



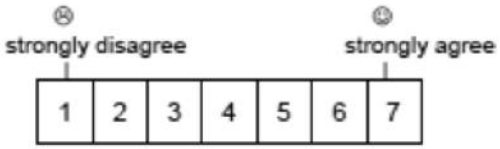
3. Stakeholders are able to influence decision-making at all levels in the management process



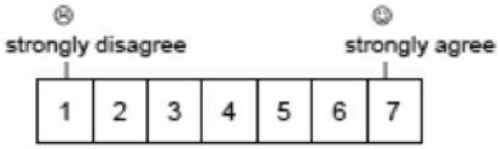
4. Stakeholders would like to bear more responsibility for taking fishery management decisions



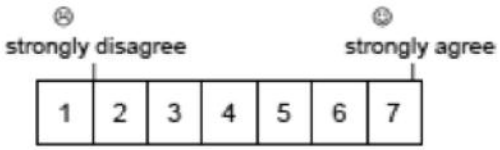
5. The provision of scientific advice relating to commercial fisheries within Scotland is adequate



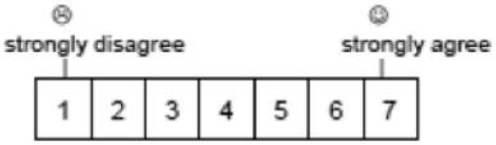
6. Stakeholder knowledge is fully considered in the assessment of stocks and scientific advice



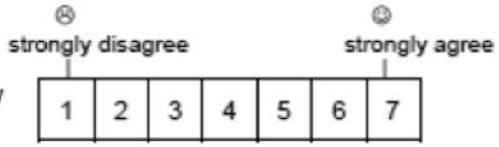
7. Stakeholders should contribute more to the cost of providing fishery management or scientific advice



8. There are too many meetings stakeholders are expected to contribute to



9. The balance of stakeholder groups involved in fishery management is about right



10. What single change would you like to see to improve stakeholder engagement in fisheries management?

B) Information about you

1. What is your role in the industry? (Please tick one of the following)

Representative ☐ Skipper ☐ Crew ☐ Processor ☐
Producer Organisation ☐
Other (please specify) .....

2. If you are a skipper or crew a fishing vessel, what is your main fishing target? (Please tick one of the following)

Demersal whitefish ☐ Pelagic fish ☐ Prawns ☐
Mixed demersal (prawns and fish) ☐ Crabs and lobster ☐ Scallops ☐
Other (please specify) .....

Thank you for taking the time to complete this survey. Please drop your completed survey in the box next to the auditorium's desk.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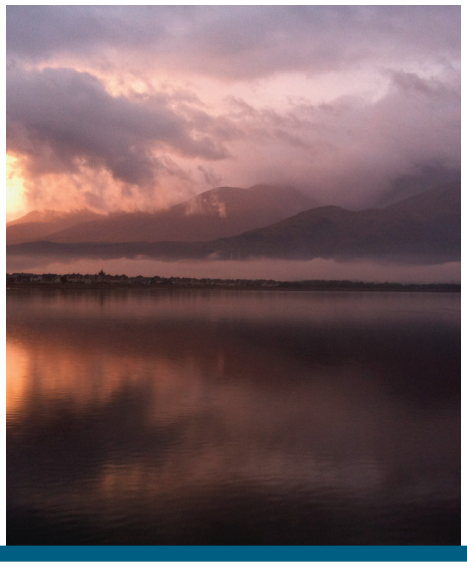

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