KnowSeas

Knowledge-based Sustainable Management for Europe's Seas

Deliverable 4.4 Recognising Cost in the Assessment of Management Strategies and Options

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March 2013

The research leading to these results has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement number 226675

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[a] An accompanying Excel worksheet is available through the KnowSeas website at: http://www.knowseas.com/partners-area/completed-deliverables.

Introduction and Overview

Philip Cooper (UoB)

This deliverable deals with the costing of actions associated with management of the marine environment and thus complements previous Work Package 4 deliverables (D4.1 – 4.3) which were primarily concerned with the benefits delivered by the marine environment. In the context of such benefits, drivers that cause their loss or diminution impose welfare costs but the focus here is on costs that attach to responses. The significance of these response costs lies in their relevance to deciding whether a specified response is worthwhile in the context of the benefit achieved (i.e. whether the value of the benefit is equal to or greater than the management cost) and in selecting the most efficient response (i.e. identifying the least cost option for achieving a given level of benefit). For example, if a member state wished to introduce a new marine protected area (MPA), one component of the impact assessment of the proposed MPA might be an economic justification based on the balance of costs and benefits judged likely to result.

Response costs may conceivably include lost benefits whose value is not revealed in markets (e.g. designation of a marine protected area may put pressures on marine ecosystems at other sites) but often such costs are internal to the economic system, for example the costs of labour and other resources deployed in monitoring or remediation. Thus, the evaluation of response costs may appear more straightforward than evaluating environmental benefits but even where costs are internalised care needs to be exercised in identifying relevant costs and how they are evaluated. Consequently, this deliverable commences with a description of costing principles in section I. We describe the main economic concepts and identify when their use is appropriate. Complementary guidance on the principles and measurement of the benefits of management options is provided in our previous deliverable D4.1 (Luisetti and Turner, 2011). Following the outline of principles, we apply these cost concepts to the case studies on which the KnowSeas project has focussed in the subsequent sections.

Section II investigates the costs of alternative management options for halting or remedying anthropogenic damages to cold water reefs in the North East Atlantic as a corollary to a case study of this problem conducted in Work Package 10. For each option, relevant costs are identified and evidence from existing studies used to evaluate them. Thus, the case study is used to illustrate the principles of costing outlined in Section I. Section III represents an extension of the alternative management options for European fisheries presented in our last .deliverable D4.3. That deliverable evaluated the effects of various management options on revenues derived from the landing of catch in member states. Here, the impact of fisheries' costs in each of these options is factored in to the analysis. Thus, the value added or profit under each option is calculated, providing a better basis for distinguishing the options – changes in such 'bottom line' measures constitute a more comprehensive basis for decision-making than changes only in the revenue realised.

These case study applications serve to demonstrate how, and when, cost information is relevant. Specifically, they show that cost information comprises a key component of any marine management and policy evaluation. Other cases from within the KnowSeas project could have been employed to illustrate general costing principles but details were unavailable to Work Package 4 at the appropriate time and the cases described here nevertheless provide an adequate basis for doing so.

In common with previous deliverables, we would emphasise that economic analysis of the type employed here can contribute to better decision-making but should not be seen as determinative – many social decisions involve factors that are difficult to capture in this form of economic analysis.

Section I Principles of Costing

Alistair Hunt (UoB) and Philip Cooper (UoB)

1. Use of Cost Information

As highlighted above, cost information is important in establishing whether the total costs associated with a management option, or policy, are outweighed by the benefits, i.e. does a cost-benefit analysis, (CBA), justify the action on the grounds of economic efficiency? CBA is used as a decision-support tool when both benefits and costs can be identified and quantified in monetary terms. Where benefits cannot so easily be monetised, cost information may be used in cost-effectiveness analysis, (CEA). CEA is also used to evaluate trade-offs between benefits and resource costs, except, in contrast to CBA, the benefits are measured in units other than money. It can be used to identify ways of minimising (or maximising) some physical effect with available resources (e.g. delivering the maximum improvement in bathing water quality in EU coastal areas subject to a budget constraint), or to identify the least-cost method of reaching a prescribed target (e.g. a given level of coastal bathing water quality). These - and related - decision-support rules are described in more detail in Luisetti and Turner, (2011).

In addition to using cost information in these types of decision support methods, cost information may serve to inform an initial scoping of the scale of resources required to meet a new policy challenge such as ocean acidification. Related to this, cost information may also be used to raise general public awareness of the extent of the resource commitment associated with managing such a public policy problem.

2. What Are Costs?

The basic premise of cost analysis that the term, 'cost' expresses the idea of scarce resources[1] that are used in satisfying people's material wants and needs. When speaking about costs we normally think of a positive number, reflecting a payment that has to be made in return for some goods or services. In the wider context in which the cost concept is being used here, however, it is necessary, in some cases, to allow for negative costs - i.e. cost savings. It is essential that any cost assessment consider all changes in resources demanded and supplied which will result from adoption of a given management measure.

The conceptual foundation of all cost estimation is the value of the scarce resources to individuals. Thus, values are based on individual preferences, and the total value of any resource is the sum of the values of the different individuals involved in the use of the resource. This distinguishes this system of values from one based on 'expert' preferences, or on the preferences of political leaders. Individual preferences are expressed in two, theoretically equivalent, ways. These are:

- the minimum payment the owner of the resource is willing to accept (WTA) for its use, or;
- the maximum amount a consumer of the resource is willing to pay (WTP) for its use.[2]

[1] Resources include natural resources, labour and capital. Clearly, there are only limited quantities in the world available to be used by society and thus they can be said to be scarce.
[2] The concepts of WTP and WTA are also central to the valuation of benefits in economic analysis.

Actions taken to manage the marine environment divert resources from other alternative uses. The measure of the cost of management options, therefore, is the total value that society places on the goods and services foregone as a result of the diversion of resources from alternative uses. A cost assessment should ideally consider all value, or welfare, changes in resources demanded and supplied by a given management option. The outline of cost types in the remainder of Section 2 is derived – inter alia – from the texts of Squire and van der Tak (1975) and Winpenny (1995).

3. Cost Types

3.1 Opportunity costs

As indicated in the previous paragraph, the economic cost of a good is the full value of the scarce resources that have been used in producing it. These resources, in turn, are measured in terms of the value of the next best alternative, which could have been produced with the same resources (i.e. the value of the opportunity foregone). Hence, the term "opportunity cost". This notion of cost may differ greatly from the common, accounting (financial), notion of cost expressed through market prices – as explained below.

An illustration of opportunity cost can be taken from the cost of establishing a new MPA that has been designated in response to a perceived loss of habitat. In estimating the costs of such an enterprise, the private cost of the area is zero if it is not rented out and no money actually flows from the implementing agency to the (perhaps non-existent) owner. This, however, is incorrect from society's perspective. In economic analysis the cost of the area is measured in terms of the value of the output that would have been received from that area, had it not been designated a protected area. Such output may be a market good or service (e.g. fish output), and/or a non-market good or service (e.g. recreational use[3]). When valued in this way, the cost of the area is given by its opportunity cost.

3.2 Private costs

It is not always the case that individuals' WTP is fully reflected in the allocation of scarce resources mentioned above. A basic distinction that needs to be made in cost analysis is between the social cost of an activity or intervention and the private cost. Private cost is the more easily understood concept, and refers to those costs which people take into account when making everyday decisions, buying or selling in markets. Typically, private costs are taken from the market price of the resource inputs – e.g. land, materials, labour and equipment. Such costs are private in the sense that they are internal to the decision making process of the individual consumer or producer. To illustrate: a fisherman's decision on how many, and what sort of, nets to use as a response to a change in fish populations mainly depends upon the relative prices and effectiveness of the type of nets available. In this case the price of the nets, the cost of labour used to apply them form the private cost, which is the main factor in the fisherman's decision.

3.3 External and social costs

The private costs of a decision do not necessarily reflect all the costs that this decision imposes on society. Many projects and policies have external effects, which may not be accounted for in the decision-making process. In the example of the fisher's actions given above, the use of larger nets may have negative impacts on fish populations other than that targeted. However the additional costs imposed on other fish populations, and the food webs of which they are a part, do not play a part in the farmer's decision as to whether to use the larger type of net. One reason for this type of cost not

[3] In some cases recreation benefits may be marketed. Other examples of non-marketed services include soil erosion control and biodiversity conservation.

being recognised in private transactions is that the cost is not captured in the form of a market price. Thus, the cost needs to be estimated using non-market valuation methods.

Therefore, the full cost of an activity to society comprises both the external cost and the private cost, collectively defined as the social cost. If society's scarce resources are to be used to maximum effect, then decisions governing resource allocation should, as far as possible, be based on social costs.

3.4 Sunk costs

The previous sub-section suggests that economic costs may include some costs that a private individual does not consider. Conversely, some costs are excluded from the definition of economic costs though they may be considered by a private individual. Such costs include those that have already been committed and so cannot now be recovered. These costs are known as sunk costs. An example of a sunk cost is the historic expenditure invested in sonar technologies; a current economic decision as to whether to invest in further sonar technologies considers those costs that would be incurred by such an investment, irrespective of previous investments.

3.5 Economic and financial costs

In addition to the distinction between private cost and social cost, it is often necessary in economic analysis to make a further distinction between the economic cost of any activity or intervention, and the financial cost. The discussion outlined above emphasises the fact that scarcity of resources necessitates trade-offs between alternative resource uses. The trade-offs are made on the basis of values that are expressed to some extent at least in market prices – themselves an expression of WTP. The economic cost of a good is therefore the full value of the scarce resources that have been used in producing it. These resources, in turn, are measured in terms of the opportunity cost. This notion of cost may differ greatly from the common, financial, notion of cost which is the cost that reflects the price of purchasing goods and services by a private individual or organisation. A measure of financial costs is critical in determining whether an investment is possible within a given budget.

3.6 Capital costs and recurrent costs

As noted above, the total social cost of a project, policy or management option includes the private costs of all resources used by the provider(s) of the project over some pre-defined time horizon (usually the useful life of the project/policy), plus any costs imposed on third parties (i.e. the externalities). The private cost category is commonly broken down into two elements: investment expenditures and recurring costs. (These are sometimes known as fixed and variable costs, respectively).

Investment expenditures are incurred towards the start of a project, and do not tend to recur throughout the project's life, hence they are also known as non-recurring costs. This category of costs typically includes land and property costs, infrastructure and equipment expenditures, plus associated installation ('set-up') costs.

