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COBECOS

Workpackage 5

Summary Report

For deliverable D5

Edited by Leyre Goti and Raúl Prellezo

AZTI-Tecnalia

February 20 2009

Preface

The Estimation of the theoretical relationships is one of the necessary inputs for driving the simulation model of the COBECOS project. According to the COBECOS contractual obligations a report on this part of the project (WP5), should be made available as a deliverable (D5) in month 24. The following report constitutes the fulfilment of this obligation.

Sukarrieta February 2009

For the lead contractor in WP5

Raúl Prellezo

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1. Introduction

This report is part of an ongoing research project called "Costs and Benefits of Control Strategies" (COBECOS). The project is funded by the European Union's (EU) Sixth Framework Program, Policy-Oriented research. The fundamental objective of COBECOS is to conduct a "cost-benefit analysis of control schemes for management strategies relevant for the CFP and, based on this analysis to infer the potential economic benefits to the fisheries which might accrue from proper enforcement of the management measures."

The objective is to be obtained on the basis of:

(1) An appropriate theory of fisheries enforcement,

(2) Empirical research including intensive case studies and estimation of theoretical relationships for particular fisheries and

(3) Computer modeling of the fisheries enforcement situation (based on the theory and empirical estimations) that will allow us to provide answers to the questions suggested by the fundamental objective of this proposal.

On this basis we expect to be able to contribute significantly to answering questions such as: What are the costs and benefits of increased enforcement effort in particular fisheries. If compliance alters (exogenously) in certain fisheries what are the costs and benefits. What are the impacts of increased penalties for violations of fisheries rules. How do different control schemes compare when the cost of enforcement is taken into account.

The appropriate theory of fisheries enforcement, referred to above, has been developed under work package 3.[1] All the estimations will be based on the data collection which is available under the deliverable for work package 2, which should be harmonized in work package 4. Finally all these estimations should be useful for work package 6, which will deal with the modeling part. This scheme is shown in Figure 1.1.

[1] The technical annex and the deliverable for all work packages completed can be found at the project website: http://cobecos.jrc.it/

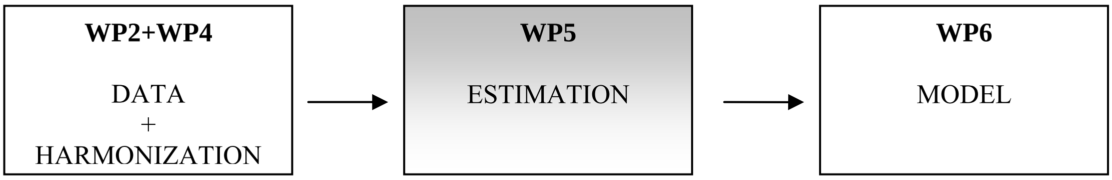

Figure 1.1. Main role of WP5 in the project.

Following the scheme WP5 should estimate:

(1) A fisheries benefit function.

This is basically a standard bioeconomic model involving a fisheries profit function and a fish stock growth function. Given that the development of a bio-economic model is not the aim of this project, some of the case studies will condition an existing one. Table 1.1 presents the bioeconomic model that has been used in each case study.

Table 1.1. Overview of software used for the Bio-economic model

Case Study	**Bio-economic Model**
Northern Hake	FLR
The Bay of Saint-Brieuc Scallops	"Ad hoc" Using Excel®
CCAMLR South Georgia/ Kerguelen	FLR (biomass dynamics)
Ligurian and Northern Tyrrhenian Sea bottom trawling fishery	R and FLR
Norwegian fisheries	"Ad hoc" Using Maple®
Icelandic cod fishery	"Ad hoc" Using Excel®, Mathematica® and Matlab®
Dutch beam trawl	FLR
Kattegat & Skagerrak nephrops fishery	FLR
UK South West fishery	FLR

(2) A fisheries enforcement cost function.

This function simply relates enforcement effort (along its various dimensions) to costs of enforcement. To estimate this function properly requires data on enforcement costs and enforcement effort. This has been provided in WP-4.

(3) A probability of penalty function

This function relates enforcement effort to the probability that a violation will entail a sanction. To estimate this function properly requires data on enforcement effort and the above probability of sanctions if a violation occurs. These latter data, while of course fundamental, are difficult to obtain. A major task of this project (WP-3 and WP-4) is to discover ways to obtain measures of this kind. In the absence of good numerical measures approximations to this function, based on qualitative and technical data will have to be employed.

In order to have a clear view of what has been done in the estimations of these functions in each case study, this report is being produced. The structure followed is to provide on case study basis, the estimations used as well as the alternative models tested (Part I of the report).

This will also be used as input in the Part II of the report which will provide a comparison between all the case studies.

Part I Case Studies

2. Northern hake

2.1 Authorship and affiliation

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2.2 Introduction

Since the mid 20th century, hake has been the main demersal species supporting trawl fleets on the Atlantic coasts of France and Spain. In recent years Spain has taken around 60% of the landings, France 30%, the UK about 5%, Denmark 3%, and Ireland 2%. In all these countries the main gear types used by vessels fishing hake as a target species are lines, fixed-nets and bottom trawls. In addition to these gear types, fishermen in France also use pelagic trawls and Spanish fishermen have recently (mid nineties) started using Very High Vertical Opening (VHVO) trawls.

Hake fishery is a very economically important fishery to Spain, France, UK and Ireland. In 2003, and in a very gross approximation, the value of the Hake TAC was estimated in not less than €90 m.

The main part of the fishery (close to 80 per cent of the total landings) was conducted in five Fishery Units, three of them from Sub-area VII: FU 4 (Non-Nephrops trawling in medium to deep water in Sub-area VII), FU 1 (Long-line in medium to deep water in Sub-area VII), and FU 3 (Gill nets in Sub-area VII), and two from Sub-area VIII: FU 13 (Gill nets in shallow to medium water) and FU 14 (Trawling in medium to deep water in Sub-area VIII) From the information reported to the Working Group, Spain accounts for the main part of the landings

Northern Hake is caught as part of a multi-species and multi-gear fisheries. Thus, several other species, some of them also of great economical importance, are usually caught together with the Hake. Some of them are routinely assessed by the ICES Working Groups and their catches are regulated by the TACs and Quotas system (Anglerfish,, Megrim, Sole, Nephrops Whiting, Cod, Horse mackerel…and others) but others not yet Cephalopods, Rays, Pouts…). The relative importance of these "other species" in relation to the Northern Hake is very variable depending on the country, fleet and sea area involved. In many cases, "the other species" represent a major importance in terms of incomes than the Northern hake for a particular country or fleet.

2.3 Description of the enforcement system

GENERAL OVERVIEW

Enforcement and control of fisheries is clearly influenced by the existing rights of the territorial waters. In the case of Spain, this sovereignty starts at the level of the Exclusive Economic Zone (200 miles) and has different levels depending on how close to the seaside is the sea (Figure 2.1).

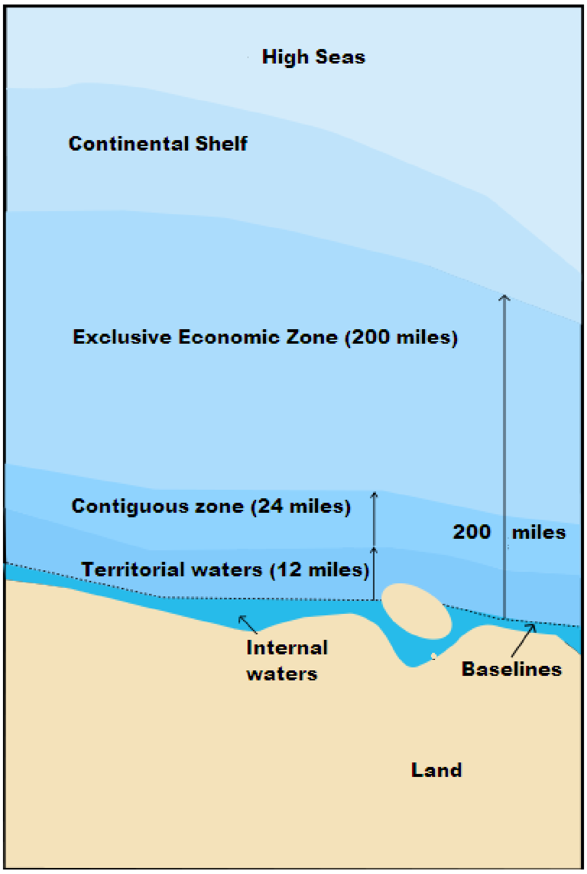

Figure 2.1. Different administrative segmentation of sea-areas

With that in mind Figure 2.2 shows the existing scheme of dependencies of the different levels of administrations inferring the system of control and enforcement of fisheries in Spain. Apart from the EU regulations, which give the general guides from control and enforcement, the central administration is the only with capacity of enforcing sea activities for the case of Northern Hake (hake within the baselines is under the control of the autonomous communities but it belongs to another stock (the so-called southern stock of hake), and both have the capacity of controlling and enforcing once the fish has been landed. In the case of the Northern Hake, four are the communities with competences (Galicia, Asturias, Cantabria and the Basque Country).

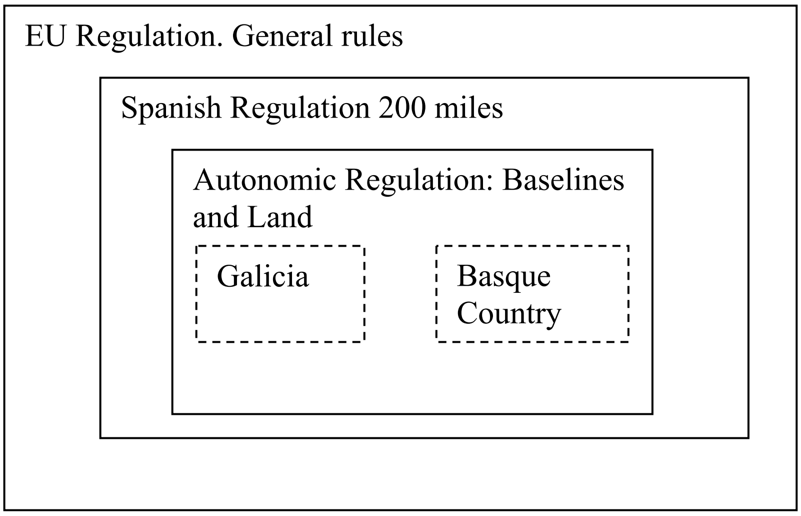

Figure 2.2. Spanish Control and Enforcement system

LEGISLATION

The Spanish Constitution currently in force provides for a division of competencies in several fields between the central state authorities and the 17 Autonomous Communities covering the whole territory of Spain. Concerning the field of fisheries, the central authorities have thus remained in charge of the management of sea fisheries, whereas fishing activities carried out in internal waters (within base lines) fall in the competence of the Autonomous Communities: this applies also to the adoption of legislation on these topics. The Autonomies are charged also of the ordination of the fishery including the regulation of the economic or productive fishery sector (specially regarding the stake holders, the fleet, the establishment of base ports and changes in the base) and the

first sale. This dichotomy has had a clear influence on monitoring and control responsibilities, as well.

On the central level, general rules for Spanish fisheries are provided by the 3/2001 law, of 26 March of the State Marine Fishery (Ley de Pesca Maritima). In this law the general rules for control an inspection in external waters are defined. The Royal Decision of 14 February 2003 (176/2003) regulates the exercise of control and inspection activities in marine fisheries.

ADMINISTRATIONS

Central Administration

The Ministry of Agriculture, Fisheries and Food (*Ministerio de Agricultura Pesca y Alimentación,* hereafter MAPA) is responsible for fisheries policies and legislation. Within MAPA, there exists the General Secretariat of Fisheries (*Secretaría General de Pesca Marítima,* hereafter SGPM) composed mainly of two general directorates, the Directorate General of Fisheries Resources (*Dirección General de Recursos Pesqueros*) and the Directorate General of Structures and Markets (*Dirección General de Estructuras y Mercados Pesqueros*). SGPM has thus responsibilities for planning, direction and co-ordination of fishery matters as well as for control and inspection. It acts as the control authority in vessel licensing matters and keeps the national fishing fleet register. In practice, the different directorates of the Directorate General of Fisheries Resources have been delegated the licensing competencies within SGPM, each directorate in its own field, whereas the Directorate of Fleet and the Fishing Structural Matters (*Subdirección General de Planificaicón de la Flota y Estrucutras Pesqueras*) within the other general directorate of SGPM takes care of the fleet register.

The data concerning the vessel characteristics is transferred to SGPM from the Ministry of Infrastructure (*Ministerio de Fomento*), more precisely its *Dirección General de la Marina Mercante*, responsible for the physical inspections of all Spanish vessels.

Whilst the headquarters of MAPA and SGPM are based in Madrid, MAPA maintains a direct presence in the coastal Autonomous Communities by the existence of *Delegaciones del Gobierno* (hereafter the delegations). Those are under the supervision of the Ministry of Public Administration (*Ministerio de Administraciones Públicas*), providing the support services required – salaries, vehicles, clerical help, office accommodation etc. However, the performance, competencies and responsibilities of the MAPA officials based in the delegations remain to a large extent under the direction of SGPM. Within the internal organisation of SGPM, one of the sub-directorates of Directorate General of Fisheries Resources, *Subdirección General de Inspección Pesquera*, forms the national fisheries inspectorate. Its headquarters and some of its inspectors are also located in Madrid, but the majority of the inspectors is positioned continuously to the said peripheral delegations in the Autonomous Communities.

Regional Administration

The administrative structure of most Autonomous Communities comprises fisheries inspectorates as well; at least some of their officials have been assigned to these tasks. However, owing to the autonomy granted to these entities, the arrangements currently in force vary.

COMPETENCES

According to the 3/2001 law the control responsibilities of the central administration (MAPA/SGPM) refer to:

- Fishing activities in waters outside of base lines. This includes the control of regulations about the fleet structure and vessel characteristics, licensing and conditions of fishing activity, but also about the marketing, protection and conservation of fisheries resources.
- The control of landing of catches before first sale or beginning of transport when fish is removed from the port of landing.
- The import of fish when the first sale or landing is not taking place in the auctions or ports.

The functions of the Autonomous Communities concern primarily:

- Fishing activities and regulations inside baselines.
- Aquaculture and the promotion and management of the fishing economic sector.
- Marketing control of fishing products after the first sale.
- Establishing its own competencies and basic rules for the management of the fisheries sector within its own territory.

With regard to fisheries matters the competencies transferred by central government imply that all Autonomous Communities have a similar level of legislation. However, not all Autonomous Communities have yet adopted common competencies in the fields of fisheries activity in the Spanish coastal areas.

Powers of control

The powers of Spanish fisheries inspectors (both national ones from MAPA/SGPM and those employed by Autonomous Communities) derive from the organic laws concerning the said institutions. The 3/2001 law, refers to the inspectorate as an entity exercising monitoring, inspection, surveillance and control functions on professional fisheries. In addition to this, The Royal Decision of 14 February 2003 (176/2003) contains provisions about the functions of inspection.

Follow up of infringements

The Spanish sanctioning system is predominantly relying on administrative penalties. When an offence is detected by the national officials, the local MAPA office prepares a file containing all the evidence and relevant legislation. This file is then submitted to MAPA/SGPM headquarters (or, for lesser misdemeanours, to the delegation), where it is decided on whether to proceed or not. If demanded, the owner/master of the vessel has either to pay the fine or to dispute the case in the courts.

The system of sanctions applicable to sea fishing in waters outside baselines belongs solely to the jurisdiction of the central national authorities. The Autonomous Communities are able to regulate, apply and to carry out sanctioning activities such sanctions in the areas where they have competencies (internal waters and ordination of the fishery as defined above).

The Law 3/2001 categorizes the offences in minor serious and extremely serious offences in articles 95The Law 3/2001 sets forward the sanctioning powers for the protection of the fishing resources and fixes the infractions regime in relation to administrative, fishing and marketing offences. Articles 107 and 108 of this law define the extent of jurisdiction of either the central administration or the Autonomous Communities. Pursuant to this law , (articles 96 and 97 in the case of external waters and in articles 98, 99 and 100 in the case of fishery ordination), the infringements are graded in three levels, and the competence to sanctions changes depending of the level of the fractions (article 107) :

- **Minor** offences are sanctioned by the delegations
- **Serious** offences are sanctioned by Directorate General of Fisheries

Resources);

- **Extremely serious** offences are sanctioned either by SGPM or by MAPA:; and

- All the offences regarding the **ordination of the fishery** are sanctioned by the Autonomous Communities

The sanctions are divided in different categories ranging from simple reprimands to fines and finally to the impoundment of the vessel. The fines for the different types of infringements (article 102) range from 60.10 € and 300 € in the case of minor offences from 301- to 60.000 in the case of serious offences and finally from 60.001 to 300.000 € for extremely serious infringements.

MONITORING, INSPECTION AND SURVEILLANCE

Waters under Spanish sovereignty or jurisdiction

Controls of all activity carried on in internal waters, i.e. inside baselines, are carried out by the inspectors from the Autonomous Communities. MAPA is concerned with all vessels fishing in international waters and the EEZ (or Mediterranean protection zone) outside these internal waters.

International and third country waters

A number of measures have been taken to monitor fishing activities in waters outside the Spanish EEZ. A mutual exchange of inspectors with Morocco has taken place in the ports of Las Palmas and Agadir, as part of the EU-Morocco Agreement. Co-ordination of maritime patrols has undergone with France, Ireland, United Kingdom and Portugal on fishing grounds of common interest; this has been especially important with ICCAT during the albacore fishing season. Via MAPA the Spanish Navy will continue with a commitment to undertake fisheries patrols in NAFO and recently also NEAFC Regulatory Areas.

Landings

There are 15 coastal MAPA offices based in the main landing ports. Their main role is to make controls on fish appearing in the auctions, transport documentation and on vessels discharging. A designated ports system is not applied, so controls can only be made on an opportunistic basis. MAPA’s competencies are limited up to the first point of sale. Inspectors from the Autonomous Communities are generally present on all auctions and in landing ports but are primarily concerned with controls after the first point of sale.

Marketing and transport

In Spain the competencies for controls of the Common Market Organisation in fisheries are shared between MAPA, in particular SGPM, at the national level and the Autonomous Communities at regional level. All activities that are performed after the first sale of fishing products are the exclusive competence of the Autonomous Community within whose areas these activities occur, or alternatively of each City (Municipal) Council. In practice the majority of the Autonomous Communities do not have the resources to implement the existing extensive rules about these matters. In Spain there are thirty-eight Producer Organisations. Fifteen of these have been recognised on the national level (mostly concerned with aquaculture, frozen products and tuna) and the 23 remaining ones at the level of the Autonomous Communities. The POs are responsible for the operation of the intervention regime. According to MAPA it is the responsibility of the POs to assure that the grading and sorting of catches is adequate. Both the withdrawal and carry-over scheme are applied in Spain as is the allowance for tuna processing. No private storage aid scheme is in operation. The Autonomous Communities operate the different schemes. In Spain no prosecutions have taken place for infringements of the various market regulations.
Transport documentation of overlanded fish is checked systematically. Several offences have been cited for infringements. The Spanish authorities consider logsheets and accompanying T2M documentation as satisfactory.

MEANS OF CONTROL

The MAPA/SGPM inspection service had a total of 46 fisheries inspectors in 1999 but this number has increased during last years until it reached 91 inspectors in 2006. However, in 2003 the national authorities assessed the required number of inspectors as 139. The Autonomous Communities nationally employ some 250 inspectors.
Some of the vessels of the Spanish Navy and some light patrol vessels of *Guardia civil* are available to MAPA. Additionally, some of them are dedicated exclusively to fishery inspection. The number of this vessels dedicated to the inspections has increase from 8 to 11 since 2003. In 2006 the SGPM owned four helicopters based in

Santander, Jerez (Cádiz), Coruña and Alicante and also four aircrafts are at MAPA's disposal, too. The Autonomous Communities avail of 78 light patrol vessels of all sizes as well as 6 helicopters and one light aircraft, the latter ones all hired.

The assessment and final collation of the national catch registration is made by MAPA in Madrid. The whole system is based on information received from either the port auction centres, offices of the port authorities or the Autonomous Communities. Although the data obtained from logbooks/landing declarations is entered into the system at port authorities by personnel specifically dedicated to these tasks, the MAPA offices in the ports are not directly involved in submitting landings data from either sales note or logbook/landing declaration sources. Details of fishing effort in western waters are aggregated monthly by vessel, based on hail messages. The primary sources of calculations for MAGP fishing effort are the Producer Organisations and other vessel owners associations/federations (*cofradias*) who supply this information to MAPA/SGPM.

The Spanish Fisheries Monitoring center is situated in the offices of the inspectorate in Madrid. In 1998 and 1999, Spai set up its VMS, and all the vessels fishing northern hake (the 300 fleet) is equipped with VMS.

COORDINATION AND COOPERATION

Various efforts have been made to strengthen co-operation between the national authorities and with international partners for the monitoring of fisheries activities.

Cooperation at national level

In order to improve co-operation between the competent authorities, a framework agreement was concluded between MAPA and the Ministry of Home Affairs *(Ministerio del Interior).* By this agreement, joint operations of inspection, control and surveillance can be carried out by the combined maritime and airborne services of MAPA, *la Guardia Civil* and the Autonomous Communities regarding the control of catching and landing of fish, minimum sizes and the transport and marketing of fish. – Moreover, an agreement exists about annual programmes for the integrated monitoring of fisheries activities (*Programa Annual de Control Integral de las Actividades Pesqueras – PACIAP)*, covering the inspection and monitoring of fisheries activities by *Guardia Civil´s* Maritime Service. Co-operation between the appropriate services within the Autonomous Communities has included the exchange of information and joint monitoring in inshore waters, ports and roads of the marketing of undersize fish. Liaison and co-ordination between MAPA for aerial surveillance and the Naval Service for sea-borne inspections has been developing.

Cooperation at international level

Internationally noteworthy occasions include a tripartite co-operation agreement between the fisheries authorities of Ireland, United Kingdom and Spain for the monitoring of landings in Spanish ports by British and Irish fishing vessels. The UK authorities have also been contacted on the exchange of information concerning landings in British ports by Spanish vessels and vice-versa. A mutual exchange of inspectors has also taken place with Morocco in the ports of Las Palmas and Agadir, as part of the EU-Morocco Agreement.

Maritime patrols have been co-ordinated with France, Ireland, United Kingdom and Portugal on fishing grounds of common interest. This has been especially important within ICCAT during the albacore fishing season. Joint inspections were carried out in the years 1996-1998 with Italy, as well, within a common programme for the control of driftnet fisheries in the Mediterranean Sea area. Also within the NAFO framework, the coordination and exchange of information about inspections has been lively.

CONCLUSIONS

Different administrations take part in the control and enforcement in the case of Northern Hake. Firstly, the EU regulations give the general guides from control and enforcement. Secondly, the Spanish central administration, and more concretely the SGPM of the MAPA, has exclusive competence enforcing sea activities in the case of north Hake. Finally, both the central administration, and the autonomies of Galicia, Asturias, Cantabria and Basque Country, have the capacity of controlling and enforcing once the hake has been landed.

The assessment and final collation of the national catch registration is made by MAPA in Madrid. The whole system is based on information received from either the port auction centres, offices of the port authorities or the Autonomous Communities. Although the data obtained from logbooks/landing declarations is entered into the system at port authorities by personnel specifically dedicated to these tasks, the MAPA offices in the ports are not directly involved in submitting landings data from either sales note or logbook/landing declaration sources. The primary sources of calculations for MAGP fishing effort are the Producer Organisations and other vessel owners associations/federations (*cofradias*) who supply this information to MAPA/SGPM.

The Spanish Fisheries Monitoring Center is situated in the offices of the inspectorate in Madrid. In 1998 and 1999, Spain set up its VMS, and all the vessels fishing northern hake (the 300 fleet) is equipped with VMS.

The Spanish sanctioning system is based mainly on administrative penalties. According to the aforementioned competences, the central administration is charged of all the sanctions in waters outside the baselines, while the autonomous communities are able to regulate, apply and to carry out sanctioning activities in internal waters and once the hake has been landed.

2.4 Data used

In order to achieve the objectives of COBECOS, we have made a great effort to obtain information. Although other aspects of the Northern hake fishery have been deeply studied, this is the very first time that information regarding control and enforcement for this fishery has been compiled.

There have been two main axes in which we have worked:

- Compilation of documents regarding control and enforcement in Spain (See table). We have made a deep search in internet. Thanks to this search, we have obtained information regarding the control and enforcement systems of fisheries in Spain.
- Contacts and meetings with the authorities involved in fisheries control and enforcement in Spain (See table). These authorities, had helped us in two different ways[2]:
    - In the meetings they had helped us in better understanding the enforcement and control systems in Spain, and more concretely the specific problems for the northern hake study

[2] We are grateful to Jose Navarro and Sonia Ruiz, from the Fishery inspectorate form the Spanish Fishery Secretariat for welcoming us and for the effort they have made to provide us with the information regarding northern hake.

- o They had supplied us with documents and data bases between 2005 and 2007. It has been possible to obtain specific data for Northern hake control only in 2007 (see table). However, we have found a relation between the information regarding Northern hake fishery in 2007, and the information of the entire fishery's taking place in the ports with northern hake fishery. In this way, as we had data regarding all the fisheries in these ports in 2005 and 2006, we have used the relation from 2007, to extrapolate the information of the northern hake fishery in 2007 to 2005 and 2006.

Although we have some information regarding the cost of the serious sanctions, we have not used this information. It has not been possible to split the sanctions regarding northern hake fishery, and we have not found any reference to be able to extrapolate this information.

Table 2.1 Information compiled for the COBECOS Project: enforcement and control in the Northern Hake study.

