Science Series
Technical Report no. 152

Examples to illustrate the impact of Cefas Science

Cefas

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July 2013

Note: This report seeks to illustrate with selected examples Cefas actual and potential impacts. The methodology of this report is not designed to provide a full economic evaluation or cost effectiveness analysis and therefore, cannot be used for comparisons with other areas of Government spend. While Cefas is the main contributor to the impacts identified, other organisations and collaborators also play a role and are identified where relevant.

This report should be cited as: Cefas 2013. Examples to illustrate the impact of Cefas Science. Sci. Ser. Tech. Rep., Cefas Lowestoft, 148: 37pp.

Additional copies can be obtained from Cefas by e-mailing a request to infoservices@cefas.co.uk or downloading from the Cefas website www.cefas.defra.gov.uk.

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Executive Summary

This report illustrates the impact that Cefas science can have on the wider economy and society. It indicates how Cefas science may directly or indirectly (via policy implementation) contribute to economic and social wellbeing. It also shows how Cefas science can generate new scientific knowledge and augment human capital through its research, creating a potential for long-term benefits for society and the economy via increased skills and innovation. This analysis does not, however, aim to provide a full process of economic efficiency appraisal; rather it seeks to illustrate with selected examples the societal 'impact' that Cefas science has provided. The context in which this impact assessment has been undertaken is that c.88% of Cefas budget (2012/13) was provided by Defra, other parts of UK government or from the EU and Cefas' role is to use these resources in a cost-effective manner to fulfil its statutory monitoring and inspection services, information and advice and national emergency response capability.

Improving societal understanding of coastal, marine and freshwater environments, including the positive and negative impacts of socio-economic activity on those systems and their wealth generating capacity, is at the core of Cefas' purpose. Cefas provides a key applied science and co-ordination role in the marine community as a partner to academic and industry sectors and sits at the heart of policy by providing the evidence base for decision-making. Cefas' work also contributes to a national blue-growth strategy by assisting in wealth creation opportunities based on natural capital in the marine environment.

This report produces "impact case studies" which are illustrations of how Cefas science makes a difference in some important way. The social and economic 'impact' of scientific activities across Cefas can be assessed using a range of criteria. These generic criteria have been used to assess the work of a range of public bodies, including Institutes and University-based research enterprises. The aim of this report has been to identify as comprehensively as possible the 'value-added' (in social welfare terms) provided by Cefas' scientific research. However, it is not intended to cover all the science undertaken or to describe the total impact of Cefas science.

In this report, the case studies are classified according to Cefas' three main science themes, namely Environment & Ecosystems, Fisheries and Aquatic Health & Hygiene; and assessed in terms of a set of generic impact criteria.

Four generic impact criteria were used:

- Financial or economic benefits linked to Cefas science, including savings in capital/maintenance costs for coastal/marine activities and the generation of patents etc;
- Contribution to public policy formulation or implementation, resulting in a more cost-effective policy instrument or implementation process, or support in the successful promotion of a policy and its stated objectives, including long-term underpinning science in terms of monitoring , regulation and risk assessment;
- Contribution by Cefas to the stock of scientific knowledge and understanding of the consequences of environmental change in the marine environment;
- Creation of human capital, via continuous development and training of Cefas staff.

Evidence from the case studies demonstrates the importance and value of Cefas science in terms of these impact criteria and is summarised in the following Table 1 to Table 3. Many of these case studies have demonstrated that Cefas research contributes simultaneously to a number of the impact criteria described above. The data in these tables are subject to the following caveats: some economic and financial impacts are not monetised and some benefits are presented as gross values e.g. in the case study 'Avoiding eutrophication in the marine environment'. This socio-economic assessment was constrained by some uncertainties and gaps in data which required the use of some simplifying assumptions.

Cefas also works with many partners to deliver some of these impacts and, where the full costs of these case studies have been quantified, Cefas' contribution is calculated using budget share. This allocation implies that the return on investment is the same across all project partners. In reality, these returns on investment may vary depending on the significance of individual contributions. Although it is clear that this allocation is not perfect, it suggests the potential magnitude of Cefas' impact. In the case studies where the full costs have not been quantified, then Cefas' contribution is expressed in qualitative terms. Under these conditions benefits are presented as gross values and not allocated across contributors to the impact identified. The use of any data from this report should therefore be based on careful reading of the individual case studies where any assumptions and data limitations are transparently set out.

Significant input to this report has been provided by Cefas Science leads and Cefas Associate, Professor Kerry Turner.

Table 1: Links between Environment & Ecosystem Case Studies and impact criteria[1] [2]

Disposal Site Monitoring Rame Head disposal site

- Avoided unnecessary additional economic and environmental costs of disposal activities of £2.63 m to £19.05 m (net of Cefas cost this equates to £1.7 m to £18.12 m)
- Cefas science evidence contributes to the sustainable operation of ports and harbours, whilst ensuring that a wide range of marine ecosystem services, goods and benefits are protected
- A core component of the PhD of one Cefas researcher member

Avoiding Eutrophication in the marine environment

- The Cefas research was critical in avoiding costly and unnecessary tertiary sewage treatment and the related infraction proceedings from the EC
- The costs of designating the Humber Estuary as a sensitive area under the terms of the UWWTD, just one of the six specific areas targeted by infraction proceedings, estimated at *£952.5 million to £2.1 billion* of avoided costs
- 7 successful PhDs

Financial or Economic Benefits

Contribution to public policy formulation or implementation

Contribution to the scientific stock of knowledge

Building human capital

Wavenet

- Net benefit of the UK Coastal Monitoring and Forecast Service (UKCMF), that is estimated at £219.5 m over the 10 year period or using budget share allocation, Cefas's share of NPV is £69 m
- Supporting the offshore wind energy sector
- Supporting the deployment of wave energy devices
- Improving maritime safety
- Providing evidence base for Climate Change studies

Aggregates Licensing – short-term licences

- For a relatively small cost to Cefas and others the aggregates industry was able to continue with interim licences, potentially extracting up to *£75 m* of marine aggregates (in terms of revenue). This equates to approximately £35.2 m in terms of GVA

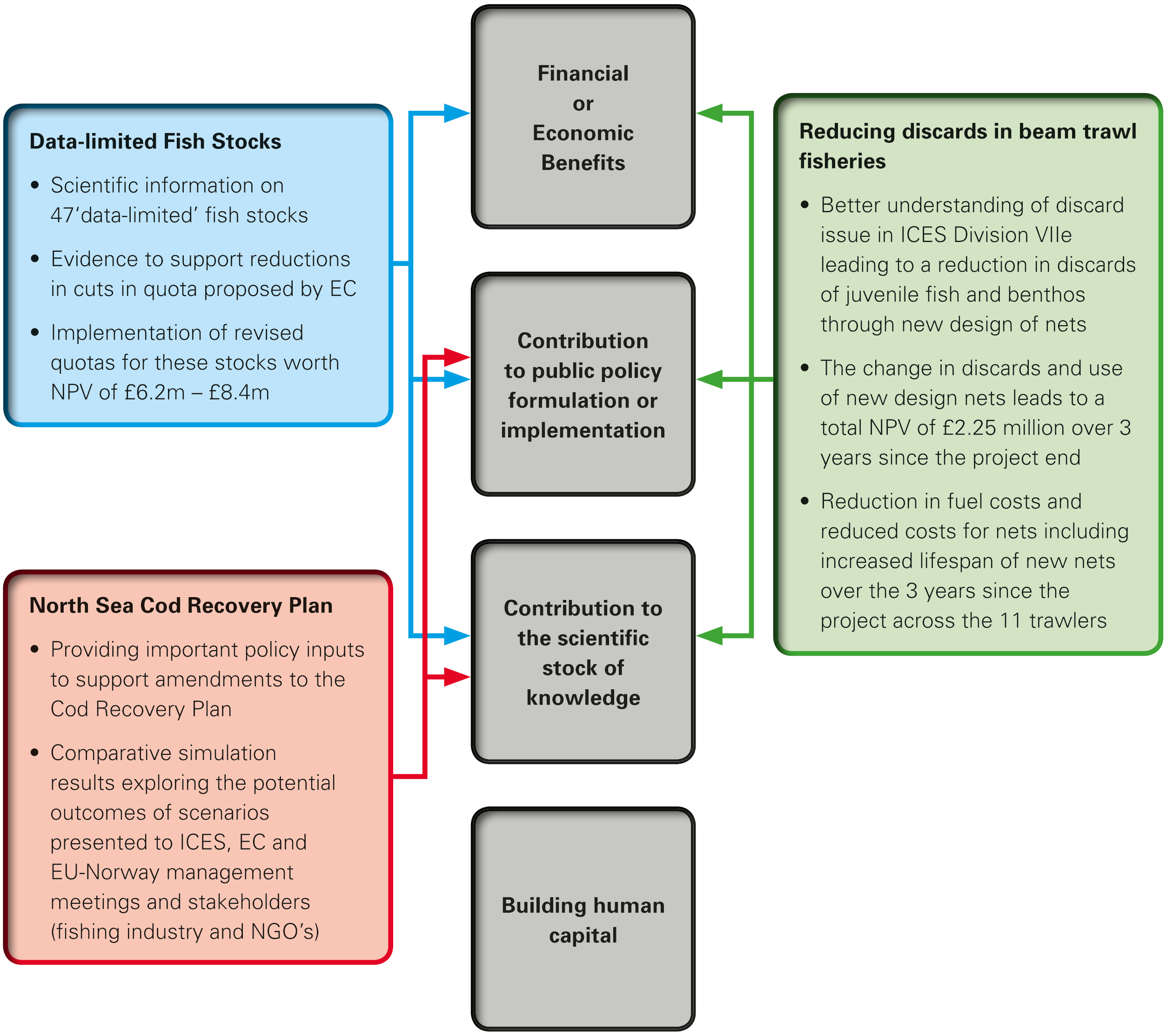
Renewable Energy

- Deepwater Turbine project – potentially avoided unnecessary cost of *£1 m* by identifying environmental problems associated with the anchor blocks proposed for deepwater turbines prior to a prototype construction.

1 Gross values are presented in *italic* font style.

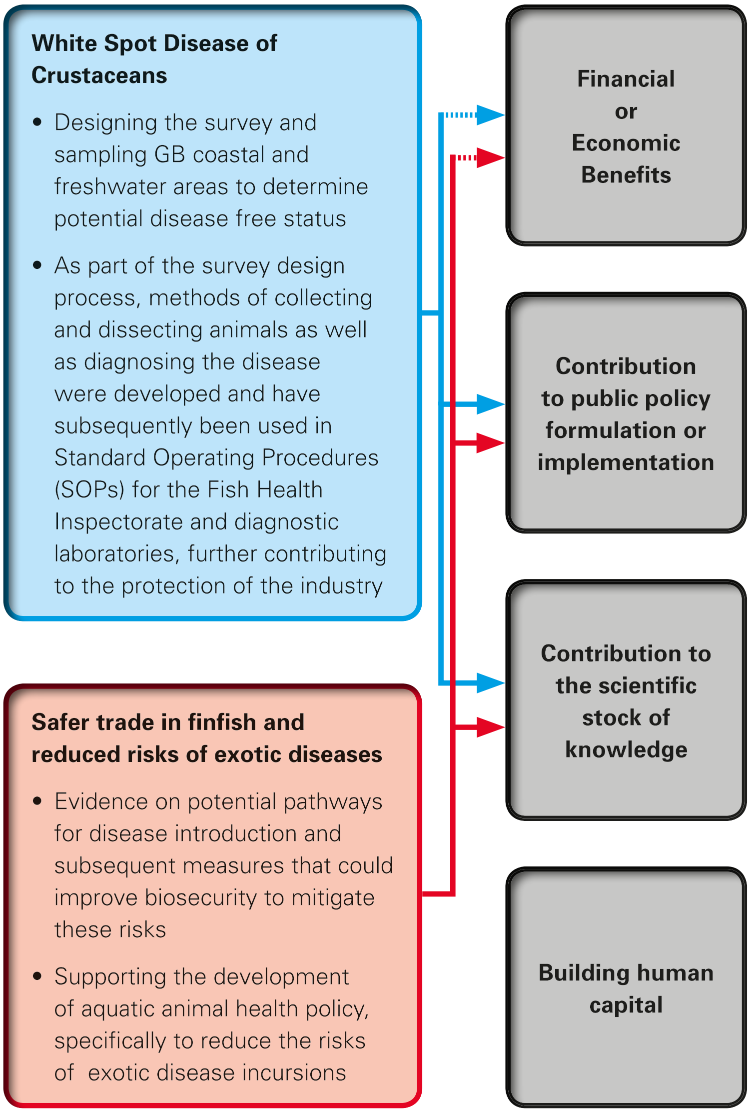
2 These case studies aim to be illustrative of Cefas actual and potential impacts.

Table 2: Links between Fisheries Case Studies and impact criteria[3]



3 These case studies aim to be illustrative of Cefas actual and potential impacts.

Table 3: Links between Aquatic Health & Hygiene Case Studies and impact criteria[4] [5]



4 These case studies aim to be illustrative of Cefas actual and potential impacts.

5 Dotted arrows represent an uncertainty over potential expected economic impacts that have not been quantified in monetary terms in this report.

Abbreviations

BMAPA	British Marine Aggregate Producers Association
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CFP	Common Fisheries Policy
CO2e	Carbon dioxide emissions
CSEMP	Clean Seas Environment Monitoring Programme
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EA	Environment Agency
EC	European Commission
EIA	Environmental Impact Assessment
EMS	Electronic Monitoring System
EURL	European Reference Library
FSA	Food Standards Agency
FVO	Field Veterinary Officer
GHG	Greenhouse Gases
GLP	Good Laboratory Practice
GV	Government View
GVA	Gross Value Added
ICES	International Council for the Exploitation of the Sea
IECS	Institute of Estuarine and Coastal Studies
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MMO	Marine Management Organization
MSFD	Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
NPV	Net Present Value
NRL	National Reference Laboratory
OIE	World Organisation for Animal Health
RAG	Regulatory Advisory Group
REAs	Regional Environmental Assessments
SOPs	Standard Operating Procedures
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total Allowable Catch
TS	Taura Syndrome
UEA	University of East Anglia
UKAS	United Kingdom Accreditation Service
UKCMF	UK Coastal Monitoring and Forecast Service
UWWTD	Urban Waste Water Treatment Directive
VHS	Viral Haemorrhagic Septicaemia
WFD	Water Framework Directive
WSD	White Spot Disease
WSSV	White Spot Syndrome Virus-1
YHD	Yellowhead Disease

1. Introduction

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) is an Executive Agency of the Department for Food and Rural Affairs (Defra). The purpose of Cefas is to be the government's foremost source of evidence, applied science and impartial expert advice for marine and closely related environments. Cefas is also a provider of statutory monitoring and inspection services including a national emergency response capability.