The operation and maintenance of a project or intervention usually, but not always, incurs expenses. As these expenses tend to be incurred annually throughout the life of the project, they are termed recurring costs. Private recurring costs tend to be grouped into three broad categories: energy costs, labour costs, and material costs.

3.7 Implementation (or 'hidden') costs

There are two further types of financial costs that may be incurred in the introduction of a marine management option but may be neglected in an analysis of the financial costs incurred by the directly responsible agency only. These costs are categorised as administration costs and barrier removal costs, under the general heading of implementation costs.

Management policies generally necessitate some costs of implementation, i.e. of changes in existing rules and regulations, ensuring that the necessary infrastructure is available, training and educating for those implementing the policy as well those affected by the measures, etc. Examples of barrier removal (or transaction) costs include the costs of improving institutional capacity, reducing risk and uncertainty, facilitating market transactions by, for example, information provision, and enforcing regulatory policies. These cost elements need to be quantified so that the reported figures are a complete representation of the true costs that will be incurred if the programmes are actually implemented.

3.8 Total costs, average costs and marginal costs

The total cost (TC) of a marine management option is the sum of all cost components over time. Since impacts may be valued differently, depending on which point of time they occur at, the cost items cannot be simply added together. Rather, where costs are spread across different time periods, it is common practice to use a procedure known as discounting (see below) in order to compute the value in today's terms (or at a fixed point in time) of the total cost stream. As long as both private and some external costs are included, and if future costs have been appropriately discounted, we can refer to the sum as approximating the present value[4] total social cost of the management option.

Total costs are clearly important in order to assess the full extent of the costs associated with the management option and to evaluate it in the context of the associated benefits. The average cost (AC) is defined as the total cost (TC) divided by the number of units of the item (Q) whose cost is being assessed, i.e.

$$\mathrm{AC} = \mathrm{TC}/\mathrm{Q}$$

Average costs are also relevant when comparing the effectiveness of management options with one another. For example, a comparison between the options could be made on the basis of the average cost over the lifetime of a project per unit of environmental benefit achieved - essentially a form of cost-effectiveness analysis based on average costs.

The marginal cost (MC) is defined as the change in total cost resulting from the provision of one more unit of the option in question – for example, an extension of the size of an existing MPA. That is, MC can be defined as the rate of change of total cost with respect to the level of damage avoidance, given by:

$$\mathrm{MC} = d\,\mathrm{TC}/d\,\mathrm{Q}$$

Decisions about the level of implementation of a management option to be pursued will need to consider marginal costs since the marginal costs need to be set against the marginal benefits of undertaking the extra unit of implementation. If the marginal social benefit (MSB) is greater than the marginal social cost (MSC) then there will be a net social benefit. This indicates that the management activity should be increased by incremental, or marginal, units to the point where MSC = MSB since up to this level of output each additional unit will add a net gain to welfare.[5] The marginal cost concept is additionally important because most of the disaggregated higher order effects are measured by estimating changes in markets that are assumed not to be large enough to change market prices. Where this is not the case, non-marginal economic costs need to be evaluated.

[4] The term present value (PV) is defined as the sum of the discounted costs for each year over the lifetime of the management option.

[5] This description deals with straightforward cases where costs and benefits are 'well-behaved' functions of quantity. In other cases, the analysis can be more complex.

3.9 Discounting

The rationales for discounting in the public and private sectors differ and reflect the distinction between private costs and social costs. Private sector interests will be primarily interested in the costs of borrowing or lending money in the financial markets. Thus, the market rate of interest(s) will be the most relevant in undertaking financial appraisal of projects or management options.

The market rate of interest is important because individuals attach less weight to a benefit or cost in the future than they do to a benefit or cost now. Impatience, or 'pure time preference', is one reason why the present is preferred to the future. The second reason is that, since capital is productive, a pound's worth of resources now will generate more than a one pound's worth of goods and services in the future. Hence an entrepreneur is willing to pay more than one pound in the future to acquire one pound's worth of these resources now. This argument for discounting is referred to as the 'marginal productivity, or opportunity cost of capital' argument; the use of the word marginal indicates that it is the productivity of additional units of capital that is relevant. The individual rate of time preference would be equal to the opportunity cost of capital if there were efficient markets and no taxes. In practice the range of individual time preference rates is large and does not coincide with the rates for the opportunity cost of capital. Broadly speaking the individual rate of time preference in the EU would be around 3-20% (depending on whether the individual is borrowing or lending), whereas the (risk free) opportunity cost of capital rate would be around 7%[6]. These effectively represent a typical range for the market rates of interest.

The private sector will, however, also be interested in how the public sector treats costs and benefits that occur in the future as part of their involvement in public policy decision making. The social discount rate attempts to measure the rate at which social welfare or utility of consumption for society falls over time, and is therefore distinct from the private sector that relies on the market interest rate theoretically determined by individual preferences expressed in financial markets. The social discount rate, as determined by time preference, will depend on the rate of pure time preference, on how fast consumption grows and, in turn, on how fast utility falls as consumption grows. Typically, the EC DGs currently use discount rates of 2 – 6%; DG Environment uses a central rate of 4%[7].

Further detail on discounting is given in Luisetti and Turner (2011).

3.10 Real and nominal costs

When making cost comparisons between, say, two management options, it is important to ensure that all cost data are expressed on an equivalent price basis, i.e. in the prices of a 'common' year. For example, there may be investment expenditure data on two potential management options; one set of cost data may be measured at current prices[8] in 2010 whereas the other set of costs may be measured at current prices in 2012. If the economy experienced inflation[9] in the intervening period, direct comparison of the two data sets would be misleading. Thus, it is advisable that this 'common' year

[6] See examples of historical rates at: http://sdw.ecb.europa.eu/browse.do?node=bbn175. Note that current rates are lower than historical averages.

[7] See http://ec.europa.eu/environment/enveco/others/pdf/recommended_interim_values.pdf as an example.

[8] Current (or nominal) price variables refer to values at the prices ruling when the variable was measured. Such prices have not been adjusted for the effects of inflation – in contrast with "real" prices or costs that remove the effects of inflation relative to a given base year. Nominal price is interchangeably used with current price.

[9] **Inflation** is the term economists use to refer to increases in the general price level over time. The **inflation rate** defines the rate at which the general price increases over a specified time period – e.g. monthly or yearly.

corresponds to the base year[10] of the analysis. For example, a reference may quote the cost of a marine monitoring system at €50,000 per unit in 2008 prices, yet the base year of the study for which the data are required might be 2012. Assuming the presence of inflation over the intervening period, if the quoted cost is used directly in the study, the final results will be biased downward. Equally, if the base year is 2005 and the quoted cost is used directly, the results will be biased upward. The cost estimate therefore needs to be adjusted to account for such inflationary effects by rebasing to 2012 year prices in this case. The cost estimate would therefore be expressed in real rather than nominal terms.

[10] In the context of processing time-dependent data such as costs in some form of economic analysis, the **base year** is the year selected for assembly of the 'raw' input data. The base year may also serve as the year from which projections of the **baseline scenario** are made.

Section II Case Study Application: North East Atlantic Deep Water Coral Reefs - Management of Impacts from Fishing and Ocean Acidification[11]

Alistair Hunt (UoB)

1. Overview

As described in KnowSeas Deliverable D10 (Busch et. al., 2010), the North East Atlantic boasts an array of cold-water coral reefs constructed from *Lophelia* species. These reefs are notably productive in supporting a large number of marine species and a food web that is provided protection by their structure. A range of associated ecosystem services are provided by these coral habitats, as summarised in Table 1 below. However, these habitats and their linked ecosystem services are identified as being threatened by environmental changes.

Specifically, there are two major anthropogenic pressures on the well-being of the reefs. First, demersal fishing is known to damage the physical structure of the reefs (Hall-Spencer et. al. 2009). Second, shoaling of the Aragonite Saturation Horizon (ASH), resulting from increased levels of atmospheric CO_2 and thus acidification of the oceans, results in the dissolving of deep water coral reefs and the corrosion of marine calcifiers more generally. Consequently, these pressures imply the need to consider reef management options to protect both the extent and quality of cold water *Lophelia* reefs in the North East Atlantic.

The KnowSeas project, Deliverable 10.3 , has undertaken illustrative economic analysis of possible actions identified to respond to ASH shoaling in the context of the interactions with fishing and its management. In the current deliverable we report on the costs that are likely to be associated with the two leading potential management options.

[11] This section deals with the cost aspects of management options identified in a case study of cold water reefs undertaken by Emma Jackson (UoP-MI) as part of Work Package 10. Further details of scientific matters can be obtained by reference to Deliverable 10.4.

Table 1 Ecosystem services and the North East Atlantic *Lophelia* Reefs

Service/ (Generic)	**Definition**	**Application to NEA *Lophelia* reefs**
Production Services	*Products obtained from the ecosystem*	
Services Provision of biomass & habitat Maintenance of food web structure/function & biodiversity	**Good:** Food **Benefit:** Extraction of marine organisms for human consumption.	Demersal Fish
Regulation Services	*Benefits obtained from regulation of ecosystem processes*	
Gas and climate regulation	Balance and maintenance of chemical composition of the atmosphere and oceans by marine living organisms.	Provided by reef system
Disturbance prevention	Dampening of environmental disturbance by biogenic structures.	Provided by reef system
Bioremediation of waste	Removal of pollutants through storage, burrowing and recycling.	Provided by reef system
Cultural Services	*Non-material benefits people obtain from ecosystem*	
Cultural heritage and identity	Benefit of biodiversity that is of founding significance or bears witness to multiple cultural identities of a community.	Provided by reef system
Cognitive benefits	Cognitive development including education and research resulting from marine organisms.	Corals as archives of past conditions
Existence value	Benefit derived from non-use. Includes bequest value (benefit from knowing resources and opportunities are available for future generations)	Reef system but also individual colonies
Option value	Importance of opportunity for future speculative uses.	Pharmaceutical values linked to the diversity of the reef (Lophelia & associated deep sea sponges, etc.);
Supporting Services	*Necessary for all other services, but do not yield direct benefits to humans*	
Resilience and resistance	Extent to which ecosystems can absorb impacts without decline or sudden flipping.	Reef system
Biologically mediated habitat	Habitat provided by living marine organisms. Incorporates breeding and nursery spaces, refuge and hiding place from predators.	Reef system (includes Demersal Fish – overall diversity which is linked to resilience)
Nutrient cycling	Storage, cycling and maintenance of nutrients such as nitrogen, phosphorus sulphur and metals by living marine organisms.	Reef system

2. Description of Management Options

Two management options have been identified that are judged to be potentially effective in mitigating the risks faced by *Lophelia* reefs:

Extension of Marine Protected Area (MPA) coverage

This option is designed primarily to prevent fishing activities from further damaging *Lophelia* reef structures through bottom trawling activities. It is estimated that the area of *Lophelia* reef in the North-East Atlantic is approximately 24,500 km^2. Of this area, just under 3,400 km^2 are located in MPAs. The management option that we consider is to ban all fishing from the entire area where coral reefs are thought to exist. Thus, the additional NEA MPA coverage is 21,100 km^2. In line with the assumption most typically used in MPA assessment (e.g. Defra, 2010), we assume a lifetime for the MPA equating to 20 years.