DOCUMENT	YEARS	SOURCE	CONTAINS	AREA	USED FOR
Fisheries control in member states (SPAIN) Commission staff working paper.	1996-1999	Internet http://ec.europa.eu/fisheries/legislation/reports_en.htm#other	Comprises the Member State descriptions of fisheries control and of the fisheries-related activities	Spain	Elaborate the document: *Review of control and Enforcement systems of fisheries in Spain: Northern Hake Case Study* and fill out the information regarding northern hake case in the project web
3/2001 law, of 26 March of the State Marine Fishery (Ley de Pesca Maritima).	-	http://noticias.juridicas.com/base_datos/Admin/l3-2001.html	General rules for control an inspection in external waters	Spain	
The Royal Decision of 14 February 2003 (176/2003)	-	http://noticias.juridicas.com/base_datos/Admin/rd176-2003.html	Regulates the exercise of control and inspection activities in marine fisheries.	Spain	
Average fine by type of behaviour	2003-2005	Internet http://ec.europa.eu/fisheries/cfp/control_enforcement/scoreboard/archives/scoreboard2005/control_en.htm	Comprises "serious" infringements detected by member states and sanctions imposed.	Spain	Fill out the information regarding northern hake case in the project web
Average fine by type of behaviour	2006	Document sent by Isabel Artime, (sub directorate of fishery regulation from the Spanish fishery secretariat)	Comprises "serious" infringements detected by member states and sanctions imposed.	Spain	
Annex to the report from the commission to the council and the European parliament on the monitoring of the member states' implementation of the common fisheries policy	2003-2005	Internet http://ec.europa.eu/fisheries/legislation/reports_en.htm#other	- Fishing Activity - Inspection resources and activity - Catch registration - Operational authorities	Spain	
Study of the impact and feasibility of setting up a community fisheries control agency	2002	MRAG	Information regarding the cost of surveillance	Spain	
Memoria anual de las actividades de inspección y vigilancia de la pesca marítima	2005-2006	Document sent by Sonia Ruiz, fishery inspector from the Spanish fishery secretariat	- Fishing Activity - Inspection resources and activity - Catch registration - Operational authorities	Spain	- Fill out the information regarding

					northern hake case in the project web
Interview in the Fisheries inspectorate from the Spanish fishery Secretariat	2007	Interviews with Jose Navarro (sub directorate of fishery inspectorate) and Sonia Ruiz (Fishery inspector)	In this meeting we obtained information regarding fisheries control in Spain. Additionally, after the meeting they send us information regarding,: - The cost of human resources - The number of inspections - The number of infractions - Cost of the VMS	North ern hake	Data from 2007 in the *enforcem ent fishery* document in the share point
Overview of inspections	2007	Document sent by Sonia Ruiz, fishery inspector from the Spanish fishery secretariat	Number of inspections and infractions in each port. – Using this document, we have found a relation between the Northern hake data in 2007 and the data of the entire fishery in the rest of the ports in 2007. As we have the data regarding all the ports in 2005 and 2006, (*Memoria anual de las actividades de inspección y vigilancia de la pesca maritima), w*e have used this relation to estimate the information regarding northern hake during 2006 and 2006	Spain	Data from 2005-2006 in the enforcem ent fishery document in the share point

2.5 *Estimation of theoretical relationships*

2.5.1 Probability of penalty function

It is defined as the relationship between the enforcement effort and the probability that a violation will entail a sanction. A possible penalty probability function ($\pi(e)$) can be defined as follows:

$$\pi(e) = p(S \mid V) = p(C \mid V) \cdot p(S \mid V \cap C) \tag{2.1}$$

where,

- *e*: Number of control actions (control effort) that have been measured as number of trips inspected.
- p_V: Overall probability of violation, $p(V)$.
- $p(C)$: Probability of being controlled.

A simplification of this approach is when it assumed that all the detected infractions are sanctioned: $p(S \mid V \cap C) = 1$, and hence:

$$\pi(e) = p(C \mid V) \tag{2.2}$$

Before estimations are made it should be remembered that enforcement effort is a vector of enforcement actions e=(e_1, e_2, e_3,..,). This consideration is important given that two important characteristics of these functions should be:

- When the enforcement level is zero (e_i=0) $p(S \mid V) = 0$. If it is not zero it could be the case that the violation is revealed by some other enforcement action.

Models like,

$$\pi(e) = a + be_i \tag{2.3}$$

or

$$\pi(e) = a + b \ln e_i \quad (2.4)$$

where a>0 imply that the violation is revealed by some other enforcement action, while if a=0, that is a model like,

$$\pi(e) = b \ln e_i \quad (2.5)$$

implies that the infraction is being revelled by the explanatory enforcement action.

- When the enforcement level is 100% (*e=total trips*) $p(S \mid V) = 1$ and then infractions are equal to sanctions. This is based on the assumption that if a violation is made and the trip is inspected the violation will be revealed. In this case we will have that equation 10 becomes.

$$\pi(e) = \frac{Infractions}{Inspections} \quad (2.6)$$

We have adjusted functions (2.3, 2.4, 2.5) of this probability to the existing data (the inspections made in the Spanish ports in which northern hake is landed)

Table 2.2. Results form the estimation of the probability of being sanctioned

Model	$\pi(e) = a + be_i$	$\pi(e) = a + bLn(e_i)$	$\pi(e) = bLn(e_i)$
a	0.0168060	-0.40441	0
p-value	0.53595	0.00831	-
b	0.0005304	0.09990	0.022043
p-value	0.00365	0.00182	3.6e-09
R^2	0.546	0.6024	0.9587
p-value (Model)	0.00365	0.00182	3.601e-09

As it can bee seen the best fit is obtained when Equation 2.5 is used, which also implies that the enforcement action is capturing the infractions made.

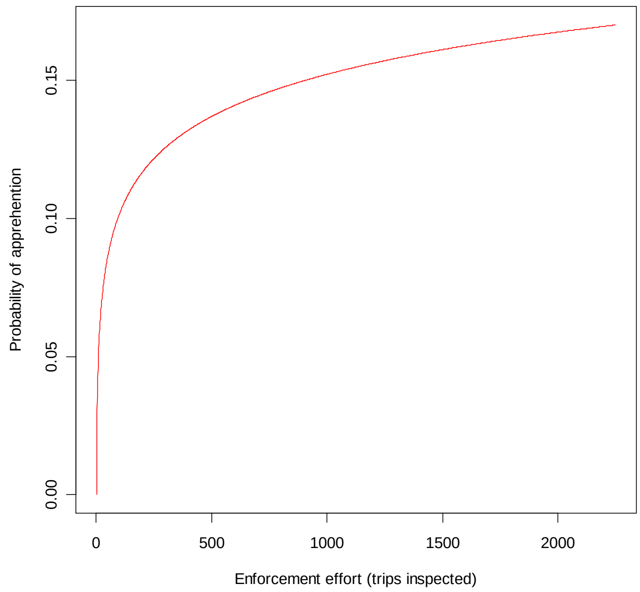

Figure 1.3. Estimated probability of being apprehended

Equation 2.5 is also capturing the issue that when all the trips are enforced it converges to equation 2.6. The estimated probability using the functional form is 0.16 while the observed mean is 0.17.

2.5.2 Enforcement cost function

To determine the shape of the cost of enforcement is not an easy task since the values observed present a linear relationship between the cost and the enforcement effort. In a first approach this relationship has been used. A further work should try to infer an exponential relationship between cost and effort (i.e., for large level of effort the cost should increase exponentially).

Following the linear approach we can obtain a variable cost of 1470€ per inspection. This value is reflecting the cost of inspection for northern hake, given that there has been some specific inspection to his stock in order to comply with the northern hake recovery plan.

Some other costs have been also obtained regarding the VMS costs

Table 2.3. VMS costs for the 300 fleet

	Total 2007	**Total 2006**	**Total 2005**
Personal	27573	28013	29187
Maintenance	14553	14785	15404
Communications[1]	90160	90160	90160

1. Costs are only for 2007 and we assume equal for the rest of the years.

2.5.3 Benefit function.

a) Private Benefit function

Private benefits follow the idea presented in theoretical memorandum 1.

$$\begin{cases} B(h,x) - \pi(e) f \cdot (h-h^*) & \text{if } h>h^* \\ B(h,x) & \text{if } h \leq h^* \end{cases} \qquad (2.7)$$

where *h* stands for harvest, *x* biomass and *h** for the “desired” target.

In this case it should be taken into account that fines are applied to a single infringement, that is, docks inspectors what they control one trip. It implies that in order to put everything in the same units (*h-h**) has been converted into fishing trips.

For doing so we assume average values and hence

$$(h-h^*)/(\text{average trip harvest}) = \text{trips with infringement} \qquad (2.8)$$

b) Social Benefit function

Given that one of the control variables of the problem is the enforcement level, the statement of the simulation has to be done following this idea.
Social benefits will follow the following rule:

$$(B_q(q,x)-\lambda)\cdot Q_e(e,f,x)=C_e(e) \tag{2.9}$$

It implies that the social benefits will follow the rule:

$$\begin{cases} B(h,x)-\lambda h - C(e)+ \pi(e)\cdot f\cdot(h-h^*) & \text{if } h>h^* \\ B(h,x)-\lambda h - C(e) & \text{if } h\leq h^* \end{cases} \tag{2.10}$$

But now:

$$\underbrace{B(h,x)-\lambda h}_{\text{Observed}} + \underbrace{\pi(e,t) * \text{Fine}}_{\text{Real}} * \underbrace{(h(t)- h^*)}_{\text{Observed}} \tag{2.11}$$

B(h,x)-λ h is just the idea that the inspectors have of the population (fleet +stock) and it is just an approximation of the real one, the same happens with the shadow value of the biomass[3], which is just an approximation of the real one.

[3] It stands for the change in the present value of future profits in the fishery from a one unit increase in catches.

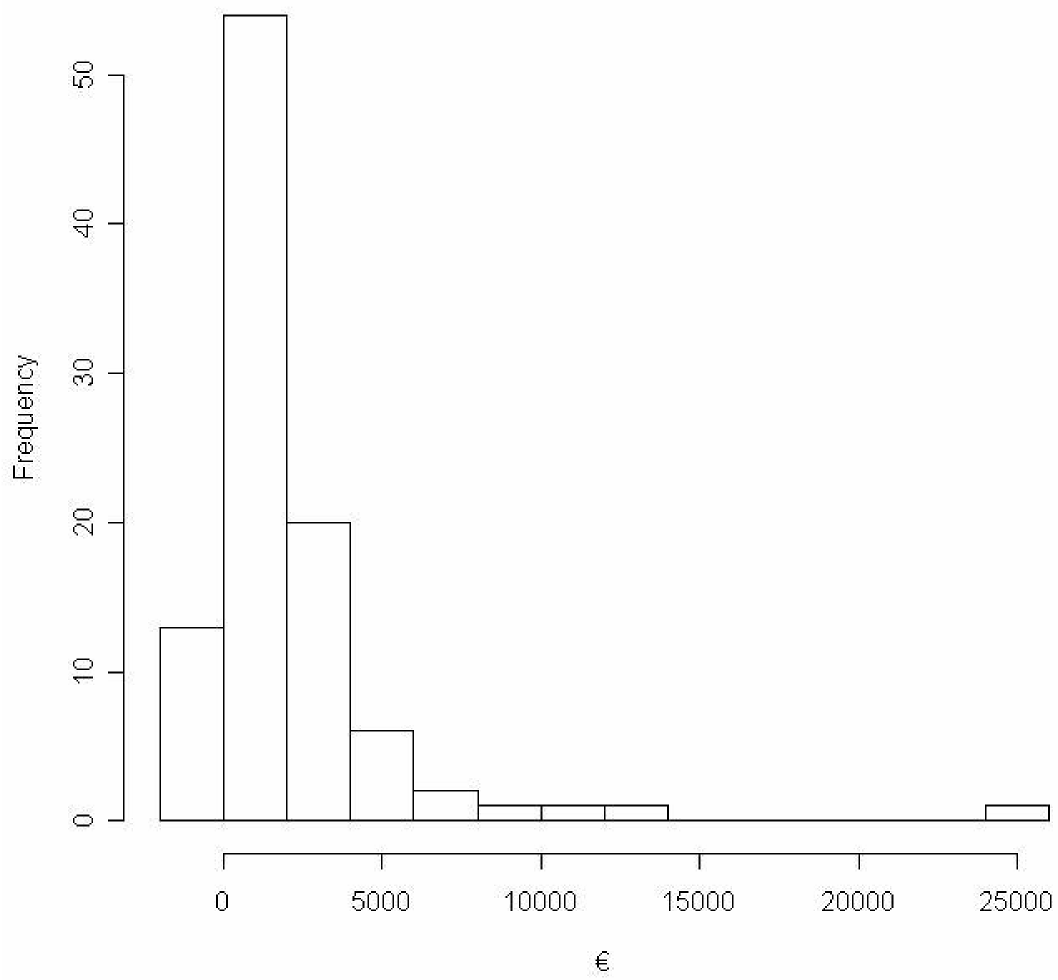

Figure 2.4: Distribution of the shadow value in the simulations

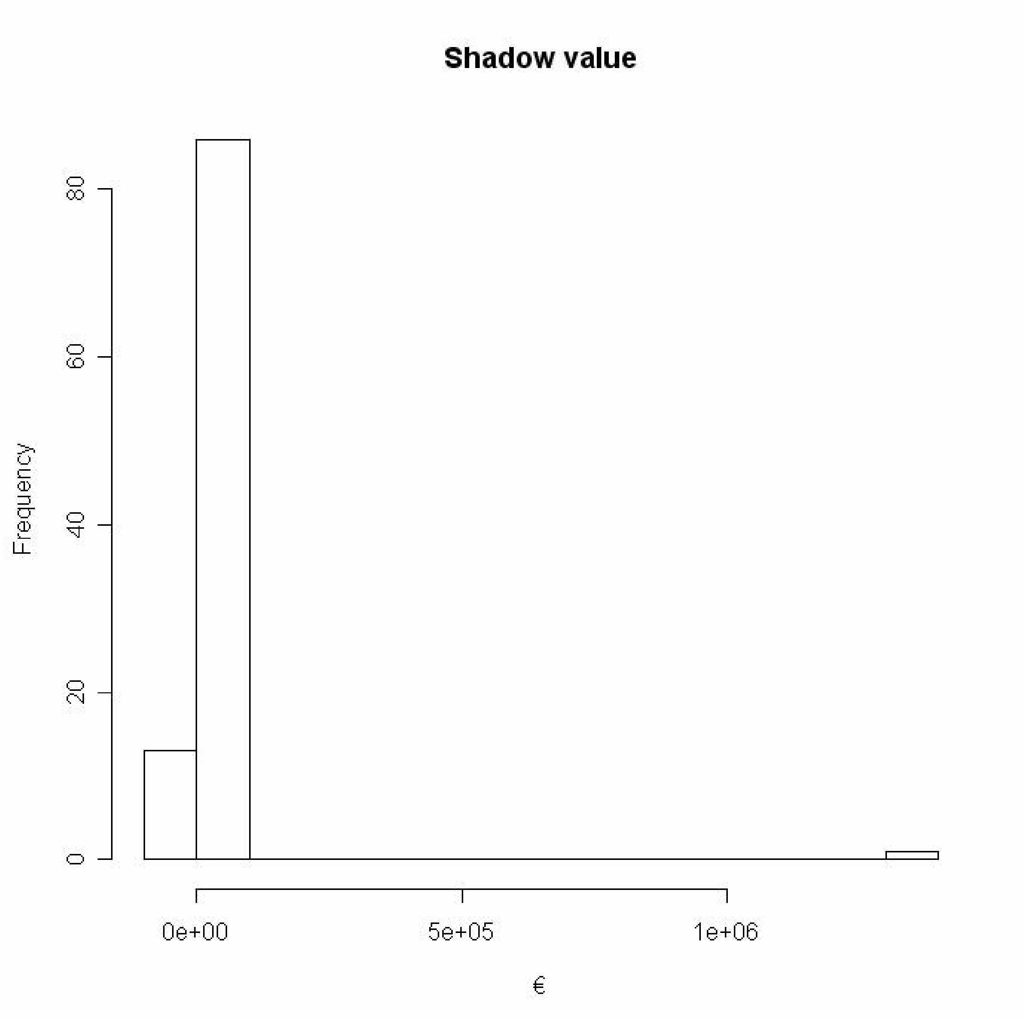

Figure 2.5: Distribution of the shadow value in the simulations with all iterations

The way of calculating the shadow value is to increase the catch in one unit respect to the desired one at the start of the simulation. Given that we are performing an age structured model, this unit value is increased proportionally to the current age structure of the catches (landings). Then the present value of the landings are calculated[4] and compared with the original one. The difference will be the shadow value of hake. Estimations show that this value is 1229€/tonne. The negative sign implies a stock effect.

[4] We have fixed the end of the simulation in year 2040.

2.6 Conclusions

The estimation procedure has been successful in terms that with the estimations obtained it as been possible to calibrate the past behaviour of the fleet.

The main problem encountered are in the estimation of penalty probability function which is has been done based on the observed enforcement effort. It implies that in the simulations if this enforcement level is increased the results will be based just on a theoretical functional form, since we are predicting in outside the range of observation.

In terms of the shadow value of the biomass, the main problem comes from the uncertainty given that some iterations generate extreme values of the biomass. In order to obtain a reliable value of it, these extreme iterations have been removed in the final value used.

3. The Bay of Saint-Brieuc Scallops

3.1 Authorship and affilation.

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3.2 Introduction

The Saint Brieuc scallop fishery is located within the western part of the English Channel (ICES area VIIe). This is one of the two major scallop producing areas in France, the other being the Seine Bay. Annual official landings reached around 8,500 tons in 2006, whilst national production fluctuating around 23 000 tons in 2006. Recent fraud estimates vary between 20% and 30% of total official landings. Non-compliance is thus a major issue in this fishery. This feature is reinforced by two factors. First, the cost of enforcement is already considered to be significant (between 2.5% and 5% of the total turnover – Guyader and Fifas, 2006[5]); second, the cost of enforcement is partly internalised through a licence fee.

The area is exploited by dredging vessels from the maritime districts of Northern Brittany. The fleet is composed of small units with an average length of 10.6 meters and 127 kW of engine power (2006). These multipurpose fishing units use different types of gear (trawls, nets, lines and pots), especially outside the scallop official landings season. The scallop turnover has oscillated between EUR 4.5 and 15 million (base 1995) over the last 20 years, and the fishery is a structuring activity for the coastal fleets in this area.

[5] Guyader, O. and Fifas, S., 2006, « La pêcherie de coquilles Saint-Jacques de la baie de Saint-Brieuc: tendances d'évolution et éléments de réflexion sur son mode de gestion ». AMURE Seminar, Brest, 5 January 2006.

Although the fishery is not shared with other European countries, it is currently managed under a European regime (special fishing permits). This case study can be considered as relevant for the Common Fishery Policy (CFP) because it deals with the exploitation of a sedentary species, making lessons to be easily transferable to other similar clams-like fisheries all over Europe. It is also interesting because the fishery is managed under a specific system of input regulation, based on non-transferable quotas of fishing effort (fishing hours). This may have some key implications regarding the cost-effectiveness structure of the enforcement activity. Here again, lessons learned from this case study can be of direct interest for the CFP.

3.3 Description of the enforcement system

In France, the Ministry of Agriculture and Fisheries is the main body in charge of fisheries control. For the implementation of its control strategy, the Ministry may also be supported by services of other ministries with complementary competences, attributions and means (See Charts in the presentation of the case study – WP2). The first one is the Directorate for Maritime Affairs under the authority of the Ministry of Ecology, Sustainable planning and development. Others ministries are also involved in the surveillance and control of French fisheries, in particular the Ministry of Defence in charge of the military personnel and equipment (this includes the Navy and the Gendarmerie). The maritime prefect (Préfet Maritime) is the direct representative of the Prime Minister for the State at sea, and has authority over all Ministries to mobilize any needed maritime means.

At regional level, there are three decentralised bodies, depending on the ministry of ecology, sustainable planning and development, involved in MCS activities:

The Regional Directorate for Maritime Affairs (Directions Régionales des Affaires Maritimes-DRAM) at NUTS II level (14 DRAM in France),
The Regional centers for operational surveillance and rescue (Centres Régionaux Opérationnels de Surveillance et de Sauvetage-CROSS) at NUTS II level (5 CROSS in France),

The Departmental Directorate for Maritime Affairs (Directions Départementales des Affaires Maritimes-DDAM) at NUTS III level (25 DDAM in France).

The DRAMs are in charge of the implementation of control strategies. Ashore, they coordinate inspections; at sea, they coordinate the action of the CROSS. The DDAM, under the authority of the maritime prefect, is responsible for most for the inshore surveillance. DDAMs have at their disposal the coastal units of the maritime affairs' administration (ULAM - Unités Littorales des Affaires Maritimes).

As the fishery studied is located inside the territorial waters, the enforcement activity is mostly conducted by the Maritime Affairs administration, especially the coastal unit (Unité Littorale des Affaires Maritimes - ULAM) of Côtes d'Armor. Its operational means are (2007):
The aircraft, for enforcement of time limits and restrictions of scallop fishery6,
1 patrol boat (11,9 meters long)
2 zodiacs (115 CV)
3 vehicles
9 officers and 1 coordinator

Other public administration's services are involved to a less extent in scallop fishing controls: Gendarmerie maritime and Gendarmerie nationale, Customs, Veterinary services, Frauds squads. The nature of the means used and the level of implication are presented in the table 1 below (table 3.1).

[6] The operational cost of hiring the aircraft is supported by the fishers themselves, through the regional committee for fisheries.

Table 3.1. Means and involvement in scallop fisheries control

2007	Origin of means	Nb	Implication in scallop fisheries control
Vessels taking part in control of the inshore fishing	*Affaires maritimes – ULAM*	3	++++
	Gendarmerie maritime	2	+
	Gendarmerie nationale	2	++
	Customs	1	+
Aircraft taking part in fishing monitoring	Aircraft, hiring supported by the fishers	1	+++
Inspectors involved in MCS	*Affaires maritimes*	10	++++
	Gendarmerie maritime	11	+
	Gendarmerie nationale	6	++
	Customs	4	+
	Frauds squads	4	+
	Veterinary services	3	+++

Source: DDAM 22

Three enforcement methods were selected for the case study: controls at sea, aerial controls and controls at quay. Each method focuses on a set of management parameters to be controlled, which varies from one method to another:

Aerial control: authorisation to fish and fishing time,

Control at sea: almost all parameters (licences, gear type, fishing time, catches, logbook)

Control at quay: mainly the landing size and the logbooks;

3.4 Data used

The data used to document this case study were provided by the Administration, the scientific institute Ifremer and the professionals.

- Administration – national level (direct interview): data on the enforcement budget "managed" by the Directorate of Maritime Affairs. Global figures for 2007.

Note: Access to annual national report to the EC regarding enforcement operation has been denied up to now.

- Administration – regional level (direct interview): data on the enforcement budget "managed" by the DRAM. Global figures for 2007.
- Administration – local level (direct interviews + tables):
  - Enforcement activity of the DDAM 22 (Department of Côtes d'Armor) per category – 2006,

- Total number of statement detected by ULAM 22 – data set from 1997 – 2003,
- Enforcement costs for ULAM 22 (operational costs) for years 2001-2002 and 2007-2008,
- Number of infringements detected by air surveillance (2003-2006)
- Interview: evolution of offences and enforcement effort during the past decade (to be completed)

Administration – “inter-regional” level (CROSS):
Data on control activity at sea and detected offences. Time series: 1998-2007
Data on control activity at quay and detected offences. 2006-2007

Côtes d’Armor Department’ Development agency (Côtes d’Armor Développement – CAD22): production and fishing effort data. Data set from 1962-2006

IFREMER:
Biomass, production and fishing effort data. Data set from 1986-2007
Fraud estimates: 1991-1996 and 2002-2007 period (averages)

Professionals:
Cost of air surveillance (average figures for 2006-2007) + Number of inspections by air (2003-2006)
Fleet characteristic (2006)
Interview7: fraud estimates

[7] A field survey was conducted during the year 2007. The results are available at http://www.gdr-amure.fr/

3.5 Estimation of theoretical relationships

3.5.1 Benefit function.

a) Private Benefit function

The estimation of the private benefit function within fishery enforcement general model is derived from those presented by Arnason (Memos, WP2). Private benefits from fishing are given by:

$$B(q,x)=p.q-C(q,x) \tag{3.1}$$

where q represents landings, p the price of landings, x the biomass level, C(q,x) the fishing cost function.

In our case (as in the Channel case for example), we supposed the fishing cost function to be quadratic. Then, we assumed it to be strictly convex in q and x, increasing in q and decreasing in x.

$$C(q,x)=\frac{c.q^2}{x} \tag{3.2}$$

Then, equation (3.1) can be written:

$$B(q,x)=p.q-\frac{c.q^2}{x} \tag{3.3}$$

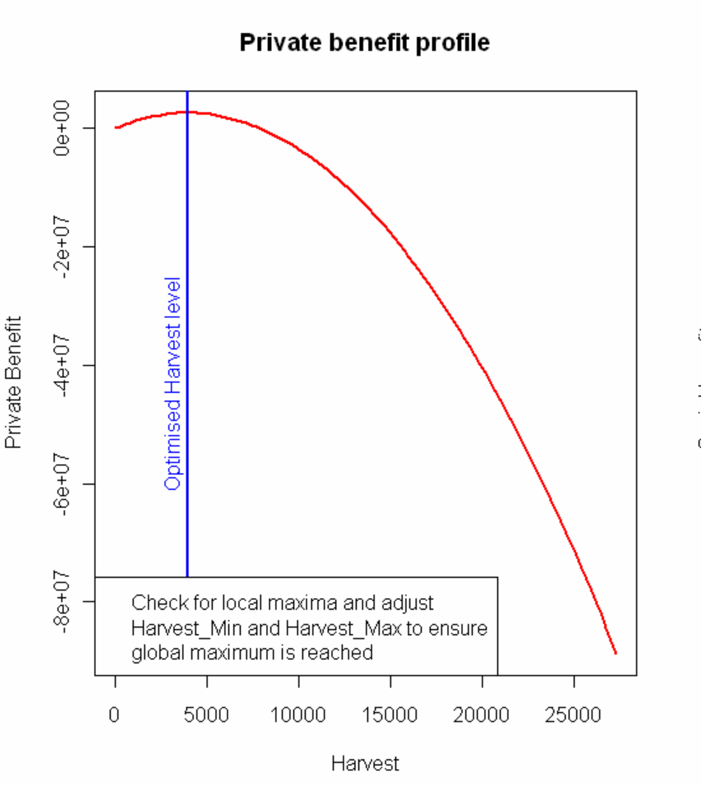
where *c* is a cost parameter estimated from observed cost data. The parameter estimates are presented in Table 3.2.