Cefas activities contribute to the UK economy and society and their value in terms of social welfare impact has been described and quantified through a number of case studies. These case studies help illustrate the potential impacts resulting from Cefas science. They show how science may directly or indirectly (via policy implementation) contribute to economic and social wellbeing. They also demonstrate how Cefas science generates new scientific knowledge and human capital from its fundamental research and then creates a potential for long-term benefits. This assessment aims to establish what impact Cefas science may have on specific policy measures and wider social objectives[6].

Cefas' focus is on marine and closely related environments and its work can be categorised under the three thematic areas of Fisheries, Environment and Health & Hygiene. These science themes provide a pragmatic and meaningful way of describing Cefas science. For each theme, a suite of case studies was developed to give the widest coverage of Cefas science and to demonstrate a range of routes to impact, together with different types of economic and social welfare impacts. The case studies are not intended to provide comprehensive coverage of all the science undertaken, so they cannot be used to describe the total impact of Cefas science.

The report is organised into 8 main sections including Appendix and List of Contributors and Reviewers. Following this introduction, Section 2 sets out background to the organization. Section 3 presents a methodology for the impact assessment of Cefas Science. Sections 4 to 6 contain all developed case studies. Section 7 is Appendix that contains additional details for one of the case studies – the North Sea Cod Recovery Plan.

6 In this respect it differs fundamentally from an economic efficiency analysis which has economic welfare maximisation as its goal.

2. Background to Cefas

Cefas' work spans freshwater to the open ocean; wild to farmed fish and shellfish; and other uses of the marine environment such as renewable energy. Cefas's areas of expertise include:

- fish and shellfish health & hygiene
- marine spatial planning and environmental licensing
- sustainable fisheries management
- marine biodiversity and habitats
- climate change impacts and adaptation
- emergency response.

In March 2012, Cefas had 520 FTE staff, 435 actively involved in science programmes. Cefas also co-funds a studentship programme. The current number of PhD students with Cefas supervisors is 48.

Its annual budget in 2011 was £53.6m. This budget comprised core funding from Defra of £33.7m; other funding from Defra and other UK public sector of £9.4m. The remainder of funding was EU £2.3m and industry £8.2m. Private sector funding represented 15.3%.

For the purposes of this report, Cefas science is divided into the following three themes which are described in more detail below:

- Environment & Ecosystems
- Fisheries
- Aquatic Health & Hygiene.

2.1 Environment & Ecosystems

This theme focuses on *'Research, monitoring, assessment and advice to describe, manage and adapt to human and environmental impacts on marine ecosystems'*. The work covers three main aspects:

- Describing and predicting effects of human and environmental pressures and the state of the environment – monitoring, advice and R&D
- Developing chemical, analytical and biological effect techniques to support environmental assessment and management – mainly monitoring, R&D and advice
- Assessing human impacts on the marine ecosystem – mainly R&D.

Notable achievements include major policy contributions to:

- UK Marine and Coastal Access Act (MCAA), the EU Marine Strategy Framework Directive (MSFD), the EU Integrated Maritime Policy, the Water Framework Directive (WFD)
- Marine Spatial Planning and status reporting through the Marine Monitoring and Assessment Strategy
- Status reports (Charting Progress, OSPAR QSR, Climate Change Risk Assessment, National Ecosystem Assessment).

Cefas supports Defra and other public bodies including the Marine Management Organisation (MMO), Food Standards Agency (FSA), Maritime and Coastguard Agency (MCA) and statutory nature conservation bodies. Cefas also provides science-based advice, monitoring and impact assessment following oil and chemical spills at sea.

Five case studies are presented under this theme:

- Disposal Site Monitoring – Rame Head Disposal site
- Aggregates Licensing – Short-term Licences
- Avoiding eutrophication in the Marine Environment
- WaveNet
- Renewable Energy.

2.2 Fisheries

This theme focuses on *'Research, assessment and advice to assess and manage marine and freshwater fisheries and the ecosystems that support them'*. The work covers three main aspects:

- Surveillance of the state of target and non-target fish species and fisheries – mainly monitoring, R&D and advice
- Ecosystem approach to understanding fish and shellfish dynamics – mainly R&D and advice
- Assessment and advice – advice, monitoring and R&D.

Notable achievements include:

- Contributing to the development of international legislation such as the Common Fisheries Policy (CFP), the MSFD, the Habitats Directive and the EU Integrated Maritime Policy, as well as the Convention on Biological Diversity
- Close collaboration with the fishing industry and non-governmental organisations to collect data and inform advice on trade-offs between different fishery and environmental objectives
- Strategies to reduce discards e.g. beam trawl fishery in the South West
- Development of robust models to help the industry move towards maximum sustainable yield.

Three case studies are presented as follows:

- Data-limited Fish Stocks
- North Sea Cod Recovery Plan
- Reducing Discards in Beam Trawl Fisheries.

2.3 Aquatic Health & Hygiene

This theme focuses on *'Research, monitoring and assessment programmes to ensure safe, clean and healthy aquatic animal resources'*. The work has three main aspects:

- Aquatic animal diseases – R&D and advice
- Impact of environmental contamination and disease on the aquatic environment – mainly research and development
- Seafood contamination from microbes, algal toxins and other pollutants – mainly monitoring and advice.

Notable achievements include:

- Designation as European Reference Library (EURL) for crustacean diseases and viral and bacterial contamination in bivalve molluscs
- Designation as World Organisation for Animal Health (OIE) laboratory for specific diseases
- Emergency response capability for seafood safety in England and Wales
- Contributing to new standards across Europe in Biotoxin and Norovirus evaluation
- Field Veterinary Officer (FVO) missions on food safety and aquatic animal diseases
- Good Laboratory Practice (GLP) compliant aquarium; and
- Much of the laboratory is accredited to United Kingdom Accreditation Service (UKAS) standards.

Two case studies are presented as follows:

- White Spot Disease of Crustaceans
- Safer Trade in Finfish and Reduced Risks of Exotic Diseases.

2.4 Inter-Disciplinary Science

As well as the three main themes, Cefas also undertakes multidisciplinary science that cuts across all three areas. Examples include:

- **Climate Change** – The Cefas Marine Climate Change Centre co-ordinates current thinking on marine climate change issues, investigates gaps in knowledge and helps the UK to develop a robust response to these important challenges.
- **Renewables** – Knowledge gaps identified by Cefas and partners include understanding the impacts of tidal stream and wave energy devices and predicting their effects; understanding the potential for more direct interactions (e.g. collision) and/or enhancements of marine mammals and fish; and impacts of underwater sound.
- **Major Infrastructure** – including studies to underpin the Environmental Impact Assessments (EIA) for two new nuclear power stations at Hinkley and Sizewell and a proposed fixed link between Germany and Denmark.

The case study on renewable energy is one example of Cefas' inter-disciplinary science.

3. Methodology for the impact assessment of Cefas Science

From a general overview of Cefas research work, this report has identified examples of Cefas science where economic and social welfare impacts can be quantified and valued in meaningful terms and with some degree of precision. Developing the more detailed case studies based on these examples was an interdisciplinary process that provided the foundation for the rest of the work. The case studies were selected to show those aspects of Cefas science that demonstrate a range of routes to impact and also different types of impact.

A methodology was developed for assessing the economic and social welfare impacts of Cefas science for these selected case studies. Four Cefas relevant generic impact criteria have been used to identify and distinguish the different types of impact; and note that some case studies provide evidence of more than one impact benefit:

- Financial or economic benefits linked to the science, including savings in capital/maintenance costs for coastal/marine activities and the generation of patents etc;
- Contribution to public policy formulation or implementation, resulting in a more cost-effective policy instrument or implementation process; or support in the successful promotion of a policy and its stated objectives, including long-term underpinning science in terms of monitoring, regulation and risk assessment;
- Contribution to the stock of scientific knowledge and understanding of the consequences of environmental change in the marine environment;
- Building human capital, via continual staff development training and the production of PhDs.

In some cases the impact of Cefas science has been assessed in monetary terms. This involved identifying and measuring as many of the costs and benefits as possible that relate mainly to financial or economic impact criteria and/or contribution to public policy impact criteria, to determine a net impact. The time horizon for the analysis was adapted to individual case study contexts. As a rule, where the time horizon was not clearly defined by the case study itself, a 10 year time period was chosen to discount any economic impact, using a 3.5 percent discount rate. Discounted net impacts are 2010 present values and expressed in 2010 prices throughout this report[7] except for the case study 'Avoiding eutrophication in the marine environment'. In this particular case study 2009 was chosen as the base year.

Some of these case studies cover a joint collaboration between Cefas and other bodies to produce financial or economic benefits, contribution to public policy and other impacts. The Cefas contribution can then be calculated using budget share. This allocation implies that the return on investment is the same across all project partners. In reality, these returns on investment may vary depending on the significance of individual contributions. Although it is clear that this allocation is not perfect, it is suggestive of the potential magnitude of Cefas' impact. In the case studies where the full costs have not been quantified, then Cefas' contribution is estimated in qualitative terms. Under these conditions benefits are presented as gross values and not allocated across contributors to the impacts identified.

Non-monetised impacts, i.e. contribution to the stock of scientific knowledge and/or building human capital, are included in a qualitative discussion. To highlight that Cefas creates human capital via PhDs, this impact is mapped to those case studies that provided support under their research scope for Cefas PhD studentships (see Table 1 to Table 3). Cefas also invests in various forms of learning and development to help their scientists to be at the centre of new scientific challenges in the marine and closely related environments. The latter is not captured through this assessment of case studies.

Finally, some of the economic impacts are based on robust market data, while other impacts are conditioned by simplifying assumptions and are therefore less certain, drawing on evidence from relevant literature from the UK and elsewhere. As mentioned before, Cefas also works with many partners to deliver some of these impacts and there may be funding from other sources that contribute to impacts. The use of any data from this document should be based on careful reading of the individual case study where assumptions are transparently set out.

7 Main costs and benefits are expressed in 2010 prices using GDP deflator obtained from http://www.hm-treasury.gov.uk/data_gdp_fig.htm [Accessed 21 November 2012].

4. Environment & Ecosystems Case Studies

4.1 Disposal Site Monitoring – Rame Head Disposal Site

For a number of years there have been concerns about the impact of depositing dredged material at the Rame Head disposal site near Plymouth (Figure 1), where material from Devonport Harbour (and other sources in the Plymouth area) is dumped. In the case of Rame Head, Cefas monitoring has provided supporting information to indicate that the current disposal site is acceptable and can remain operational, thus negating the need to either relocate the site and/or find a new disposal site to receive material from Plymouth[8]. Without scientific evidence there would be no analytical basis on which to make these decisions. This evidence helps ports and harbours to operate sustainably whilst ensuring that a wide range of marine ecosystem services benefits are conserved. Cefas's work on marine disposal site monitoring includes avoiding unnecessary additional economic and environmental costs of disposal. Illustrative examples suggest these avoided costs could be in the region of £2.63m to £19.05m (over a 10 year assumed time period). Taking into account Cefas costs, to provide evidence to support this decision leads to a potential net impact of £1.7m to £18.12m[9].

Cefas provides independent monitoring on behalf of the MMO. It should be noted that recommendations based on Cefas' monitoring have no bias regarding whether a change in the license conditions is required. The monitoring purely reports on the ecological impacts without regard for economic implications.

Cefas has undertaken on-going monitoring and a detailed study of the Rame Head site, at a cost of around £926k between 2001 and 2009. Several reports have been produced during the course of this monitoring programme, together with stakeholder discussions and presentations. The outcomes of the monitoring indicated that there were no detectable impacts outside the immediate area of the site, i.e. impacts observed were in accordance with those predicted for the site. These findings were recently verified by an independent review by the Institute of Estuarine and Coastal Studies (IECS) at the University of Hull[10].

Alternative solutions to depositing material at Rame Head are presented by the following scenarios shown in Table 4:

- The nearest alternative existing site to Rame Head is at Falmouth, which is 58 km away from the Rame Head site
- A review by IECS, Hull University indicated that relocating the site further offshore to a location below the 50m contour would require a minimum 7km of additional travel[11].

Solutions that do not involve depositing material at sea are unlikely to be sustainable options in the long-term due to the volume of material. However, these include:

- The material could be left *in situ* within Plymouth Sound and Tamar Estuary
- The material could be removed and treated at portside to reduce the water content and disposed of in landfill.

To illustrate the potential cost of relocation the first two scenarios have been assessed. These scenarios have been informed by Cefas scientists. It must be noted that these two alternative scenarios are tested at a high level to provide an illustration of possible economic impacts in the absence of science to provide the evidence that the current disposal site is operated within acceptable environmental impact limits. Other alternative options include disposal of the material on land (which would involve investment in treatment facilities) or leaving the material *in-situ*, which could have a detrimental impact on port operations. These options are, therefore, not long-term options.