Whilst the scope of this option reflects the adoption of a precautionary principle with regard to both the geographical extent of coverage and the type of coverage, it is possible to envisage that alternative management options could be constructed by varying these parameters. In this case, the costs identified below would change accordingly.

Mineral accretion for coral reef rehabilitation through electrolysis in sea-water

This option is designed to encourage the re-growth of coral damaged either through fishing activities or though ocean acidification. In this option, coral re-growth is encouraged by electrical currents flowing through seawater with a voltage difference between two conductive terminals. This process generates pH gradients as a result of the electrolysis of water and allows the reef organism to calcify more efficiently than would otherwise be possible. The reef structure is created by the minerals that coat the cathode, and that are supersaturated in sea-water (Goreau and Hibberz, 2005).

Stimulated mineral accretion is a technological response to the threat of coral degradation and is proposed in recognition of the fact that natural growth recovery from fishing damage is likely to be constrained in future decades as a result of ocean acidification (Strömberg et al., 2010). In the context of this study, it is used as an illustration of one of the possible measures for coral reef restoration. Other measures include the use of artificial reefs, coral transplantation, gardening of coral reefs, restoration of ship grounding sites, and a variety of novel technologies such as the use of coral nubbins and molecular biology tools. These measures are described in Rinkevich (2005).

Following Goreau and Hibberz (2005), we assume in this study that mineral accretion is applied to one-tenth of the full extent of *Lophelia* reef coverage in the North-East Atlantic, i.e. 2,110 $kilometres^2$ – reflecting their assumption at the global scale that the extent of coral reef of most direct human concern is equivalent to around 10% of the total area of coral reef world-wide. It is recognised that, in reality, an application of this scale is not currently envisaged and this option should be viewed as an illustration of the principles of costing. As with the MPA option outlined above, this illustration allows some basis for scaling up or down to different scopes of action and we assume a project lifetime for the technology of 20 years.

The two options may be considered independently of each other and in this analysis we do so. However, it should be noted that to the extent that the imposition of the MPA allows for the benefits of mineral accretion to be more easily realised, there is likely to be some degree of complementarity in their effectiveness.

3. Costs of Options

As identified above, support for the implementation of these, or other, types of management option is likely to be dependent on the consideration of their costs – either in appraisal or in the initial scoping of potential options. In this sub-section we identify the costs likely to be associated with the MPA and the mineral accretion options, based on the principles outlined in Section 2. As discussed in Section 3.4 below, such costs are relevant in cost-effectiveness analysis if we assume that the effectiveness of the two measures per km^2 is equivalent, or in cost-benefit analysis, where these costs are compared with the resulting monetised benefits.

The cost estimates are derived on the basis of transfer from those values given in the academic and grey literatures (see, Ghermandi and Nunes (2010) in Deliverable 4.1 for further details of the value transfer method). Thus, it is emphasised that the estimates provided are illustrative rather than actual, reflecting the fact that the primary purpose of this exercise is to demonstrate the principles that are involved in the economic appraisal of marine management. All costs are presented in Euro; the price base year for these is 2010.

3.1 Extension of Marine Protected Area (MPA) coverage

The relevant costs associated with an extension of MPA coverage to be considered are identified and summarised in Table 2, with further detail following. The identity of the "regulating authority" is not material to the analysis as this title is used merely represent a body acting in the public interest.

Table 2 Taxonomy of Costs associated with MPAs

Costs types associated with MPAs	Cost category	Cost bearer(s)
Start-up costs	Private; Financial	Regulating authority
Direct operating costs - Management costs - Monitoring/enforcement costs	Private; Financial	Regulating authority
Foregone costs - Fishing - Other industries, including: o Aggregates o Telecommunications o Power cables o Offshore wind energy o Wave energy o Oil and Gas	Opportunity; Economic	Fishers Other industry operatives

Source: Kaphengst et al. (2011) and own assumptions

Costs of the MPA Area Extension: Identification of Cost Types

Financial and economic costs incurred by the regulating authority and other stakeholders are described under the headings below.

Private costs

Start-up costs include:

i) Establishment costs include the research costs associated with formulating the MPA, as well as the barrier removal and hidden costs resulting from the provision of information and

education to stakeholders and the wider population. They also include the costs of discussions and negotiations – including public consultations – incurred by the regulatory authority and other stakeholders with an interest in the putative MPA.

ii) Investment expenditure on capital items such as the purchase of survey boats and equipment for the monitoring and enforcement of the MPA

Direct operating costs comprise:
Management costs that include:

i) Labour (staff) costs associated with the maintenance of the regulatory agreement, including legal and administrative expertise
ii) Rental and other property-based costs of office space required to house legal and administrative personnel

Monitoring and enforcement that costs

i) Labour (staff) costs incurred in day-to-day management of MPA, including monitoring and interpretation of data received on the location of fishing vessels in the vicinity of the MPA, and enforcement, with the legal/regulatory action implied.
ii) Costs of electricity associated with the use of monitoring equipment

Foregone Costs
For the fishing industry, these private opportunity costs have been split into short-term and long-term components. We also indicate whether the cost components are financial or economic.

Short-term costs include:

- The loss of revenue associated with the net decrease in fish catch (Financial)
- Additional travel costs associated with displacement and relocation of fishing activities to other areas (Financial)
- Additional capital costs incurred as a result of changing fishing practices (Financial)

Long-term costs include:

- Crowding externalities in new fishing locations, where there are now more fishing participants, which might lead to unsustainable fish stock levels and reduced catches for all participants (Financial)
- Loss of way of life and attachment to place (Economic)

The net foregone costs comprise the change in the balance of revenues and costs. We highlight that the time profile of these foregone costs is uncertain. Specifically, it is suggested that disallowing fishing in the MPA will facilitate a revival of fish populations that can lead to compensating catches in the areas surrounding the MPA; the time required for species revival will depend, at least in part, on the fish species affected.

Other foregone costs that may be relevant include:

- Loss of value resulting from reduction in extraction of aggregates from the sea-floor of the MPA
- Increased costs associated with diversion of sea-floor cabling that would be used to facilitate telecommunications and power transmission
- Lost opportunities for siting of wind and wave energy generating equipment
- Lost opportunities for siting of oil and gas extraction

External costs
As indicated above, external costs may result from the effects on fishers in other areas that now become competitive in seeking their fish catch with those fishers who formerly operated in the MPA

area but who have now relocated to these other areas. These third party effects - or externalities – have welfare costs that would be captured in financial cost terms.

Total social costs
To derive the total social costs of the adaptation measure, we need to add the private costs and the external costs together. We assume in this example that no further adjustment needs to be made to the cost elements in order to give the opportunity cost of the measure, i.e. financial cost and economic costs are equivalent. Therefore, the opportunity cost equals the total social cost.

Costs of the MPA area extension: Empirical evidence

In order to derive cost estimates of the MPA extension we rely on a transfer of values currently existing in the literature. This transfer data is used to offer a first order estimate of the likely scale of costs that would be associated with such a measure. The cost estimates presented are in terms of ranges, reflecting the uncertainties identified in the estimation procedure. More precise estimates could be derived through further research, including conducting in-depth interviews with the regulatory authorities and stakeholders that would be associated with the delivery of the measure in practice. All costs have been converted to 2010 prices.

Private Costs
Start-up costs
The first of two estimates of start-up costs associated with the establishment of a MPA in Europe that we have identified is given by Defra (2010). This study – undertaken to estimate the costs of establishing and running an additional 71,000 km^2 of the Marine Conservation Zone (MCZ) network – gives estimates of total one-off costs in the range of €9.8 – 10.5 million, the range being determined by potential variations in the resource commitments required. In contrast, Defra (2006), quoted by Kaphengst et al. (2011), suggests much lower costs of €223,000 to establish an MPA site. This latter reference gives no further details so that it is difficult to interpret in our context. However, the fact that it is in reference to a site, rather than a network as in the case of Defra (2010), suggests that the Defra (2010) estimate is likely to better approximate to our context of establishing a network of MPAs that cover *Lophelia* sites.

Direct operating costs
Both the Defra (2010) and Defra (2006) studies provide estimates of annual operating costs. Defra (2010) suggests an annual cost of €3.1 million for implementing the MCZ network, and an annual enforcement cost in a range of €0.7 – 1.14 million. In contrast, Defra (2006) gives an aggregate annual recurring cost of €0.12 million. A further estimate is given by RCEP (2004). This study presents annual costs of €39-54/km^2 for the operation of a MPA in the North Sea. In our context, these unit costs translate to a total cost range of in a range of €0.82 – 1.13 million. These costs fit well in our range and so we adopt them in our overall cost estimation below.

Foregone Costs
The principal foregone costs from the implementation of an expanded MPA network to cover the *Lophelia* areas might be expected to be diverse – as indicated above. They are also very site-specific, implying that transfer of costs from other areas could introduce substantial uncertainty in the application of these costs to the present context. However, in order to provide first-order illustrative cost estimates we adapt the industry cost estimates made to inform decision-making relating to the expansion of the MCZ network. Specifically we adjust the annual cost estimates made for the 71,000 km^2 MCZ expansion and adjust for the difference in size of area. Thus, we adjust the estimates by a factor of 0.3. The resulting annual costs are presented in the table below.