Table 3.2. Parameter estimate – private benefit function

Parameter	**Value**	**Source**
p - price	1 980 per tonne	Landings database (CAD22)- 2006
c – cost parameter	4 563 per tonne	Accounting sheets - 2006
x - biomass	27360 (tons)	S.Fifas (Ifremer) - 2006

Using the COBECOS model (version 1.5), the private benefits function is given by the figure 3.1

Figure 3.1. The Private Benefit function (benefits versus harvest). (In this case only illegal harvest)



The private benefit estimated is 2.6 million € corresponding to an optimised harvest level of 3 959 tons. For calibration purpose (see WP7), this has to be compared with observed profits and catches, respectively 2.6 million € and 7 500 tons.

b) Social Benefit function

The estimation of the social benefit function within the fishery enforcement general model is based on those presented by Arnason (Memos, WP2). Social benefit from fishing is given by:

$$B(q,x)=p.q-\lambda.q-C(e) \tag{3.4}$$

where C(e) is the enforcement cost function and λ the appropriate shadow value of biomass. In this case, it has been defined as the marginal benefit of fishing. Then, λ is:

$$\lambda = p - C_q(q,x) \tag{3.5}$$

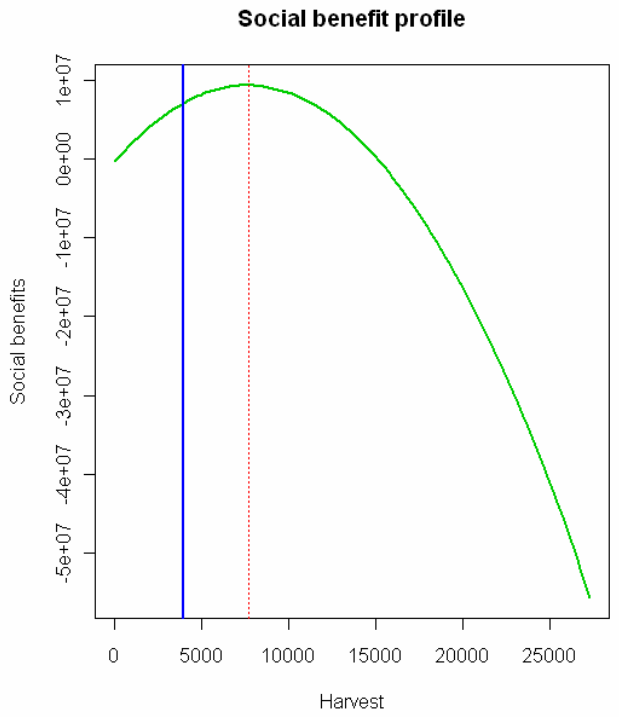
where Cq(q,x) is the partial derivative of the cost function of fishing. Then, in our case:

$$\lambda = p - \frac{2.c.q}{x} \tag{3.6}$$

Using 2006 data, the shadow value of biomass λ = - 564 (€/tons). This negative value reflects the relative abundance of the biomass in the recent years.

The cost of enforcement (C(e)) estimates are provided below. Using the Cobecos model (version 1.5), the social benefit versus harvest (including the optimal fisher response harvest) are shown in figure 3.2:

Figure 3.2.The Social Benefit function (benefits versus harvest). ((In this case only illegal harvest))



Hake@Effort<-c(0.48,0.01,0.01)

Hake@Price<-1980

Hake@ShadowVB<--564

Hake@Fine<-4000

Hake@FCost<-4563

Hake@Biomass<-27360

Hake@UnitTax<-0

Hake@Harvest<-7505

Hake@TotalCost<-472291

The social benefit for a harvest of 3959 tons is 7074773 €.

3.5.2 Enforcement cost function

Methodology:

Based on extensive interviews with stakeholders, estimates of direct control costs (or operational costs) are firstly presented. These estimates cover:

- running costs (100% of oil and lubricant costs and 80% of the maintenance cost)
- direct wage costs, based on the time spent for control activities.

In a second step, an evaluation of indirect costs is proposed. This covers mainly:

wage costs associated to control activities, that can not directly be linked to one type of control (e.g. reporting, meeting, training, etc.),

capital costs: depreciation costs and 20% of maintenance costs.

Estimates of enforcement cost functions are then presented using the COBECOS software, where indirect (fixed) costs are taken into account.

3.5.2.1. Air surveillance

The operational cost of hiring the aircraft and the wages of the pilot are supported by the fishers themselves, through the regional committee for fisheries. In 2006-2007, these costs were 23,267 € for 122 hours (i.e. 190 €/ hour) or for 53 surveillance trips. . With the assumption of 100 controls conducted during one surveillance trip, the cost per control operation is estimated to be: 4.39 €.
In addition, wage costs are supported by the administration8, as the control is conducted in the plane by one official. It is estimated that for each aerial trips, the officer is spending at least one and a half day including one day of preparation, reporting and debrieffing. Based on the annual wage cost of an inspector (41 500 €, source DRAM), a cost of 2.90 euros per operation of control was derived.

As a result, the average cost for a surveillance control operation is around 7.28 euros. Assuming 100 controls conducted during one surveillance trip, the average variable cost per trip is around 728 euros.

For years 2006-2007, the number of aerial trips is 53, and according to estimates, the total annual direct cost would thus be around 35,600 euros.

3.5.2.2. Inspection at sea[9]

The costs associated to the controls at sea can be divided into three main categories: oil, repairs and maintenance (including depreciation costs) and wage costs. For the Maritime Affairs administration only, the corresponding budgets for the year 2008 were:
13,500 euros: average annual budget for oil and lubricant, 11,000 euros: annual budget for maintenance (80% considered as variable).
On average, a control implies 3 officials (2 days full time equivalent, incl. preparation and debriefing).

[8] Maritimes Affairs is the only administration involved in aerial controls.
[9] Data for section 1.5.2.2 and 1.5.2.3 are derived from extensive interviews with the Administration.

Based on the activity figures from the Maritime Affairs (112 at sea controls for 2006[10]), an average costs of 780 euros can be estimated for a control at sea.

Taking into account the other administrations involved in controls at sea[11] ,,in addition to Maritime Affairs, the number of operations at sea is around 125 (see below). Using the average cost of 780 euros per control, the average total annual variable cost for this enforcement method would thus be around **97,300** euros.

3.5.2.3. Inspection at quay

The costs associated to the controls at quay can be divided into the same three main categories: oil, repairs and maintenance (including depreciation costs) and wage costs. For the Maritime Affairs administration only, the corresponding budgets for the year 2008 were:

3,250 euros: average oil (and lubricant) annual budget,

1,000 euros: annual budget for maintenance (80% considered as variable),

On average, a control implies 6 officials (2 teams of 3 inspectors) (1.5 days full time equivalent per person, incl. preparation and debriefing) –

Based on the activity figures from the Maritime Affairs (264 controls at quay for 2006), an average costs of 232 euros can be estimated for a control at quay.

Considering the control activity of the other administrations involved (674 – see table below), the average total variable annual cost for this enforcement method would thus be around 156,700 euros.

3.5.2.4. Estimation of indirect costs

NB: From the above estimates, the current enforcement budget for direct controls in the studied area would be around 292,600 euros, for all administrations involved (with a wage cost of around 234 000 euros).

[10] NB: primary analysis, taking into account the 2 seasons (fishing season vs. non-fishing season where catches of scallops are prohibited), resulted in around 85 controls at sea during a year.

[11] Mainly *Gendarmerie maritime* and french Customs

For ULAM only, the respective costs would be 164,000 euros for direct control activities including 138 000 euros for wage cost. Such estimates need to be compared to other sources.

1. When considering the estimates of the Commission (around 400 millions euros for control and enforcement) and the total production in the EU (4,820,000 tons for 2007), the average cost of control is around 83 € / tons. When applying the same ratio to the production of the bay of Saint-Brieuc scallops fishery (8000 tons), the resulting figure for the cost of control would be around 660,000 euros. But these estimates cover a very different control system.

2. The direct wage cost in ULAM is around 374 000 € for 2007 (DRAM), with 80 % of this budget dedicated to professional fishing control activities (300 000 euros). The discrepancy between the two wage cost estimates (300,000-138,000 = 162 000) can be linked to the general organisation of the control activity (the overheads – drafting reports, meetings, training)), *ie.* the indirect wage costs.

It can be assumed that this is a minimum level for fixed wage cost. In addition, fixed capital costs and some of maintenance costs (20 %) have to be taken into account for the calculation of fixed cost, as presented in table below.

As usual, some assumptions need to be made when allocating the indirect fixed costs to the various activities. In the absence of any further information on this, it is proposed here to equally allocate the fixed wage costs between the three types of control activities analysed. The fixed wage costs then amount to around 54,000 euros for each category (162,000/3).

Table 3.3: Estimations of indirect costs - ULAM

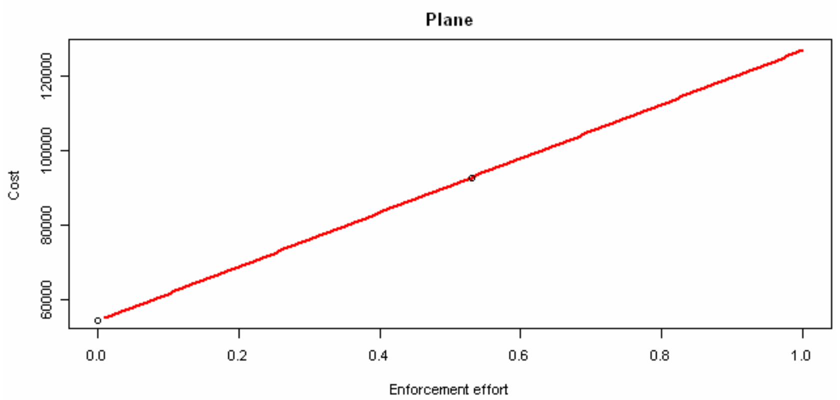
	Wages cost	Depreciation cost	Maintenance cost	Total fixed costs
Air surveillance	54,000 €	-	-	54,000 €
Inspection at sea	54,000 €	13,300 €	2,200 €	69,500 €
Inspection at quay	54,000 €	1,500 €	200 €	55,700 €

Note: For air surveillance, the plane is hired by the professionals. Depreciation and maintenance cost are not available.

Taking into account both direct and indirect costs, the total budget for the operation of control, is around 472,000 euros. This budget does not cover the indirect costs for the other administrations involved.

Using the COBECOS software, the resulting estimates are presented in the figures below (figure 3.3).

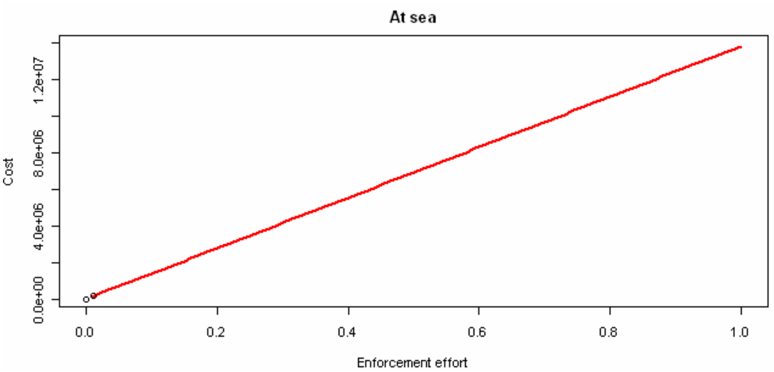
Figure 3.3: The estimated costs of aerial control versus enforcement effort



----- Cost of enforcement versus enforcement effort ----------
User defined: linear model
Parameter values:

Slope	intercept	<NA>
72852.83	54157.00	NA

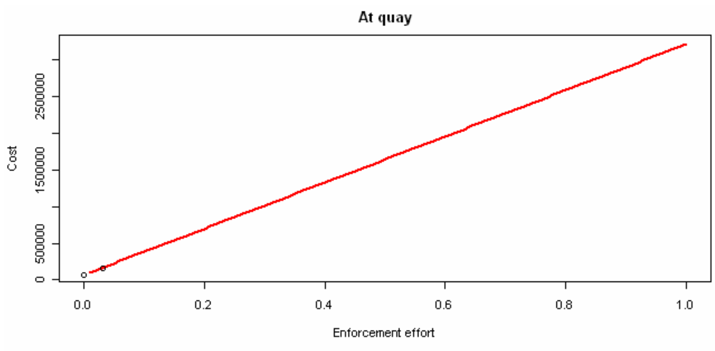
Figure 3.4: The estimated costs of sea inspections versus enforcement effort



----- Cost of enforcement versus enforcement effort ----------
User defined: linear model
Parameter values:

Slope	intercept	<NA>
3149797	69690	NA

Figure 3.5 : The estimated costs of port inspections versus enforcement effort



----- Cost of enforcement versus enforcement effort ----------
User defined: linear model
Parameter values:

Slope	intercept	<NA>
13754724	55857	NA

3.5.3 Probability of penalty function

3.5.3.1.: Methodology

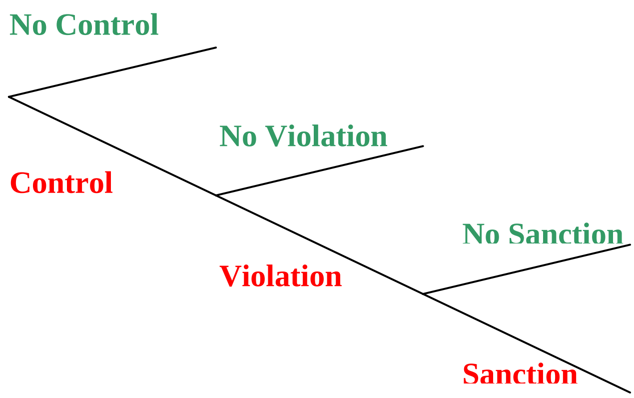
According to the definition agreed for the project, the probability of the penalty function provides a relationship between the intensity of the enforcement effort and the probability to be sanctioned when committing a violation. It is generally expected that the higher the enforcement effort is, the greater the probability to be sanctioned should be.

The probability of the penalty function results from two separate items:

the probability of being controlled
the probability of being sanctioned when a violation is detected

This sequence is captured in the figure 3.6, presented by the Danish team during a COBECOS meeting and reproduced in the Danish chapter.

Figure 3.6 : The probability of being sanctioned



A possible penalty probability function ($\pi(e)$) can then be defined as follows:

$$\pi(e) = p(S \mid V) = p(C \mid V) \cdot p(S \mid V \cap C) \qquad (3.7)$$

where,

- e: Number of control actions (control effort)
- $p(S|V)$: Probability of being sanctioned when violating

- $p(S \mid V \cap C)$: Probability of being sanctioned when an offence has been committed and detected
- $p(C)$: Probability of being controlled
- $p(C|V)$: Probability of being controlled when violating

As in most case studies, a simplification is introduced assuming that the probability of being sanctioned given that the person is violating and is controlled equals one (see for instance the discussion on the "simplified" approach in the Danish case). This means that in any case, a sanction occurs (whatever the sanction is).

$$p(S \mid V \cap C) = 1 \qquad (3.8)$$

The conditional probability rules also suppose that, when two events are independent:

$$p(C|V) = \frac{p(C \cap V)}{p(V)} = p(C) \qquad (3.9)$$

The question of the independence of the two events has been raised in various COBECOS meeting and in some case studies. As long as the control are conducted randomly, which is the case here the assumption can be seen as fairly valid. Using equations (3.8) and (3.9), equation (3.7) can be the written as follows for each type of enforcement activity:

$$\pi(e) = p(S \mid V) = p(C) \qquad (3.10)$$

As the COBECOS model proposes to estimate the function for each enforcement type, the following describes how the functions have been calculated for the three enforcement method relevant for our case study, namely air surveillance, inspection at sea and inspection at quay (including controls at the auction). For each category, if appropriate, we present information available at national, regional and local level (case study) to better understand the situation.

3.5.3.2. Air surveillance

Based on the data provided by the Brittany CRPMEM (professional organisation), the number of aerial controls was estimated in the following way: during each surveillance trip, around 100 control operations are conducted (relatively to the registration / characteristics of the vessel, the fishing area, etc.).

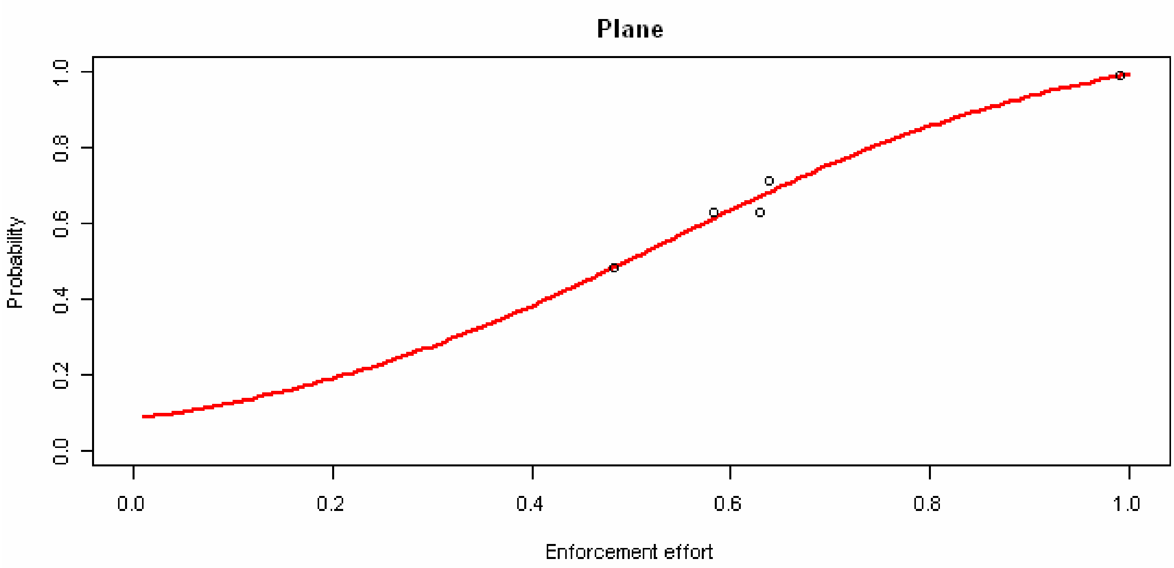
Table 3.4: Elements for the calculation of the probability of detection and sanction by air surveillance

	Number of controls	Number of fishing trips	Probability of being controlled
2003	7 000	9 836	0,71
2004	6 900	10 929	0,63
2005	6 400	10 150	0,63
2006	5 300	10 974	0,48

In order to fit the requirements of the COBECOS model, the enforcement effort was scaled to 1, by dividing the observed number of controls by the total number of fishing trips during the fishing seasons (10 974 for the 2006-2007 season).

Assuming a logistic functional form, the COBECOS code provides the following probability of detection function.

Figure 3.7: Probability of detection versus air surveillance effort



----- Probability of detection versus enforcement effort -----
AIC selected: logistic model

Parameter values:
Asymptote location slope

1.1089611 0.5362396 0.2143421

3.5.3.2. Inspection at sea

A. National level

Elements for the calculation of the rate of offence

Information regarding inspections at sea was presented in the report describing the enforcement system in place in France (COBECOS web site and Lesueur et al., 2008, for further details). This data were made available by the French government in the context of the UE regulation on "serious infringements" (COM/2007/0167). The number of inspections at sea was 4 116 for 2004 and 3 241 for 2005 in France. Unfortunately, the number of associated infringements detected is not provided for each category. The total number of "serious infringements" detected was 956.
However, two "global rates of offence" can be estimated by taking into account also the number of inspection at quay (total number for 2005: 3222 – see below) and the number of inspections occurring during the commercialisation process (including inspections of auction: 9603 in 2005):

Ratio 1: $= \dfrac{\#\,serious\text{ infringements}}{\#\,\text{Inspections at sea} + \#\,\text{Inspections at quay}} = \dfrac{956}{3241+3222} = 15\%$

Ratio 2:
$$= \frac{\#\,serious\text{ infringements}}{\#\,\text{Insp at sea} + \#\,\text{Insp at quay} + \#\,\text{Insp at commercialisation}} = \frac{956}{3241+3222+9603} = 6\%$$

Globally, it is interesting to note that both ratios are consistent with the order of magnitude proposed by the British MFA for the "performances indicators" (see the British chapter on the Western Channel fisheries): the coastwide targets for the *no. of fisheries offences detected as a % of inspections on land and sea* are set as 4% and 13% respectively.

Elements for the calculation of the probability of being controlled:

The probability of being controlled can be estimated by comparing the number of inspections to the total number of days at sea or to the total number of fishing trips (assuming that only one inspection can be conducted during a fishing trip).

The Annual Economic Report published by the STECF indicates that the number of total fishing days in France was 853 320 in 2007. The resulting probability of being controlled at sea is thus (3241 / 853320)=0.4%

B. Regional level

More detailed information was made available to us by the CROSS (Regional Centres coordinating the fisheries enforcement, see the description of the French enforcement system). The following control figures were provided by the CROSS Etel, in charge of the Atlantic zone + Western Channel waters (thus encompassing our case study). The corresponding figure for the fishing activity (number of fishing trips) has been derived from Ifremer – SIH[12] reports.

Table 3.5: Elements for the calculation of the probability of sanction by control at sea

Year	Number of controls	Number of fishing trips	Probability of being controlled
1998	805	217,740	0.004
1999	815	217,740	0.004
2000	553	217,740	0.003
2001	745	217,740	0.003
2002	512	188,670	0.003
2003	535	176,640	0.003
2004	785	167,340	0.005
2005	1,086	167,340	0.006
2006	1,677	167,340	0.010
2007	1,723	167,340	0.010

C. Local / case study level

Enforcement activities within the territorial waters (i.e. the situation of the fishery studied) is delegated by the CROSS Etel to the CROSS Corsen. For the whole zone covered by the CROSS Corsen, the total number of inspections for 2007 was 693, with the following participation of the administrations involved in the MCS process:

Table 3.6: Participation of the control activities, by Administration - 2007

Administration	Number of inspections
Gendarmerie maritime (dont BSL)	227
Gendarmerie départementale	14
***Affaires maritimes* (dont ULAM)**	418
Douanes	34
Total	693

Interestingly, the 2007 activity report of the CROSS Corsen notes that "the more sensitive areas are the Bay of Saint-Brieuc (endemic fraud for scallops and abalone), the coast of the North-Finistère and the Bay of Mont-Saint-Michel" (MEDAD, 2007, p. 23)

12 https://www.ifremer.fr/isih/affichagePageStatique.do?page=produits/rapports_syntheses/flottilles/flottilles.htm

Further detailed information was made available by the DDAM22 (Côtes d'Armor Department), as the fishery of Saint-Brieuc is fully located within their jurisdiction.

The table below summarises the total number of inspections conducted in the department of Côtes d'Armor for the year 2006.

Table 3.7: Number of controls made in 2006 in "Côtes d'Armor" (NUTS III level)

	Type of control								
	Inspection on board at sea	Inspections on board in port	Inspection of landings	Inspection of landing in auction	Wholesale inspections	Transport inspection	Fish retailers	Hypermarket	**Total**
Affaires Maritimes (ULAM)	112	77	16	134	4	1	25	7	**376**
Veterinary services	-	-	11	57	5	3	13	20	**109**
Frauds squads	-	-	-	2	4	-	32	53	**91**
Customs	-	-	-	3	-	25	10	-	**38**
Gendarmerie maritime	12	-	10	3	9	10	68	25	**137**
Gendarmerie nationale	1	-	26	-	6	-	9	6	**48**
Total	**125**	**77**	**63**	**199**	**28**	**39**	**157**	**111**	**799**

Source: DDAM 22

Note: The discrepancy between the two sources (CROSS and DDAM) results from the different scopes reported.

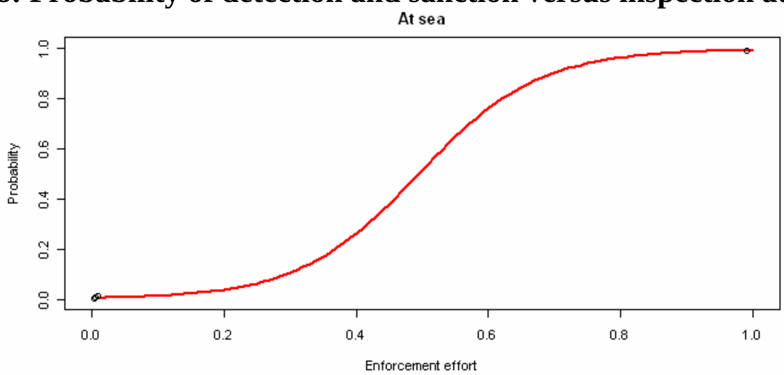
In order to fit with the COBECOS approach, the following data are derived from the table:

- Total number of inspections at sea: 125
- Total number of inspections at quay (min): 140 (77+63)
- Total number of inspections at quay (max – incl. auction): 674.

NB: For the year 2006, the probability of being controlled then equals to 0.01 (125 controls at sea divided by 10 974 fishing trips). This is totally in line with the probability obtained at the regional level. This suggests that the trend observed for the regional area can be applied to the sub-area of the bay of Saint-Brieuc[13].