The additional cost, calculated for a new site and an alternative existing site located at Falmouth, is based on additional distance the dredger would need to steam, daily rate of GHG emissions and the cost of dredger hire per day, see Table 5. Establishing a new disposal site would also require an Environmental Impact Assessment (EIA) to quantify any potential environmental impacts, estimated to cost between £250,000 and £400,000[12] depending on the extent of field monitoring required. For example, if ship surveys are required, Cefas estimates costs ranging from £2,000 to £20,000 per day, depending on the vessel size but not including staff costs. Altering the boundaries of the existing site is assumed to require a more limited EIA. Relocating the disposal site also has potential economic implications for the port, increasing the risk of delays

8 The majority of the maritime industry in Plymouth Sound and the Tamar Estuary relies on the Rame Head site to dispose of the dredged material removed to ensure navigable passage. Between 2000 and 2009, a total of 1,860,238 wet tonnes were placed at the Rame Head site with an annual average of 175,180 tonnes[a]. The marine and maritime sector in Plymouth alone accounts for approximately 13,500 jobs of which at least 8,500 are provided at Devonport (the largest naval base in Western Europe)[b]. Indirectly, the sector also supports another 3,400 – 6,800 jobs in Plymouth's sub-region. Together this is equivalent to approximately 19% of total employment in the city of Plymouth and generates some £1billion of GVA[b].

[a] M. Elliot, K. Mazik, 2011. Rame Head Environmental Impact Study: Review evidence. Institute of Estuarine and Coastal Studies, University of Hull.

[b] Atkins, 2010. Port of Plymouth Evidence Base Study.

9 Cefas monitoring cost on Rame Head site equals to £874k to £926k for 2000 to 2009. The cost is expressed in 2010 prices.

10 M. Elliot, K. Mazik, 2011. Rame Head Environmental Impact Study: Review evidence. Institute of Estuarine and Coastal Studies, University of Hull.

11 M. Elliot, K. Mazik, 2011. Rame Head Environmental Impact Study: Review evidence. Institute of Estuarine and Coastal Studies, University of Hull.

12 Based on discussion with Cefas experts, 31st May 2012.

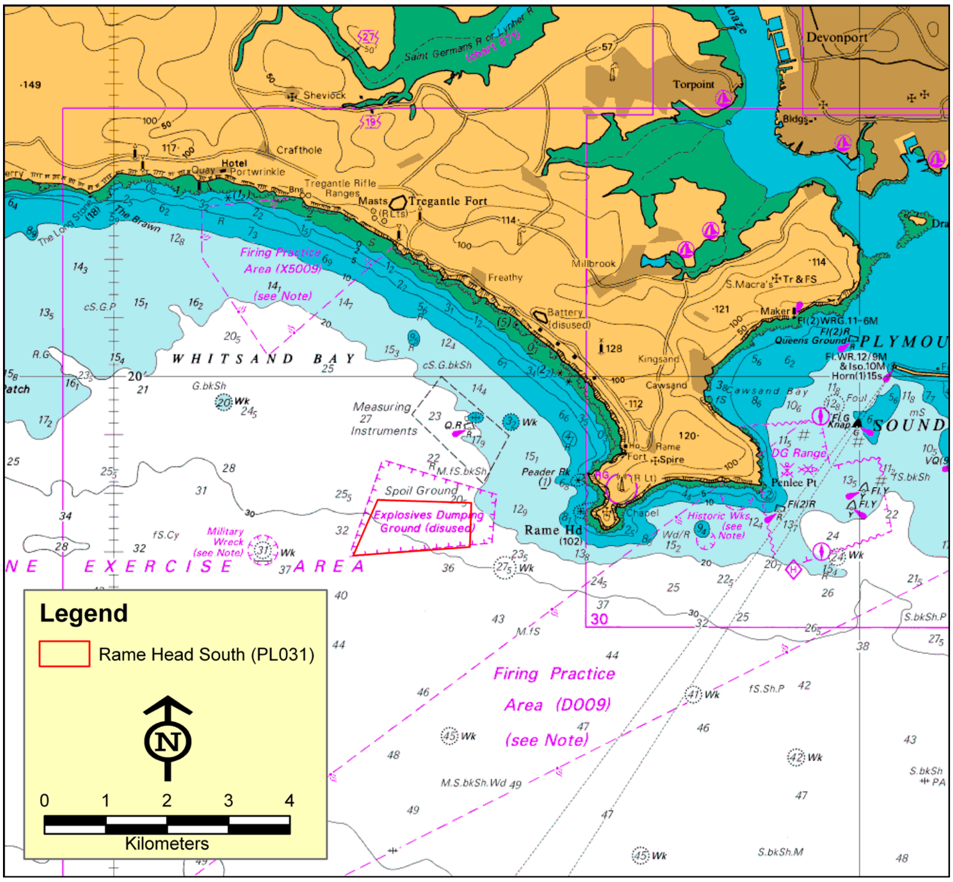


Figure 1: Location of the Rame Head Disposal Site. Source: Cefas. Reproduced by permission of the Controller of Her Majesty's Stationery Office and the UK Hydrographic Office (www.ukho.gov.uk). © Crown Copyright.

Table 4: Scenarios for alternative sites to Rame Head

Site	Initial Cost	Additional Cost (per annum)	Additional CO_2 emitted per annum	Assumption
Rame Head (current)	–	–	–	No Change
Relocating site to below 50m contour (new site)	£250–£400k[a]	£276k	90.2 tonnes	Based on additional distance of 7 km and requirement for the full EIA
Nearest alternative existing site – Falmouth	–	£2,209k	721.6 tonnes	Based on additional distance of 58 km by sea
Disposal of material to landfill	Cost of treatment plant (£ millions)	Cost of treatment and land occupied by plant	At least 46 tonnes (emission from transporting material 2 km)	New portside facility may be required to dewater material
Leave material in-situ	–	c. £10m	–	1% loss in port activities due to build-up of material[b]

[a] Based on discussions with Cefas on typical costs of Environmental Impact Assessments (EIA)
[b] £1billion of GVA is estimated to be generated by the marine and maritime sector in Plymouth. 1% loss in port activities due to build-up of material is assumed to illustrate the order of magnitude of this scenario impact.

due to bad weather, increasing steaming time, crew time and fuel costs. At present, a dredging cycle in Plymouth Sound can be completed in a working day (dredging, loading, steaming, disposal, return). Increased distances could result in it taking longer to complete the dredging works and impact on the operations at the port. Based on the assumptions set out in Table 5, relocating the disposal site just 1hr further[13] from the port could increase dredging costs by around £280k per annum. Using these assumptions, over 10 years the illustrative additional discounted cost associated with relocating the disposal site could range from £2.63m to £2.78m and £19.05m if using the nearest alternative existing site (Falmouth).

13 M. Elliot, K. Mazik, 2011. Rame Head Environmental Impact Study: Review evidence. Institute of Estuarine and Coastal Studies, University of Hull.

Table 5: Costs associated with a new site and an alternative site at Falmouth

Assumption	New site	Alternative Site (Falmouth)
Tonnes of dredged material (annual)	175,180 t	
Cubic metres of dredged material (annual)	120,814 m^3	
Cubic metres per trip based on average capacity	3,685 m^3	
Number of trips required to disposal site	33 trips	
Distance	7 km	58 km
Additional steaming time (hours)	2 hrs	16 hrs
Total additional hours (annual)	66 hrs	528hrs
Total additional days (assuming 12 hr operation time)	5.5 days	44 days
Cost per day to hire a dredger[a] [14]	£50,000	£50,000
Additional annual cost to hire a dredger	£275,000	£2,200,000
Emissions (CO_2e) per day[b]	16.4 tonnes per day	
Annual emissions (CO_2e)	90.2 tonnes	721.6 tonnes
Annual cost of emissions[c]	£1,173	£9,381
One-off EIA cost	£250 k to £400 k	–
Discounted additional cost over 10 year period[d]	£2.63m to £2.78m	£19.05m

[a] Cost per day to hire a dredger is variable as it depends on the state of the market at any one moment in time (M. Russel, pers. Comm., 1st November 2012).
[b] The quantity of emissions is a product of the total quantity burnt of fuel, multiplied by a conversion factor for the quantity of GHG in one tonne of fuel consumed. For fuel (oil and gas) used by dredgers, the conversion factor is 3483.5kg CO_2e per tonne. The rate of fuel consumption for a TSHD is 4.7 tonnes/day[15].
[c] The traded price of carbon per tonne is £13 for 2010 (based on DECC traded carbon price projections -central scenario).
[d] The total discounted additional cost over 10 years includes both cost to hire a dredger, EIA cost if applicable and cost of emissions. The central projection of DECC traded price of carbon per tonne from 2010 to 2019 is used to reflect annual changes in carbon.

4.2 Aggregates Licensing – Short-term Licences

Cefas has supported the marine aggregates industry regulator to ensure all licences have valid Environment Impact Assessments in place by the revised deadline set by Defra. Cefas has led on the project to find an interim solution for licensing marine extraction activities as a result of a change in the date (from 2013 to 2012) by which all licences required a valid Environment Impact Assessment (EIA). Marine Aggregates Licences are now required to be compliant with EU regulations on EIA. Cefas, in collaboration with MMO and other statutory nature conservation bodies, developed a mechanism to enable industry to demonstrate compliance with the regulations while the work is undertaken to prepare full impact assessments. For a relatively small cost to Cefas and others the aggregates industry was able to continue with interim licences, potentially extracting up to £75m of marine aggregates during this period. This equates to approximately £35.2m in terms of GVA.

In the 1960's, the 'Government View' (GV) procedure was introduced whereby the Crown Estate would not issue a dredging licence unless the Government expressed a favourable view on the environmental implications of the proposed dredging operation. In 1989 the GV procedure was amended to reflect the requirements of EC Directive 85/337/EEC and to require Environmental Impact Assessment (EIA) to be undertaken for all applications. However, the procedure remained a purely informal process with no statutory backup.

In 2007, a new statutory system was introduced to replace the non-statutory GV system, with Licence Permissions provided under the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007. However, there were still a number of licences that were operating without a valid EIA under the old GV system. Defra provided a deadline date of October 2013, by which time all aggregate licences in operation required an EIA. Therefore, over the past few years, the industry has been working to secure their renewals by applying for new 15-year licences, more recently (since 2011) under the new legislation contained within Part 4 of the MCAA.

However, due to policy changes, it was necessary to bring forward the date of EIA compliance to October 2012, which was too soon for some licence areas to undertake the work needed to inform a renewal for a 15 year licence. Therefore, Cefas was working with the MMO, statutory nature conservation bodies and industry, to create an interim process to ensure continuation of aggregate extraction between October 2012 and renewal of 15 year licences. This work led to the development of short-term licensing for marine aggregates.

As a result of the Government bringing forward the implementation of EU marine regulations requiring EIA, the

14 K. Cooper, D. Burdon, J. Atkins, L. Weiss, P. Somerfield, M. Elliot, K. Turner, S. Ware, C. Vivian, 2010. Seabed Restoration following marine aggregate dredging: Do the benefits justify the costs? MEPF-MALSF Project 09-P115, Cefas, Lowestoft, 111pp.
15 Ibid.

marine aggregates industry faced the prospect of having to halt dredging activities while full assessments were being prepared. Cefas had been instrumental in developing a mechanism by which extraction could continue in the interim while still being compliant with the legislation.

Prior to industry preparing EIAs for licensing applications, four Regional Environmental Assessments (REAs) were undertaken by industry to set the baseline and inform site specific EIA. The regional assessment process took longer than expected and industry was still preparing these assessments in 2012. As a result it was expected that site specific EIAs for longer term renewal applications could not be completed in time to meet the deadline for EIA compliance. EIAs take around 18 months to prepare and require a significant amount of input following the completion of the regional assessments.

As the founding member of the Regulatory Advisory Group (RAG) Cefas led the development of an approach to bridge the gap between the start of the new regulations and the preparation of full EIAs. The approach was to put the 25 licence areas on short-term licences which included EIAs that were proportionate to the amount of material being extracted during that period. There were a number of limits set for these licences:

- Companies could only dredge in areas that were dredged after 1991 when the Electronic Monitoring System (EMS) was implemented[16]
- Companies could only dredge at their historical limits – i.e. they could only extract the amount of material that had previously been found to be acceptable
- These licences were only granted for the short-term.

These short-term licences, which are no longer than 27 months, allow existing operations to continue until the more important long-term licences are issued. The EIAs for these short-term licences are prepared using a desk-based methodology taking into account that the limiting factors are designed to significantly reduce any potential environmental risk. Cefas is involved in reviewing the draft Environmental Statements and providing advice to industry to ensure all possible impacts are described and assessed to an appropriate and proportionate level, given the caveats that are in place to reduce environmental risk.

Out of more than 70 licence areas where dredging takes place[17], there were 25 licences without a valid EIA that were not expected to be completed in time to meet the deadline. Extraction in these areas could have been suspended for up to 27 months while full impact assessments were prepared. In total, up to 19,361,844[18] tonnes of material was permitted under the 25 short-term licences that used this process. This is not to say that this material would never have been extracted but it would have taken place at a later date and the delay would have been problematic for the industry. Short-term licensing revenues are important to finance all the work, including marine surveys, that need to be undertaken to produce full EIAs in order for the industry to be awarded a long-term marine aggregates licence. The type of material that is extracted is also important and varies across licences implying that this would have potentially had some detrimental effect on the domestic aggregates industry, for instance, the market filling the resulting demand gap through overseas imports.

There is also a possibility that the UK could have been subject to infraction proceedings if aggregate extraction was allowed to continue without a full EIA[19]. However, it is more likely that the UK aggregates industry would have had activity halted, with the 25 licences not being renewed until the EIAs were complete.

This case study has assessed the economic impact of recent changes made to regulations which govern marine aggregates operations in UK marine waters. The key assumption adopted was that marine aggregates extraction subject to short-term licensing continues on the same basis as the last five years i.e. the last 5 year average annual extraction rate. This does not apply to licences where the total maximum annual tonnage and/or maximum tonnage allowed over the whole license period stated in licence conditions are exceeded by the last 5 year extraction pathway. Under these circumstances it is assumed that the licence holder will extract the maximum tonnage allowed, equally distributed over the whole license period. This path of marine aggregates extraction under short-term licences produces total revenue of £75m – see Table 6.

Cefas' cost for developing aggregates short-term licensing activities is estimated at £101k. The MMO also incurred some costs that are estimated at £157k. These costs include development of a framework for short-term aggregates decision making, pre-application and application work for industry to obtain a short-term licence. The majority of these costs is recovered through licence application fees and charges.