Table 3 Foregone Costs to Industry of MPA Imposition

Industrial sector	Cost estimates (€ million, annual, 2010)
Aggregates	0.09 – 0.34
Telecommunications	0.06 – 0.21
Power cables	0.03 – 0.06
Wind energy	0.11 – 0.42
Wave energy	0.001 – 0.001
Oil & Gas	3.10 – 9.57
Fisheries	1.90 – 4.18
Total	**5.29 – 14.77**

External Costs

As mentioned above, the principal external costs of the MPA expansion are likely to be those associated with the dislocation of fishing activities from the new MPA areas to others where they impinge on the catch values of other fishing vessels. There is no empirical evidence relating to this cost component available in the literature that we can consider for transfer. We therefore assume that this cost has been incorporated in the foregone cost estimate for the fishing sector, as presented in the table immediately above.

Total Social Costs

Based on the empirical evidence reported above, we are able to compile estimates of the total costs of introducing an expanded network of MPAs where fishing is banned. The cost estimates are summed over the 20 year time period and discounted by a 4% discount rate. The discounting can be undertaken using a discount factor (d.f.) calculated from the formula:

$$d.f. = \frac{1}{(1+\mathrm{r})^t}$$

Where r is the discount rate, and t = number of years from the base year. With a 20-year project life-time and a discount rate of 4%, the average discount factor over the time period is 0.71.[12] The total recurring costs – direct operating costs and foregone costs can therefore be approximated by applying the formula:

$$\mathrm{TC} = 0.71 * Annual\cos t * 20$$

The start-up costs are assumed to be incurred in the first year. Consequently, they do not need to be discounted for future years.

The present value estimates for the component costs are presented in Table 4. It is notable that the resulting total cost ranges are dominated by the foregone cost component which – because of the uncertainty associated with transferring site-specific values - we would judge to be the least reliable. As a consequence, these indicative estimates may be best viewed as identifying their potential sensitivity to this category. The implication of this finding is that a formal appraisal of a policy initiative of this type should perhaps focus on generating estimates of foregone costs that directly recognise their site-specific nature.

[12] An average may be used in this case as the recurring costs are level over the life of the project.

Table 4 Present Value Costs of MPA Expansion

Cost category	Cost estimates (€ million, discounted, 2010)	
	Low	High
Start-up Costs	10	11
Direct Operating Costs	12	16
Foregone Costs	75	210
Total PV Costs	97	236
Total costs € per km^2	4,600	11,190

The mid-point PV cost is therefore €167 million. From these estimates, we can calculate average costs per km^2. As shown in Table 4, these equate to a range of €4,600 to €11,190, including foregone costs, with a mid-point cost of €7,895. Excluding foregone costs, the range of costs falls to €995 to €1280, with a mid-point value of €1,140.

3.2 Mineral accretion for coral reef rehabilitation through electrolysis in sea-water

The relevant costs to be considered in employing a large-scale application of mineral accretion electrolysis technologies to North-East Atlantic *Lophelia* reefs are identified and summarised in the table below.

Table 5 Taxonomy of Costs associated with Mineral Accretion Technologies

Costs types associated with MPAs	Cost category	Cost bearer(s)
Start-up costs	Private; Financial	Regulating authority/private operator
Direct operating costs - Management costs - Electricity - Capital repair costs	Private; Financial	Regulating authority/private operator

Source: Goreau and Hibberz (2005) and own assumptions

<u>Start-up costs</u>
The principal start-up cost associated with mineral accretion through electrolysis is likely to be the investment expenditure on the capital equipment required to generate and conduct the electrical current required for the electrolysis to occur. The cost of transporting the capital equipment to the site, plus the labour required to install it, need to be taken into account. The capital cost elements include the anode and cathode plates, together with the cabling required to transmit the electricity supply from the point of generation to the reef site.

<u>Direct operating costs</u>
The direct operating costs include the management costs such as:

i) Labour (staff) costs associated with the monitoring of the functioning and effectiveness of capital equipment, including scientific and administrative expertise, and;
i) Rental and other property-based costs of office space required to house scientific and administrative personnel

Also included in this cost category are: a) the electricity required to generate the electrical current in the electrolysis, and; b) any repair costs that might be incurred in the event of damage to the capital equipment.

Foregone costs

It may be assumed that there are no foregone costs; certainly none are identified in the available literature. However, it is possible that the capital structures required for the electrolysis, i.e. the anode, cathode and cabling, may constrain fishing activities in the immediate area, or more widely as regards the cabling. Similarly, oil and gas exploitation may also be inhibited. However, it is also conceivable that renewable energy technologies may be sited close to the site of electrolysis and – as a result of the reduced transmission length – reduce the cost of electricity required.

External costs

No external costs are identified in the literature. The electricity used for the electrolysis can be assumed to be immaterial to meeting other demands and external costs from its generation are assumed nominal in the context of generation overall.

Costs of the Mineral Accretion Technology application: Empirical evidence

Start-up costs

Goreau and Hibberz (2005) are the sole source of cost estimates related to the mineral accretion technology. They estimate that the geometric mean cost of the installation of such technologies can be assumed to be €10 per square metre of ocean floor. This equates to €10 million per km^2. However, the authors emphasise that the range of cost is substantial and depends on the specific nature of the restoration. They suggest a range of €1 – €100 per m^2.

Direct operating, foregone and external costs

These cost components have not been quantified in the literature to date. Therefore, we assume that these costs can be subsumed in the start-up cost range.

Total social costs

The start-up costs are assumed to be incurred in the first year. Consequently, they do not need to be discounted for future years. Since we assume that the start-up range incorporates the present value of the recurrent cost components, i.e. the direct operating, foregone and external costs, the present value of total costs equate to between €1 million and 100 million per km^2, with a central cost estimate of €10 million per km^2. When this cost estimate is applied to the 2,100 km^2 area of *Lophelia* reef assumed to be of most concern, the central estimate is therefore a cost of €21.1 billion. However, it should be noted that Goreau and Hibberz (2005) argue that the application of the technology on a large scale – such as that assumed in this study – will result in substantial economies of scale and consequent unit and aggregate cost reductions. We might also suppose that these costs would fall as a result of technological innovation over time.

4. Discussion

This section provides two empirical examples of application of cost principles in the context of *Lophelia* reef protection. The results are sets of total social cost estimates that serve an illustrative purpose rather than reflecting possible costs associated with current proposals. The examples serve to contrast the application of cost principles and highlight the different levels of cost data coverage that currently exist. Thus, it is clear that the cost components of MPAs are increasingly well understood, though their empirical estimation in the European context remains limited on the basis of evidence consulted for the current purposes. On the other hand, the understanding of the cost components of coral reef restoration technologies is undeveloped and partial, reflecting the current experimental

nature of these technologies (Abelson, 2006), and empirical estimation remains in its infancy. Our illustrative application highlights the uncertainties that currently surround cost estimations.

The limited development of cost estimates of alternative reef management options, however, needs to be viewed in the context of a growing awareness of the potential value of these reefs, as indicated in Table 1, and their increasing vulnerability to human-generated environmental pressures. Placed in this decision context, the total cost estimates presented above – central values being €167 million for MPA expansion and €21.1 billion for the application of mineral accretion technology – provide a first-order indication of the economic resources required to respond to the most significant threats to North East Atlantic *Lophelia* reefs. Their average costs – of €7,895 and €10 million per km^2 for MPA extension and mineral accretion technology respectively – may superficially suggest that the MPA extension is more cost-effective. However, the two measures are not direct substitutes since they address fishing and acidification to different degrees and their effectiveness has not been quantified in our regional context. Nevertheless, it is striking that even for the option with relatively high unit costs (mineral accretion technology), Goreau and Hibberz (2005) are able to construct a simple cost-benefit analysis at the global scale that shows that whilst total costs of applying the technology to one-tenth of the world's coral reefs equate to €300 billion, annual economic benefits are €375 billion. This finding at least indicates that improved quantification of both costs and benefits is already relevant in determining current resource allocation decisions related to marine management.

Section III Recognising Costs in the Assessment of Fisheries' Management Scenarios

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with contributions from Ian Goulding (MegaPesca) and Philip Cooper (UoB)

1. Introduction

This section deals with the calculation of the value added (VA) in fishing activities within the European Union. VA is defined here as cash operating profit (inflation adjusted income from landings) minus cost of the fishery activities (e.g. fuel, maintenance, repairs). Hence, in contrast to Deliverable 4.3 'Economic Valuation of European Commercial Fisheries under Good Environmental Status' which only considers the revenues from particular fishery species in the different fishing zones, Deliverable 4.4 seeks to extend the analysis by integrating the species specific fishing cost share in a multispecies fishery. The starting point of the estimation is therefore the disentanglement of the total cost into the incremental separate cost, i.e. costs of each joint product between spill-off point and the point of sale. For this purpose, the incremental separate cost is defined as variable fishing cost less labour expenses per unit (kilogram) of each joint product (harvest of particular species) in multiproduct industry (multispecies fishery).

Based on the calculated value added, the stock index for the next year is approximated in a second step. Furthermore, the multiplier effects of fishing activities on economic output are discussed.

Note: Definitions and scenarios applied in Deliverable 4.3 are applied here unless indicated otherwise.

2. Data

The detailed harvest data for the years 2006-2009 with division into specific stocks and zones was extracted from the fishery statistical time series FishStat (FishStat, 2012). The fishing zones included in the analysis are as follows (subzones according to ICES):

1. Arctic Waters Area (I, II, V, XIV)
2. Greater North Sea (IIIa, IV, VIId, VIIe)
3. Celtic Sea (VIa, VIIa, VIIb, VIIf, VIIg, VIIh, VIIj)
4. Bay of Biscay and Iberian Coast (VIIIa, VIIIb, VIIIc, VIIId, IXa)
5. Wider Atlantic (VIb, VIIc, VIIk, VIIIe, IXb, X, XII)
6. Baltic Sea (IIIb (23), IIIc (22), IIId (24-32)

A map of the ICES zones is attached as an Appendix figure.

The data on stock condition and harvest volumes originate from ICES annual advices (ICES, 2012) and prices quoted in the paper are per kilogram of fresh fish weighed at the time of the first sale of the product per Eurostat (2012).

The major extension to Deliverable 4.3 is the disentanglement of the cost structure of the fishing activities in order to calculate the VA. Data on the Total EU Fleet's Costs can be found in "The 2011 Annual Economic Report on the EU Fishing Fleet" published by the Scientific, Technical and Economic Committee for Fisheries (STECF-11-16). This aggregated data includes costs of fuel, labour, maintenance, repairs and other variable costs associated with harvest volumes for major fishing fleet segments within the European Union for the years 2006-2009.