In order to estimate the probability of the penalty function, and based on the data available, it was decided to estimate the functional relationship between the intensity of control and the probability to be detected in violation and sanctioned[14] using the data available at the regional scale.
In addition, it is assumed that the use of the logistic functional form for the relationship is more reasonable as the exponential functional form (see other studies and the Channel case). The resulting probability of detection function is provided by the COBECOS code:

Figure 3.8: Probability of detection and sanction versus inspection at sea effort



----- Probability of detection versus enforcement effort -----
User defined: logistic model

[13] This assumption has also been confirmed during interviews with officials.
[14] Assuming the inspectors to be able to detect and fine any infraction when an infraction has been committed.

Parameter values:
Asymptote location slope
0.99418599 0.49398626 0.09073743

3.5.3.3. Inspection at quay

As for the estimation of the probability of detection related to the control at quay, a similar approach as above has been followed.

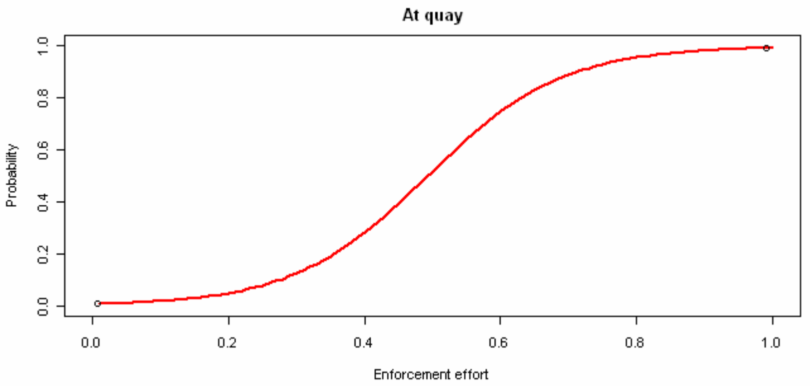
The relationship between the intensity of control and the probability to be sanctioned was estimated at the regional scale on a 2 years basis (source: CROSS Etel).

Table 3.8: Elements for the calculation of the probability of sanction by control at quay

	Number of controls	Number of fishing trips	Probability of being controlled
2006	1,292	167,340	0.01
2007	1,155	167,340	0.01

As previously, the logistic functional form has been used. The resulting probability of detection function is provided by the COBECOS code:

Figure 3.9: Probability of detection versus inspection at quay effort



Probability of detection versus enforcement effort
User defined: logistic model
Parameter values:
Asymptote location slope
0.9964289 0.4922768 0.0988208

3.6Conclusions

3.6.1. Estimation of the benefits function

The benefit functions were estimated in accordance with the equations underlying the COBECOS model.

3.6.2. Estimation of Enforcement cost function

- Estimates of running costs calculated with and agreed by several officials from the Maritime Affairs administration.
- Uncertainty regarding the actual costs supported by the other administrations for similar control activities. It was assumed that the cost is the same for each type of control (air, sea, quay)
- Figures available only for one year in most cases

1.6.3. Estimation of Probability of penalty function

- Uncertainty regarding the intensity of control and the rate of offence observed at the local (fishery) level.
- Data available at the regional level has been used, assuming similar behaviours
- For inspections at quay, data available for only 2 years.

4. CCAMLR South Georgia

4.1 Authorship and affiliation.

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4.2 Introduction

The South Georgia toothfish fishery occurs within both the Convention Area of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Subarea 48.3, and the South Georgia Maritime Zone (GSGSSI) and is confined to a depth between 500 and 2000 meters. South Georgia and Shag Rocks toothfish are considered a single stock, separate from all other stocks in the Southern Ocean or Patagonian Shelf off South America (Agnew, 2004). Toothfish are being exploited mainly by longlines but a small number of fish have been taken by pots.

Total catch quota is set annually by CCAMLR for Subarea 48.3 and smaller management areas in recent years. Catch quota and mitigation measures are also set on major bycatch fisheries such as macrourids and skates / rays.

GSGSSI allocates individual vessel quotas within this overall limit to a set number of vessels for a defined season (May – August) at a level that will take the quota within the season. In 2007/2008 season, fishing licences were given to 10 vessels.

4.3 Description of the enforcement system

Enforcement systems currently in place are as follows:

- Vessel Monitoring System (VMS) was introduced in 1998. All vessels in the regulated fishery inside CCAMLR waters are tracked by VMS with 100 % coverage. Vessels are tracked by their flag state and also either directly to a centralised Commission VMS. VMS data available to patrol vessels on active patrol.

- At-Sea patrols: All the main coastal states where toothfish fisheries occure have a surveillance presence. Other CCAMLR members can perform CCAMLR inspections on other member vessels operating in CCAMLR waters.
- Port State Control: The South Georgia fishery, which is certified by the Marine Stewardship Council, monitors 100% of all landings from the fishery weighing all the catch to verify the weight of catch reported to the Commission. 100% coverage has been attained since 2005.
- Catch Documentation Scheme (CDS) was introduced in 1999. All imports and exports of toothfish into CCAMLR member states should be associated with a catch document which allows the catch to be traced.
- The Observer Programme was introduced in 1995. The CCAMLR scientific observer programme has 100% coverage on the longline fisheries (excluding the French and South African EEZs which are exempt) since 1996. CCAMLR Scientific Observers monitor every setting and hauling operation, monitor compliance, collect biological data from target and bycatch species; and
- Logbooks: The CCAMLR system of logbooks provides for some of the most accurate and in depth recording of fisheries information. Haul by haul logbooks.

The majority of these enforcement measures are designed to ensure compliance of the legal fleet, and for the purposes of this case study we assume that they are effective. We are therefore concerned only with fishery patrol vessel (FPV) effort since this is the only enforcement measure with a direct impact on IUU vessels.

4.4 Data used

The cost of enfocement was obtained from the annual running cost of the fishery patrol vessel averaged across days in operation to give the cost per day. There was no data available to estimate the relationship between enforcement effort and probability of detection.

4.5 Estimation of theoretical relationships

The relationship between enforcement effort and cost is linear, given an estimate of the cost per day of fishery patrol vessel effort. Estimation of the relationship between enforcement effort and probability of detection was derived through simulation. In terms of available data, we have no direct measurements of the probability of detection in conjunction with total IUU and enforcement effort estimates. As such, we cannot directly fit a functional relationship between these variables. We do, however, have some information that will prove useful in this regard:

- Information on the mean trip lengths (in terms of days) for both IUU vessels and the fishery patrols around the island (Agnew and Kirkwood, 2005).
- An estimated relationship between the probability of observing an illegal vessel given the overlap proportion of the illegal and patrol cruise (Agnew and Kirkwood, 2005).

This information in itself is insufficient to solve the problem so what we do is simulate both the enforcement and illegal fishing processes to generate 'observations' of the probability of detection and then explore potential parametric models for these detection probabilities, in terms of the illegal and enforcement effort.

For given illegal, τ_I, and enforcement, τ_P, trip lengths and an associated number of trips per year denoted by, n_I and n_P, respectively (limited so that the total number of days cannot exceed 365 if the period is a year), these trips are independently and evenly spread over a pre-defined period (i.e. normally a year). The start point of these trips within the year is randomly allocated over many Monte Carlo trials and, if we assuming complete detection with any overlap of an IUU and a patrol cruise, for each of these trials the probability of detection can be calculated as the number of days for which the two activities overlap, divided by the total number of days in the pre-defined period. Using this approach we then have a Monte Carlo sample of detection probabilities, conditional on given trip lengths and the number of trips. This distinction will prove to be important – trip length as well as total effort (be it illegal or enforcement) has an effect on the detection probabilities and should be considered as an extra control feature in the evaluations.

However, this would assume that even with one day of overlap between an IUU and patrol cruise the IUU vessel would be detected, and the work done in Agnew and Kirkwood (2005) showed this was very likely not the case. They showed that there was a linearly decreasing relationship (over the available data range) between the probability of

actually sighting an illegal vessel fishing in the zone and the proportion of overlap between the illegal and patrol cruise. Interestingly, this detection probability reached a maximum at just less than 0.8 – even 100% patrol coverage will not detect all illegal activity within the zone. To account for these factors we proceeded as follows:
We have a set of illegal and patrol cruises – D_I and D_P, respectively – with cardinality n_I and n_P. For each patrol cruise cruise, p, we compute the relative overlap with all of the IUU cruises:

$$\Xi_p = \frac{|D_I \cap D_p|}{|D_I|}. \tag{4.1}$$

A piecewise linear relationship is then employed to turn this value into a relative sighting probability:

$$\kappa_p = \max\left(0, 1.9 \times \Xi_p - 1.11\right), \tag{4.2}$$

given the values estimated in Agnew and Kirkwood (2005). Then we compute the number of days in which a given patrol cruise overlaps with the IUU cruises, $\psi_{I,p}$ so that the effective number of IUU days detected in a given period is given by

$$\Theta = \sum_P \psi_{I,p} \times \kappa_p. \tag{4.3}$$

Now we can simply express the probability of detection, conditional on the mean trip length and number of trips not just the level of illegal and enforcement effort in total, as the ratio of detected to total illegal effort days:

$$\Pi\left(E(n_I, \tau_I), e(n_p, \tau_P)\right) = \frac{\Theta}{n_I \times \tau_I}. \tag{4.4}$$

To simulate these detection probabilities we first defined two types of IUU cruise as detailed in Agnew and Kirkwood (2005): a short cruise of around 30 days and a long cruise of around 60 days. For the patrol vessel, given the data on the cruise lengths, we assumed that the mean trip length was 10 days. Then we simply increased the number of trips as a way of increasing the illegal and enforcement effort and then calculated the detection probabilities given the method already outlined above.

Figure 4.1 shows the simulated (median) probability of detection in terms of illegal and enforcement effort days, assuming short IUU trip length (30 days) and 10 day patrol trips. There is a clear and perhaps not unexpected linear relationship between enforcement and detection probability. Whatever the potential relationship between illegal effort and detection probability, it is likely quite weak given no apparent obvious increase in the detection probability with increasing illegal effort. We chose to try to fit the following model to the detection probability simulations:

$$\Pi = \gamma e + \delta e^{IUU} + \chi e e^{IUU} \tag{4.5}$$

Using a basic non-linear least-squares approach we found that the only significant parameters were the enforcement effect (γ) and the interaction effect (χ) – there was no significant effect for illegal effort alone. Upon running this reduced form of the model in Eq. (4.5) the two effects were highly significant, with γ = *2.2e-03 (7.5e-06)* and χ = -*1.9e-07 (3.4e-08)* – bracketed terms are the standard deviations – with a residual standard error of 0.015. What is interesting is that the interaction term is small but actually negative – for a given enforcement level, increasing illegal effort can actually decrease the chance of being caught. This somewhat counter-intuitive relationship is a result of the relationship between trip overlap and probability of being sighted and the relative lengths of the illegal and patrol trips. For short IUU trips and short patrols, increases in IUU activity mean there is actually a small decrease in the mutual overlap of activities for a given enforcement level, thereby decreasing the probability of getting caught. To verify this we looked at two alternative trip length scenarios: (1) mean IUU trip length of 60, not 30 days; (2) short IUU trip length (30 days) with a longer patrol trip length of 20 days, not 10. For the longer IUU trip length there is a marked decrease in the interaction term – it is still negative but more than twice as small as in the shorter IUU trip length case. Upon increasing the patrol vessel trip length we also see a decrease in the interaction term although not as much as that seen when increasing the IUU trip length. With this simplistic model of illegal and enforcement effort dynamics we have been able to incorporate estimates of patrol efficiency of sighting to generate a plausible range of parameters for the probability of detection, in terms of both absolute levels of illegal and patrol effort and in terms of their respective characteristic trip lengths.

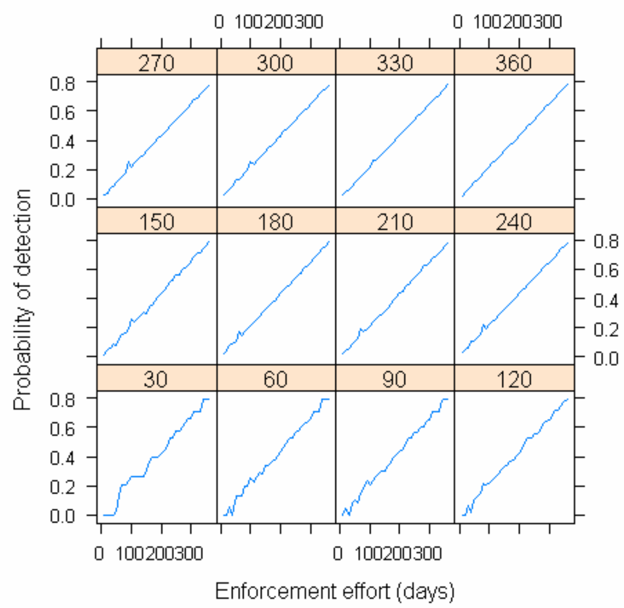

Figure 4.1: Simulated (median) probability of detection in terms of enforcement and illegal effort (expressed in days) assuming 30 day illegal and 10 day patrol trips. The panel numbers represent the illegal effort in days.

In one sense we are fortunate in that we have effectively seen approximately what level of enforcement seemed to remove the IUU activity from the fishery – from Agnew and Kirkwood (2005) the rapid disappearance of IUU activity seemed to coincide with a patrol coverage (days patrolled per year) of around 30-40%, and accounting for the relationship between IUU and patrol overlap we would expect this to equate to a probability of detection of around 0.2-0.3.

4.5.1 Benefit function.

a) Private Benefit function

The case study assumes two mutually exlusive fleets, namely the legal fleet and IUU fleet. The legal fishery is managed according to the articles of and the conservation measures as defined by the Commission for the Conservation of Antarctic Living Resources (CCAMLR), of which the UK is a member. For this stock, the TAC for a given year is set according to one harvest control rule (SC-CAMLR, 2007; Hillary et al, 2006):

The TAC will be the maximum catch that satisfies the following two conditions:

1. After a projection period of one generation time (35 years), the probability of the spawning biomass being greater than 50% of the un-fished spawning biomass should be greater than or equal to 0.5
2. During this projection period, the probability that the spawner biomass drops below 20% of the un-fished spawning biomass should not exceed 0.1

This rule corresponds to a target/limit reference point form of harvest control rule, in that the target for the spawning biomass is 50% of un-fished levels, unless the uncertainty in the stock dynamics is great enough to force the predicted stock dynamics below 20% of un-fished conditions greater than 10% of the time. Legal catches are set solely by this harvest control rule: the legal fleet dynamics are such that every year they will take the legal TAC (if possible) with the potential bias and uncertainty in the actual catch taken modelled using historical catch statistics for the legal fleet.

The private benefits to the legal fleet can therefore be defined as:

$$B = h(p + l) - ec$$

where p is the price, l is the license fee per tonne of quota, e the fishing days and c the cost per day. The harvest is given by

$$h = qe\overline{E}X$$

where q is the catchability, E is the number of hooks per day and X is the biomass. Both q and X are estimated parameters.

The private benefit to an IUU vessel operating within the fishery is of a similar form, with the exception that a license fee is not paid:

$$B^{IUU} = h^{IUU} p^{IUU} - e^{IUU} c^{IUU}$$

Entry of an IUU vessel into the fishery is partially determined by the expected benefit. The expected private benefit for an IUU vessel is given by:

$$B^{IUU} = h^{IUU} p^{IUU} (1 - \Pi) - e^{IUU} c^{IUU} - \Pi f$$

where Π is the probability of detection and f is the fine. Provided this benefit is positive, an IUU vessel will enter the fishery with a probability related to the probability of detection.

b) Social Benefit function

The social benefit function is considered to represent the overall benefits to the state and the legal fleet. The IUU fleet is not considered a recipient. The state generates revenue from confiscations and the sale of illegal catch. Social benefit is therefore given as:

$$SB = \Pi(h^{IUU} p^{IUU} + f) + hp - e^{FPV} c^{FPV} - ec$$

Since the stock is being fished down to a target biomass that is 50% of K, the legal harvest is set at the maximum value consistent with the CCAMLR conservation measures. Even if meeting these conservation measures can be assigned monetary value, it is constant, and therefore will have a simply scalar effect on the relationship between enforcement effort and social beneft. The shadow value of biomass is therefore omitted from the social benefit function.

4.5.2 Enforcement cost function

The cost of enforcement is simply the number of fishery patrol vessel days multiplied by the cost per day:

$$C = e^{FPV} c^{FPV}$$

4.5.3 Probability of penalty function

The probability of detection (and therefore penalty) is given by:

$$\Pi = \gamma e + \chi e e^{IUU}$$

where γ and χ are estimated constants.

4.6 Conclusions

We have assumed that the legal fishery is compliant with regulations and are concerned only with the effect of FPV enforcement on a distinct IUU fleet. Good data is available on the cost of FPV effort per day, however we rely on simulation to estimate the relationship between FPV effort and the probability of detection and sanction.

5. Ligurian and Northern Tyrrhenian Sea bottom trawling fishery

5.1 Authorship and affiliation

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5.2 Introduction

Bottom trawl fishery in the waters of the GSA 9 is a typical multi-species and multi-gear fishery, as most of the Mediterranean fisheries. The case study selected focuses on vessels fishing exclusively or predominantly with trawl nets (fishing days >50%), but also other fleet segments active in the demersal fisheries are considered. As for the bottom trawls, even if trawling is predominant, vessels are generally authorised to use more than one fishing gear (in many cases, beside trawls, they can use gillnets and long-lines). These fishing gears are used in specific areas or seasons. As for non-trawl vessels involved in the demersal fisheries in GSA 9, they generally use a combination of fishing gears and are classified in two fleet segments, named polyvalent and small scale. Polyvalent are vessels over 12 m in length, while small scale vessels are under 12 m in length.

The fishery under analysis is multi-species: more than 40 different species are landed. The target species of bottom trawl in GSA 9 are mostly demersal species. The main species are hake, mullet, octopus, shrimp and lobster. These are medium migratory species. Among the main target species only hake is a long live species (it can live until 20 years), while the others are medium live species (not more than 4 years). In the bio-economic model used for this case study, simulations are performed for the following species: European hake, striped mullet, shrimp, and a group consisting of all the other species.

Management measures regulating demersal fisheries in GSA 9 are applied at national level. In Italy, fishing activities are managed trough a combination of input control and technical measures. The main management measures consisting in:

- Input control measures:
    - fishing activity regulated by a closed license scheme;
    - seasonal withdrawal of fishing activity during certain periods, generally in the summer months.
    - technical ban of fishing activity on Saturday and Sunday.
- Technical measures:
    - minimum distance from the coast;
    - area closures;
    - minimum mesh size;
    - minimum landing size for some target species.

5.3 Description of the enforcement system

Law no. 963 of 14 July 1965 (Rules and Regulations governing maritime fishery) entrusts the Commander of the Harbour office with the tasks of keeping under control the fishing and marketing of fish products and assessing possible violations of attendant laws and regulations. Furthermore, the Commander chairs the Local Consultative Commission for Maritime Fishery.

The Harbour Offices Body consists of about 10 thousand men with the status of Navy Seamen. It is a national Body which, for its functioning, is under the authority of the Ministry of Transports and Infrastructures. Moreover, it co-operates with the Ministry for Agricultural and Forest Policies (for maritime fishing), with the Ministry of the Environment (for the protection of marine habitat), with the Ministry of Cultural Heritage and Environmental Conservation (for the conservation of marine areas of archaeological interest), with the department for Civil Defence and with the Regions (for the administration of maritime state property devoted to recreational-tourist use). The activities of the Harbour Offices Body are conducted through technical/operational units which were appointed as Coastguard by Intergovernmental Decree as of 8 June 1989.

A central and a peripheral structure organise the Harbour Offices Body Coastguard. The former structure is under the authority of the General Command and is responsible for co-ordinating and controlling all the activities conducted by the Harbour Offices. Furthermore, it is specifically entrusted with research and rescue tasks, which are conducted by the pertinent Operations Centre.

Distributed along the 8.000 km of the Italian coastline, the peripheral structure of the Body, consists of: 13 Harbour Master's Offices, from which depend the same number of Maritime Area Operations Centres; 50 Harbour Offices; 45 Maritime District Offices; 138 Local Maritime Offices and 31 Shore delegations.

A number of enforcement tools are applied for the control and the surveillance of fishing activities: inspections at sea (on board), landings inspections at port, aircraft surveillance and inspections at the selling places (markets and restaurants). The last type of enforcement tool is not applied to fishing vessels, but to markets and restaurants. Therefore, the variations in the intensity of this enforcement tool have not a direct effect on the level of compliance with fisheries regulations. As for aircraft surveillance, this is not an independent enforcement tool able to detect infringements and produce sanctions. Aircraft surveillance can be better classified as a technical support for the inspections at sea. For these reasons, in this case study, the analysis will be focused on the enforcement tools inspections at sea and landings inspections at port.

5.4 Data used

Data used in this case study are collected from different sources. The economic data for the three fleet segments analysed are obtained by elaborations on the IREPA database. IREPA collects data on landings, revenues and costs by fleet segment and administrative region along the Italian coast. Data on landings and prices by fleet segment and species, and costs by fleet segment for the period 2005-2007 are used to estimate the economic parameters in the bio-economic model.

The only biological data used for estimating biological parameters in the bio-economic model are the biomasses of European hake, striped mullet and shrimp in the GSA 9.

These data have been estimated for the period 2005-2008 by the Aladym model within a study developed for the definition of the Italian management plans.
Finally, data on the enforcement system are collected from two different sources:

- *The database COGESTAT, designed for managing the balance of the General Command of the Harbour Offices Body.* The number of inspections and the number of infringements by the two enforcement tools landings inspections and inspections at sea have been collected by this database for the years 2005, 2006 and 2007. For the same period, other information derived from COGESTAT are the number of missions at sea and the number of nautical miles covered during the fishing activity control.
- *The reports Italian Ministry for Agricultural and Forest Policies sent to the EC as foreseen by the EC Reg. no. 1447/1999.* The data used to produce these documents for the period 2002-2004 have been processed to estimate the number of detected violations and the average fine by illegal behaviour in the GSA 9.

5.5 Estimation of theoretical relationships

5.5.1 Benefit function.

a) Private Benefit function

As vessels involved in the fisheries under analysis are classified in three different fleet segments, private benefit for the fleet is the sum of the private benefits for each of the fleet segments. Private benefit by fleet segment are calculated as revenues minus costs:

$$B = B_1 + B_2 + B_3, \qquad (5.1)$$

where $B_i = R_i - C_i$.

As the fisheries are multi-species, revenues produced by a fleet segment are obtained by the sum of revenues by species, where revenues by species is landings multiplied by price. Mediterranean fisheries are generally characterized by a high number of species landed. In this model, the three species contributing the most to total revenues are used to estimate partial revenues. Total revenues are obtained by multiplying partial revenues by a parameter r estimated on the period 2005-2007:

$$R_i = r_i(p_{i,1}L_{i,1} + p_{i,2}L_{i,2} + p_{i,3}L_{i,3}), \qquad (5.2)$$

where $p_{i,j}$ and $L_{i,j}$ represent price and landings respectively by fleet segment i and species j.

While the prices are supposed to be constant, the landings dynamic is simulated by the following equation:

$$L_{ij} = q_{ij}\left(1 + \frac{V_q}{E}\right)E_i X_j, \qquad (5.3)$$

where q is the catchability coefficient by fleet segment i and species j, E_i is the fishing effort by fleet segment i, E is the fishing effort for the entire fleet, and X_j is the biomass estimated by species j. The catchability coefficients are corrected to take into account the violations regarding unauthorized fishing activity, V_q. It is assumed that violating the regulations associated to the temporal and spatial restrictions can determine an increase in catchability up to two times the value estimated when all vessels comply with the regulation.

Biomass at time t, X_t, is a function of biomass, biomass growth and landings at time $t-1$:

$$X_{j,t} = X_{j,t-1} + G_{j,t-1}(X_{j,t-1}) - \sum_i L_{ij,t-1} - L^{il}_{j,t-1}, \qquad (5.4)$$

where L^{il} represents illegal landings produced by vessels without a fishing licence and therefore not included in any of the three fleet segments considered above. These landings are calculated as in (5.3), where fishing effort is equal to the number of violations associated to the regulations on fishing licence V_E (this value is estimated in terms of days at sea), and the catchability coefficient is supposed to be equal to that estimated for small scale vessels, q_{ss}. This assumption is based on the empirical observation of the vessels violating this regulation, generally small size vessels using not expensive fishing gears:

$$L_j^{il} = q_{ssj}\left(1+\frac{V_q}{E}\right)V_E X_j \,. \tag{5.5}$$

The biomass growth function is given by the following equation:

$$G_j(X_j) = \alpha_j\left(\frac{1}{1+V_s/E}\right)X_j - \beta_j X_j^{\ 2}\,, \tag{5.6}$$

where the intrinsic growth rate α is corrected to take into account the violations of the regulation on the selectivity of fishing gears. As the maximum number of violations equals the number of days at sea, the corrector factor is included in the range [0.5 1]. Therefore, the intrinsic growth rate is supposed to vary from α, when all vessels comply with the regulation, to an half of α, when all vessels do not.

Costs by fleet segment are estimated as a linear function of fishing effort, where fishing effort is measured in terms of days at sea:

$$C_i = c_i E_i \,. \tag{5.7}$$

The parameters c_i, i.e. cost per unit of effort, are estimated for each of the fleet segments on historical data.