There were other costs to other statutory nature conservation bodies[20] to support short-term marine aggregates licensing. These costs are unknown. However, these costs as per individual contribution are not expected to be above Cefas cost. It is reasonable to assume that individual costs incurred by other nature conservation bodies are within the same order of magnitude as a cost for Cefas work.

16 The EMS was put on all dredge vessels to enable enforcement monitoring to ensure there is no out of licence area dredging or dredging in exclusion zones.

17 British Marine Aggregate Producers Association.

18 Figure provided by Cefas based on the 25 licences.

19 The maximum fine EU can impose is £256m per annum. Infractions of EU legislation. Available at: http://www.scotland.gov.uk/Topics/International/Europe/Legislation/Infractions [Accessed 10 January 2012].

20 Other agencies including Natural England, JNCC and English Heritage.

Table 6: Estimated Value of Maximum Volume Aggregates Permitted under Short-Term Licences

Total tonnage licensed under short-term licences	19,361,844 tonnes
Total tonnage assumed extracted under short-term licences	12,572,244 tonnes
Total revenue (at £6.62 per tonne[21])	£75m[22]
Total additional GVA (landed value*47%[23])	£35.2m[24]
Cost of Cefas advice	£109,500
Cost of MMO input	£157,000

The estimated value produced under these short-term marine aggregates licences is based on simplified assumptions. An actual level of economic activity, the speed and amount at which the allocated resource is to be exploited under these short-term licences, are conditioned by the prevailing demand and supply conditions in the market. An actual economic agent decision is made taking into account technology, costs and prices. A more complex analysis that considers these aspects would improve the accuracy of current estimates.

4.3 Avoiding Eutrophication in the Marine Environment

The research undertaken by Cefas, alongside monitoring undertaken by the Environment Agency (EA), demonstrated that eutrophication was not as widespread within the UK waters as previously thought. As a result, in the Humber Estuary (just one of the six specific areas targeted by infraction proceedings under the Urban Waste Water Treatment Directive (UWWTD)) industry has not had to invest in unnecessary tertiary waste water treatment, thereby saving £952.5 million to £2.1 billion of economic costs of installing and operating tertiary facilities including external environmental costs from additional energy use emissions. These are the total gross benefits and Cefas' share of net impact is not calculated.

The EC accused the UK of not designating as 'sensitive areas' the Humber, Wash, Deben, Colne and Thames estuaries, Southampton Water and the North East Irish Sea under the UWWTD. The European Court of Justice has found that the UK has strong evidence to support its conclusions that these areas do not suffer from eutrophication and that the UK interpretation of the requirements of the Directive, which is strongly based on Cefas understanding of the ecological harm caused by eutrophication, was correct.

Since the late 1980s the UK research on eutrophication has been driven by a number of legislative and regulatory needs including public concerns. The cost incurred by Cefas research was necessary in order to develop a clear understanding of what was required to identify eutrophication, to cover monitoring of England and Wales Marine Waters and to fulfil Cefas' lead role, on behalf of OSPAR, in drawing together an assessment for the entire UK for input to an OSPAR assessment. Besides this there were other agencies (i.e. EA) and academic institutes that contributed towards evidence and science under this particular topic. To the degree that these total costs, including Cefas and other bodies, were driven by a number of other needs, the additional cost to defend the UK's position were marginal because of the scientific knowledge that has already been accumulated.

The cause of eutrophication has been traced back to the increase in population growth from the 1950's onwards. Historically, eutrophication has been considered a problem affecting surface standing waters, such as freshwater lakes. However, during the 1980's it was observed that nutrients leaching into the sea could be affecting the marine environment. Therefore, the EU introduced a number of directives that all Member States, including the UK, are required to comply with to assess and mitigate the risks from nutrient enrichment. The main instruments include the Nitrates Directive, UWWTD and the WFD. The Clean Seas Environment Monitoring Programme (CSEMP)[25] was initiated in the late 1980s to ensure that marine monitoring in the UK was undertaken in a co-ordinated way. The Programme aims to detect long-term trends in the quality of the marine environment by collecting high quality, standardised data. The Programme also ensures that the UK meets the OSPAR monitoring requirements[26] and supports compliance with the EC Directives.

Throughout the 1990's Cefas undertook research to develop a coherent understanding of the issues, including specific work on a number of estuaries. The assessment undertaken by Cefas suggested that most of the UK coastal waters were not adversely impacted. Cefas has confirmed that a very small proportion of the seas around the UK, have eutrophication problems and that, for these specific cases, there would be no environmental benefit from additional treatment of waste water being discharged

21 BMPA's average 2006 price for landed sand and gravel presented in Charting Progress 2 is used, but inflated to 2010 (UKMMAS, 2010).

22 Present value.

23 Presented in Charting Progress 2 and sourced from the UK input-output tables for 2004 (UKMMAS, 2010).

24 Present value.

25 Previously known as the National Monitoring Plan (NMP) and the National Marine Monitoring Programme (NMMP).

26 The Common Procedure for the Identification of the Eutrophication Status of the OSPAR maritime area provides an assessment framework for Contracting Parties to evaluate the eutrophication status of their parts of the OSPAR maritime area and for identifying those areas for which actions are needed under the Eutrophication Strategy.

into the sea. However, in the late 1990s the EC was of the opinion that the impact on the UK estuaries and coastal waters was much more widespread.

As a result of its assessment of eutrophication in UK coastal waters, the EC took legal action against the UK for failing to identify all sensitive areas. Under the UWWTD the UK faced infraction proceedings from the EC which questioned whether the UK's assessment of the impact of nutrients in several UK marine water bodies was sufficient. Cefas' research demonstrated that the UK has dynamic waters so there is much less opportunity for algae to grow, therefore fish kills do not occur in areas where discharges are similar to vulnerable catchments elsewhere in Europe. In addition, the research found that light is restricted in UK waters leading to poorer growth conditions for algae. As a result, the UK was able to demonstrate that its assessment was sufficient, and in 2009 the European Court of Justice published the judgement that the infraction proceedings had failed[27].

If the EU had been successful in its case against the UK, the costs would have been high. The UWWTD normally requires secondary treatment but, in response to the infraction proceedings, UK water companies in the six areas targeted in the case, would have been required to undertake more stringent tertiary treatment to strip out nutrients that secondary treatment is not able to remove. This would have been extremely costly. For example, a report prepared in response to the infraction proceedings by AEA Technology in 2002 estimated that the cost to the water industry of meeting the additional treatment requirements, if the Humber Estuary was designated as a sensitive area under the UWWTD, would be £1,331 billion of capital expenditure and £56 million of on-going operating costs see Table 7[28]. In addition, the energy required to carry out the treatment works was estimated to result in £420k of environmental costs from additional energy use emissions associated with tertiary treatment[29]. Costs presented are expressed in 2010 prices[30].

Table 7: The Costs[31] to the Water Industry from Designating the Humber as 'sensitive area' under the UWWTD[32] – the upper bound

Cost Criteria	Water Industry Costs £million
Capital expenditure	1,331.50
Annual operational expenditure	56.14
Annual external costs of additional pollutants (energy use emissions)	0.42
Discounted Costs over 20 years (3.5% discount rate)[a]	2,106.90

[a] 2009 is assumed to be a base year.

The study that assessed the environmental, economic and social consequences of designating the Humber Estuary as a 'sensitive area' concluded there was no case for arguing that this designation would bring environmental or social benefits to the region. In contrast, this study indicated the external costs associated with increases in GHG emissions, generation of waste, and social dis-amenity would have been of the magnitude that does not justify this investment, given the small or no environmental benefit.

Another report by Yorkshire Water in 2010 indicates that the capital cost of meeting the requirements of the Humber Estuary being designated as a sensitive area under the UWWTD would be £600m[33]. The lower capital cost could be potentially explained by technological progress that tends to reduce the associated capital and operational costs over the time. To account for the possibility of technological progress a percentage decrease in capital costs is calculated. It is then assumed that the maintenance costs decrease at the same rate as capital costs. The following Table 8 summarises the costs for a lower bound. It is important to note that environmental costs remain the same for the lower bound as for the upper bound calculation.

27 Judgement of the Court (Third Chamber) – 10 December 2009. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:62007CJ0390:EN:HTML [Accessed 20 November 2012].

28 AEA Technology plc (2002). The Environmental, Economic and Social Consequences of designating the Humber Estuary as sensitive area (nutrients) under the Urban Waste Water Treatment Directive. Available at: http://www.keldagroup.com/kel/csr/ourenv/reports_pub/2004/humber/humber.pdf [Accessed 21 November 2012].

29 Ibid.

30 Costs are expressed in 2010 prices using GDP deflator obtained from http://www.hm-treasury.gov.uk/data_gdp_fig.htm [Accessed 21 November 2012].

31 Costs comprise two main parts: capital expenditure on new plant and equipment as well as operational costs in terms of electricity, chemical and sludge disposal. On the issue of sludge disposal it is assumed that incineration is looking like the most plausible option in the long-term and is used for the capital and operation figures above. The quantified external environmental costs are also added.

32 The costs are expressed in 2010 prices.

33 Yorkshire Water Services Ltd (2010). Periodic Review 2009 Part B4 – Sections 4-6 Quality Enhancements (Sewerage Service).

Table 8: The Costs to the Water Industry from Designating the Humber as 'sensitive area' under the UWWTD- the lower bound

Cost Criteria	Water Industry Costs, £million
Capital expenditure	600.00
Annual operational expenditure	25.30
Annual external costs of additional pollutants (energy use emissions)	0.42
Discounted costs over 20 years (3.5% discount rate)	952.55
Impact of technological progress on capital and maintenance costs as a percentage decrease	54.94%

4.4 WaveNet

Building on its previous eutrophication monitoring experience, Cefas worked with partners to develop and deploy a network of buoys that provides real-time data on wave height, direction and period that are processed into wave forecasting models. This network of 13 core monitoring buoys around the UK coast is called WaveNet (see Figure 2)[34]. Through WaveNet Cefas provides a positive contribution in terms of the following economic impacts:

- Total net benefit of the UK Coastal Monitoring and Forecast Service (UKCMF), that is estimated at £219.5 million over the 10 year period. Using budget share methodology, Cefas delivers a net impact of £69m over the same 10 year period
- Supporting the offshore wind energy sector
- Supporting the deployment of wave energy devices
- Improving maritime safety
- Providing an evidence base for Climate Change studies

Cefas contribution to the value of the UKCMF service

WaveNet is a major component of the UK Coastal Monitoring and Forecast Service (UKCMF) which is the national component of the EA warning service that ensures that those people at risk of coastal flooding can be warned in good time to save lives and reduce the impact of flooding on homes, businesses, infrastructure and communities. There are three datasets that comprise the main inputs into the UKCMF and shown in Figure 3.

The total estimated annual average cost of damage from flooding from river and coastal sources in England is £1 billion[35]. These values are likely to grow significantly as the climate changes. Sea levels are rising and storms will become more frequent and more intense. The UKCMF service therefore helps to reduce these potential damage costs of flooding and inundation.

The UKCMF Position Statement forecasting service estimates the annual benefit of the forecasting service to be £23 million based on the following assumptions[36]:

- Annual damage cost of flooding in England from all sources is £1 billion
- On average, 46% of current flood risk in England is coastal
- The EA warning service helps to avoid flood damage equivalent to 10% of the total damage costs
- Assuming UKCMF contributes 50% to flood damage cost avoided by coastal flood warning (with the remaining contribution from local operational services in areas prone to flooding).

The UK government currently spends around £325 million a year maintaining sea defences and shore protection along its 4300km coastline[37]. Wave data collected by WaveNet help to provide a more accurate assessment of the nature of waves during storms around the coast and, along with tidal data, informs the types of sea defences required. These data direct investment to deliver cost-effective government spending. It is likely that, in the absence of firm data, defences are constructed conservatively to allow for the uncertainty. It is therefore possible to build more efficient structures using less material to achieve a reliable sea defence using the archived observational data from UKCMF.

In addition to estimating the impact of flood damage avoided, UKCMF Position Statement also estimates an additional benefit of £4.8 million per year from observational (wave and tidal) data[38]. The additional benefit that includes a saving in the design and build costs for coastal flood defence and a saving in time for planning and deployment of staff, rests on the following assumptions that are presented in the UKCMF Position Statement:

34 One of the benefits of WaveNet is that additional buoys can be plugged into the system. Although there are only 13 buoys managed by Cefas, there are more than 100 other 3rd party data streams going into the WaveNet data hub. For instance, industrial customers plug buoys into the network under a commercial licence and agree that data can be put into flood forecasting system.
Data are transmitted from the monitoring buoys via satellite and are quality assured by Cefas. The data are live and refreshed every 10 minutes. Wave buoys are changed once a year and, post recovery of the buoys allows recovery of more detailed data, which enables a retrospective look over the previous year.