3. Methodology and Assumptions

Incremental Separate Cost

Based on the cost data provided by STECF, an incremental analysis is conducted in order to divide the total variable and labour cost on several fish stocks per zone. An overview of the data structure is given in **Error! Reference source not found.**, showing that costs in each member state are split according to the fleet segment category and then allocated to the fish species based on their harvest volume.

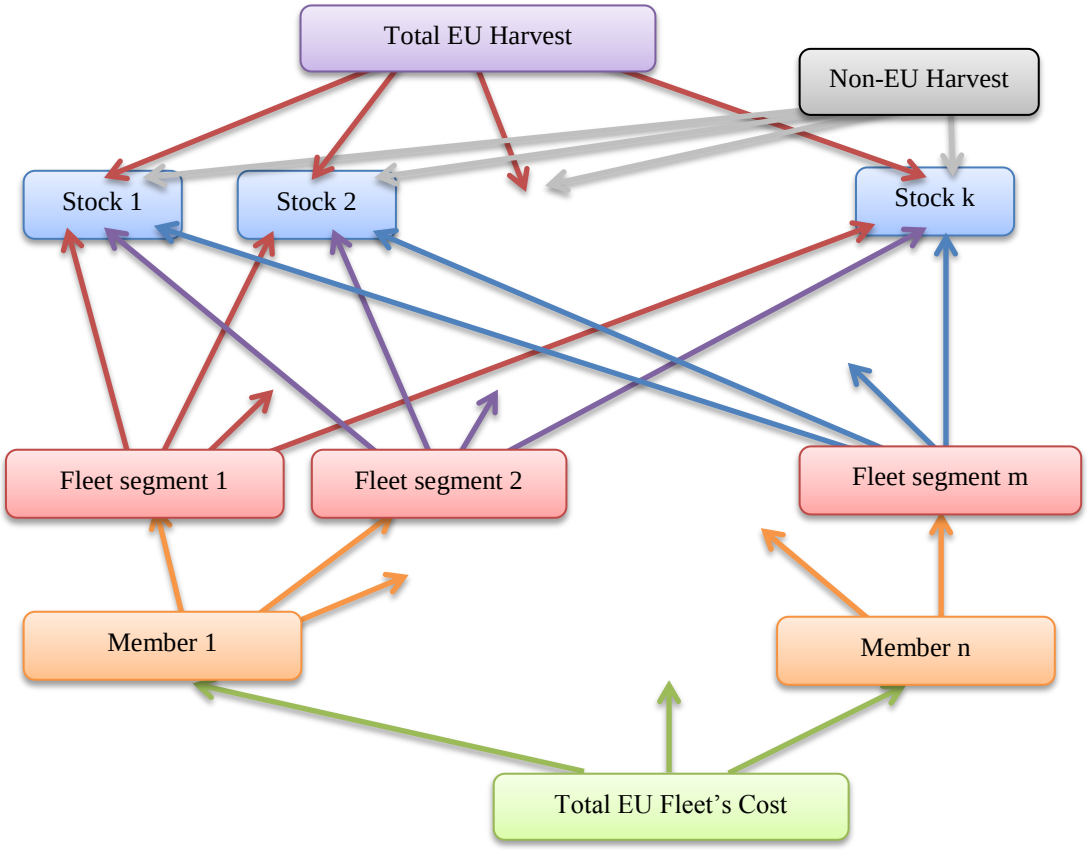

Figure 3-1: The structure of the data used in D4.4.

The total value added (TVA_j) per species and fleet segment for each country j ($1 \leq j \leq m$) are calculated as a weighted average by the following formula:

$$TVA_j = \sum_{i=1}^{k} p_i \cdot h_i - \sum_{i=1}^{k} (\hat{c}_{v,i} + \hat{c}_{l,i}) \cdot h_i$$

where p_i is the inflation adjusted price per kilogram fish of species, i, $1 \leq i \leq k$, $c_{v,i}$ is the estimated inflation adjusted incremental separate variable cost for species, i, $c_{l,i}$ is the estimated inflation adjusted incremental separate labour cost for species i, and h_i is the harvest volume of species i for member states with an active fishing fleet in the area considered to be the habitat of that particular stock (according to description available through ICES).[13] Total labour expenses are added to the cash operating profit following the assumption that these costs generate a positive impact on the national economy as the wages earned are spent again.

[13] Note that $\hat{c}_{v,i}$ and $\hat{c}_{l,i}$ are jointly estimated.

The estimates of $(\hat{c}_{v,i} + \hat{c}_{l,i})$ are approximated by the coefficients β_i taken from the following three-stage estimation for systems of simultaneous equations (based on ordinary least square estimation): $\sum_{i=1}^{k}(\hat{c}_{v,i} + \hat{c}_{l,i}) \cdot h_i = \sum_{i=1}^{k} \beta_i \cdot h_i + \varepsilon$ constrained by $\sum_{i=1}^{k}(\hat{c}_{v,i} + \hat{c}_{l,i}) \cdot h_i = \beta_i \cdot h_i + \sum_{i=1}^{k} \beta_r \cdot h_r + \varepsilon$, with $r \neq i$; $1 \leq i, r \leq k$. Thus, the incremental separate variable cost for species *i* is approximated by the harvest volume of species *i* while considering simultaneously the harvest volume of the other species of the other fleets of the respective member state. It is assumed that each country has a unified incremental value added for each species, independent of stock or zone. This simplified approach excludes subsidies, capital costs and potential value of fishing rights from the analysis.

Due to limited data availability, the estimation for each country was undertaken only for species producing over 1% of the total profit of segments included in the data set.

Value Added

The calculated VA in the initial study period is used in a second step to forecast the future VA and thus as the net present value of the VA for the period 2010-2035 for the three different scenarios applied in Deliverable 4.3:

- Scenario 1 (S1) assumes exploitation of the stocks under the current management regime meaning continuation of harvest at the same (2010) rate over all years. However, the harvest rate is adjusted wherever it leads to the biomass falling below its safe biological limit (SBL). This precautionary approach implies reduction of the harvest whenever it causes stock to fall below SSB_{pa}. The stocks with no SSB_{pa} estimates are assumed to be within SBL if biomass is at least 40% of the SSB_{MSY}. In the situation of reaching SSB_{MSY}, the harvest is assumed to continue further on at the MSY level.

- Scenario 2 (S2) assumes cessation of exploitation to allow stock recovery to the SSB_{MSY} level and reopening with fishing mortality maintained at F_{MSY}. This scenario represents the quickest way of complying with the MSFD but it implies the closure of certain fisheries for prolonged periods. However, it constitutes here a benchmark against which to assess alternative scenarios. Note that some stocks may suffer regime change: permanent change to stock structures due to fishing and environmental factors e.g. climate change.

- Scenario 3 (S3) assumes adjusting harvest rate to the maximum level delivering SSB_{MSY} in 2035 for overfished stocks. In case of stocks above SSB_{MSY} in 2011, the adjustment path assumes linear stock adjustment to SSB_{MSY} until 2035. The scenario assumes constant MSY harvest from 2035 indefinitely.

The discount rate employed is 4% as in Deliverable 4.3.

Stock index

Taking into consideration the bio-economic modeling principle that variable fishing costs decrease with increasing stocks (see e.g. Clark, 2010; Conrad, 2010), calculations of the influence of stock changes on the final result have also been undertaken. For this purpose, the incremental analyses were performed for each year separately. The estimation process in this case included a set of dummy-variables in the linear regression model representing each member state, in order to allow for differences in the average value of observations across member states, as well as adjusting the standard errors taking into account intra-group correlations.

4. Results

The incremental separate variable costs with added labour cost and the calculated VA per kg are shown in Tables 1 and 2 (Appendix) respectively. Table 1 reveals that species for which fishing activities involve high costs play only a minor role in the total harvest volume of the region. In other words, fishing activity is concentrated predominantly on these species segments which involve low estimated variable fishing cost in the region; species with a high estimated unit cost of fishing are rarely harvested. However, the reasons for this effect might be manifold and can be found in, for example, historical fishing habits, political regulations/subsidies (imply cost for fishing), or lack of alternative income creating activities.

Considering the whole area under observation, sole has the highest overall VA (average of 10.23 in our six fishing zones), followed by cod (average of 2.09), and plaice (average of 1.85) (see Table 2, Appendix). For comparison, the estimated VA and revenues for the period 2010-2035 under scenarios 1-3 for the each zone are presented in the form of graphs as shown in **Error! Reference source not found.** to **Error! Reference source not found.**. In most of the zones a short-term reduction in the harvest values leads in the long term to a higher level of revenues and value-added of the fishery.

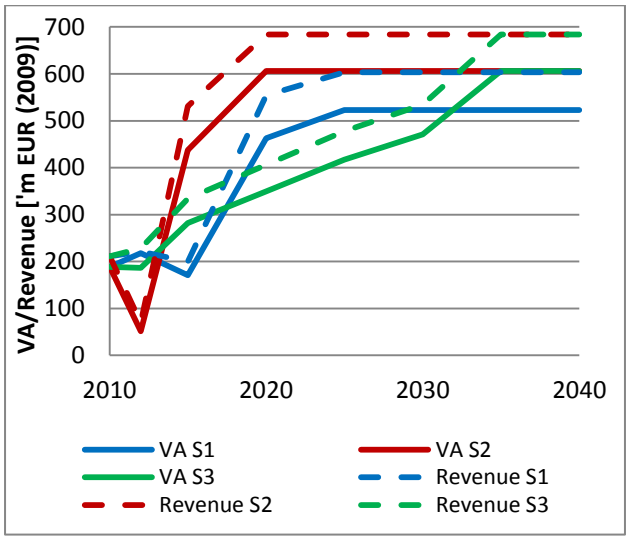

Figure 4-1: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Baltic Sea.

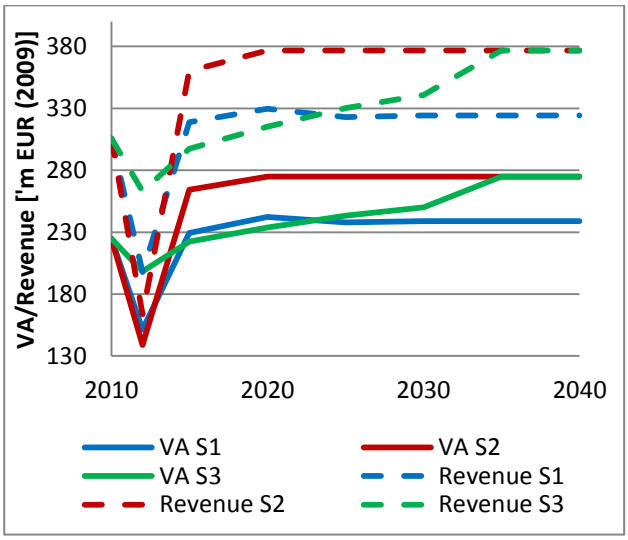

Figure 4-2: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Celtic Sea.