Table 5.1. Parameters in the bio-economic model

a) Landings price by fleet segment and by species

	European hake	Striped mullet	Shrimp
Trawl	9.03	6.91	15.61
Small scale	11.53	4.85	
Polyvalent	8.61		

b) Economic parameters

	r	c
Trawl	3.58	9.00E-04
Small scale	6.91	1.81E-04
Polyvalent	3.18	3.41E-04

c) Catchability coefficients by fleet segment and by species

	European hake	Striped mullet	Shrimp
Trawl	4.95E-06	2.51E-05	1.18E-05
Small scale	1.02E-06	1.74E-07	
Polyvalent	5.32E-06		

d) Biological parameters

	α	β
European hake	1.56	2.84E-04
Striped mullet	4.28	3.87E-03
Shrimp	1.73	2.20E-03

Source: Elaborations on data provided by the IREPA database

b) Social Benefit function

The social benefit function is given by the private benefit function minus the costs of enforcement and the change in the social value of biomass. As three species are simulated in this case study, three social values of biomass are included in the social benefit function:

$$SB = B - CC + \lambda_1(G_1(X_1) - L_{.,1}) + \lambda_2(G_2(X_2) - L_{.,2}) + \lambda_3(G_3(X_3) - L_{.,3}),$$

where B represents the private benefit function for the entire fleet, CC the cost of enforcement, λ_j the shadow value of the biomass for the species j, $G_j(X_j)$ the biomass growth function for the species j, and $L_{.,j}$ the total landings of species j:

$$L_{.,j} = \sum_i L_{i,j} + L_j^{il} \qquad \text{for j = 1, 2, 3.}$$

The shadow values of the biomasses of European hake, striped mullet and shrimp in GSA 9 are estimated as profit per unit of biomass. As fishing activity in the

Mediterranean Sea is multi-species, profit cannot be directly allocated to each species. Furthermore, profits result from the landings of more than 40 different species, while only three species are included in the bio-economic model. Nevertheless, a level of profit has been allocated to each of these species based on their contribution to revenues.
The shadow values of biomass have been estimated as follows:

- European hake: 7.67 €/kg;
- Striped mullet: 16.23 €/kg;
- Shrimp: 17.03 €/kg.

5.5.2 Enforcement cost function

In this case study enforcement is measured in terms of number of inspections. Two enforcement tools are assumed, landings inspections and inspections at sea. Costs associated to landings inspections are estimated as a linear function of people employed in this enforcement activity:

$$CC_1(e_1) = cc_1 H_1^{man}, \tag{5.8}$$

where cc_1 represents the cost per man-hour employed in landing inspections. Unfortunately the number of man-hours is not available, but the number of man-hours per inspection can be guesstimated in around 3 hours. Therefore, (5.8) can be reformulated as follows:

$$CC_1(e_1) = 3cc_1 e_1, \tag{5.9}$$

where e_1 is the enforcement effort employed in landings inspections.
As for inspections at sea, enforcement costs include the costs of man-hours employed and the costs of the nautical miles covered for this enforcement activity:

$$CC_2(e_2) = cc_2 H_2^{man} + cc_3 M^{sea} \tag{5.10}$$

where cc_2 and cc_3 represent the cost per man-hour employed and the cost per nautical mile covered. As done for landings inspections, also in this case (5.10) is rewritten in terms of enforcement effort. Taking into account that each inspection at sea needs around 20 man-hours and 15 nautical miles, the enforcement cost function can be expressed as follows:

$$CC_2(e_2) = 20cc_2e_2 + 15cc_3e_2 = (20cc_2 + 15cc_3)e_2, \quad (5.11)$$

where e_2 is the enforcement effort employed in inspections at sea.

The parameters cc_1 and cc_2 in the enforcement cost functions, estimated by an average of the salaries per hour earned by people employed as coastguard, are equal to around 33 €. The parameter cc_3 is estimated in around 28 €.

5.5.3 Probability of penalty function

In deliverable D3 (report of working package 3), the penalty probability function is defined as the probability of having to suffer a penalty if one violates management measures. This probability is a monotonically increasing function of the enforcement effort. Therefore, increasing enforcement effort results in an increase in the probability to be controlled and sanctioned when violating.

To estimate the penalty probability function it is needed to define first the enforcement effort e. For the case study described above, enforcement effort can be feasibly estimated in terms of number of vessels inspected during a period, for example one year. Under the assumption that a vessel is not inspected twice during the same day, the maximum number of inspections for a fleet in a year equals the total number of days at sea for that fleet. As fishing effort E is estimated in terms of number of days at sea:

$$\max(e) = E \quad (5.12)$$

In this case study, it should be clear that we are using the same unit of measure for both fishing effort (the total number of days at sea) and enforcement effort (days at sea inspected).

The penalty probability function is the probability to be sanctioned when violating. A necessary but not sufficient condition for a violating vessel to be sanctioned is that it is inspected. Not any one inspection is able to detect all possible violations of fishery regulation. However, cases where inspecting a violating vessel does not produce any sanction generally represent a small minority of the total number of inspections. Therefore, it seems acceptable to assume that an inspection of a violating vessel always produces a sanction. This means that the probability to be sanctioned when violating equals the probability to be inspected when violating:

$$\pi(e) = p(S|V) = p(I|V) \tag{5.13}$$

Equations (5.12) and (5.13) determine that when all units of fishing effort *E* are inspected the probability to be sanctioned when violating is 1:

$$\pi(E) = 1\,. \tag{5.14}$$

The probability to be sanctioned when violating is associated to the illegal behaviour occurring, and to the enforcement tool adopted to detect that behaviour.

In this case study, three illegal behaviours are included in the analysis:

- Fishing without holding a fishing licence;
- Using or keeping on board prohibited fishing gears;
- Unauthorized fishing.

The three categories of violations listed above can be associated to the management measures regulating demersal fisheries in GSA 9. They cover all possible violations of the fishery regulation. Fishing without holding a fishing licence is the violation of the input control measure defined as “fishing activity regulated by a closed licence scheme”. Using or keeping on board prohibited fishing gears consists of the violations of the technical measures “minimum mesh size” and “minimum landing size for some target species”. Unauthorized fishing can be associated to the temporal and spatial restrictions.

The enforcement tools considered in this case study are as follows:

- Landing inspections;
- Inspections at sea.

The categorization of enforcement tools is based on both the different capacity in detecting illegal behaviour and the different cost per vessel inspection. For example, it is expected that landing inspections are less expensive than the other tool but also less efficient in sanctioning violators. On the contrary, the inspections at sea should be the most efficient tool but also the most expensive.

Given three categories of violation and two categories of enforcement tool, six different penalty probability functions should be expected for this case study. Unfortunately, inspection reports do not describe in much detail the type of elementary control made. For this reason, we assume that each of the enforcement tools can and does investigate on all types of illegal behaviour. As a consequence, the efficiency in detecting violations will be independent on the category of illegal behaviour. Therefore only two penalty probability functions can be estimated, one for landings inspections and one for inspections at sea.

Random and non-random enforcement tools

The penalty probability functions to be estimated can have different functional forms. First of all, we distinguish the enforcement tools where the vessels inspected are randomly selected from other enforcement tools where vessels inspected are selected because they are considered as potential offenders. We are not interested here in discussing the methods employed to identify potential offenders, but it is evident that inspections at sea can be directed to specific groups of vessels while landings inspections cannot. As a consequence, landings inspections can be assumed to be randomly operated, while the other enforcement tool is not random.

For a given level of enforcement effort *e*, the probability to be sanctioned when violating can be measured as the percentage of violations sanctioned during a period. This percentage is calculated for both random and non-random enforcement tools as the ratio between sanctions and infractions:

$$\pi(e) = p(S|V) = \frac{S}{V} \tag{5.15}$$

The main problem in estimating this probability is related to data available. Even if data on the number of sanctions *S* can be available by enforcement tool and violation, the total number of violations *V* by illegal behaviour is not available and needs to be estimated.

A value for *V* can be estimated by using the data on the number of sanctions *S* and the number of inspections *e* for an enforcement tool randomly implemented, like landing inspections for this case study. When vessels inspected are randomly selected, the percentage of infractions detected and sanctioned on the number of cases *e* can be considered as statistically representative of the total fishing effort. Consequently, *V* can be estimated by multiplying this percentage by the fishing effort:

$$V = \frac{S_r}{e_r} E \tag{5.16}$$

From equations (5.15) and (5.16), the probability to be sanctioned when violating can be estimated as follows:

$$\pi(e_r) = \frac{S_r}{V} = \frac{S_r}{\frac{S_r}{e_r} E} = \frac{e_r}{E} \tag{5.17}$$

For an enforcement tool with random controls, equation (5.17) shows that the probability of penalty is a linear function of the enforcement effort. This penalty probability function is used for the enforcement tool defined as landing inspections. As shown in equation (5.17), for this specific case the probability of penalty is always independent on the category of illegal behaviour. Therefore, the same function holds for all categories of violation when associated to landing inspections.

Based on the data collected for the period 2005-2007, the penalty probability function for landings inspections can be expressed as follows:

$$\pi(e_r) = 4.00\text{E - }06 * e_r \qquad (5.18)$$

When vessels to be inspected are not randomly selected, the probability of penalty is not a linear function. It should be a concave smooth function, monotonically increasing in the enforcement effort. If a two parameters functional form is used to describe this function, at least two points should be known for its estimation. Equation (5.14) provides one point, i.e. $\pi(E) = 1$, while the others should be estimated on the data available.

Given the level of enforcement effort e_t collected at time t, the probability of penalty at that time can be obtained as the ratio between sanctions applied and number of violations estimated. The number of sanctions applied at time t, S_t, is collected by inspection reports; while the total number of violations can be estimated as in equation (5.16) by using the data for the random enforcement tool at time t:

$$V_t = \frac{S_{r,t}}{e_{r,t}} E_t \qquad (5.19)$$

Therefore, the probability of penalty at time t for a non-random enforcement tool can be estimated as follows:

$$\pi(e_{nr,t}) = \frac{S_{nr,t}}{V_t} = \frac{S_{nr,t}}{S_{r,t}} \frac{e_{r,t}}{E_t} \qquad (5.20)$$

To estimate the penalty probability function for inspections at sea, we assume the following functional form:

$$\pi(e_{nr}) = \frac{a * e_{nr}}{b + e_{nr}}. \tag{5.21}$$

Based on the data collected for the period 2005-2007, the penalty probability function for inspections at sea can be expressed as follows:

$$\pi(e_{nr}) = \frac{1.69 * e_{nr}}{171746 + e_{nr}}. \tag{5.22}$$

The penalty probability functions for both enforcement tools are graphically reported in the following figure.

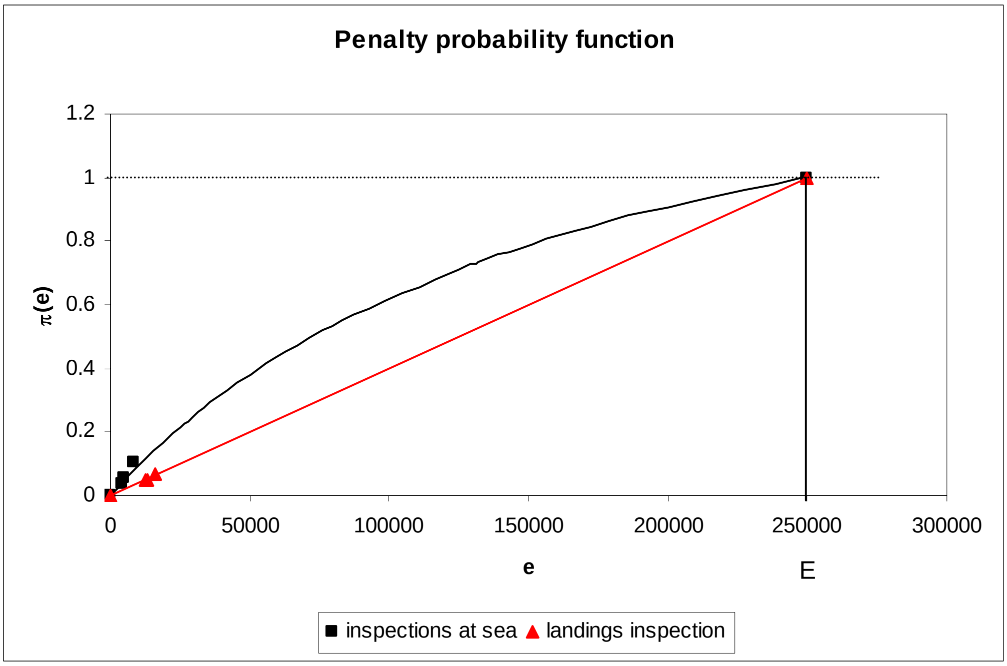

Figure 5.1. Penalty probability functions for landings inspections and inspections at sea.

Private cost of violation

The cost for fishers of violating a management measure defined as the private cost of violation is reported in deliverable D3 of this project as follows:

$$\psi(q;e,f,q^*) = \pi(e) f(q-q^*), \qquad \text{if } q \geq q^* \qquad (5.23)$$

$$\psi(q;e,f,q^*) = 0, \qquad \text{if } q < q^*, \qquad (5.24)$$

where q^* is a management measure, and f is the sanction for violating the regulation. Sanctions are here expressed in terms of fines.

For this case study, the private cost of violation has exactly the form shown in equation (5.23), but management measures equal zero, $q^* = 0$. Therefore, using the notation V instead of q for violation, the private cost of violation can be rewritten as follows:

$$\psi = \pi(e) f V. \qquad (5.25)$$

As reported above, two enforcement tools are considered for each category of infraction. Therefore, for each violation i, the private cost of violation is:

$$\psi_i = \pi_i(\mathbf{e}) f_i V_i, \qquad \text{for } i = 1, 2, 3. \tag{5.26}$$

where **e** is the vector of enforcement effort consisting of two values, one for each enforcement tool. The probability of having to suffer a sanction when violating the regulation i, $\pi_i(\mathbf{e})$, is given by the union of the probabilities associated to each of the enforcement tools, $\pi_{ij}(e_j)$:

$$\pi_i(\mathbf{e}) = \bigcup_j \pi_{ij}(e_j) \qquad \text{for } j = 1, 2, 3. \tag{5.27}$$

Assuming that a vessel cannot be sanctioned more than one time for the same infraction during the same day, the conjoint probabilities associated to more than one enforcement tool are zero:

$$\pi_{im}(e_m) \cap \pi_{in}(e_n) = 0 \quad \forall m \neq n, \tag{5.28}$$

and the equation (5.27) can be rewritten as:

$$\pi_i(\mathbf{e}) = \sum_j \pi_{ij}(e_j) \qquad \text{for } j = 1, 2. \tag{5.29}$$

Combining equations (5.26) and (5.29), the private cost of violation for the generic illegal behaviour i can be written as follows:

$$\psi_i = f_i V_i \sum_j \pi_{ij}(e_j), \quad \text{for } i = 1, 2, 3. \tag{5.30}$$

Consequently, the private cost of violations for all violations can be calculated by the following formula:

$$\Psi = \sum_i \psi_i = \sum_i \left(f_i V_i \sum_j \pi_{ij}(e_j) \right). \tag{5.31}$$

As in this case study the penalty probability functions are independent on the categories of violations, equation (5.31) can be written as follows:

$$\Psi = \sum_j \pi_j(e_j) * \sum_i f_i V_i = (\pi_1(e_1) + \pi_2(e_2)) * \left(f_q V_q + f_E V_E + f_s V_s \right). \tag{5.32}$$

5.6 Conclusions

The main problems encountered in estimating the functions described above are related to the availability of few data on the enforcement activities. As reported above, inspection reports do not describe in much detail the type of elementary control made. Moreover, the number of violations and the number of inspections are available either by enforcement tool or by category of illegal behaviour, but they are not available by enforcement tool and illegal behaviour at the same time. Therefore, it is not possible to measure the efficiency of enforcement tools in detecting specific violations. As a consequence, it is assumed that each of the enforcement tools investigates on all types of illegal behaviour with the same efficiency.

Furthermore, data on the enforcement activities are available only for three years, from 2005 to 2007. Given this short period and the relationships among enforcement and bio-economic variables, parameters for all functions are forced to be estimated using very few data.

6. Norwegian fisheries

6.1 Description of the enforcement system

There are several kinds of inspections and several agencies involved in the different stages of the fishing operation. The vessels can be boarded and inspected at sea, inspected upon landing the catch or irregularities can be exposed and subsequently traced back to the vessel upon inspections of land-based plants and processing companies.

Inspections while at sea:

1. Vessel can be boarded by Directory of Fishery inspectors while in fishing areas. These inspectors are organised under the unit *Sjøtenesten*, and it is division *Nord* that is responsible for the northern part of the country, which is relevant for the NEA cod fisheries. The focus of *Sjøtjenesten*'s inspections is on using illegal gears, targeting illegal species, discarding, and fishing in closed areas. Although most inspections are carried out on the sea, some inspections by *Sjøtjenesten Nord* are also done in harbours (ca 27% in 2005). Out of ca 600 inspections in 2005, 145 (ca 24%) focused on cod. The inspections targeted at the cod fishery covered ca 1025 tonnes of cod landed. This only accounts for 0.45% of the total Norwegian cod quota for 2005 of 225,700 tonnes.

2. Fishing vessels can be boarded and inspected by the Coast Guard. Coast Guard North are responsible for the NEA cod fisheries. After boarding a vessel, the Coast Guard will control all available and relevant information and documentation, such as whether the vessel has the appropriate license to take part in the fishery, that the log book is OK and corresponds to what is reported and the vessel's quotas. Controls typically occur while gear is in use, and the inspectors control the gear and the share of undersized fish. Coast Guard North carried out a total of 1405 inspections in 2005. Over the period 2003-2005, the total was 4112, of which the cod fishery accounted for 1914 inspections (46.5%). However, only a small share of the cod related inspections were of Norwegian vessels; 22% in 2005 (30% over the 2002-2005

period). Bottom trawlers account for the vast majority of inspections (over 70%). Looking only at vessels with cod trawl licenses, during a year, the Coast Guard carried out 0.60 inspections per vessel in 2005 (similar numbers for 2003 and 2004 are 0.68 and 0.74, respectively). The Coast Guard also patrols fishing areas by helicopters and planes.

Inspections after landing:

3. Upon landing, fishing vessels are automatically controlled as the landed fish is registered in a database and checked up against quotas and previous landings. Quantities landed in excess of quota are confiscated.[15] Two documents must be produced upon landing; a landing document (*landingsseddel*) and a final document (*sluttseddel*). These documents should contain detailed information on the catch, the vessel, the buyer of the fish, the fishing area, etc. The sales organisation operating in the area in which the fish is landed is responsible for this control. Two sales organisations handle almost all landings from the NEA cod fisheries; the Norwegian Fishermen's Sales Organisation (*Norges Råfisklag*) and SUROFI (*Sunnmøre og Romsdal Fiskesalgslag*). Over the period 2002-2005, the Norwegian Fishermen's Sales Organisation confiscated almost 350 tonnes cod (value: ca. 6.1 mill. NOK), out of the total cod quantities of 772,000 tonnes (value: some 8,600 mill. NOK). Also for SUROFI the fraction of fish confiscated is very low. Further controls by the sales organisations:
    a. Norwegian Fishermen's Sales Organisation: Employs ca. eight inspectors who carry out approximately 200 controls of plants/processing firms that deal with landed fish. These controls cover approximately 700-1000 vessels per year, and inspectors from the Directorate of Fisheries take part in half of these. In these inspections one controls the scales used and the final documents from landings (*sluttseddel*). Sometimes also trade numbers and accounts are inspected.

[15] Confiscated landings belong to sales organisation, which is owned by the fishermen. Thus, the value of confiscated landings actually ends up on the hands of the fishermen.

b. SUROFI does not have inspectors (argues that an organisation owned by fishermen should not control fishermen). Thus, no control apart from registering landings and checking up against quota.

4. The regional offices of the Directorate of Fisheries (DoF) also carry out dock-side inspections. Five out of the seven regional offices are relevant for the NEA cod fisheries: Finnmark, Troms, Nordland, Trøndelag, and Møre og Romsdal. 80% of the inspections are targeted at the approximately 250,000 individual landings of fish in Norway per year. There are two types of controls: (a) document inspection, which involves checking the log book and the final landing document, and to check the two up against each other, and (b) full inspection, which is a document inspection complemented by inspection of the actual landed fish. The frequency of inspections (inspections per landing) varies between the regional offices, the nationality of the vessels, and with the size of the vessels. All Russian vessels landing fish in Norway are inspected, whereas the rate for Norwegian vessels is much lower. Furthermore, larger vessels are more likely to be inspected than smaller vessels. For coastal vessels there are 0.015 inspections per landing, whereas for the larger off-shore vessels there are 0.060 inspections per landing. Coastal vessels account for 95% of the number of landings in the five northernmost regional offices, but the quantity share of coastal vessels is lower. Over a year, the smallest vessels (<10m) are inspected on average 0.07 times, whereas the larger vessels (>15 m) are inspected, on average, more than once. Focusing only on landings of cod, the shares of landed quantity inspected are available for four regional offices. These are Finnmark 4.0%, Troms 14.7%, Nordland 10%, and Møre og Romsdal 23.4%.[16]

The regional offices of the DoF perform inspections of plants and processing firms. There are three types of inspections: (a) Documentation inspections, where one inspects landings documents for a specific period. These controls can expose violations such as

[16] The large variation between regions can, at least in part, be explained by differences in the types of vessels landing their catches in the different regions. In Finmark and Nordland, 80% of the quantity was landed by coastal vessels (i.e., relatively low quantity per landing), whereas in Møre og Romsdal, 90% of the quantity was landed by larger offshore vessels (i.e., relatively large quantities per landing).

transhipments. (b) Stock inspections, where the stock of fish in storage is checked up against landings documents. (c) Trade inspections, which are combined with stock inspections, where one checks the stock of fish in storage and trade data up against landings documents. These controls can expose attempts to not report the complete quantity landed. The majority of these inspections include controlling landings from the NEA cod fisheries. For the cod fisheries, there were on average 0.1 inspections per plant over the period 2003-2005 in the five northernmost regional offices of the DoF. These controls covered 1.8% of the total cod quantity landed.

6.2 Data used

6.3 Estimation of theoretical relationships

6.3.1 Probability of penalty function

Having determined estimates of the inspection probabilities for various types of inspections, the next step is to derive estimates of the risk of detection given that a violator is inspected. As mentioned above, the main issue here is that we only have information on the vessels that are detected for violating various regulations. The information on the vessels that are not detected for their violations is, on the contrary, very limited.

Another issue that arises is that there is a clear relationship between certain types of inspections. For instance, we know the number of full inspections and document inspections carried out upon landing. We also know the share of landed quantity controlled in these inspections. However, it is highly likely that the decision of whether to do a full inspection in many cases depend on what the inspectors find in the document control. It is also likely that the probability of detection, given that one has violated the regulations, is much higher if there is a full inspection rather than just a document inspection. Thus, these two types of inspection cannot be treated independently of each other. The same goes for other forms of inspections that there are dependencies between.

When estimating probabilities of detection, we simplify the analysis to consider only closure of areas, quota violations and incorrect use of gear. Furthermore, we ask about controls at sea (Kystvakten) and at/after landing. Thus, we ask industry experts about probabilities for detecting illegal behaviour if illegal fishing takes place. During control of landings of catches, only quota regulations are relevant. While for inspections of vessels at sea, also area regulations incorrect use of gear is controlled. Control of areas at sea takes place electronically since authorities can trace vessels while at sea, and this type of inspection is said to give a very high probability of detecting illegal activities. Also, the Kystvakten is said to have fairly precise measures when estimating catches and will also be in a position of detecting. However, for small violations one will be less able to detect quota violations. This also seems to be the case when vessels use the wrong type of gear, though the estimates vary more on this.

Table 6.1: Evaluation of probability (percent) of detection provided violation of regulations

Type of violation	Type of inspection	
	Control of landings	At sea
Area	-	80 – 100
Regulation of quota	5 - 25	75 – 95
Gear	-	50 - 90

Finally, there are several types of inspections for control at landings. When inspecting a landing facility one most likely inspects catches from several vessels at the same time, this is in contrast to automatic controls of landings. We simplify by assuming that there is only one probability of detection. Thus, we assume that any inspection of landing facilities (either periodic or turnover) will only add to the likelihood of detection from automatic landing controls. The likelihood for detecting a violation of quota at automatic control is said to be rather low, ranging from 5 % to 10 %. Furthermore, periodic inspections and inspections of turnover of processing plants will only add slightly to the probability of detection. However, these inspections are said to add only slightly to the likelihood of detecting quota violations. As noted above, the inspections may be interrelated and we will not estimate the true probability of detection when disregarding these. However, the true nature of the relationship between the various inspections and their individual probabilities of detection are not well known, as also is described by the range of probabilities. Once again, the likelihood of detecting a substantial violation is higher than detection of smaller violations.

6.3.2 Enforcement cost function

The objective of this section is to derive the enforcement cost function. The approach taken is to use cost and enforcement data to estimate the cost per inspection, etc. Then, in the next step, to relate this to the probability of inspection based on the estimates presented in a previous sections. The result is an enforcement cost function that depends on the control effort in the various parts of the enforcement; a function with the same arguments as the probability of detection function.

The cost of inspections before landing

Two units are involved in this part of the enforcement; *Sjøtjenesten* and the Coast Guard.

Sjøtjenesten Nord carried out a total of 600 inspections in 2005, of which 145 inspected vessels were targeting cod. According to cost data from the Directorate of Fisheries, the total cost of *Sjøtjenesten Nord* in 2005 was NOK 19.5 mill. Dividing the total cost by the total number of inspections yields a cost of Norwegian kroner (NOK) 32,500 per inspection. *Sjøtjenesten* also has other responsibilities, in addition to vessel inspections. Consequently, the estimated cost of 32,500 NOK/inspection is likely to be too high. On the other hand, it is very likely that there are other costs not directly related to the every day operations of *Sjøtjenesten*, such as various staff functions, that are also relevant. In lack of more accurate information, we therefore assume that the cost per inspection is NOK 32,500. According to Riksrevisjonen (2007) 1,025 tonnes of cod were covered by these 145 inspections. That gives a cost per inspected kilo of ca 32 NOK.