35 EA (2009).Flooding in England: A National Assessment of Flood Risks.

36 EA (2010). UKCMF Position Statement.

37 Ibid.

38 Ibid.

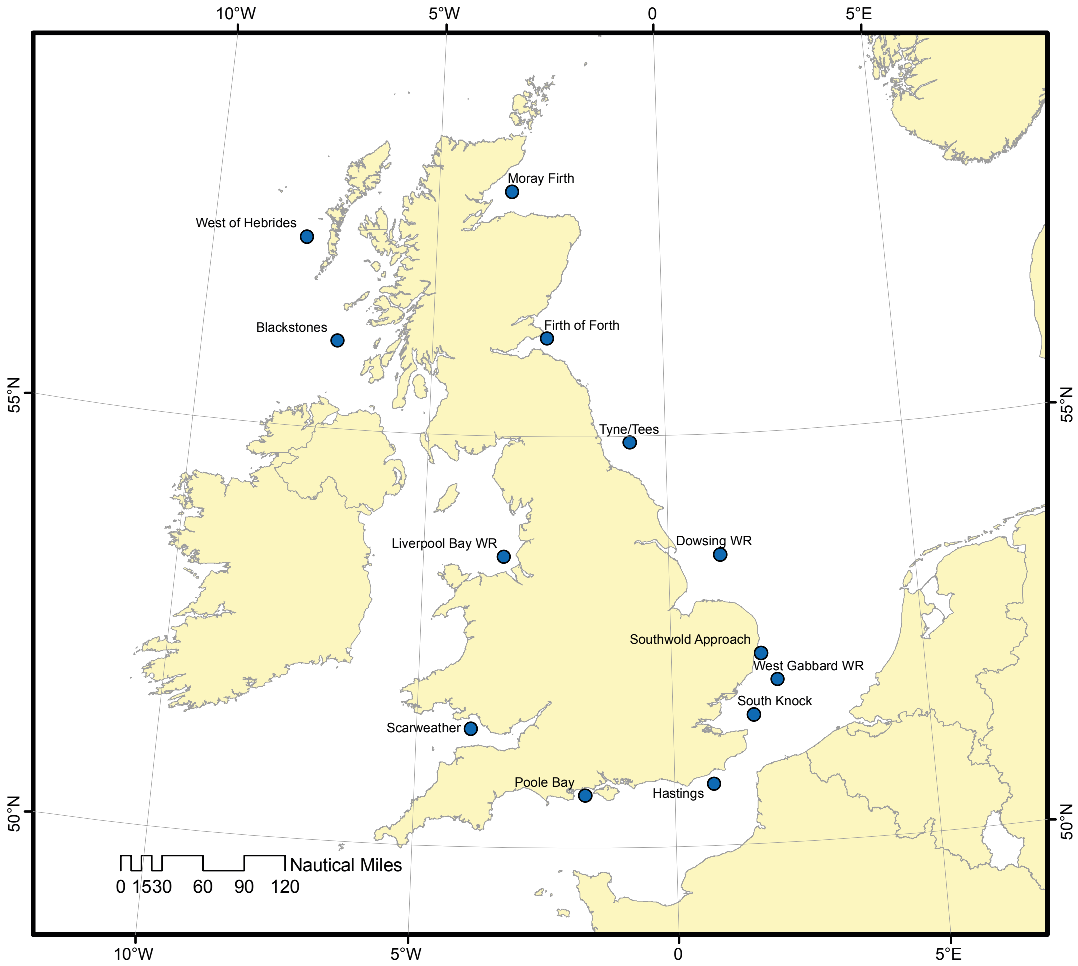


Figure 2: Network of WaveNet buoys showing locations around the UK coast. Source: Cefas

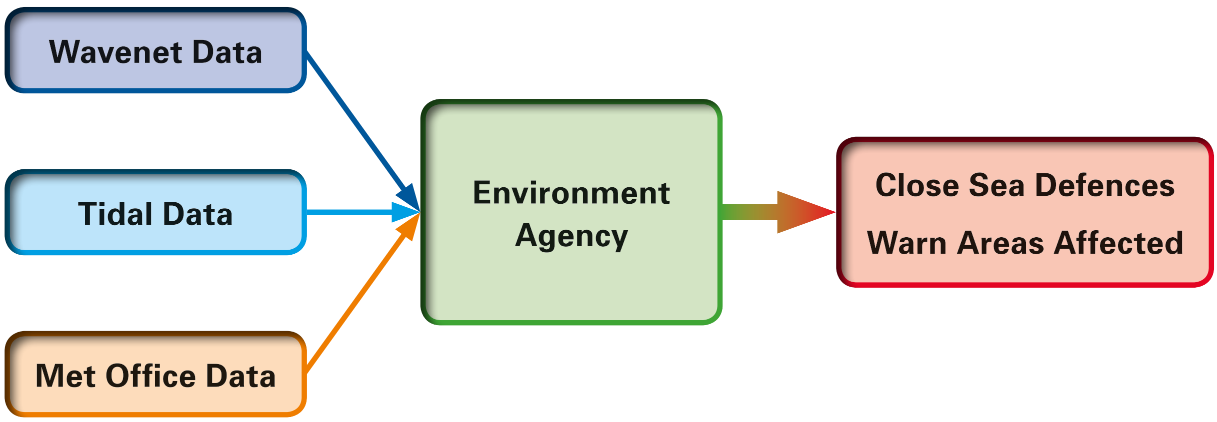


Figure 3: The UK Coastal Monitoring and Forecast Service (UKCMF)

- An annual spend of £325 million on sea defences and shore protection
- Design and build costs represent a third of expenditure on sea defences and shore protection
- 50% coverage of the coast
- Archived observational data saves 5% of construction costs as a result of being able to build structures more cost effectively
- The UKCMF service saves one week of time per year for all other (i.e. not design and build) work.

Table 9 summarises the value of the UKCMF, including the costs to operate this service. It is important to note that the value of the UKCMF service is based on broad assumptions and more comprehensive assessment would be needed if this value is used beyond illustrative purposes.

The UKCMF costs approximately £2.7 million a year[39 40]. The value of the UKCMF is presented as net benefit discounted over a period of 10 years using a discount rate of 3.5%. Wavenet is one of the major components of the UKCMF and therefore, it is reasonable to argue that WaveNet contributes to the UKCMF which is estimated to deliver a net benefit of £219.05 million. Using budget share methodology, Cefas delivers a net impact of £69m over the same 10 year period.

Table 9: Estimated net benefits of the UKCMF Service (£ millions)

Damage cost avoided per year	23
Annual saving in the design and build costs for coastal flood defence	2.7
Annual saving in time for planning and deployment of staff	2.1
Cost to operate the UKCMF	2.3
NPV of the UKCMF over the period of 10 years	219.5

Supporting the offshore wind energy sector

The offshore wind energy sector needs WaveNet data to support its construction and on-going maintenance of offshore wind turbines. For construction activities, the wind farm developer needs to profile the waves to inform the location and nature of the foundations that are required for turbines. In some of these cases developers purchase the data from WaveNet to complement other information that they collect as part of the development. For maintenance of offshore wind turbines, engineers going out to service turbines need the right weather and wave conditions to be able to transfer from boats onto the turbines. In general, people can only be transferred from ships onto the turbines where the wave height is less than about 1.3 metres. The better validation of models delivered by WaveNet allows cost savings as industry can identify times and target optimum conditions when it will be safe and efficient to work and avoid wasted journeys and reduced wind turbine downtime.

The report from the Kentish Flats wind farm for 2008 shows that there were 89 days when access was not possible, but this varied from 0% of June days to 53% of March days[41]. At the more exposed Barrow wind farm, in the Irish Sea, access was not possible for 49% of the time from July 2006 to June 2007 and this contributed to a low availability of 67%[42]. The availability means the accumulated time in which the turbine is operating or is ready and available for operation. Developers are looking at ways to increase this operational time and avoid lost energy production, i.e. when wind turbines are broken and adverse weather conditions mean that engineers are unable to get to them.

Better information about the wave conditions may, through more informed planning, reduce operational downtime. Typical offshore wind turbines have a capacity of less than or equal to 5-6 MW[43] and load factors most used in calculations of the amount of electricity produced by offshore wind are 0.3 to 0.35. Therefore, it is estimated that each turbine can generate 36MWh to 50.4MWh of electricity, with an estimated value of £4,554 to £6,376[44]. In 2012 there were 568 operational wind turbines in the UK and a further 665 in construction[45]. Reducing the operational downtime of 100 offshore wind turbines by just 1 day through better wave information, would lead to additional energy production worth £455,400 to £637,560 annually.

Supporting the deployment of wave renewable energy devices

Developers that are planning to install wave energy devices need to understand the nature of the resource and, in particular, the maximum wave length in order to determine the energy output of wave devices. Although wave and tidal systems use their own models and buoys, by connecting into WaveNet, industrial customers are able to access the infrastructure for managing and collecting the data which is particularly useful for wave energy developers. Through WaveNet, Cefas is therefore supporting the wave energy sector in its early stages of development, reducing its data costs and providing better information about the resource.

Improving maritime safety

There are around 100 maritime related deaths and almost 4,000 maritime related injuries each year with the recreational sector consistently accounting for over 60% of those accidents. For instance, Maritime and Coastguard Agency (MCA) found that in 2007 at least 245 people got into difficulty at the coast and in the sea because they were not experienced in their environment. 234 incidents

39 The UKCMF cost is estimated at £2.35 million. This cost subtracts added value through selling/sharing data. The UKCMF cost also includes Cefas input, that is estimated at £740k to £860k. The UKCMF cost is presented at 2010/11 prices.

40 EA (2010).UKCMF Position Statement.

41 DECC (2008). Offshore Wind Capital Grants Scheme. Kentish Flats Offshore Wind farm, 3rd Annual Report.

42 Milborrow, D. (2010). Cutting the cost of offshore wind energy. Available at: http://www.windpowermonthly.com/go/europe/news/1021043/Cutting-cost-offshore-wind-energy/ [Accessed 26 November 2012].

43 Low Carbon Innovation Co-ordination Group (2012). Offshore Wind Power, Technology Needs Assessment, 2012.

44 Based on DECC Domestic Energy Price Statistics (Quarterly energy prices table 2.2.3), electricity price of 12.65 p/kWh in 2010 is applied. Available at: http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/prices/prices.aspx [Accessed 03 January 2012].

45 UK Trade & Investment (2012).Offshore Wind Energy: A UK Success Story.

were caused because people were unaware of weather conditions and 29 people died because they failed to wear a lifejacket[46]. Based on these statistics and with the aim to reduce marine related injuries and accidents, MCA issued top messages for people to take on board including checking the weather.

Marine leisure consultation by the Met Office found that users need information on wind direction & speed, tide times, sea state, wave height, general weather, probability of forecast stability and confidence, tidal streams/currents[47]. This suggests that access to good information on wave conditions contributes to marine safety. Public access to the WaveNet data through the WaveNet site encourages the data uptake and use in port, leisure, construction or maintenance operations. Typically, there are 50,000 hits on the WaveNet website each week, although this increases to 70,000 during storms.

According to the Department for Transport, every fatality and serious injury avoided is valued at £1,653,687 and £185,831, respectively in 2010 prices and values[48]. These values are primarily derived for use in the appraisal of road schemes, but may be also relevant in the context of some marine related accidents.

Providing evidence for Climate Change studies

As well as the many uses of the real-time data provided by WaveNet, the accumulated time series data will be useful for climate change studies. The long-term record of measured wave conditions can be included in models to identify trends and aid predictions of future wave conditions. Therefore, in the longer term, data from WaveNet will help with more accurate forecasting of the impacts associated with climate change such as flood risk.

4.5 Renewable Energy

The UK Government is committed to increasing the proportion of energy we use from renewable sources including offshore wind. However, it is important that this transition to increased use of renewable energy is economically viable, i.e. we achieve these preset targets at the least cost to society. The following examples illustrate the Cefas contribution to efforts to promote the use of such technologies.

The research undertaken by Cefas was as a partner in the Energy Technologies Institute (ETI) project aimed at developing offshore wind technologies – Project Deepwater Turbine. ETI is a UK based company formed from global industries and the UK government.

4.5.1 Deepwater Turbine project

Project start 2009, Project end 2010[49]

Cefas has helped to avoid unnecessary costs by identifying environmental problems associated with the anchor blocks proposed for deepwater turbines prior to a prototype construction. This has potentially saved over £1m of unnecessary costs.

The direct return on investment is £10.8 for each £ invested in Cefas research, based on unnecessary costs avoided. In this example costs avoided are a direct result of Cefas advice, so return is calculated solely on the funding provided to Cefas. Cefas has received funding of approx £92.6k (expressed in 2010 prices) to participate in this project.

Without the input of Cefas, it is likely that the negative impact of the concrete block on the seabed would only have been identified once a prototype had been deployed with all the associated costs. This would have resulted in delays to the development through prototype redesign and approval, including the costs of the concrete block estimated at £1m (based on 20,000m^3 of concrete required to produce block of 50m diameter and 10m high, a density of 2 tonnes/m^3 and an approximate price of £100 per tonne of concrete in 2010 [50]), in addition to the costs of transporting it and placing it *in situ* on the seabed.

In addition, developing novel foundations for depths greater than 30m are identified by DECC as one of the potential priorities that can deliver the greatest benefits to the UK. Therefore, in addition to the direct benefits of Cefas' input to the design of the foundations on 'Project Deepwater', the research undertaken by Cefas contributes to overcoming one of the major obstacles to achieving the potential of deployment of 20GW-100GW of offshore wind by 2050[51].

46 MCA. Recreational Safety Strategy. Available at: http://www.dft.gov.uk/mca/mcga07-home/leisurenandtheseaside/coastalsafety/recreationalstrategy.htm [Accessed 26 November 2012].

47 Met Office (2011).Leisure Marine Consultation Report.

48 DfT (2012). Transport Appraisal Guidance. Unit 3.4.1.

49 ETI investment of £3.39m for all partners including Blue H, BAE Systems, Cefas, EDF Energy, Romax Technology, SLP, PAFA Consulting Engineers.

50 ONS. Division 23. Manufacture of other non-metallic mineral products -2010 provisional figures.

51 Low Carbon Innovation Co-ordination Group (2012). Offshore Wind Power, Technology Needs Assessment, 2012.

5. Fisheries Case Studies

5.1 'Data-limited' Fish Stocks

Cefas' advice on 'data-limited' fish stocks has allowed the UK to resist very significant proposed cuts in fishing quotas for 2012. Cefas' advice contributed to an estimated additional £14.2m–£19.3m of fish landings available to the UK fishing industry. Taking into account the costs of fishing activity to generate these additional landings and Cefas' advice, this suggests a net benefit in the range of £6.2m–£8.4m to the UK fishing industry[52].

Quotas for 'data-limited' species have historically been set in line with those of other stocks, as there has been no direct advice available on such stocks. However, because the International Council for the Exploration of the Sea's (ICES) 2011 proposals were not clear cut, the European Commission (EC) adopted a generic approach which was to impose 15-25% reductions in quotas for stocks where data were judged to be poor. This included 47 stocks of interest to the UK. The proposals had no basis in ICES' or the EC's own Scientific, Technical and Economic Committee for Fisheries (STECF) science and in specific cases this proposal would have resulted in increased discarding of marketable fish.