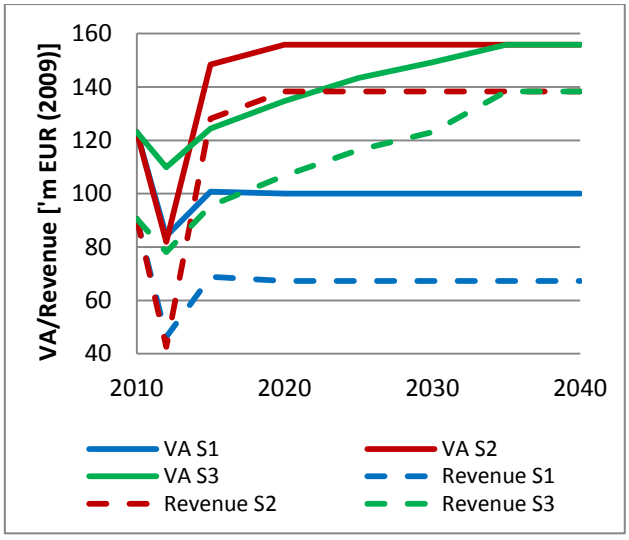

Figure 4-3: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Arctic Waters Area

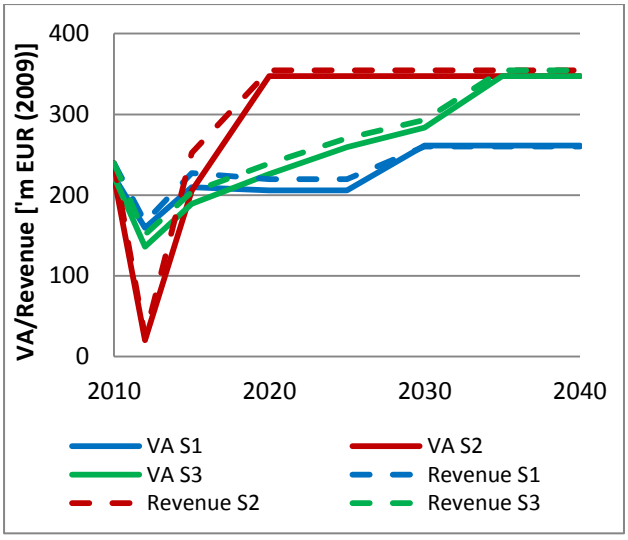

Figure 4-4: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Bay of Biscay and Iberian Coast.

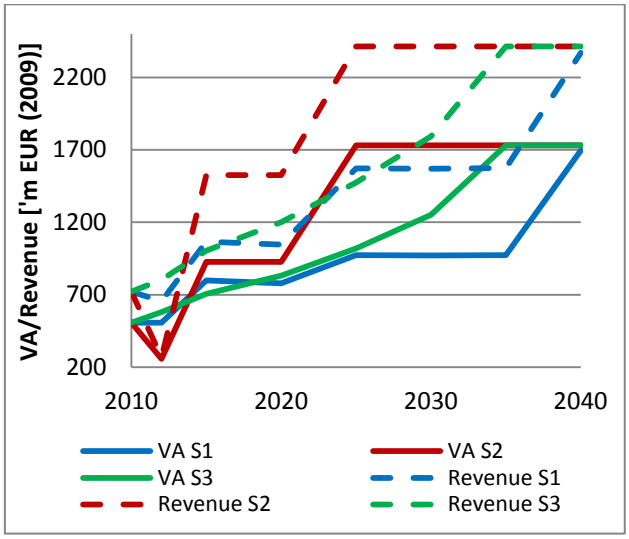

Figure 4-5: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Greater North Sea.

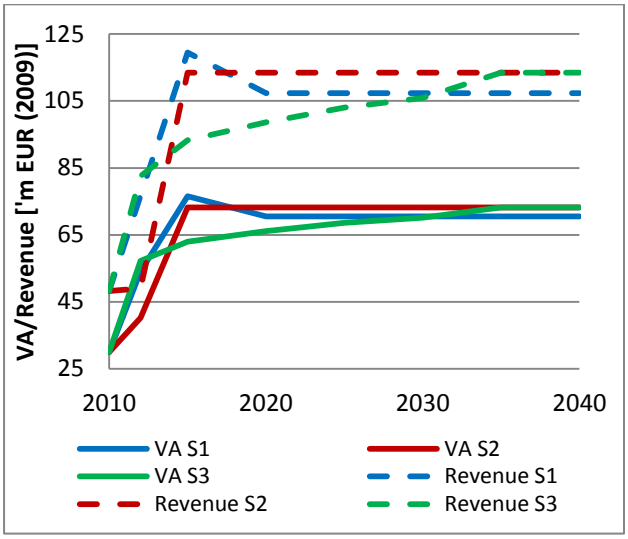

Figure 4-6: Estimated revenues and VA over 2010-2035 period under scenarios 1-3 for the Wider Atlantic.

The calculated Net Present Values of the VA and revenues for the period 2010-2035 under the above three scenarios for each zone are presented in **Error! Reference source not found.** to **Error! Reference source not found.** (with the same value units as above, €'m).

Even recognising costs, scenario 2, which assumes the total abandoning of the exploitation to allow stock recovery to SSB_{MSY} level and reopening with maintaining fishing mortality at F_{MSY}, yields the highest NPV in all six areas. However, the differences in the NPV among the zones are partially attributable to data limitation and should not be overly interpreted.

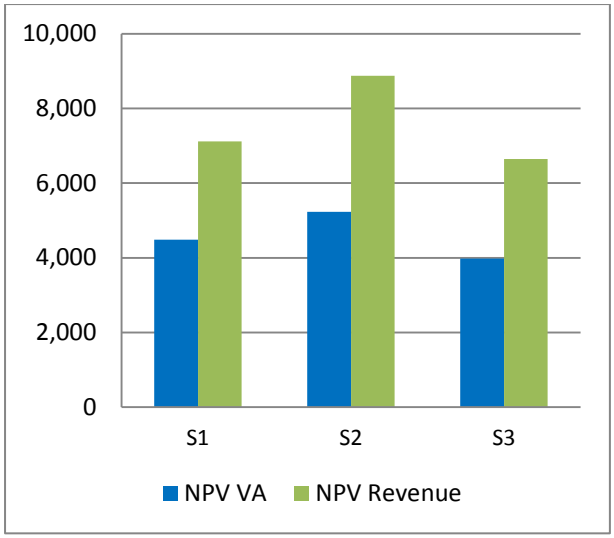

Figure 4-8: Net Present Value of VA and Revenue for the period 2010-2035 under scenarios 1-3 for the Baltic Sea.

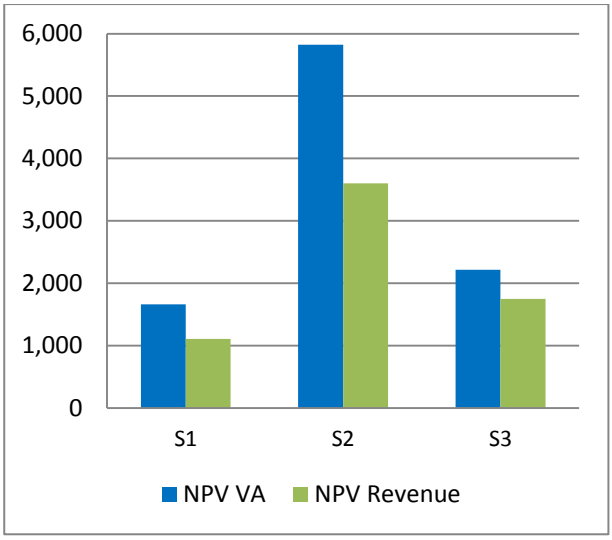

Figure 4-7: Net Present Value of VA and Revenue over 2010-2035 period under scenarios 1-3 for the Arctic Waters Area.

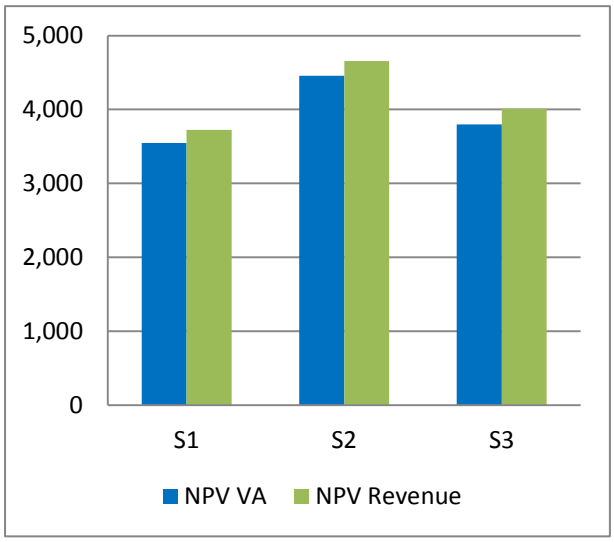

Figure 4-9: Net Present Value of VA and Revenue for the period 2010-2035 under scenarios 1-3 for the Bay of Biscay and Iberian Coast.

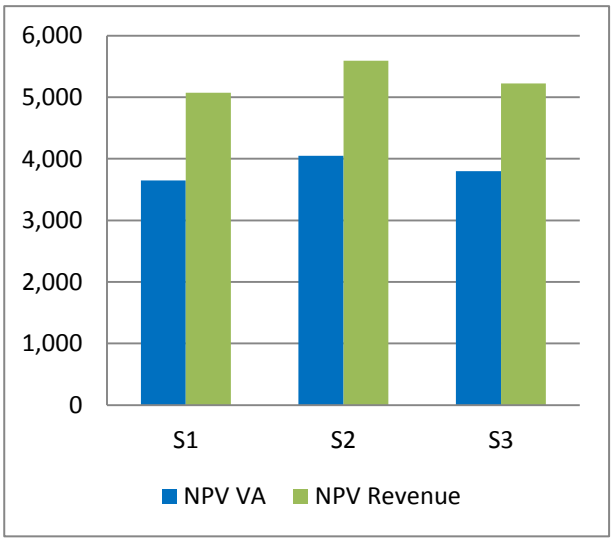

Figure 4-10: Net Present Value of VA and Revenue for the period 2010-2035 under scenarios 1-3 for the Celtic Sea.