Coast Guard North carried out a total of 1405 inspections in 2005. Over the period 2003-2005, 46.5% of the inspections involved cod vessels. However, the majority of vessels inspected by the Coast Guard are foreign. For simplicity, we make the assumption that the cost of an inspection does not depend on what species the vessel is targeting, the harvesting technology used, or the nationality of the vessel.

As was the case for Sjøtjenesten, also Coast Guard North has many other responsibilities than inspecting fishing vessels. Furthermore, a large share of the inspected vessels is not Norwegian cod vessels. According to the Coast Guard,[17] roughly 70% of their resources are allocated to fisheries enforcement activities. From the annual report of the Coast Guard, the number of so-called patrol days and the total annual costs of the Coast Guard per year are available.[18] The number of patrol days is further divided into patrol days produced by *Indre KV* (coastal) and *Ytre KV* (ocean) (Riksrevisjonen, 2007). This is summarised in Table 6.2.

Table 6.2. Patrol days and total cost 2003-05, Coast Guard total.

	Patrol days, *Indre KV*	Patrol days, *Ytre KV*	Patrol days, total	Tot. costs (mill. NOK)	Cost per patrol day (mill. NOK)
2003	2995	3453	6448	676	0.105
2004	3114	2996	6110	730	0.119
2005	3065	2457	5522	747	0.135

The drop in patrol days from 2003 to 2005 is said to be due to a reorganisation. The numbers for 2005 are therefore of most relevance for subsequent years. In 2005, *Ytre KV* accounted for 44.5% of the total number of patrol days.

In lack of data on costs by Coast Guard activity, we make the assumption that the Coast Guard's ratio of patrol days for non-fisheries enforcement activities to costs is the same

[17] Source: http://www.mil.no/sjo/kv/start/oppgaver/fiskerioppsyn/ (visited 05 June 2008).

[18] A patrol day is a full day when a Coast Guard vessel is fully manned and on patrol. A vessel on patrol may spend time in harbour, as long as the duration of the stay is less than 24 hours.

as for fisheries enforcement. We can then use the average cost per patrol day as a measure of the cost per fisheries patrol day.
Riksrevisjonen (2007) reports the corresponding numbers for Coast Guard North. These are given in Table.

Table 6.3. Coast guard vessels, patrol days, and number of inspections 2003-05, Coast Guard North.

	Vessels	Patrol days	Inspections
2003	17	4004	1285
2004	16	4137	1422
2005	15	3458	1405

We know that 70% of the costs of the Coast Guard are related to fisheries enforcement. Before dividing total costs by the number of inspections to find the cost per fishery inspection, we therefore deduct 30% from total costs. Furthermore, from budget data provided by the Coast Guard for 2008, we find that for KV North, *Ytre KV* accounts for 70.7% of the total costs, *Indre KV* accounts for 13.5%, and 15.8% relates to shared functions. If we distribute the cost of the shared functions to *Indre KV* and *Ytre KV* according to their cost shares, their shares of KV North's total costs becomes 16% and 84%, respectively for *Indre KV* and *Ytre KV*. The 2008 budget numbers also show that the total costs of the unit KV North are 2.3 times higher than the costs of the unit KV South. We therefore assume that KV North is reliable for 70% of the total costs of the Coast Guard. The corresponding allocation of the total cost of the Coast Guard to the different units is shown in Table 6.4.

Table 6.4. Estimated costs by Coast Guard unit, 2003-2005.

	2003	2004	2005
Total cost, Coast Guard (mill. NOK)	676	730	747
KV South (30%)	203	219	224
KV North (70%)	473	511	523
Indre KV (16%)	76	82	84
Ytre KV (84%)	397	429	439

The total cost per patrol day for the various vessels under Coast Guard North has been made available to us for 2008 by the Coast Guard. The cost data are summarised in Table 6.5. Note that only vessels that were in operation the full year are included in the table. Furthermore, the costs are total costs for vessels, and therefore exclude costs of shared functions for the vessels in KV North.

Table 6.5. Cost per patrol day, KV North, 2008 (only vessels operating the whole year are included).

	Total costs (1,000 NOK)	Patrol days	Cost/patrol day (NOK)
Total *Ytre KV*	351,547	1,732	202,972
Ytre KV: vessels with helicopters	219,061	940	233,044
Ytre KV: vessels without helicopters	132,486	792	167,280
Total *Indre KV*	60,725	607	100,041

Notice from Table 6.5 that total vessel costs per patrol day are twice as high for an *Ytre KV* vessel as it is for an *Indre KV* vessel. Based on the data presented above, we turn to the calculation of cost per inspection carried out by the Coast Guard.

In lack of more detailed data, we assume that there is no difference between the number of inspections made per patrol day for Coast Guard vessels operating off shore (*Ytre KV*) and along the coast (*Indre KV*). To calculate the cost per inspection for the two units, the number of inspections is allocated to *Indre KV* and *Ytre KV* based on the number of patrol days produced. The calculation of cost per inspection is shown in Table 6.6 based on cost data for 2005. These cost estimates includes all costs, including the cost of Coast Guard Command and the various staff functions, and therefore not only the costs of operating the vessels. These costs are included, as the activities they cover are necessary for the fisheries enforcement activity of the Coast Guard.

Table 6.6. Cost per inspection 2005, Coast Guard North.

	TC fisheries insp. KV North (mill. NOK)	Patrol days and shares	Inspections	Cost per inspection (NOK)
Total KV North	523	5522 (100%)	1405	372,000
Ytre KV	439	2457 (44.5%)	*625*	*702,000*
Indre KV	84	3065 (55.5%)	*780*	*108,000*

Table 6.6 shows that the cost of an inspection offshore is much more expensive than an inspection carried out by the *Indre KV* that operates near shore. A significant difference is expected, as the offshore Coast Guard vessels are larger and more expensive to operate. Furthermore, the vessels inspected inshore are significantly smaller than the vessels inspected offshore, which adds to the cost difference. However, the cost estimates are based on the assumption that both *Indre KV* and *Ytre KV* inspect the same number of vessels per patrol day. It is possible that Ytre KV inspects more vessels per patrol day, which would reduce the cost difference for inspections between the two. Furthermore, the assumption that all inspections carried out by *Indre KV* and *Ytre KV*, respectively, are equally costly was also implicitly made in the calculations above.

Notice that only a part of the Coast Guard vessels fisheries enforcement activity involves inspections; KV North produced 5522 patrol days in 2005, but only inspected 2378 vessels that year (i.e., less than one inspection per two days). Patrol days and vessel inspections should therefore be seen in connection.

The cod fisheries only account for some of the costs of the Coast Guard. Furthermore, with Russian and other foreign vessels being the targets of the majority of cod inspections, only a relatively small share of the total resources of the Coast Guard is devoted to controlling Norwegian cod vessels.

The final step is to estimate the inspection cost per kilo fish inspected. In order to do this we need estimates of the average quantity of the vessels inspected by Indre KV and Ytre KV, respectively. Data on inspected quantities are not available. Instead, we use landings data. As vessels may be inspected before they have caught the quantity they subsequently land, the corresponding estimates may be biased downward. On the other hand, many of the inspected vessels have finished harvesting when they are inspected (such as Russian and other foreign vessels that are required to report at certain check points and make themselves available for inspection, before they are allowed to leave Norwegian waters). Furthermore, the Coast Guard typically board vessels for inspection while the vessel is about to pull up the harvesting equipment. This enables them to inspect the mesh size and other technical restrictions, and the share of by-catches of other species and under-sized fish, in addition to documents and harvested quantity. On the other hand, the data on landings are based on the document produced upon landing. In some cases, more than one landing document is produced for one landing. Thus, the average quantity landed per fishing trip calculated from landing documents underestimates the actual quantities landed. Thus, this contributes to cancelling out the downward bias from using landing data in the calculations.

The quantities per landing document for landings handled by the NFSO are reported in Table 6.7. The numbers are based on landings statistics provided by the NFSO. Whereas the trawlers typically land quantities well over 30 tonnes, the average for other vessels is much lower. However, the variation among the vessel types (defined by harvesting technology) is large. Still, using the numbers for trawlers as an approximation of the volume of offshore operating vessels and the numbers for “other vessels” as an approximation of the volume of coastal vessels seems reasonable.

Table 6.7. Quantity per landing, by vessel type, NFSO, 2003-05 (in kg)

	Trawlers	Other vessels	Total
2003	48,050	1,835	3,443
2004	38,908	1,501	2,704
2005	42,181	1,533	2,878
2003-05	42,769	1,608	2,975

Combining the cost estimates from Table 6.5 with the numbers for 2005 in Table 6.6, gives us estimates of the inspection cost per kilo fish inspected. The calculations are shown in Table 6.7. Notice that after accounting for the quantities inspected, the unit cost is lower for inspections done by *Ytre KV* than for inspections by *Indre KV*.

Table 6.8. Estimated cost per kilo fish inspected by the Coast Guard (KV North), 2005.

	Ytre KV	*Indre KV*
Cost per inspection	702,000	108,000
Quantity per vessel	42,181	1,533
Cost per kilo fish inspected	**16.6**	**70.5**

As was evident from Table 6.7, the quantity per vessel varies over time. This is likely to depend on among other things the quotas and the availability of fish. Thus, by using the cost estimates in Table 6.8, the cost per kilo fish inspected may be underestimated in years with relatively high catches, and overestimated in years with relatively low catches.

The cost of inspections during/after landing

As described above, all landings that are reported according to regulations will be checked up against a database of vessels' quotas and previous landings. The cost of this involves the cost of developing the database and the necessary computer system and the cost of drifting and using the database and computer system. It is difficult to estimate the annual cost of this, but relative to the quantities landed and entered into the system (and then automatically controlled against quotas) it is very small. The presence of this system and its cost are therefore assumed fixed and disregarded.

Inspections upon landing are carried out by the Directorate of Fisheries and inspectors employed by the Norwegian Fishermen's Sales Organisation. NFSO employs ca eight inspectors who carried out approximately 200 inspections annually. The inspection activity is mainly funded by the value of confiscated fish; typically landed fish that exceeded the quota of the vessel. The value of landings confiscated by the NFSO over the period 2003 to 2005 was NOK 6.1 million. This gives a cost per year of approximately NOK 2 million, which gives a cost per inspection of NOK 10,000.

The Directorate of Fisheries carries out two main types of inspections; dock-side inspections (individual landings) and inspections of plants and processing firms. Furthermore, the degree of thoroughness varies. For dock-side inspections one distinguishes between document inspection and full inspection (see above), where the latter is far more time consuming than the first. For inspections of plant and processing firms, one distinguishes between document inspections, stock inspections, and trade inspections. The seven regional offices of the DoF are responsible for the controls of around 8000 Norwegian and 1500 foreign vessels that annually make ca 250,000 landings to about 1,000 companies.

The DoF regions most relevant for the cod fishery are Finnmark, Troms, Nordland, Trøndelag, and Møre og Romsdal. Cost data for these regions have been made available to us by the DoF and the numbers for 2005 are summarised in Table 6.9.

Table 6.9. Costs and Man Years by Directorate of Fisheries Region, 2005 (costs in 1,000 NOK)

	Finnmark	Troms	Nordland	Trøndelag	Møre og R.	Sum
Salaries, etc.	11,267	20,208	18,448	6,615	14,876	71,414
Supplies	6,392	11,465	10,466	3,753	8,440	40,516
Total costs	17,659	31,672	28,914	10,367	23,315	111,927
Man years	28	50	46	16	37	177
Inspectors [a]	11	8	13	2.3	8	42.3

[a] *The number of inspectors per region is from Riksrevisjonen (2007).*

As is evident from Table 6.9, only a quarter of the man years in the regions are inspectors. In addition to the cost of the inspectors comes the cost of staff organised under the control section of the DoF who working on the cases following inspections. According to Riksrevisjonen (2007), approximately ten man years in the control section of the DoF are devoted to this. Table shows the average total cost per man year in the regions of the Directorate of Fisheries included in Table 6.10

Table 6.10. Costs per man year in DoF Regions, 2003-2005 (in 1,000 NOK).

	2003	2004	2005
Total costs	193,981	152,051	145,154
Total man years	300	237	229
Cost per man year	646.6	641.6	633.9

The total number of inspections carried out by the inspectors is only available as the total inspections for all regions. Total inspections also include export controls, transportation controls, and a few other types of controls. These types of inspections only account for a minor share of the total number of inspections. For that reason, we treat all inspections after landing as either dock-side inspections or inspections of plants and processing firms. Based on information from Riksrevisjonen (2007) of the share of dock-side inspections etc. of total inspections, estimates of the number of inspections by type are given in Table 6.11.

Table 6.11. Number of inspections by type, 2003-2005.

	2003	**2004**	**2005**
Total inspections	6384	5854	4699
Dock-side insp. (80%)	5107	4683	3759
Document inspections [a]			1316
Full inspection [a]			2443
Plant/processing (20%)	1277	1171	940
Document inspections (80%)	1022	937	752
Storage & trade insp. (20%)	255	234	188

[a] *According to Riksrevisjonen (2007) the share of full inspections of dock-side inspections was ca. 65% in 2005. Information not available for 2003 and 2004.*

Riksrevisjonen (2007) reports that for inspections of plants and processing firms, a document inspection requires an average of about three hours, whereas the average storage and trade inspection lasts for over 23 hours. Thus, although the travel cost for the inspectors are independent of the type of inspection, the storage and trade inspection is significantly more costly. According to the DoF, the corresponding numbers for landings inspections are that the average document inspection requires approximately five man hours, and the average full inspection requires 9.5 man hours. The numbers are summarised in Table 6.12.

To calculate the cost per inspection by inspection type, we start out by calculating the total cost of inspections. This is based on the number of inspector man years presented in Table 6.11, with the addition of ten man years employed at the control section of DoF (see above), and the cost per man year from Table 6.10. Consequently, the estimated average total cost of inspections in the regions in question is: $\left(42.3+10\right)\cdot 633.9=33{,}153$ thousand NOK per year (based on 2005 numbers).

To calculate the cost per inspection, we base the calculations on the number of inspections for 2005 as presented in Table 6.11. The total cost of inspections (33.152 mill. NOK) is allocated to the different inspection according to inspection man hours used. The calculations are shown in Table 6.12. The cost of an inspection man hour turns out to be NOK 912. As the table shows, most resources are spent on dock-side inspections (ca 80%).

Table 6.12. Calculating the cost per inspection by type (costs in NOK).

	Inspections	Hours/insp.	Tot. hours	Cost share	Cost/insp.
Dock-side inspections					
Document inspections	1,316	5	6,580	18.1%	4,560
Full inspection	2,443	9.5	23,209	63.8%	8,660
Plant/processing insp.					
Document inspections	752	3	2,256	6.2%	2,740
Storage & trade insp.	188	23	4,324	11.9%	21,000

According to Riksrevisjonen (2007) is 1.8% of the total quantity in the five northernmost regions covered by the inspections of plants and processing firms. The total quantities of fish sold through NFSO and SUROFI was 711,153 tonnes in 2005. Thus, estimated inspected quantity is about 12.800 tonnes, since plant and processing inspections account for 18.1 % (6.2+11.9) of overall costs, inspection cost per kg is NOK 0.4687 per tonne(overall costs of inspection is NOK 33.152 mill.). Assuming that fish entering into plants or processing facilities are landed from vessels, the total quantities landed is 711,153 tonnes in 2005. All of these landings are automatically inspected. The costs of these inspections are NOK 27.151 mill., and overall inspection cost per tonne is NOK 38 per tonne.

7. Icelandic cod fishery

7.1 Authorship and affiliation

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7.2 Introduction

The Icelandic cod fishery is a major fishery with a maximum sustainable yield of over 300 thousand metric tonnes annually and landed value of some 500 million Euros. The fishery has been managed on the basis of ITQs for several years with supplementary restrictions on fishing gear, time and area restrictions. So, fisheries enforcement is primarily concerned with these management measures. A special agency, the Fisheries Directorate, was established 15 years ago to conduct this enforcement. In recent years, in order to restore the cod stock annual TACs (total allowable catches) have been cut back substantially and some of the other management measures have been made more restrictive. Notwithstanding this, the fishery is still quite profitable, but economic incentives for violations may have increased.

7.3 Description of the enforcement system

There are three main legislations for fisheries management in the Icelandic EEZ; the Fisheries Management Act, No. 116/2006, the Treatment of Exploitable Marine Stocks Act, No. 57/1996, and the Fishing in Iceland Fisheries Jurisdiction Act, No. 79/1997. These legislations define fisheries management tools, how the corresponding measures may be set and specify sanctions for violating these measures. Violations may lead to written reprimands, revocation of fishing license, fines and imprisonment up to six years, depending on the seriousness of the violation.

According to these legislations, penalties for first violations are less heavy than those for repeated offences. The length of the period of revoked fishing license depends on the seriousness of the violation, from one week to a permanent revocation. The maximum fine for first violation is ISK 4,000,000 (approximately US$ 57.000) for first offences and a minimum fine of ISK 400,000 and maximum fine of ISK 8,000,000 for repeated offences. The above minimum fine used to apply to all offences, but was altered to distinguish between first and repeated offences in 2006. In addition to monetary fines, there is a clause in all three Acts allowing a special fine on illegal catch to be issued on the basis of Act 37/1992. The Fishing in Iceland Fisheries Jurisdiction Act, No. 79/1997, further includes a paragraph (§16) allowing for the confiscation of illegal gear.

The Directorate of Fisheries is the main public institute charged with enforcing fisheries legislation. Among other things, it issues reprimands and fines and revokes fishing licenses. More serious offences are forwarded to the public prosecutor to be dealt with by the courts.

It is clear from the above text that existing legislation allows for quite severe penalties for serious violations. The actual use of this scope for penalties is another story. Fishing license revocations have been used quite extensively, but usually for short periods. The average fine was close to the minimum fine prior to the 2006 modification of the legislation and has been reduced since, indicating that most violations are regarded as small. Relatively few cases, less than 8% of reported violations, have been sent to the prosecuting authorities. Actual convictions have been fewer still.

7.4 Data used

Data on efforts and costs during the period 2001-2006 was obtained from the Icelandic Directorate of Fisheries regarding on board monitoring.

To assess the cost of violation of the quantity restriction we assume that all methods of sanctioning are used but the level increases with the severity of the violation. A small violation (10%) is assumed to lead to a fine of ISK 400,000 and license revocation for one week. A medium violation (20%) is assumed to lead to a fine of ISK 2,000,000 and license revocation for four weeks. A major violation (30%) is assumed to lead to the maximum fine of ISK 4,500,000 and license revocation for eight weeks. Further we assume that all illegal catch is confiscated. Based on these assumptions the parameter *f*1 in equation (7)[19] is estimated to be 1476. ISK/kg2. Similarly, assume that the cost of violating the mesh size restriction also increases with the severity of the violation. A small violation (10%) is assumed to lead to a fine of ISK 150,000 and license revocation for one week. A medium violation (20%) is assumed to lead to a fine of ISK 1,000,000 and license revocation for three weeks. A major violation (30%) is assumed to lead to the maximum fine of ISK 2,500,000 and license revocation for six weeks. Further we assume that all illegal catch is confiscated. Based on these assumptions the parameter f2 in equation (7) is estimated to be 40.9 ISK/unit2. Ar

[19] All equation numbers in this case study refer to Arnason R. et al., Fisheries enforcement: the case of the Icelandic Cod fishery, preliminary findings (project COBECOS 2007)

7.5 Estimation of theoretical relationships

7.5.1 Benefit function.

a) Private Benefit function

The bioeconomic part of the model covers the pure private benefits from fishing, the biomass growth function and the shadow value of biomass[2]. Many of the parameters involved in this bioeconomic model are obtained from a previously estimated bio-economic model (Agnarsson et al 2007). However, it has been necessary to specify values for the special additional parameters associated with the fisheries management and enforcement activity. The parameters and the estimates are listed in Table 7.1

Table 7.1 Parameters in the bio-economic model

Parameters	Value	Estimation method	Source
Landings price, p	220 ISK/kg.	Econometric estimation	Agnarsson et al 2007
Fishing costs, a_0	100	Econometric estimation +adjustment	Agnarsson et al 2007 Authors
Fishing costs, a_1	60	Econometric estimation +adjustment	Agnarsson et al (2007) Authors
Fishing cost, a_2	0.5	Guesstimate	Authors
Fishing cost, γ	1.1	Econometric estimation	Agnarsson et al 2007
Biomass growth, a	0.6699	Econometric estimation	Agnarsson et al 2007
Biomass growth, b	0.3353	Econometric estimation	Agnarsson et al 2007
Biomass growth, α*	1	Guesstimate	Authors
Base year biomass	715.000 mt	Biological estimate	Marine research Institute 2007
Shadow value of biomass, λ	150 ISK/kg	Bio-economic estimate	Agnarsson et al 2007 Arnason et al. 2007.

2 We ignore the theoretical fact that the shadow value of biomass is an endogenous variable depending inter alia on the enforcement parameters and activity.

The impact of mesh-size (the α parameter) on biomass growth and private profits according to the above specification is illustrated in Figures 7.1 and 7.2 below. As can be seen from Figure 7.1, the impact on biomass growth is quite pronounced. With α=1, the MSY (maximum sustainable yield) occurs at biomass approximately equal to 1 million mt (metric tonnes) and sustainable harvest of 0.335 million mt (Agnarsson et al 2007). With a smaller mesh-size (α=0.5), the MSY is lower and occurs at a lower biomass level. Note that the carrying capacity of the biomass is reduced if α deviates from the value 1. The careful reader will realize that this doesn´t make much sense — in a sustainable equilibrium at the carrying capacity there can be no harvesting and therefore no negative effect by harvesting on biomass growth. The effect illustrated in Figure 1 is a consequence of the relatively simplistic specification of how α affects biomass growth.

Private profit function also depends strongly on the "mesh-size" used. Basically the closer the mesh-size is to the value of 0,5 the higher the private profits. (Remember the private profits are instantaneous profits ignoring impacts on future biomass). Thus, at harvest levels 0.215 and biomass 0.715 million mt., private profits are 21.5 billion ISK when α=0.5, but only 17.6 billion ISK or 18% less when α=1.0.

It is similarly useful to understand how, according to the above model, private and social benefits from the fishery vary with (i) harvests for a given mesh-size and (ii) and mesh size for a given harvest. These relationships are illustrated in Figure 3, panels (a) and (b), respectively. Panel (a) compares the private and social benefits for different levels of harvest. As explained in section 2 of Arnason (2008), in the absence of enforcement the difference between private and social benefits lies only in the shadow value of biomass changes which private decisions ignore. For this reason, the social benefits of small harvest can be high, while private benefits are small and vice versa. Interestingly, under the above specifications, the maximum social benefits are at no harvest whatsoever. This is in accordance with the results of previous studies (Arnason et al. 2007) when biomass is only 715.000 mt. Note also that the private benefits have virtually no relationship with the social ones. They do not even depend in the same way on harvests.

Similar considerations apply to the “mesh-size” as represented by α (panel b in Figure 7.3). For a harvest level of 215.000 mt, the social optimum is at α=0.9 (below α=1 which maximizes biomass growth). The private optimum, however, is at α=0.5 which minimizes harvesting costs.

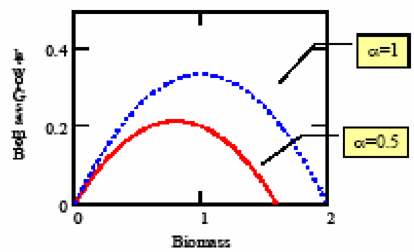

Figure 7.1 Biomass growth under different αs

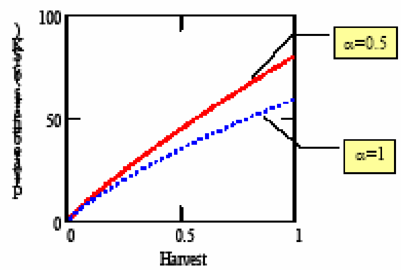

Figure 7.2 Private profits under different αs

Finally it may be informative to consider sustainable fishery in the above model. This is depicted in benefit (value) – biomass space in Figure 7.4 below. Note that the harvest level may be inferred from the biomass level in the diagram — it is simply the biomass growth G(x) because this is the sustainable fishery and biomass is constant. Note also, that since biomass is constant, private and social benefits are identical — there is no charge for a zero biomass change. Therefore it is not necessary to consider them separately in the diagram. In the diagram, sustainable revenues are just a multiple of net biomass growth (harvest rate). It may be noted that costs in Figure 7.4 increase very fast initially and then decline with sustainable biomass. The reason is that initially, sustainable harvests, i.e. G(x,α) raised to the power of 1.1 increase faster than biomass. This however is reversed at a relatively low biomass level (approx. 0.170 million metric tonnes) beyond which harvesting costs fall with biomass. As indicated in the diagram, the social optimal sustainable fishery is at biomass 1.244 million mt. with sustainable catches of 314.000 mt.