To counter the proposal, which would have had significant economic impact on UK fisheries, Cefas provided information to the Commission, through Defra, on recent stock assessment surveys, relative abundance analyses and simple assessment approaches that allowed such information to be taken into account ahead of Council decisions. Cefas prepared various briefing documents based on its knowledge of these lesser studied stocks. Working with Defra, Cefas was able to reverse proposed cuts for 40 of the stocks. This decision was agreed by Ministers in December 2011 and impacted fishing opportunities in 2012. The reversal of proposed cuts in quotas has been of significant benefit to the UK fishing fleet as it increases total available catches for 40 of the minor fish species in comparison to the cuts proposed by the EU.

Table 10 presents the assessment of economic impact of Cefas' advice on 'data-limited' stocks and their quotas for 2012.

5.2 North Sea Cod Recovery Plan

Cefas' advice on the cod stock is influencing the EU-Norway management of the jointly shared stocks and the approach to the CFP reform. It is providing a focus for the UK negotiations to achieve a balance between the short-term needs of industry, the long-term security of cod stocks and the yield from them.

Cefas advises on appropriate science-based management targets for sustainable exploitation of the North Sea cod. Using computer-based projections Cefas has assessed scenarios for achieving Maximum Sustainable Yield (MSY) of North Sea cod over the long-term. This is a function of cod landings, discards and spawning stock biomass. Aside from future fishing, adult spawning and recruitment will determine the future cod available. Cefas' model indicates a net benefit of £8.7m to £30.1m under a low recruitment scenario and £138.5m to £237.1m under a high recruitment scenario over the next two decades. The net benefit is expressed as additional GVA to the UK economy and society from 2010 to 2029.

In the case of cod, despite several years of cuts in quota, the stocks in many areas are not recovering as hoped. There is a need for an independent, science based approach to develop a strategy to return the industry to sustainable fishing. Cefas has the resources, reputation and expertise to do this when the private sector could not. Cefas' activities in relation to the Cod Recovery Plan include the following areas:

Management and advice – advice to Defra, EC, ICES and the fishing industry on the status and management of cod, including what needs to be done to take the industry to MSY in the long-term.

Stock monitoring and assessment – assessment and monitoring of cod stock dynamics through collection of data within the Data Collection Framework and the Cefas survey program. Development of bespoke assessment models for the estimation bias in cod mortality rates. Provision of management advice on short-term cod dynamics.

Simulation Modelling – analysis of individual cod stock life history parameters. Development of computer simulations exploring potential cod recovery and long-term management scenarios controlling fishing mortality and evaluation of the potential yield and stock trajectories including risk of exceeding management thresholds under differing environmental (recruitment) regimes.

There is significant potential to increase the long-term level of the UK North Sea cod landings given the management strategies below. Figure 4 shows historic and projected landings assuming no discard ban. Solid lines represent the high recruitment scenario (top line above) while hashed lines show the low recruitment scenario (lower line above) (for additional information with regard to Cefas' cod model and recruitment refer to Appendix 7). In addition, the other lines represent the following management strategies:

green lines – 10% reductions in fishing mortality to the current management target of 0.4
red lines – 10% reductions to the current management target of 0.19
brown lines – 1.5% reduction per annum
black lines – no change.

Figure 4 shows that to 2030, landings could increase from current annual levels of around 50,600 tonnes to

52 The net benefit is expressed as discounted Gross Value Added (GVA) adjusted to take into account expenditure on Cefas' advice.

Table 10: The potential net impact from Cefas' work on 'data-limited' fish stocks

Stock	Area	EC TAC[a] Proposal %	TAC 2011	TAC 2012	TAC % Diff	Extra Tonnes of fish through Cefas work	Price for 2010 (£)[b]	Total Potential Value (£)	TAC Uptake 2010 (%)	Potential value based on uptake in 2010
Anglerfish	IV	-25	7846	7455	-5	1569.2	3280	5146976	63	3242595
Anglerfish	VII	-25	5807	5517	-5	1161.4	3280	3809392	92	3504641
Megrim	VII	-25	2624	2492	-5	524.8	2844	1492531	67	999995.9
Pollack	VII	-25	2353	2353	0	588.25	2047	1204148	49	590032.4
Anglerfish	VI	-25	1679	1595	-5	335.8	3280	1101424	87	958238.9
Whiting	VIIb-k	-25	1740	2045	18	740	1053	779220	71	553246.2
Haddock	VIIb-k	-25	1332	1665	25	666	1140	759240	87	660538.8
Megrim	IIa, IV	-15	1775	1775	0	266.25	2844	757215	85	643632.8
Turbot & Brill	IIa, IV	-15	717	717	0	107.55	6903	742417.7	82	608782.5
Ling	VI, VII, VIII, IX, X, XII, XIV	-15	2641	2647	0	396.15	1382	547479.3	75	410609.5
Skates & Rays	VIab, VIIbc, e-k	-25	2941	2562	-13	352.92	1420	501146.4	56	280642
Other stocks with additional value of less than £500k at 2010 prices								2414464		1721019
Total additional fishing income in 2012								19,255,653		14,173,973
Total additional GVA[c] in 2012								9,054,877		6,665,242
Cost of Cefas advice[d] in 2011								27,214		27,214
NPV (discounted using 3.5%)								8,426,531		6,195,781

[a] Total allowable catch
[b] MMO fisheries statistics
[c] GVA factor of 0.47 is applied to estimated total additional fishing income. GVA factor is estimated as average value based on 2008, 2009 and 2010 Seafish data. First, GVA as a percentage of total income is calculated. The total income of a fishing fleet consists of fishing income and non-fishing income. Fishing income comes from the value of the landings made by a fishing fleet in a year (i.e. revenue). Non-fishing income is other income, i.e. tourism, subsidies and is usually only a small proportion of total income. From this, it is reasonable to assume that GVA as a proportion of total income is relatively the same GVA as a proportion of the value of landings. The proportion of GVA of the value of landings is assumed to stay constant.
[d] Cost of Cefas' advice is estimated as the number of days required to prepare advice times daily rate at a senior scientist level in 2010 prices. Stock monitoring and assessment is an annual mandatory Cefas activity[53]. Therefore, cost associated with this activity is not taken into account.

anywhere between 82,000 and 87,600 tonnes under low recruitment scenario and 456,900 and 487,800 tonnes under high recruitment scenario for the North Sea fleet. The UK's potential share of these landings is from 26,978 to 28,820 tonnes under low recruitment scenario and from 150,320 to 160,486 tonnes under high recruitment scenario. Whilst this is a very broad range of values, Cefas' model indicates the potential that could be realised from the North Sea cod fishery.

These landings are conditional on achieving the targets set under EU and EU–Norway cod management plan initiatives. These targets aim to achieve a fishing mortality that achieves MSY in the long-term. Fishing mortality to achieve MSY in the long-term is considered to lie between 0.19 and 0.4 management target.

To assess the potential UK benefits of management strategies aiming to achieve MSY fishing mortality, it is

53 To illustrate the order of magnitude of Cefas' costs to undertake stock monitoring and assessment in 2012/2013 these costs are estimated at £5.3m in current prices. Note that this estimate covers all fish stocks that are monitored and assessed by Cefas.

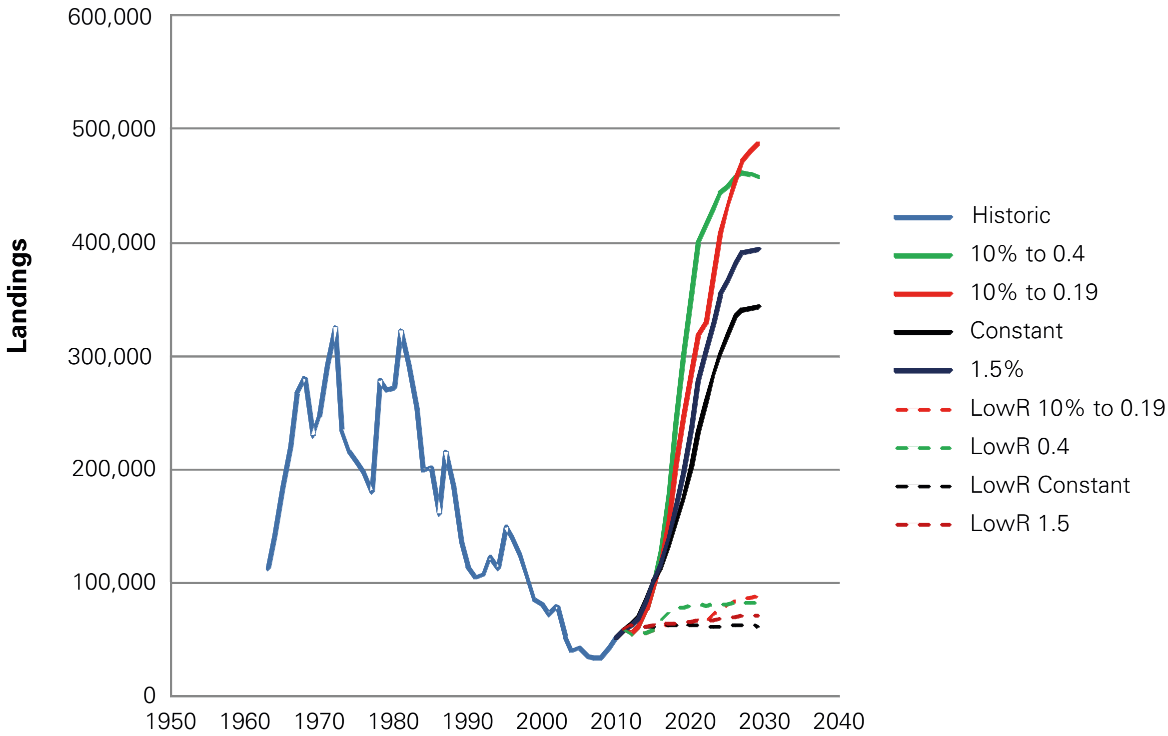


Figure 4: Historic and future North Sea cod landings under different scenarios. Source: Cefas

assumed that the North Sea cod fishery achieves a 1.5% reduction on fishing mortality per annum[54] in the baseline scenario. This is based on the current trajectory of fishing mortality achieved since the EU-Norway North Sea cod management plan was established.

Current policy initiatives, including the EU–Norway cod recovery management plan aim for a higher cut in fishing mortality than 1.5% a year. This plan was adopted by the EU and Norway based on Cefas' advice. Subsequently, unforeseen increases in discarding did not result in the expected reduction in mortality rates. However, mortality is now being reduced by industry and management and in the long-term the plan is expected to result in the stock rebuilding.

The UK share of North Sea cod is around 32.9 % of the TAC while the 2010 price for cod was £1,950 per tonne[55]. It is estimated that successful management strategies, that achieve 10% annual reduction in fishing mortality to the current management target of 0.19–0.4 in the long-term, will generate an additional GVA[56] of £8.7m to £30.1m under low recruitment scenario and £138.5 to £237.1m under high recruitment scenario to the UK economy and society over the next 19 years. These values are discounted using a 3.5% discount rate over the assessment period.

This assessment of economic impact does not include the discard ban under discussion with a view to being introduced by 2013/2014. The impact of a discard ban would assume that undersized fish caught have to be landed. Cod discards are likely to be a marketable fish that yields a lower average price than cod landed under the normal circumstances.

Cefas is able to project the landings potentially available to the UK and other fishing fleets based on the different scenarios. This information is valuable to Defra, the EU and Norwegian managers as it allows testing of the robustness of proposed management plans in terms of the levels of exploitation, stability clauses (restraining annual changes in TAC) and management thresholds.

5.3 Reducing Discards in Beam Trawl Fisheries

In 2009-10, an innovative partnership with Devon beam trawlermen known as 'Project 50%', was set up as a result of a Cefas initiative. Cefas involvement in 'Project 50%' aimed to reduce discards by 50% amongst the Devon beam trawl fleet in ICES Division VIIe. Initially, this was considered to be an unrealistically high target, however it

54 Based on recent trend on fishing mortality that was achieved since the EU–Norway North Sea cod management plan.

55 MMO UK Fisheries Statistics.

56 GVA factor of 0.47 is applied to estimated additional revenue. For GVA factor calculation, please refer to the case study of 'Data-limited Fish Stocks'

was exceeded by 7% – the final reduction in discards was 57% on average. This change in discards and use of newly designed nets has led to a net benefit of £2.25m over 3 years since the project[57]. This net benefit is discounted to 2010 using a 3.5% discount rate.

The fact that beam trawlers tow two nets makes them ideal for side by side trials of old and new nets. Figure 5 shows direct comparisons of catches with the two types of net. They highlight the significant reduction in juvenile fish and the amount of benthos.

Whilst market research revealed that most fishermen acknowledged the need to reduce discards, they did not have the means to do it on their own. Cefas' work with the beam trawl fleet addressed the financial costs of producing new trial nets designed by the fishermen to reduce discards. By using nets designed by themselves but provided by the project, the industry was more open to testing many different types of beam trawl nets. The results of the pilot study enabled Cefas to secure Defra funding that allowed the project to be taken forward. Over 20 vessels wanted to take part in the project, but numbers were limited to 11 due to the funding available. Without Defra and Cefas' funding, the industry would have been unlikely to take on such a project and there would have been no robust data to show the benefits of the project.

The effect of the collective action approach to the project should not be underestimated. A single vessel would not want to be disadvantaged relative to his competitors in the fleet by taking a chance on a new trawl, making it more difficult for a net maker to convince a skipper to start using a new design. Thus, having all vessels in a fleet encompassed within the same project, negates this barrier, including credible validation of results over a larger sample.

Reports from the skippers, so far, say the reduced benthos is giving an improved catch quality. Just as important, if the reduction in discards is maintained, the sustainability of ICES Division VIIe fisheries will be significantly improved and the value of the fishery safeguarded for the future. The total value of the Division VIIe UK sole fishery safeguarded was £3.03 million in 2010 based on 363 tonnes at an average price of £8,340 per tonne[58]. Since that time the value has increased substantially as prices have risen and quotas have increased. This is vital for the financial viability of the local fishing industry.