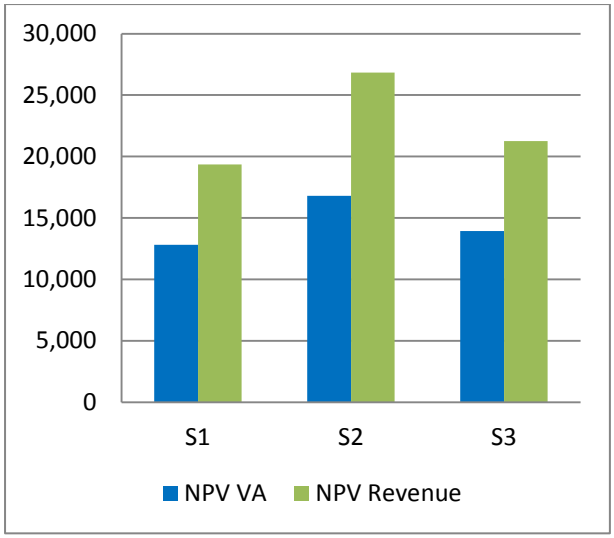

Figure 4-11: Net Present Value of VA and Revenue for the period 2010-2035 under scenarios 1-3 for the Greater North Sea.

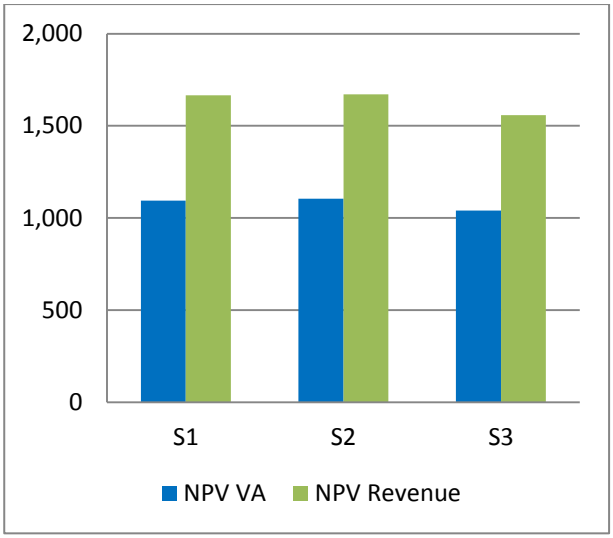

Figure 4-12: Net Present Value of VA and Revenue for the period 2010-2035 under scenarios 1-3 for the Wider Atlantic.

Estimation of the impact of the stock condition revealed that for 2006-2009, cost decreased by about €0.05 (standard error €0.03, R-squared 46%) for an increase in stocks by an average of 100%.

Due to our scope restriction and data limitations, the analyses were performed only in respect of a limited part of the total harvest volume within each zone: Baltic Sea 86%, Greater North Sea 44%, Celtic Sea 40%, Bay of Biscay and Iberian Coast 31%, Wider Atlantic 30%, and Arctic Waters Area 3%. Consequently, the results reflect only these elements and can be used to make comparisons among scenarios or proxies per unit but should not be taken to represent absolute values for the total harvest.

The complete calculations and data sets are available in the accompanying Excel file (D4.4 Fisheries).

5. Discussion and Conclusions

General conclusions

This project aimed to evaluate the value added from fishing activities within the European Union under different future fisheries' management scenarios. Emphasis was laid on the extent to which revenues are depleted if variable costs of fishing are incorporated into the calculation of the final profit of the EU fishing fleets. Therefore, the value added per kilogram of each fish species in a multispecies fishery was calculated such that the profits of fishing (including labour cost) were reduced by variable cost of fishing.

The calculated VA for the majority of stocks was positive, implying a positive impact of fisheries for the national economies, with the exception of whiting in sub-areas IV and VIId which had negative value for the United Kingdom, although it is a species of minor importance for demersal trawlers and seiners in this country. The negative value may suggest lack of incentives to harvest this particular species, whereas it may also be considered as a cost of multispecies harvest in the particular area (e.g. as by-catch). The final VA of each specie weight unit cannot be taken directly since it is the cost of catching the particular specie in particular combination. The potential necessity to increase selectivity in order to follow particular scenario is expected to increase costs. This is especially applicable to scenario 2 which assumes total lack of harvest of some species for some time periods.

On the contrary, the model assumes increased harvest of so far underexploited stocks, whereas often the reason behind this is lack of profitability.

As noted above, the second scenario is found to dominate the others in terms of both financial measures in each zone. Thus, it represents the optimum scenario from an economic perspective. However, it would perhaps be the most challenging to implement given that it would involve the complete closure for certain fisheries over prolonged periods.

Although supporting comparison among scenarios, the results are subject to limitations in terms of the availability of high quality data and therefore the need to utilize an unbalanced panel dataset covering a relatively short time period (2006-2009). Therefore the results can only suggest the value range and serve as a proxy for the real cost structure, and caution should be exercised in interpreting the numbers in absolute terms. Nevertheless, the results provide a basis for comparing the impact of scenarios within the zones and establish a methodology that could be applied to an expanded and updated dataset.

It may also be noted that the STECF data present analytical difficulties in their available form. The fishing grounds analyzed are shared with non-EU countries which are excluded from the dataset. Those countries include Faroe Islands, Greenland, Iceland, Norway and Russia, and have a significant share in some of the relevant waters (e.g. about 96% in the Arctic Waters, 48% in the Wider Atlantic and 27% in the Greater North Sea). Furthermore, due to confidentiality regulations, cost data from small vessels are excluded from the report, making the estimations incomplete and biased for missing observations. In addition, the data do not distinguish harvest between fishing zones but only indicate species caught. This difficulty is present in the unbalanced form of data due to different structures of fishing fleets in each country caused by access to different waters.

Owing to the varying ratio of variable costs to labour costs, the final adjustment of price used to calculate VA was positive or negative. In the case of Arctic Waters, the VA was higher than revenue which was influenced by generally high labour expenses in the countries performing fishing activities in the area (**Error! Reference source not found.**). This could be explained on the basis that fishing in this area might be subject to political influence, especially subsidies (see also STECF 2011). However, in the case of Arctic Waters, missing data bias might also occur as we only include 4 % of the harvest volume in the analysis of the cost structure (see above, data for Non-EU members are excluded although they are the major actors in this zone). However, cost calculations are based on the total harvest volume in the area. Hence, results in particular for this area should be interpreted with caution.

We would also highlight the following issues connected with the data and areas for further refinement:

1. The lack of fleets' harvest distinction between particular stocks required unifying cost of species for each country without distinguishing it over the areas it was caught. It would be expected that the unit cost of harvesting the same species under comparable stock conditions is higher in more distant waters given that similar technology is available to each fleet segment.
2. The estimation result of the stock condition influence on cost had the expected negative sign confirming the general bioeconomic assumptions. However, the absolute value is likely to be highly dependent on the length of the data time series.
3. Cost estimates exclude capital costs (depreciation and interest rates) and investments which may be a significant part of the yearly budget for some fishing fleets. Including capital costs would

be an interesting extension, especially considering possibility to improve fleet management and increase average use of vessel up to its full potential.

Multiplier Effect

The above analysis captures only one dimension of the economic value of commercial fisheries. It omits economic activity linked to the supply chain associated with fishing activities including other businesses and sectors supporting harvest e.g. production of gear or bite, and benefiting from it along the supply chain, e.g. sales, retail. Those effects constitute the indirect economic impact of commercial fishing. Further, the employees of the units directly supported by the fishing industry receive their income and use it at other businesses. This additional contribution to the national economy is defined as induced economic activity. Therefore, the total economic output includes direct, indirect and induced economic effects, as defined in Figure 5-1.

Although the potential importance of multiplier effects has been revealed in previous studies around the world where commercial fisheries are closed due to overfishing (e.g. WWF, 2011), this matter lay beyond the current project's scope. This constitutes a potentially fruitful area for future research, especially given some indications of large multiplier effects from fisheries in the EU. For example, it has been found in one study that fisheries in coastal areas generated downstream benefits of €1.8 of value added for every €1.00 of value added in fishing (MegaPesca, 2000).