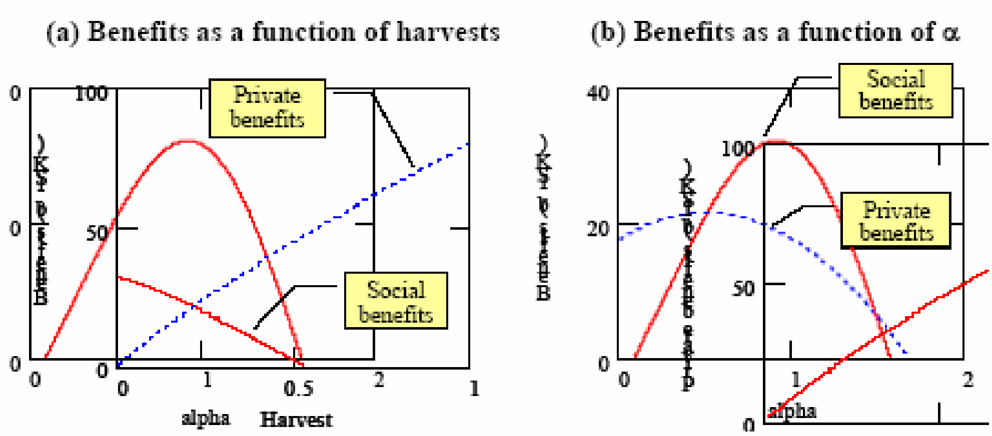

Figure 7.3 Benefits from fishing (B.ISK)

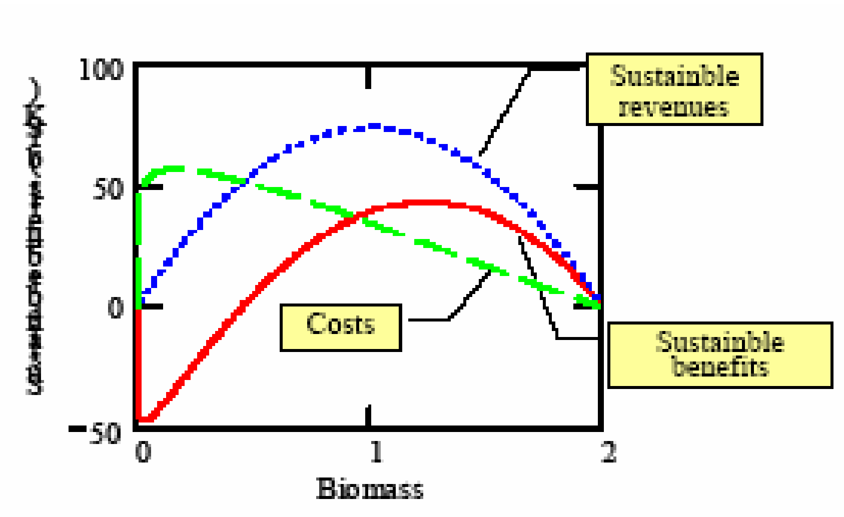

Figure 7.4 The sustainable fishery (α=1)

b) Social Benefit function

The above model can be used to determine the optimal levels of enforcement effort given any fisheries management measures. This, as pointed out in section 2 (Arnason 2008), involves a two-tiered maximization procedure. First, the enforcement agency selects values for enforcement effort, e_1 and e_2. Taken these as well as the fines and other parameters as data the fishers respond by their profit maximizing harvest and mesh size, q and α. This leads to certain social benefits from the fishery. On that basis the enforcement agency selects new enforcement efforts to which the fishers respond. This process continues iteratively until the optimal e_1 and e_2 have been located.

The essence of this procedure is illustrated by the flow diagram in Figure 7.5. Note that in programming terms, what is involved here is double loop maximization. Employing standard numerical search routines to select the maximizing levels of the controls in each loop (in this particular case, routines in the widely available MATLAB package (Mathworks 2008) were used) this procedure lead quite quickly and reliably to the solution.

Assume that the government has decided on the following management measures for the fishery:

- TAC = 0.215 million mt.
- "Mesh size" restrictions, α=1.

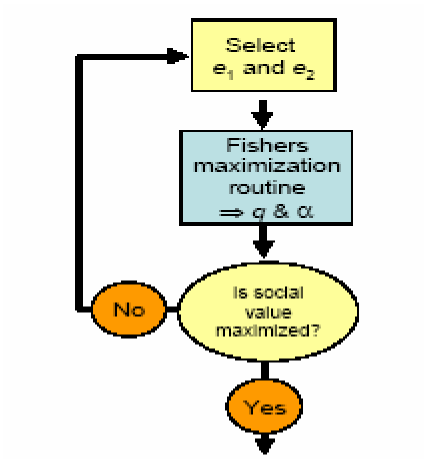

Figure 7.5 Numerical calculation: Flow diagram

Given this, as well as the other conditions of the situation, the enforcement problem is to determine the optimal enforcement mix. The optimal enforcement and other key enforcement results are summarized in Table 7.2.

Table 7.2 Enforcement of the Icelandic cod fishery: Key results

Enforcement situation	Enforcement e1	e2	Harvest q	Mesh-size α	Private benefits (b.ISK)	Social benefits (b.ISK)
No enforcement	0	0	0.600* (+179%)	0.5 (-50%)	52.3	-6.0
Optimal enforcement	0.855	0.284	0.243 (13%)	0.884 (-16%)	19.8	29.5
Voluntary compliance	0	0	0.215 (0%)	1.0 (0%)	17.6	31.5

* The harvesting capacity level.

Numbers in parentheses indicate deviations from the management measures q=0.215 and α=1

The message in the first line in Table 7.2 is that if there is no enforcement, fisheries actions will deviate hugely from the management stipulations. The harvest is 179% higher and the mesh size 50% smaller than what is allowed by the management measures. With these very high catch levels (approximately the fleet capacity level), private benefits (profits) are very high. This is because this is a very valuable fishery and the fishing capacity is sufficient to expand harvest greatly without substantially increaseing average costs. The social benefits from this policy, however, are highly negative. This is because the high catch level decimates the stock of cod, which expressed by the shadow value of biomass entails a huge social cost.

The optimal enforcement entails quite a high level of effort to enforce the harvest level and a much lower enforcement effort on the "mesh-size" variable. Remember that enforcement is measured in units of 20 man-years in the field. Under optimal enforcement, both private and social benefits are positive. The social benefits are quite high compared to the maximum, which is found under full voluntary compliance, and much higher than the private benefits. The reason private benefits are smaller are the fines paid by the industry and the gain in biomass under optimal enforcement, which is not included in private benefits. Deviations from the harvest and "mesh-size" management measures are 13% and 16%, respectively. These deviations may be regarded as substantial. However, they are much less than under no enforcement and have no economic relevance as such; only actual catches and "mesh-sizes" have.

If there is full voluntary compliance (fishers are perfectly law abiding), no enforcement is needed. This means that the social benefits achieve the maximum (for the given management measures). Private benefits on the other hand decline slightly compared to optimal enforcement. This may be regarded as the private cost of respect for the law (honesty). The difference between social benefits under full voluntary compliance and optimal enforcement, (2 b. ISK) may, on the other hand, be regarded as the social cost of disrespect for the law (dishonesty). If there is no enforcement, this cost would be 25.5 b. ISK. So, the social gain of the enforcement activity is 23.5 b. ISK. It may be informative to compare this gain of enforcement with the cost of enforcement at the optimal level which is approximately 0.850 b. ISK (approx 0.008 b. Euros, or 8 million Euros). So, for this model at least, the economic return on enforcement seems to be huge. It is interesting, moreover, that the fines collected exceed this cost by a substantial amount.

To better understand the nature of the enforcement optimal solution, it is useful to inspect the benefit function surfaces. This is done in Figure 7.6 below. The first diagram in Figure 7.6 provided the surface of social benefits over the space enforcement efforts. Note how flat this surface is close to the optimal enforcement mix. This, if empirically accurate, is an advantage for practical enforcement. For it implies that relatively modest deviations in enforcement effort mix from the optimal cost relatively little in social benefits.

The second diagram provides surface of private benefits over the space of private controls, namely α and q at the above optimum enforcement. The most striking aspect of this surface is that it is quite peaked close to the optimal level. Consequently, fishers will incur heavy costs if they deviate much from what maximizes their profits. This suggests that uncertainty with regard how fishers will actually behave may be relatively small.

As should be clear for the above there is a great deal of uncertainty regarding the appropriate empirical specifications of this model. This may to some extent be gauged by inspecting the sensitivity of the results with respect to alterations in the empirical specifications. Some exercises in this respect are summarized in Table 7.4.

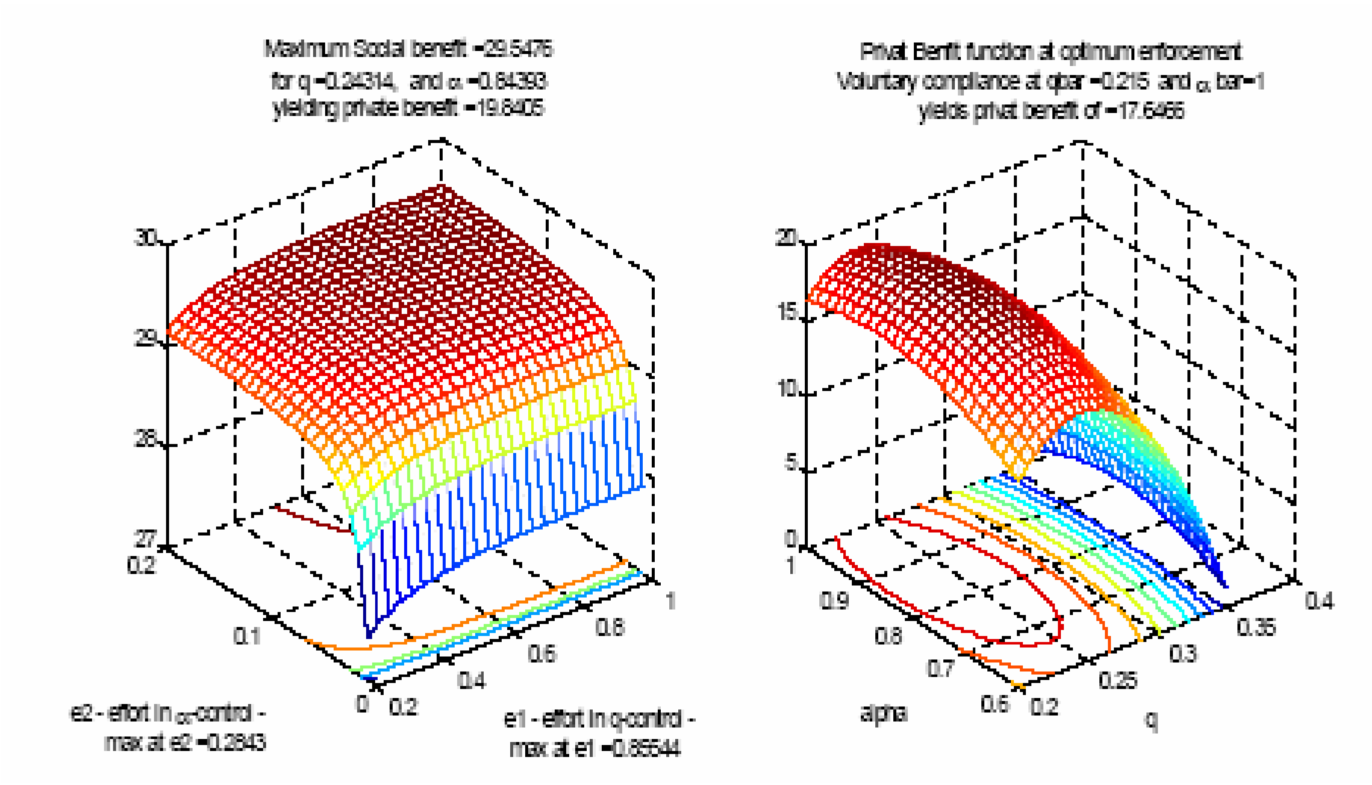

Figure 7.6 Value function surfaces

At minimum enforceme Social benefit =-4616.7 for q =35.7569, and α yielding private benefit:

Table 7.3 Sensitivity analysis

	Social benefits (B.ISK)	Private benefits (B. ISK)	Harvest q	Mesh-size α	Enforce-ment effort, e1	Enforce-ment effort, e2
Reference points						
Optimal enforcement	29.548	19.840 5	.2431	.8439	.8554	0.2843
Voluntary compliance	31.463	17.646 6	.2150	1.000	0	0
Parameters						

	Value	Base value						
Fine, fq	1600	1476	29.715	19.760	.2411	.8449	.8221	.2818
Fine, fq	1400	1476	29.431	19.897	.2446	.8433	.8777	.2862
Fine, fq	3000	1476	30.918	19.025	.2290	.8846	.5901	.1599
Fine, fα	30	40.9	29.082	20.139	.2437	.8098	.8729	.3641
Fine, fα	50	40.9	29.738	19.668	.2428	.8637	.8456	.2290
E. cost c1	0.1	0.185	29.659	19.808	.2426	.8455	1.163	.3838
E. cost c1	0.3	0.185	29.432	19.874	.2437	.8424	.6725	.2250
Biomass x	0.9	0.715	39.003	26.520	.2536	.8634	.8089	.3124
Biomass x	.5	0.715	10.801	6.984	.2224	.8136	.5607	.2314
S. value, λ	130	150	28.492	19.863	.2435	.8428	.7285	.2388
S. value, λ	170	150	30.611	19.826	.2429	.8446	.9659	.3239
F. cost, a0	80	100	34.959	25.883	.2530	.8392	.8062	.2824
F. cost, a0	120	100	24.644	14.067	.2336	.8486	.8020	.2858
F. cost, a1	85	60	28.409	19.059	.2427	.8053	.8636	.3261
F. cost, a1	35	60	30.904	20.853	.2440	.8937	.8422	.2113

Table 7.3 conveys some interesting results. Note first that increasing fines (penalties) leads to uniformly increasing social benefits from the fishery. This is because with higher fines, less enforcement effort is needed to achieve the same level of compliance, while the fines themselves are assumed to be costless to society as a whole. Needless to say, this effect is in accordance with theoretical predictions (Becker 1968, Arnason 2006). Figure 7.7 illustrates the relationship. Note, how social benefits monotonically approach the maximum benefits (given as 31.463 b. ISK according to voluntary compliance) as the fines are increased. With fines going to infinity, the upper bound in benfits would be reached. Note further how the benefits fall off at an increasing rate as the fines are reduced. Thus, if both fines were reduced by say 50%, the maximum social benefits would fall to about 25 b. ISK compared to the optimal of 29.5 (Table 7.4).

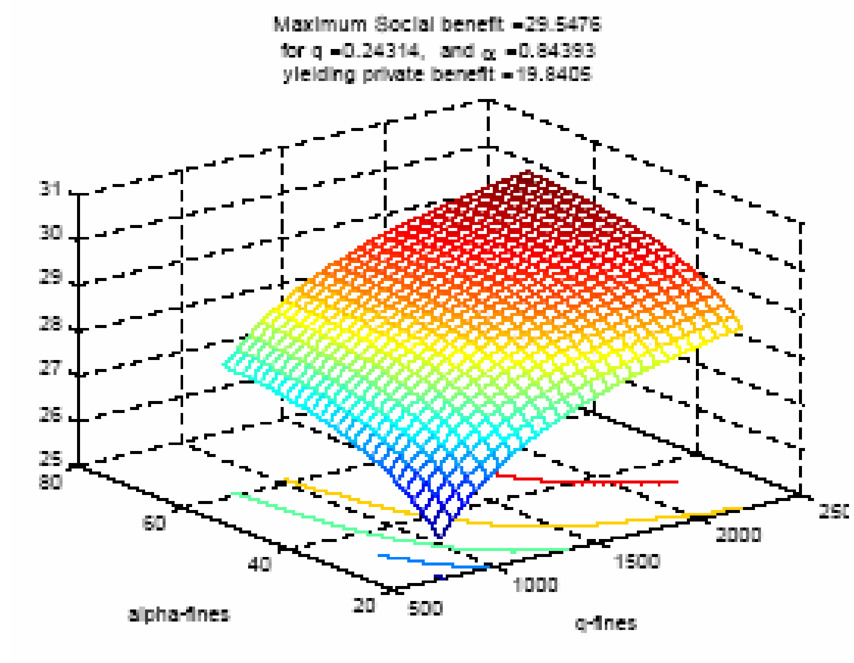

Figure 7.7 Sensitivity of social benefits to penalties

Another interesting aspect is that as fines for harvest violations are increased and effort to enforce them (e1) is reduced, the enforcement effort for mesh-size is also reduced. This effect, which is repeated in other sensitivity experiments reported in Table 7.3, demonstrates the interdependency between the two enforcement activities although they are totally separate as seen by the enforcement activity. The reason seems to be that as harvest violations go down because of increased fines, the marginal benefits of "mesh-size" violations to the fishers also go down. Therefore they violate less and less mesh-size enforcement is optimal. This kind of effect, which is repeated in the other sensitivity checks reported in Table 7.4, show how the overall model connections lead to interdependencies of controls which have no direct links.

The impacts of alterations in the other parameters of the problem are for the most part as expected. With a higher shadow price of biomass, the optimal enforcement effort goes up and vice versa. As enforcement costs go up, the optimal enforcement goes down and vice versa.

The effects of the private cost parameters are slightly less intuitive. With a smaller a0 (the basic private cost parameter; see section 2 (Arnason 2008), both enforcement efforts are reduced and violations increase. Obviously when this cost term is reduced, the marginal profitability of fisheries actions and the tendency for violations increases. This might at first sight seem to suggest that enforcement should increase. That is not so, at least not as a general rule. The reason is that with lower marginal fishing costs, the social benefits of fishing are increased. So, in fact, it would be socially optimal to fish more. In this particular case, to induce the socially optimal fishing (given the other data of the problem), it is necessary to reduce the enforcement effort.

Given the above results for a smaller basic private cost parameter, it might seem puzzling to note that when this parameter is increased, the same effect is observed — enforcement effort for harvest quantity also goes down. This, however, is eminently understandable. With a higher marginal cost of fishing, the private benefits of violations are reduced and therefore the tendency to commit them. Thus, the same or increased compliance may be attained by less enforcement. Because of the marginal benefits of mesh-size violations are not changed and the socially optimal mesh-size is now higher because of lower profitability of fishing, the enforcement of the mesh size increased slightly.

Arguments along similar lines explain the impact of alterations in the second fishing cost parameter, a1. A lower a1 means that the cost of deviating from the privately optimal "mesh-size" is reduced. Hence, a reduced incentive to do so and less enforcement is needed. This applies in reverse for a higher a_1. Alternations in a_1 also have an impact on the optimal enforcement of harvest quantity. This is because changes in a_1 imply a change in the marginal cost of fishing.

7.5.2 Enforcement cost function

The parameters for the enforcement cost function were estimated using data from the Icelandic Directorate of Fisheries regarding on board monitoring efforts and costs during the period 2001-2006. The data are shown in Figure 7.8.

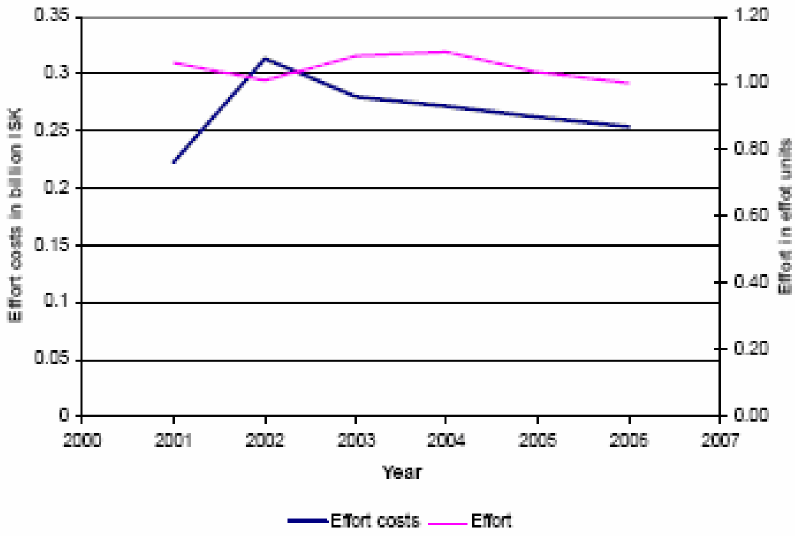

Figure 7.8 Effort and effort costs data

The effort variable was normalized to units of 20 enforcement officers, as mentioned above, and costs per unit effort are measured in billions of ISK. The parameters of the cost function were estimated to be:

$$c_0 = 0.0663$$
$$c_1 = 0.185$$
$$c_2 = 0.00000578$$

The estimated cost function has all the expected properties:

$$C(0) = F > 0,\ \frac{\delta C(e)}{\delta e} > 0 \text{ and } \frac{\partial^2 C(e)}{\partial e^2} > 0.$$

In summary the enforcement parameters are

Table 7.4 Enforcement parameters

Parameters	Value	Source
Probability function, A_1	0.0678	See above
Probability parameter, A_2	0.0136	See above
Fining parameter, f_1	1476 ISK/kg^2	See above
Fining parameter, f_2	40.9 ISK/α-unit^2	See above
Enforcement costs, c_0	0.0663 billion ISK	See above
Enforcement costs, c_1	0.185 billion ISK/effort unit	See above
Enforcement costs, c_2	$0.578 \cdot 10^{-5}$ billion ISK/effort unit^2	See above

7.5.3 Probability of penalty function

This function relates enforcement effort to the probability that a violation will lead to a sanction. To estimate this function properly requires observations on enforcement effort and the probability of sanctions given a violation. Data on the second variable are quite difficult to obtain. The actual occurrence of violations is unknown and cannot apparently be inferred from data on the enforcement activity only.

A simple example illustrates the problem with estimating probability of penalty functions, (5) and (6), from the available data. Assume an increasing relationship between $e1$ and the number of actual observations (inspections, controls) on fishing vessels. Let C be the event that a vessel is observed. Assume that violations are always detected when the vessel is observed and that a detected violation always leads to a sanction. Let V be the event that a vessel is in violation. We would like to estimate:

$$p(e) = p(C|V)$$

However, we only have data on p(V|C) .Applying the rules of conditional probabilities we have:

$$p(C|V) = \frac{p(V \cap C)}{p(V)} = \frac{p(V|C) \cdot p(C)}{p(V)}$$

It is clear that p(C) pcan be estimated from enforcement effort and the data on number of vessels and trips/days at sea. Enforcement data reveals p(V|C). On the other hand there is no data on p(V). Assuming that events V and C are independent (which leads to p(V|C)=p(V)) is extremely unlikely to be true. The decision to violate is based on it being expected to be profitable, which again depends on enforcement effort, as seen in the results from equation (7). The higher the enforcement effort the less profitable is the violation, all else being equal. The probability of violation and the probability of being observed are therefore linked. Furthermore, in real world applications it seems highly unlikely that an enforcement agency has no strategy of focusing controls on expected violators. This would result in biased estimates of the real extent of violations. Therefore, assuming p(e)=p(C|V)=p(C)will almost certainly lead to biased estimate

We have therefore chosen to model the relationship based on assumptions about the behavior of fishermen and the nature the violation. In this paper we consider two types of violations. One is a mesh size regulation and the other is a total quantity of landing restriction. The current number of fishing days in the Icelandic cod fishery is about 80,000 and the total number of landings is about 33,300. We normalize the enforcement effort variable so the current effort level is 1. We assume a linear relationship between enforcement effort and number of observations.

With only one parameter the estimation problem simplifies to identifying one or more points on the line and fitting the model to those points. Here we define only one point; the lowest level of enforcement effort that ensures full compliance (defined as 0.99 compliance since unitary compliance is not feasible given the functional form of the probability function). Stopping all violations of underreported quantity is difficult since no detectable investment is required to carry out violations and violation costs simply consist of fines. It is assumed that compliance would not become complete until every other trip was controlled. The effort needed to reach this would be e1=6.71. This is sufficient information to estimate the parameter A1 in equation (5), which is simply solved for A1, given the required probability and effort level. The resulting parameter estimate is A1=0.0678.
Violating mesh size regulation requires investment in gear and it is assumed that violations only occur as long as increased profits cover confiscated gear and fines. It is assumed that at least 10 trips with violations are needed to cover the cost of being detected once. The effort that gives full compliance is therefore e2=1.34. The corresponding parameter estimate for equation (6) is A2=0.0136.

Graphs of the two probability of penalty functions is drawn in Figure 5

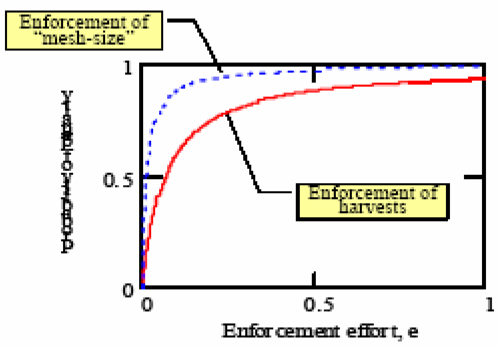

Figure 5 Probability of penalty

7.6 Conclusions

The above demonstrates first of all the feasibility of applying the theoretical fisheries enforcement model (Arnason 2006) to real fisheries situations. The model developed involves two fisheries management tools and two fisheries enforcement tools. This for convenience may be referred to as enforcement model. From the perspective of modelling and numerical calculations, there are no particular obstacles to extend this model to a much higher dimensionality. The calculations would just take longer.

The second important finding from the above is that the benefits of fisheries enforcement may be very high compared to the cost. In the particular empirical example examined, they were easily 30 to 40 times the cost of enforcement. Although, these results are based on quite imperfect empirical data and, therefore, subject to a fairly wide uncertainty bounds, there is no particular reason to expect them to be seriously misleading. Therefore, similar results may be expected to apply to similar fisheries around the world. Note, however, that the gains from enforcement depend on several factors. First, the potential value of the fishery is crucial. With low value fisheries, the gains from enforcement can never be very large. Second, the type of fisheries management system that is being enforced is also crucial. With a poor fisheries management system which is not going to generate any significant economic benefits anyway, the benefits to enforcement will be correspondingly smaller.

The third important lesson to be drawn from the foregoing sections is that optimal enforcement and how it depends on the parameters of the situation is quite a complicated matter. Even in the relatively simple model of this paper, the optimal enforcement effort-mix responds in unexpected and quite possibly unforeseeable ways to alterations in the conditions. This suggests that, in general, simple enforcement rules are not going to work very well. In fact, it appears that due to the complexity of most real enforcement situations the most appropriate enforcement policy can hardly be located, even approximately located, without the assistance of the appropriate empirical model and computer code.