Prior to the project on discards, sole quota in ICES Division VIIe had been reducing on an annual basis since 2006. Sole quota was set taking into account the level of juvenile fish being caught, but excluding discards due to the lack of information. For fishing opportunities in 2010 the EC had proposed an automatic 15% reduction on the previous year's quota as the state of the stock was not known precisely and ICES/STECF advised a reduction in fishing effort. As the 'Project 50%' net substantially reduced the overall level of discards and, in particular, the level of juvenile fish caught, the evidence from the project was able to mitigate a reduction in the cut in quota from -15% to -5% for 2010[59].

Council Regulation (EC) No 509/2007 established a multi-annual plan for the sustainable exploitation of ICES Division VIIe sole – calendar years 2007, 2008 and 2009 were deemed a recovery plan with subsequent years being deemed a management plan. Coinciding with the management plan, the project's findings have contributed to an increase in quota leading to an increase in potential revenue for UK fishermen. Note that the UK takes a 60% share of the sole quota in ICES Division VIIe and, therefore, has a considerable influence on the status of this sole stock. Taking ICES Division VIIe alone, the UK quotas for sole were able to be increased from 363 tonnes in 2009/10 to 457 tonnes in 2011/12 (see Table 11).

Figure 5: Typical haul. Source: Cefas

57 The net benefit of 'Project50%' is the total of discounted GVA and discounted reductions in costs of replacement of nets and consumption in fuel over 3 years since the project. The net benefit of 'Project50%' takes into account the total project cost that is estimated by Cefas at £190k as well. Note 2010 is a start date for all impacts of 'Project50%'.

58 Source: MMO UK Fisheries Statistics and Council Regulation (EU) No 43/2009.

59 EU TAC(2009)= 650 t, EU TAC(2010)=620 t, reduction is 4.6% = c.5%.

Table 11: Change in UK share of ICES Division VIIe sole quota 2006-2012. Source: MMO UK Fisheries Statistics and EU Council Regulations[60]

Year	Quota (Tonnes)	% difference
2006	966	–
2007	531	-45%
2008	465	-12.5%
2009	382	-18%
2010	363	-5%
2011	418	15%
2012	457	9%

Table 12 quantifies the avoided reductions in sole quotas as a result of the project. It is assumed that, in the absence of the project, quota would have been unchanged given the management plan in place. The table shows that the Cefas project has led to potential additional revenue and GVA for Devon fishermen of £2.82m and £1.32m respectively over the 3 years since the project.

With the new net design there was a significant reduction in the amount of twine used to construct the net as it has a 20–30% larger mesh size. This larger mesh size allows the smaller fish to pass through the net as it is held more open. The lighter net, using less twine, resulted in a reduction in the cost of the net. The new nets cost on average £2,000 each whilst previously they would have cost around £2,300 – a 15% reduction in net cost[62].

The average lifespan of the original net is 10–12 months and two are required per boat. Given that the new nets are lasting 6 months longer, they will only need to be replaced every 18 months. Previously this would mean 6 nets per boat over the course of 3 years, but with the new nets only 4 would be required over 3 years. Across 11 boats with two nets each, replacement net costs would be reduced by £60,212 in total over 3 years discounted to 2010. It is assumed that the first expense of both types of nets occurs at the beginning of year 1, then the replacement of old design nets occurs at the beginning of year 2 and the beginning of year 3 and the replacement of new design nets occurs only in the middle of the second year. There is no replacement of new design nets in year 3. The discounted value over the period of 3 years is the difference between the cost of old design and new design nets – see Table 13.

Also, with the increased mesh size the net flows through the water more easily resulting in less wear and tear. With less strain there is also a reduction in strain on the winch and lifting gear. Whilst reduced wear and tear is not quantifiable at this stage, it does represent a further reduction in overall cost to the trawlers in the long-term.

Table 12: Value of additional sole quota gained through Project 50% over 2010-12. Source: UK Fisheries Statistics, Project 50% data and Fishing News prices

Year	Actual Quota	Likely change in quota in absence of project	Possible Quota in absence of project	Average price/Tonne	Additional quota gained as a result of the project	Total rise in Sole value	Total additional GVA[61]
2010	363	-15%	325	£8,340.00	38	£316,920	£149,030
2011	418	0%	325	£11,730.00	93	£1,090,890	£512,986
2012	457	0%	325	£11,730.00	132	£1,548,360	£728,109
Total additional potential revenue and GVA over 3 years						£2,956,170	£1,390,125
Total additional potential revenue and GVA over 3 years discounted to 2010 at 3.5% discount rate						£2,816,331	£1,324,366

60 Note these are official EU Council Regulation figures which differ slightly from those published in UK fisheries statistics due to the practice of countries swapping un-fished quota.

61 GVA factor of 0.47 is applied to estimated additional revenue. For GVA factor calculation, please refer to the case study of 'Data-limited Fish Stocks'.

62 Advised by local net maker.

Table 13: Reductions in net costs for trawlers in ICES Division VIIe

Cost over 3 years with old nets (per boat)	£2,300*2*3 over 3 years = £13,800
Cost over 3 years with new nets (per boat)	£2,000*2*2 over 3 years = £8,000
Saving in net replacement cost over 3 years for 1 boat	£5800 (= £600 in year 1, £600 in year 2 and £4600 in year 3)
Total saving in net replacement cost over 3 years for 11 boats	£63,800(=£6,600 in year 1, £6,600 in year 2 and £50,600 in year 3)
Discounted saving in net replacement cost over 3 years for 11 boats	£60,212

Also, a lighter net causes less drag on the boat which therefore has reduced fuel consumption. On average, the project reported a reduction of 2,000 litres of fuel per trip. Assuming 30 fishing trips per year[63] per beam trawler, this represents a reduction of 660,000 litres of fuel per annum across 11 trawlers. At a cost of £0.55/l[64] this represents an annual cost saving to industry of £363,000 per year or £1.05 million discounted over 3 years to 2010 – see Table 14.

Table 14: Reduction in fuel costs for trawlers in ICES Division VIIe

Reduction in fuel for beam trawler per 30 fishing trips per year	2,000 litres * 30 trips per year = 60,000 litres
Reduction in fuel cost for beam trawler per 30 fishing trips per year	£0.55l * 2,000 litres * 30 trips per year = £33,000
Reduction in fuel cost for 11 beam trawlers per year	£33,000 * 11 trawlers = £363,000
Discounted saving in fuel cost for 11 beam trawlers in the 3 years	£1,052,589

63 Estimated by Cefas as a typical annual number of trips.

64 Based on an estimate from the fishermen involved.

6. Aquatic Health & Hygiene Case studies

6.1 White Spot Disease of Crustaceans

White Spot Disease (WSD) may affect all key British species of marine and freshwater decapod crustacea. It is of concern due to the quantity of wild harvest crabs and lobsters traded internationally. Cefas was awarded funding from Defra to undertake a survey of WSD across GB over the two-year period 2009-2010[65]. As part of the survey design process, methods of collecting and dissecting animals, as well as diagnosing the disease, were developed and have subsequently been used in Standard Operating Procedures (SOPs) for the Fish Health Inspectorate and diagnostic laboratories, further contributing to the protection of the industry. Sampling procedures and diagnostic capabilities have been refined as a result of the surveillance programme. Therefore, the Cefas research for WSD conducted in 2010/11 puts the UK in a better position to detect any outbreak of disease and prevent its spread thus helping to minimise economic loss and environmental impact[66].

The economic assessment contains scenarios for losses to the UK from WSD and estimates potential economic losses in the presence of disease outbreak given different sets of assumptions and consequent conditions. Under the scenarios that are more applicable to UK industry conditions, the potential losses associated with an outbreak of White Spot Syndrome Virus-1 (WSSV) in the UK lies between £16 million (outbreak last 1 year) and £80.5 million (outbreak last 2 years)[67] in terms of lost revenues. Early success in detecting WSD presence would potentially lessen these impacts on commercially and ecologically important crustacean populations in the UK.

Initial European legislation on aquatic animal health (EC Directive 91/67/EC) did not cover control of crustacean diseases. However, in recognition of the increased threat to farmed and wild stocks as a result of the growth in international trade in crustacea, the recent Aquatic Animal Health Directive from the European Commission (Council Directive 2006/88/EC) includes crustacean diseases.

Under the current Directive, there is a requirement for Member States to designate a National Reference Laboratory (NRL) to co-ordinate standards and methods for the diagnosis of aquatic animal diseases. Cefas' Weymouth Laboratory is the designated NRL for England and Wales for crustacean diseases. The NRL investigates mortalities and disease outbreaks in susceptible crustacean species for the presence of the listed viruses and for other pathogens. The Directive aims to prevent the spread of diseases between EU Member States, prevent the introduction of exotic aquatic animal diseases into the EU and to lessen any impact on commercially and ecologically important crustacean populations.

The Directive lists two categories of disease:

- Exotic Crustacean Diseases to the Community: Taura Syndrome (TS) and Yellowhead Disease (YHD)
- Non-Exotic Crustacean Diseases to the Community: WSD

The first category of diseases are of no concern to the UK as they affect Penaeid shrimp, of which there is very limited production and no wild stocks in the UK. It is WSD that is of most concern for the UK. WSD is caused by infection with the White Spot Syndrome Virus-1 (WSSV). The potential impact that WSD could have, if found in the UK, may be significant in economic and environmental terms[68]. The disease is included in the Directive as untreatable pathogens have been proven to cause significant environmental and/or economic impact. WSD was first found in shrimp farms in Taiwan in 1992 and since then has spread around the world causing the devastation of shrimp farming industries in several countries[69].

The UK does not have significant crustacean aquaculture facilities so it is unlikely that WSSV would have as great an impact as in countries with extensive aquaculture production. However, WSSV has been found previously in wild populations. In Taiwan, WSSV prevalence in Peneus shrimp populations has been 58–67%[70]. In the UK, wild caught animals are often moved to holding facilities throughout England and Wales prior to sale and transport. They can be stored at high stocking densities and in poor quality, which can result in the animals becoming stressed. As it is suspected that the replication of the virus is triggered by stress, the presence of WSSV in wild populations could result in significant losses under these conditions either during holding or transportation.

The value of decapod crustacea landings into the UK in 2010 was £161m, as shown in Table 15. The evidence from areas that have been infected by WSD has shown that production can fall by 60–70% and the decline can last for around five years (see Table 16). The following production loss scenarios are established based on this evidence. It needs to be emphasised that these scenarios are not forecasts and they are designed only to illustrate the outcomes of the potential losses in the event of WSD outbreak under different sets of assumptions and consequent conditions; and in the absence of outbreak probability data.

65 Cefas designed the survey that was used to sample the GB areas. Cefas was responsible for sampling in England and Wales while Marine Scotland was responsible for sampling in Scotland.

66 Cefas has received Defra funding of £181k.

67 These estimates of potential losses are not discounted values.

68 Stebbing, P. (2012) Cefas National Reference Lab for Crustacean Diseases. *Finfish News* 12, 24–25.

69 Ibid.

70 Lo, C-F., S-E Peng, Y-S Chang and G-H Kou. (2005) White Spot Syndrome – What we have learned about the virus and the disease. In P. Walker, R. Lester and M.G. Bondad-Reantaso (eds). *Diseases in Asian Aquaculture* V, pp. 421–433. Fish Health Section, Asian Fisheries Society, Manila.

Table 15: Total crustacean landings into the UK in 2010. Source: Shellfish Statistics[71]

Type	Tonnes	Value (£ millions)	Unit value (£ per tonne)
Crabs	27,154	36.43	1,342
Lobsters	2,727	26.59	9,780
Nephrops	38,379	95.54	2,490
Shrimps	944	2.03	2,148
Total	69,204	161	15,760

Table 16: The evidence from areas that have been infected by WSD

Evidence from countries where there has been an outbreak of WSD shows the devastating effect the disease can have on aquaculture industries:

Ecuador – In 1998, Ecuador was the second largest producer of farmed shrimp in gross tonnage at 144,000 tonnes, second only to Thailand. At its peak, Ecuadorian farmed shrimp controlled nearly 15% of the international market. In 1998, exports peaked at 114,000 tonnes corresponding to a value of $875m[72]. Following an outbreak of WSSV in 1999, production decreased over 60% in two years, resulting in losses of over $1 billion from 1998–2001[73]. Ecuador had still not fully recovered from the WSSV pandemic up to five years later[74].

China – Following detection of WSSV in China in 1992, shrimp production fell by over 70% from a high in 1991 of around 220,000 tonnes to below 64,000 tonnes by 1994. This led to a loss of over $2 billion from 1992–1994 in lost production. It took almost a decade for China to return to previous production levels[75].

Thailand – Prior to the WSSV outbreak in 1994, shrimp production had been growing at a rate of around 34,000 tonnes annually. In 1994, production stagnated at 265,000 tonnes and in the following five years, production declined resulting in estimate losses of around £1.5 billion[76].

71 Shellfish Statistics – Shellfish Production in the UK 2010 in *Shellfish News* 32, Autumn/Winter 2011.

72 National Aquaculture Sector Overview – Ecuador. Available at: http://www.fao.org/fishery/countrysector/naso_ecuador/en Accessed 9 January 2013].

73 McClennen, C. (2004) *WSSV – The Economic, Environmental and Technical Implications on the Development of Latin American Shrimp Farming*, The Fletcher School, Tufts University.

74 Lightner, D.V. (2003) The Penaeid Shrimp Viral Pandemics due to IHHNV, WSSV, TSV and YHV: History in the Americas and Current Status, In: *Proceedings of the 32nd Joint UJNR Aquaculture Panel Symposium*, Davis and Santa Barbara, California, USA, pp.17–20.

75 McClennen, C. (2004)

76 Ibid.

Table 17 shows that if the UK experienced production losses in wild caught animals similar to those seen in aquaculture elsewhere, the impact could be up to £483m. This high estimate is very unlikely under real world conditions, i.e. lack of applicability of the scenario to the UK industry. A more realistic estimate of the potential losses associated with an outbreak of WSSV in the UK lies between the two lower scenarios of £16 million (10% reduction for 1 year) and £80.5 million (25% reduction over two years).