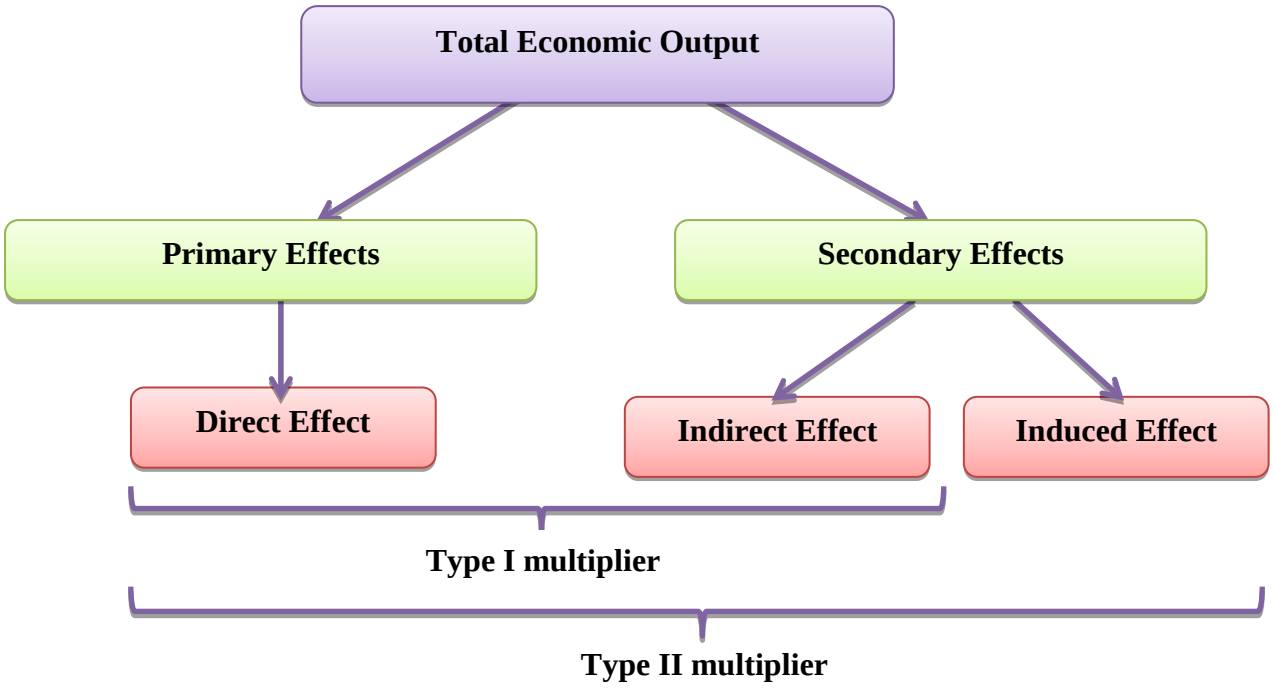

Figure 5-1: Multiplier Effect

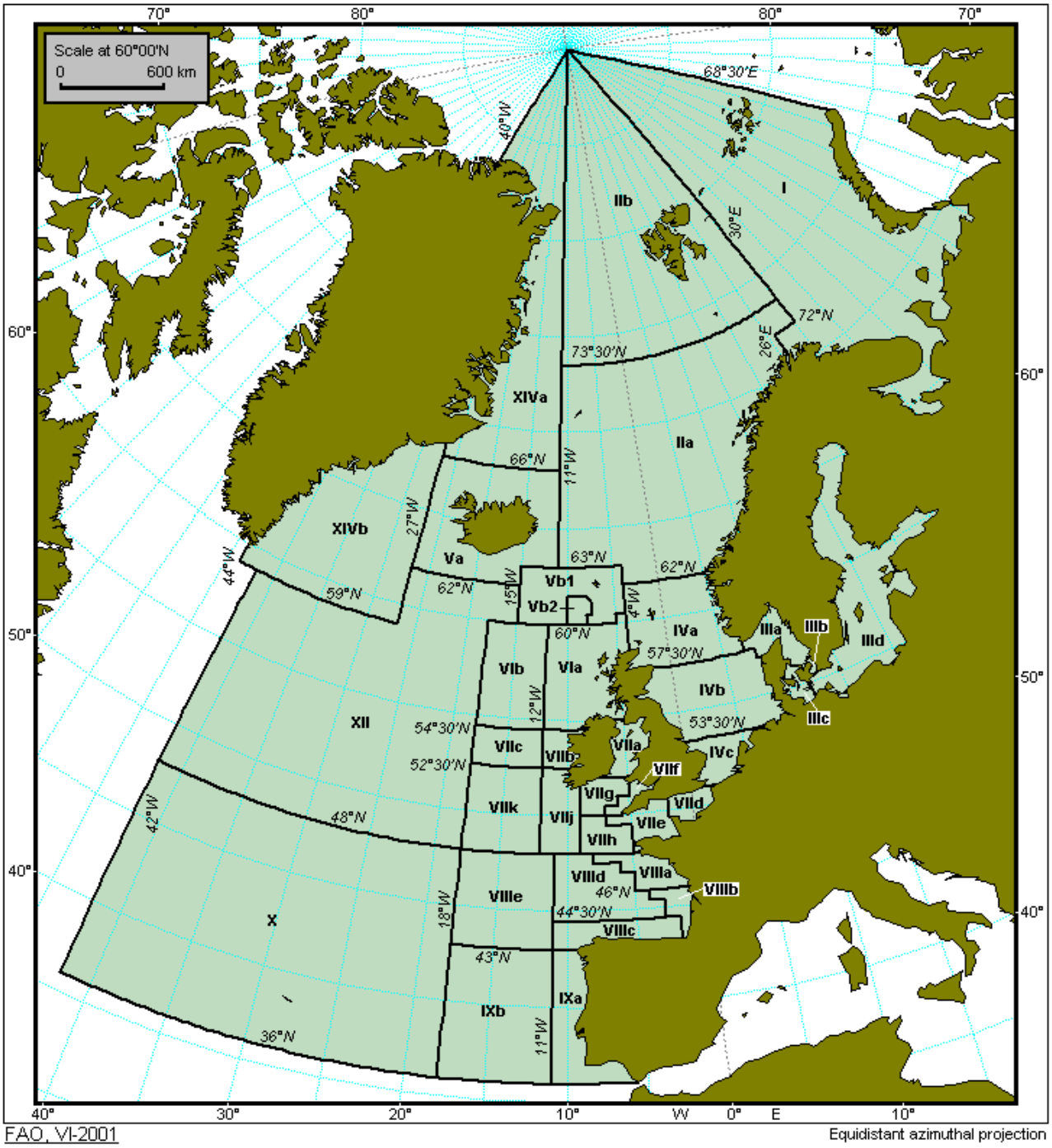

Figure: Map of ICES zones (FishStat Plus).

Table 1: Estimation results for cost coefficient (incremental separate variable costs with added labour cost per kg of fresh weight)

Member	**BEL**	**DNK**	**DEU**	**ESP**	**FIN**	**FRA**	**GBR**	**IRL**	**LTU+ LVA+ EST**	**NDL**	**POL**	**PRT**	**SWE**
R^2	*0.92*	*0.66*	*0.44*	*0.53*	*0.79*	*0.43*	*0.77*	*0.72*	*0.70*	*0.86*	*0.77*	*0.32*	*0.94*
Herring		**-0.001** (0.040)	**-0.434*** (0.143)		**-0.093*** (0.041)	-0.080 (0.186)	**-0.432*** (0.089)	**0.036** (0.354)	**-0.029** (0.033)	**-0.387** (0.247)	**0.067** (0.053)		**-0.028** (0.065)
Sprat		**-0.083*** (0.042)	-0.077 (0.176)		**0.405*** (0.152)			-0.703 (1.331)	**0.034*** (0.012)		**0.037*** (0.013)		**0.149*** (0.079)
Cod	**-3.939** (5.965)	**-0.347*** (0.154)	**0.865*** (0.286)	**0.590** (0.631)	**0.168** (2.248)	**1.211** (0.867)	**0.317** (0.331)	9.350* (3.784)	**0.401*** (0.148)	1.392* (4.970)	**0.302*** (0.078)	**0.952*** (0.321)	**0.874*** (0.125)
Pilchard				**-0.563*** (0.224)		**-0.258*** (0.145)				0.301 (0.665)		**-0.146*** (0.033)	0.040 (0.106)
Haddock			-4.085* (1.356)			3.507* (1.144)	**0.572*** (0.172)	**2.811*** (1.092)					
Whiting						**1.545*** (0.523)	**3.164*** (0.504)	**0.171** (0.870)					
Blue whiting		-0.118* (0.059)		**1.583*** (0.247)			-0.416* (0.130)	-0.041 (0.093)		**-0.113** (0.280)		2.154* (0.501)	
Saithe		0.825* (0.024)	**0.407*** (0.174)			**0.304*** (0.161)	**0.675** (0.466)						1.793* (0.830)
Norway pout[a]		-0.001 (0.116)											
Hake		4.101* (2.220)		**2.744*** (0.619)		**0.935** (0.570)	**0.738** (1.171)	6.381* (3.639)				**0.555** (1.347)	
Sandeel		**0.110*** (0.023)		5.580 (2.147)									0.001 (0.175)
Horse mackerel[b]				-0.703 (0.913)		-0.471 (0.525)						**0.320** (0.202)	
Plaice	**3.172** (2.189)	**-0.085** (0.261)	**-0.288** (0.765)			-6.538 (4.469)	**1.802*** (0.647)			**1.552*** (0.289)			
Sole	**3.774** (3.447)	-1.126* (2.979)	**1.057** (4.381)			**-3.716*** (0.918)	**6.176** (3.828)	3.326* (1.889)		**3.740*** (0.683)		-2.808* (9.952)	
Mackerel		**0.136** (0.166)		-0.145 (0.892)		2.272* (0.929)	**0.024** (0.062)	**0.147** (0.182)		**0.324** (1.347)		-0.102 (0.906)	**1.077*** (0.412)
Other	-0.226 (1.229)	-0.029 (0.036)	-0.011 (0.067)	0.097 (0.112)	1.128* (0.123)	0.049 (0.055)	0.717* (0.066)	0.150* (0.056)	0.780* (0.083)	0.395* (0.145)	0.056 (0.061)	0.107* (0.054)	1.507 (0.189)

* p<0.1, standard errors in parentheses, specie of higher importance-above 5% share in landing values are marked bold

[a] Norway pout plays an important role in the European fishery, but data is not included in the EU dataset used here.
[b] Horse mackerel plays an important role in the European fishery, but data is not included in the EU dataset used here.

Table 2: Value added per kilogram of fish (values out of interest area are left blank

	BEL	DEU[14]	DNK	ESP	EST	FIN	FRA	GBR	IRL	LTU	LVA	NDL	POL	PRT	SWE	*Average*
Herring		0.799	0.342		0.178	0.228	0.639	0.768	0.260	0.310	0.222	1.003	0.247		0.313	*0.44*
Sprat		0.200	0.235		0.125	-0.275			0.892	0.089	0.145		0.141		0.016	*0.17*
Cod	7.090	2.050	2.875	2.399	0.497	2.777	1.754	2.546		0.948	0.997	1.216	1.256		0.836	*2.10*
Pilchard				1.558			0.752							0.721		*1.01*
Haddock		6.151					-1.678	1.143	-1.150							*1.12*
Whiting							0.130	-1.868	1.066							*-0.22*
Blue whiting			0.280	-0.630				0.592	0.162			0.524		-1.504		*-0.10*
Saithe		0.644	0.233				0.858	0.222							-0.688	*0.25*
Norway pout			0.146													*0.15*
Hake			-1.468	1.121			2.538	2.155	-3.510					2.767		*0.60*
Sandeel			0.027	-3.358											0.152	*-1.06*
Horse mackerel				2.260			1.404							1.056		*1.57*
Plaice	-1.373	1.928	1.884				8.412	-0.052				0.318				*1.85*
Sole	7.094	9.624	13.204				15.829	4.901	8.035			7.071		16.117		*10.23*
Mackerel			0.989	0.674			-1.413	1.025	0.870			0.441		1.078	0.166	*0.48*
Other	3.203	0.828	1.575	2.362	0.183	2.179	2.365	2.703	0.886	0.339	0.234	1.036	-0.897	2.111	2.172	*1.42*

[14] prices for Germany taken for 2006 only, other years are inconsistent with remaining fleets

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