There is also a risk to the industry that does not emanate from disease being introduced, but rather from imposition of import controls by the UK's trading partners which the UK would not be able to meet unless it takes action to declare itself free of this disease. Countries which are increasingly looking to import live crustacea from the UK are often suppliers of crustacean products to the EU. In order to maintain their export trade to the EU they need to put in place appropriate import controls. These import controls then affect countries such as the UK, which hopes to export to them, provided it has equivalent controls in place.

6.2 Safer Trade in Finfish and Reduced Risks of Exotic Diseases

Cefas Fish Health Inspectorate has a role in the prevention of exotic disease introduction and in limiting any spread of diseases that have been introduced. Since the 2006 outbreak of viral haemorrhagic septicaemia (VHS), Defra has funded Cefas research to investigate the risks associated with the import of aquatic animal products and domestic commodity trade. This research supports the work of the Fish Health Inspectorate by "providing evidence to identify potential risk routes for pathogen introduction through import risk assessments and experimental research work".

The research concluded that there was a threat of VHS introduction into England and Wales, but that this threat could be reduced both by the treatment of liquid effluent from processing plants and by restricting the sourcing of carcasses for on-farm processing to approved VHS free areas[77]. The results of the research have been disseminated directly to the industry through articles and presentations. The British Trout Association, as the industry body, is supportive of the work and considers that it will assist in developing biosecurity. In particular, pressure within the industry is likely to be applied to farmers processing fish on site so that they only source carcasses from areas approved as VHS-free. Based on the evidence that is available, the Cefas work may help potentially to avoid the damage costs of outbreaks, the last costing industry and government an estimated £1.295 million in 2010 prices.

77 Pearce, F.M., Oidtmann, B.C., Thrush, M.A., Dixon, P.F. and Peeler, E.J. (2012) Do imports of rainbow trout carcasses risk introducing VHS virus into England and Wales? *Transboundary and Emerging Diseases*. Submitted manuscript.

Table 17: Potential impact scenarios for losses to the UK from WSD

Production losses (A)	Time period (B)	Total resulting impact[a]	Applicability of the scenario to the UK industry	Assumptions
60%	5 years	£483m	Very Low	Significant national loss of wild fisheries
25%	2 years	£80.5m	Low	Regional outbreaks in wild populations
10%	1 year	£16m	Low	Small localised outbreak in wild caught animals
0%	0 years	£0	High	If UK import controls in place including a potential positive impact on trade with non-EU partners

[a] Based on applying production loss % (A) to UK industry value of £161m multiplied for each year of loss (B)

The UK is free of a number of fish diseases including disease free status for VHS and there is legislation in place to prevent the import of infected live fish into areas free from diseases through the European Commission's Aquatic Animal Health Directive (Council Directive 2006/88/EC). However, the legislation does not cover the import of gutted fish carcasses[78]. Two incursions of exotic salmonid fish diseases in recent years have been attributed to the import of fish carcasses: VHS and sleeping disease (alphavirus)[79]. As sleeping disease is a non-notifiable disease this case study focuses on VHS and Cefas' work to reduce the risk of outbreaks of the disease.

Cefas was awarded funding from Defra to work on projects to understand the risks associated with imports of commodities and domestic commodity trade. The experimental research looked into levels of virus at different stages of infection, water borne transmission using tissue homogenates and import risk analysis for fish carcasses imported for processing. The research was part of three larger contracts, but it is estimated that around £647k was allocated to this element from 2007 to 2012.

VHS is a serious disease of rainbow trout in aquaculture and can cause up to 80% mortality in affected stocks. Using production figures from 2010 it is possible to estimate the volume and value of the farmed trout industry in England and Wales. Table 18 shows that there were 7,813 tonnes of rainbow trout and 476 tonnes of brown trout produced in 2010. Using the unit price shown in Table 18 the overall value of the industry equates to £21.1m.

Table 18: Scale and farm gate value of the trout industry in England and Wales 2010[80]. Source: Cefas, 2012

	England	Wales	Total
Volume of rainbow trout	7,525 tonnes	288 tonnes	7,813 tonnes
Volume of brown trout	448 tonnes	28 tonnes	476 tonnes
Price of rainbow trout (£ per tonne)	£2,400	£2,400	–
Price of brown trout (£ per tonne)	£5,000	£5,000	–
Total value rainbow trout	£18,058,800	£691,200	£18,750,000
Total value brown trout	£2,239,500	£141,000	£2,380,500
Overall value of trout	£20,298,300	£832,200	£21,130,500

In 2006, VHS occurred for the first time in a farmed freshwater rainbow trout population in England. This occurrence of VHS showed that despite the UK's high aquatic animal health standards, the country is still at risk from the introduction of exotic diseases. The VHS outbreak

78 Oidtmann, B. Peeler, E. and Dixon, P. (2011) Five years on – what do we know about risk of introduction of VHSV associated with commodity trade? *Finfish News* Number 11, Summer/Autumn 2011, Cefas.

79 Rodgers C.J., Mohan C.V. & Peeler E.J. (2011) The spread of pathogens through trade in aquatic animals and their products. In: The spread of pathogens through international trade (S.C. MacDiarmid, ed.). *Rev. sci. tech. Off. int. Epiz.*, 30 (1), 241-256.

80 Table 18 reports the value at the "farm gate" of fish produced for the table or for restocking into rivers and lakes. It does not include figures for production from hatcheries that are fed into the system for on-growing on the same or another farm. Fish may be released at various sizes for recreational angling, and mature fish for this purpose command a higher price than table carcasses. Small fish (fry) sold on for on-growing and restocking are excluded from Table 18, but larger fish (>80g and reported as gross weight rather than numbers) are included. Trout that are angled may be returned to the water or finally taken for consumption. The added value from angling (tackle, fees, tourism) is also excluded from this table. Hence the gross value shown is a minimum figure for the industry in England and Wales as a primary supplier of foodstuff.

in 2006 caused high levels of mortality in a Yorkshire trout farm. The outbreak resulted in serious economic losses for several farms in the Yorkshire area. Cefas undertook some work to estimate the costs of this VHS outbreak. The cost to the Government was estimated to be just over £1.1 million. This cost was required to deliver the surveillance and monitoring activity that was undertaken by Cefas as a result of the VHS outbreak. The costs to the infected farm in terms of lost stock and lost production, disinfecting and cleaning was estimated at £138k. In addition, there were costs to other farms along the river related to live fish movement restrictions for a number of months following the outbreak. These costs were not formally estimated, but were likely to be no higher than £55k. The total cost of the 2006 outbreak to Government and the trout industry was therefore estimated to be in the region of £1.295 million.

In this instance there was no spread of the disease, which was fortunate, but every disease outbreak is unique and the cost could vary with cases where the costs are higher. A VHS outbreak could be devastating for producers. From Cefas discussions with the sector, it is understood that profit margins in trout production are such that farm businesses do not generally have large cash reserves to sustain the business in the event of an outbreak.

Appendix – North Sea Cod Recovery Plan

Using computer-based projections Cefas has assessed scenarios for achieving maximum sustainable yield of North Sea cod over the long-term. This is a function of cod landings, discards and spawning stock biomass. Aside from future fishing, adult spawning and recruitment will determine the future cod available. To ensure robustness, Cefas adds stochastic[81] noise and repeats each evaluation to simulate future uncertainty. The model is a first order approximation which allows some of the variation in yield and future stock dynamics to be explored and sensitivities to known potential changes in the environment and bias in landings data. Short-term dynamics are characterised better than the medium to long-term because, as stock abundance increases, a number of changes would be expected to occur in the cod biology and its environment for which there is currently no data. For example:

- Density-dependent changes in growth and maturation
- Changes in natural mortality through increased levels of predation and cannibalism
- Changes in discarding or catch reporting practices
- Environmentally-driven changes in recruitment variation.

Figure 6 presents the time series of cod recruitment at age 1. In the 1970s and 80s recruitment and spawning biomass were both high. In the 1990s and 2000s over-exploitation reduced spawning biomass and recruitment levels declined with it. This coincides with the peak level of fishing in 1996.

In recent years, despite a reduction in fishing, recruitment levels have remained low which may be due to low stock abundance or poorer environmental conditions. Whilst this is unwelcome news for UK fishermen, it highlights the importance of objective data and science in planning the future of the fishing industry.

Figure 7 shows two alternatives modelled by Cefas for the future response of recruitment to increased spawning biomass – both assuming constant recruitment after spawning biomass exceeds a set threshold. The 'optimistic' model (upper green line) shows recovery of recruitment abundance to the historic levels of the 1970s and 80s. The 'pessimistic' model (lower black line) assumes recruitment does not recover at high biomass abundance. The models reflect the uncertainty of the future dynamics of North Sea cod and can be used to evaluate different management plans.

81 Random.

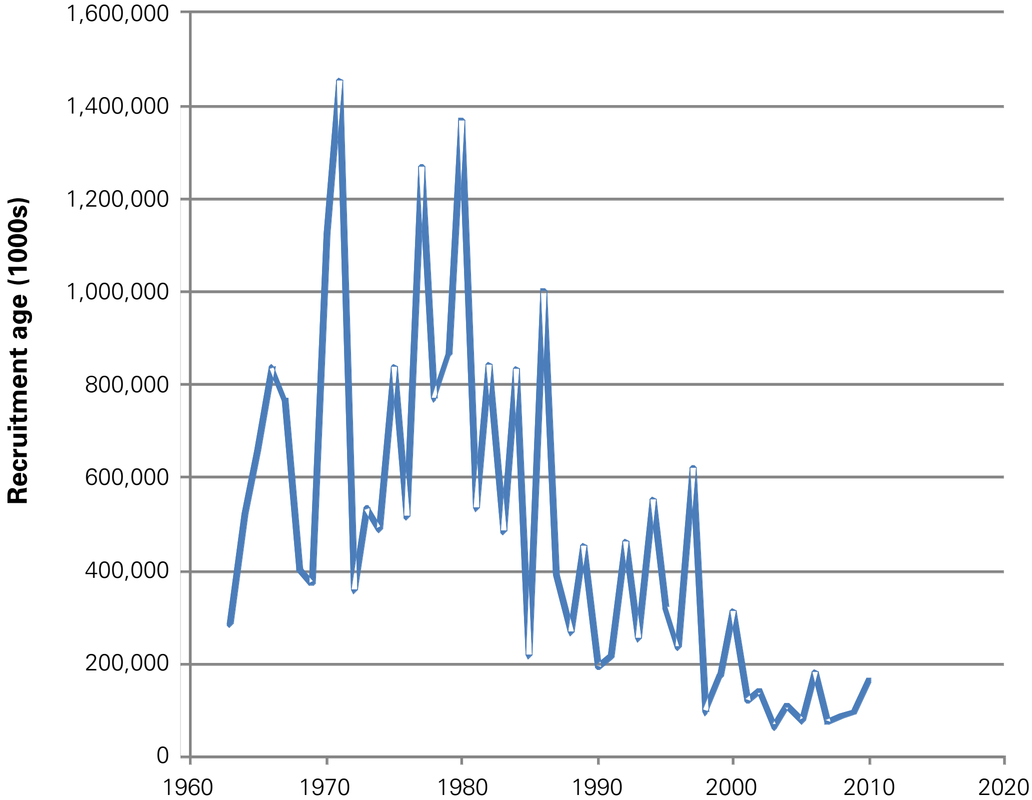


Figure 6: Time series for the North Sea cod recruitment. Source: Cefas

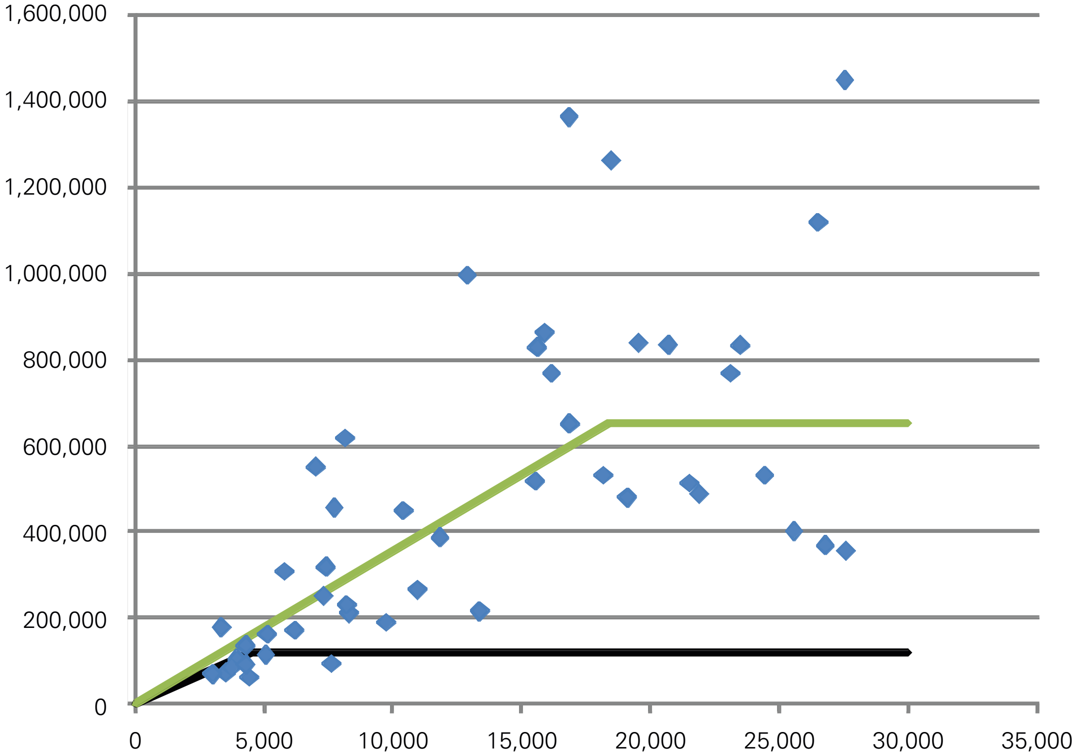


Figure 7: Two scenarios for the response of recruitment to increased spawning biomass in North Sea cod. Source: Cefas

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ISSN 0308-5589