The main obstacle in the way of building the appropriate enforcement models for different fisheries is lack of empirical data. For a variety of reasons — historically little fisheries management, fisheries enforcement conducted along traditional lines, lack of an appropriate fisheries enforcement theory and, most importantly, the lack of appreciation for the importance and benefits of fisheries enforcement — the pertinent data have simply not been systematically collected, if at all. As a result, in most cases, the empirical foundation for the models is quite weak and their precision inevitably correspondingly poor. This suggests that the crucial task in practical fisheries enforcement is to collect and organize the pertinent data. For valuable fisheries subject to a reasonable fisheries management system, this would be a highly worthwhile activity. As demonstrated above, fisheries enforcement based on a well-founded empirical model can yield huge social benefits.

Finally, one might mention that from an analytical perspective there is nothing special about the enforcement of fisheries rules. Therefore, all the main qualitative results of this paper as well as the approach to determining the optimal enforcement should apply to the enforcement of restrictions in general.

8. Dutch beam trawl

8.1 Authorship and affilation

Authors: Erik Buisman and Jeff Powell (LEI)

8.2 Introduction

In 2005, the beam trawl cutter fleet consisted of 242 vesssels, of which 102 large beam trawlers and 140 Euro cutters, also operating with a beam trawl. The cutters are fishing the coastal waters (12 miles zone) and the mid-distant waters in the North Sea: Dogger Bank, German Bight, and north of Friesland.
The main target species of the beam trawl are sole and plaice with by-catches of other demersals like cod and whiting.

The main components of the Dutch fisheries management system are quota management (ITQs), capacity and effort limitations. Since 1977 the quota system evolved from an IQ system towards an ITQ system. Since 1993 a co management scheme for the cutter sector is in place which means that part of the executionary responsibilities were delegated to the fishing industry. This co-management scheme was especially implemented to manage ITQs.

8.3 Description of the enforcement system

The National Government is responsible for enforcement of national quota, technical measures, licensing, effort management and other EU and national measures. Monitoring and enforcement is exercised by the AID, the General Inspection Service. The AID is assisted by the coast guard, the police and custom officers.

The target control group of the AID is not only Dutch sea fishermen. It also includes reflagged Dutch sea fisheries vessels that land their catches in the Netherlands; vessels of other EU Member States in the Dutch zone; fish traders and fish processing companies, and inland fisheries. Inspection is exercised from the air, at sea, in 13 harbours and 11 auction halls.
Enforcement of fisheries legislation is carried out through

- VMS monitoring
- Physical inspections at sea
- Dock-side inspections
- Air surveillance
- Satellite monitoring (VMS)
- Cross-checks of logbooks and sales notes on basis of computer registration
- Wholesale and transport controls

In the modeling of enforcement, the focus will be on three of these activities: landings inspections, inspections at sea and transport and wholesale controls. In terms of regulations the analysis will focus on enforcement of quota restrictions and mesh size regulations (including the use of blinders (to retain small fish).

8.4 Data used

The analysis is based on collected data on enforcement effort, costs and recorded infractions. Time series of enforcement data have been collected for the period 1996 – 2006. Table 8.1 gives an overview of indicators and availability of data.

Table 8.1 Indicators and availability of data

Indicator	Unit	Aggregation level	Availability
Cost of VMS poll	Euro	National fleet/Year	***Only 2006***
Controlled fisheries area as percentage of total are to be policed by country	%	Country	***Available (=100%)***
Number of Patrol vessels	Number	Country/year	***Available***
No of Onboard inspections, On board, documentation	Number	Country/year	***Available***
Costs per boarding	Euro	Country/year	***Available***
Air observations	Hours	Country/year	***Available, but not yet for all years***
Sightings	Number ??	Country year	***Available, but not yet for all years***
Costs per hour	Euro	Country year	***Only for 2006***
On board observers	Number	Country year	***Available***
Cost of onboard observer	Euro	Country year	***Available***
Dock-side monitoring	Number	Country year	***Available,***
Cost of dock-side monitoring	Euro	Country Year	***Available, but not yet for all years***
Percentage of landings checked	%	Fishery year if known otherwise Country/Year	***Available but not yet for all years***
Wholesale controls	Number	Country year	***Available but not for all years***

Indicator	Unit	Aggregation level	Availability
Cost of wholesale controls	Euro	Country year	***Only 2006***
Recorded infractions	Number	infringement category, segment, year	***Available for all years, but in different formats (not always comparable)***

8.5 Estimation of theoretical relationships

8.5.1 Benefit function.

a) Private Benefit function

The private benefit function for the Dutch beam trawl fleet has been based on the production function (catch equation) for sole, used in the IMARES LEI model and on the probability of penalty function. Sole is considered the main target species for the beam trawl fishery and as such driving the fishing effort. Catches of plaice are subsequently determined by this effort

$$q_s = \alpha_s \bullet E^{B_s} \bullet X_s \quad \rightarrow \; E = \left(\frac{q_s}{\alpha_s \bullet X_s} \right)^{\frac{1}{\beta_s}} \qquad \beta > 0 \tag{8.1}$$

$$q_p = \alpha_p \bullet E^{B_p} \bullet X_p \qquad \beta > 0 \tag{8.2}$$

If $q_s \le q_s^*$ and $q_p \le q_p^*$

Then $B = p_s \bullet q_s + p_p \bullet q_p + p_o \bullet q_o - c \bullet \left(\frac{q_s}{\alpha_s \bullet X_s} \right)^{\frac{1}{\beta_s}}$

Else $$B = p_s \bullet q_s + p_p \bullet q_p + R_o - c \bullet \left(\frac{q_s}{\alpha_s \bullet X_s} \right)^{\frac{1}{\beta_s}} - \pi(e) \bullet (f + R_t) \tag{8.3}$$

Where $$R_t = p_s \bullet q_s + p_p \bullet q_p + R_o \tag{8.4}$$

This private benefit function is for the case of enforcement of quota regulations, where the penalty is equal to a fine plus confiscation of the total catch. In case of enforcement of mesh size regulations the private benefit function will look slightly different.

b) Social Benefit function

The social benefit function equals the private benefit function excluding the costs of fines and minus the costs of enforcement and the shadow value of the fished biomass.

$$V = (p_s - \lambda_s) \bullet q_s + (p_p - \lambda_p) \bullet q_p + p_o \bullet q_o - c\left(\frac{q_s}{\alpha_s \bullet X_s}\right)^{\frac{1}{\beta_s}} - (C_{port} + C_{sea} + C_{TW})$$

Social benefits are slightly overestimated by this function because the shadow price of biomass of other landed species (λ_o) is not taken into account. The shadow value of biomass of the sole and plaice stock can be estimated from $\lambda = B_q - \frac{C_e}{Q_e}$. In the present situation (using data of 2006) , fishing mortality for sole is relatively high and the resulting λ_s (app. 8 €/kg) is quite close to the price (12 €/kg). Similarly, the biomass of plaice has been estimated 1,50 €/kg while the average price in the base year was 2.50 €/kg

Table 8.2. Values of parameters and coefficients

Coefficient	Value
α_s	0.021
α_p	0.65
β_s	1.12
β_p	0.98

Table 8.3 Base year (2006) values of variables

Variable	Name	Value
E	Fishing effort (days at sea)	19,391
X_s	Biomass sole (tonnes)	30,077
X_p	Biomass plaice (tonnes)	194,051
q_s^*	Sole quota (tonnes)	13,143
q_p^*	Plaice quota (tonnes)	21,470
p_s	Price sole (€/kg)	12.71
p_p	Price plaice (€/kg)	2.08

p_o	Average Price other (€/kg)	3.44
q_o	Catch weight other (tonnes)	38,698
f	Average fine (€/kg)	2200 + confiscation total catch
λ_s	Shadow value of biomass sole (€/kg)	8
λ_p	Shadow value of biomass (€/kg)	1.50

8.5.2 Enforcement cost function

The enforcement cost functions for three types of enforcement have been estimated using the COBECOS code (version 1). The costs of port inspections, inspections at sea and transport and wholesale controls appear to be linear functions of enforcement effort. All slope coefficients are highly significant.

$$C_{port} = c_{port} \bullet E_{port} + \overline{C}_{port} = 3.86 \bullet E_{port} + 0.012$$

$$C_{sea} = c_{sea} \bullet E_{sea} + \overline{C}_{sea} = 5.14 \bullet E_{sea}$$

$$C_{TW} = c_{TW} \bullet E_{TW}^{\beta_{TW}} + \overline{C}_{TW} = 1.46 \bullet E_{TW}$$

8.5.3 Probability of penalty function

The probability functions calculate the chance of being caught for any sort of violation for each of the three different enforcement tools.

Table 8.3. Parameters of the probability functions

	Asymptote	Location	Slope
Port inspections	0.935	0.562	0.191
Inspections at sea	0.982	0.159	0.029
Transport and wholesale inspections	0.958	0.441	0.098

8.6 Conclusions

Limitations:

1. Lack of enforcement data and lack of variability within the data to estimate the enforcement costs functions and probability functions.
2. Probability of penalty for port inspections has been estimated as the ratio of number of port inspections and number of landings. This means that, given that there is an infringement, the probability of detecting it in case of inspection is 100%.
3. Probability of penalty for inspections at sea has been estimated as the ratio of the number of inspections and the number of days at sea. This means that the probability of penalty is assumed equal to the probability of inspection. Again, this assumes that the probability of detecting an infringement in case of inspection is 100%.

9. Kattegat & Skagerrak nephrops fishery

9.1 Authorship and affiliation

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9.2 Introduction

This working paper is part of an ongoing research project called “Costs and Benefits of Control Strategies” with the acronym COBECOS. The project is funded by the European Union’s (EU) Sixth Framework Programme, Policy-Oriented research. The primary objective of COBECOS is to conduct a cost-benefit analysis of control schemes for management strategies relevant for the Common Fisheries Policy and, based on this analysis, infer the potential economic benefits which might accrue from proper enforcement of the management measures. We propose to achieve this objective on the basis of: 1) an appropriate theory of fisheries enforcement, 2) empirical research involving intensive case studies and estimation of theoretical relationships and 3) computer modeling of fisheries enforcement (based on the theory and empirical estimations). On this basis we expect to be able to contribute significantly to answering questions such as: What are the costs and benefits of increased enforcement effort in particular fisheries? If compliance alters (exogenously) in certain fisheries what are the costs and benefits? What are the impacts of increased penalties for violations of fisheries rules? How do different control schemes compare when the cost of enforcement is taken into account?

The appropriate theory of fisheries enforcement, referred to above, is developed under work package 3.[20] This working paper merely deals with the empirical research of one of the case studies, Norway lobster trawl fishery in Kattegat and Skagerrak, and the estimation of the theoretical relationships. The computer modeling and the computer application to the case studies is still on its incipient stage. This working paper therefore corresponds to the deliverable from the case study, Norway lobster trawl fishery in Kattegat and Skagerrak to work package 5 with the objective to estimate the basic relationships in the theoretical enforcement model for use in the computer model.

The following relationships will be estimated:

- A probability of penalty function that relates enforcement effort to the probability that a violation will entail a sanction. We refer to this as the enforcement-probability function.
- A fisheries benefit function including a private benefit, the shadow value of biomass and from this the determination of the social benefit function.
- A fisheries enforcement cost function that relates enforcement effort (along its various dimensions) to costs of enforcement.

All the estimations will be based on the data collection which is available under the deliverable for work package 2, where a description of the applied case study in this working paper, Norway lobster trawl fishery in Kattegat and Skagerrak, also is available. Compared to the description of work in WP5 we start out by determining the data for the enforcement level, the probabilities and the fines and then estimating the enforcement-

[20] The technical annex and the deliverable for all work packages completed can be found at the project website: https://maritimeaffairs.jrc.ec.europa.eu/web/cobecos/1

probability function. We have chosen this order of estimation since we apply the probability of being apprehended and the fines when determining the private benefit function.

9.3 Description of the enforcement system

In the mixed trawl fishery in Kattegat and Skagerrak the most important species are Norway lobster, Atlantic cod, Common sole and European plaice. Norway lobster and Atlantic cod have a catch value around half of- to more than two thirds of the total value of landings. In addition these two species are categorized as species in the control strategy for the Danish enforcement (The Danish Directorate of Fisheries 2006) with a high risk of overfishing compared to quotas and a moderate to very high consequences for the resource. Therefore the Directorate of fisheries risk-rank these two species to require a full enforcement effort and likely to substantial additional enforcement initiatives according to the control strategy (The Danish Directorate of Fisheries 2006). Thus, these two species are among the target species for the control and enforcement of the Danish fishery.

In our dataset we have all individual landings from Kattegat and Skagerrak from 2005 and 2006 having Norway Lobster or Cod included. This is a record of some 40,000 landings. Data are anonymous but all landings for a single vessel can be identified and for each landing there is information about type of control (if controlled) and violations and sanctions (if such exist).

Enforcement Effort

The Danish Directorate of Fisheries (2006) has a control strategy with the aim of working pro a biological and economical sustainable fishery. To reach this aim they perform "*thoughtfulness regulation and control*". From the report "*The control is targeted where illegal fishery has the largest consequences for sustainability. ... In addition the control is concentrated when it is considered to be crucial*." Specific information about the actual perceived increased risk of inspection and detection of a contravention resulting from selecting the businesses, persons, actions or areas to be inspected are, however, not available. Therefore we make deliberate simplification and assume there is non-selective control of potential offenders.

For adjusting our data to be applicable in the COBECOS software we need a series of data with the enforcement effort for different types of enforcements and the connected probability of being penalised. In COBECOS effort and probability are restricted on their parameter values to be between 0.001 and 0.999. In order to scale the effort we apply the following function:

$$\text{Effort} = \frac{\#\,\text{Inspections for specific vessel}}{\#\,\text{Landings for a specific vessel}} \tag{9.1}$$

Where

Inspections for specific vessel is categorised into different enforcement categories

Landings for specific vessel in the total number of types the vessel have been in harbour with cod or Norway lobster from Kattegat or Skagerrak

This scaling returns an effort value for the different types of enforcement effort (in our case (boarding or dock side) which is between zero and one. An enforcement effort equal to one corresponds to all landings are being inspected and an enforcement effort of zero corresponds to no landings being inspected. The vessels with no landings being inspected are irrelevant for the further analysis and are therefore not included in the further derivation of the enforcement probability function. The enforcement effort is therefore a function of the number of fishing trips. Thereby can a single fisherman indirectly reduce the enforcement effort (employed by the authorities) by increasing his number of fishing trips. This might not be fully in accordance with the theoretical model where the penalty probability function is strictly exogenous, but it is still our best estimate of enforcement effort.

Probability of being penalized

The probability of being penalized (or sanctioned) connected to the different enforcement effort levels are now to be derived on an individual cross-section (2005-2006) level. The probability of being sanctioned is illustrated in Figure 9.1.

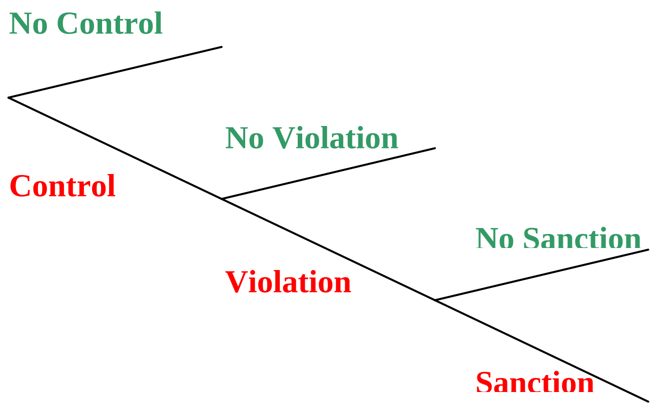

Figure 9.1 The probability of being sanctioned

Figure 9.1 illustrates that there is a probability of being controlled, and given control, there is a probability of having violated, and if violation has occurred there is a probability of being sanctioned.[21] This approach assumes that the probability of being sanctioned for the probability enforcement function is determined by the probability of being sanctioned given that violation occurs. This corresponds to follow the 'red path' in Figure 9.1. Formally written this equals the probability of being controlled given violation times the probability of being sanctioned given that the person is violating and controlled:[22]

$$p(S\,|\,C) = p(V\,|\,C) \times p(S\,|\,V \cap C) \tag{9.2}$$

Where

S: Sanction

V: Violate

C: Control

A simplification of this approach is to assume the probability of being sanctioned given that the person is violating and is controlled equals one, which is $p(S\,|\,V \cap C) = 1$. It appears from the Danish data set that it is not always true, but one can argue that if a fisherman receives a written remark about a violation it will always requires resources from that

[21] One might argue that the tree in Figure 9.1 should start with the violation/no violation then followed by control/no control and finally sanction/no sanction. The reason why we have not chosen that approach is, that we have no estimate of how large a fraction of the fishermen do actually violate, we have only estimates of how many violations does actually occur among those fishermen controlled.

[22] This approach implicitly assumes that only violators can be sanctioned.

fisherman to avoid being sanctioned, and this in itself can be regarded as a penalty. The simplified approach therefore becomes:

$$p(S \mid C) = p(V \mid C) \tag{9.3}$$

We thus need to derive the probability of violating given the vessel is controlled:

$$p(V|C) = \frac{\#\,\text{Violations for specific vessel}}{\#\,\text{Controls for specific vessel}} \tag{9.4}$$

The number of violations represents only the number of violations that are actually been sanctioned.

The probability of being sanctioned given violation, which is assumed to be equal one moving from (9.2) to (9.3):

$$p(S|V \cap C) = \frac{\#\,\text{Sanctions for specific vessel}}{\#\,\text{Violations given controlled for specific vessel}} \tag{9.5}$$

This probability is assumed to be equal to one in the following estimates.
The probability of being controlled is:

$$p(C) = \frac{\#\,\text{Controls for specific vessel}}{\#\,\text{Landings for specific vessel}} \tag{9.6}$$

If we combine the probability of being controlled with the probability of violating given the vessel is controlled (combining (9.4) and (9.6)) this reveals the probability of violation given the enforcement effort[23]:

[23] We are aware that equation (9.7) does not include the number of controls/inspections for the single vessel, but this is an ad hoc probability and it is only meaningful together with the ad hoc enforcement effort for the specific vessel.

$$\pi(e) = p(V\,|C) \times p(C) = \frac{\#\,\text{Violations for specific vessel}}{\#\,\text{Landings for specific vessel}} \tag{9.7}$$

To the Kattegat/Skagerrak we apply the above approach to derive the enforcement probability function. This approach returns the actual probability of being detected and fined given the actual enforcement effort, it is thus not the expected or perceived probability, but it is our best estimate.

9.4 Data used

The dataset for the case study, in particular for the enforcement effort and penalties for violations, are based on all landings from Kattegat and Skagerrak containing either nephrops or cod from 2005 and 2006.In the first step all vessels having a written remark (In Danish: 'erhvervsovertrædelse') are included. This corresponds to 78 written remarks. Some vessels have more written remarks and the number of written remarks is therefore not corresponding to the number of vessels. For each vessel, the actual applied enforcement effort is calculated according to (9.1) and the corresponding probability of being sanctioned is calculated according to (9.7). The enforcement effort and the corresponding probabilities are calculated for each separate type of controls. For some written remarks it is not possible to identify the type of form, which has been applied, either because the information is not available or because it is an administrative control.[24] In our case we have form 1 (dockside inspections) and form 2 (boarding) where information about controls are recorded not matter whether it results in a written remark or not. The following works with enforcement effort *E*1 (dock side inspections) and *E*2 (boardings), respectively. The applied enforcement probability dataset is summarised in table 1.

[24] For administrative and paper control the controls that do not lead to a written remark are not included in the record. It is therefore not possible to estimate a probability of being sanctioned for these types of controls.

Table 9.1. Enforcement and probability of apprehension for year 2005 and 2006 in the Kattegat/Skagerrak Norway lobster and cod fishery.

E1	*Prob*	*E2*	*Prob*
0.031	0.008	0.011	0.011
0.020	0.020	0.037	0.009
0.025	0.006	0.024	0.016
0.037	0.015	0.048	0.048
0.018	0.009	0.035	0.012
0.023	0.004	0.030	0.030
0.004	0.004	0.158	0.053
0.018	0.004	0.034	0.011
0.032	0.008	0.011	0.011
0.032	0.008	0.021	0.005
0.030	0.010		
0.020	0.020		
0.125	0.021		
0.063	0.031		
0.024	0.012		
0.081	0.012		
0.067	0.067		
0.029	0.014		
0.009	0.009		
0.036	0.036		
0.075	0.025		
0.037	0.009		
0.021	0.021		
0.055	0.014		
0.045	0.011		
0.036	0.006		
0.082	0.020		
0.016	0.016		

Note:
E1 = Dock side inspections
E2 = Boardings

In Figure 9.2 the enforcement effort and the enforcement probabilities are illustrated.

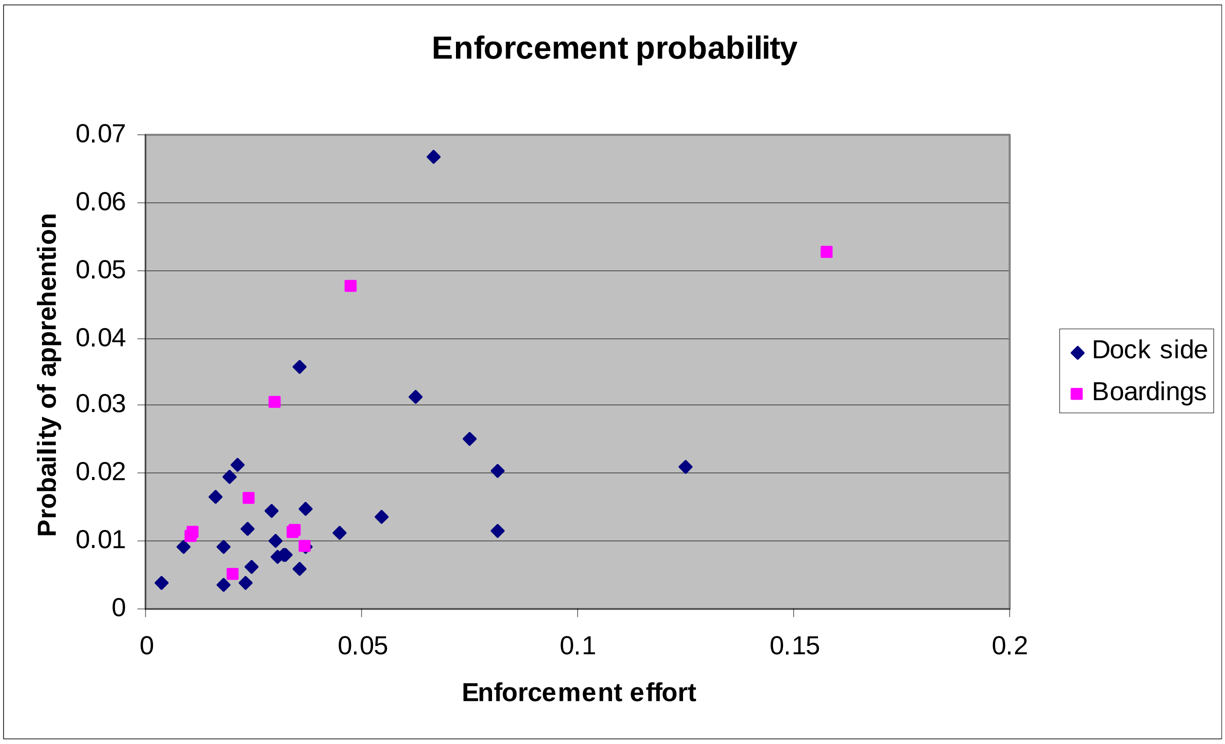

Figure 9.2. Plot of the enforcement probabilities and the enforcement effort levels

We use the data in Table 9.1 and Figure 9.2 to estimate enforcement-probability functions[25]From Table 9.1 and Figure 9.2. It can be seen that both the enforcement effort and probability data are concentrated for very low levels. We expect that a high enforcement effort would lead to a high probability of being apprehended. To give an indication of this, we therefore, include (0.9999; 0.9999) as an observation when we estimate the enforcement-probability functions.

9.5 *Estimation of theoretical relationships*

9.5.1 Benefit function.

a) Private Benefit function

The private benefit function is basically determined by a standard bio-economic model involving fishermen maximizing a profit function not taking resource restrictions into consideration. It is assumed that the fisherman maximises net profit:

[25] . Instead of the data in Table 9.1 it probably would have been more natural to have a 0 and 1 probability functions and estimate the enforcement probability function using logit. We can, however, not link a 0 and 1 probability to enforcement effort and, therefore, we estimate enforcement-probability with the data in Table 9.1 and Figure 9.2.

$$\underset{h,t}{Max}(P_h h - P_t t - C(h,t,v_t) - \pi_h F_h (h - \underline{h}) - \pi_t F_t (t - \underline{t})) \tag{9.11}$$

where:

h is the catch of nephrops.

t is the catch of cod.

$\underline{h}$ is the regulatory restriction on nephrops[26]

$\underline{t}$ is the regulatory constraint on cod.

π_h is the probability of being detected when the nephrops restriction is exceeded.

π_t is the probability of being detected when the cod restriction is exceeded.

F_h is the penalty (fine) when violating nephrops restriction.

F_t is the penalty (fine) when violating the cod restriction.

P_h is the output price on nephrops.

P_t is the output price on cod.

v_t is the stock of cod.

$C(h,t,v_t)$ is the cost of harvest function.

The control variables for the fishermen in (9.11) are the catches of nephrops and cod. When defining the net profit function it is assumed that all of regulatory restrictions can be represented in a quota system. The main problems in the Norway lobster trawl fishery in Kattegat and Skagerrak are landings of undersized lobsters and illegal by-catch of particular cod. The regulatory measures included are therefore landings of undersized lobster and exceeding the quotas for cod. In the net-profit function it is assumed that landings of undersized nephrops also can be translated into a restriction on output. From the cost of harvest function introduced in the net-profit function in (9.11) it becomes clear the cost of harvest only depends on the stock size for cod and not for Norway lobster. Note, that we assume that there is no stock effect associated with nephrops. This assumption is justified by the fact that there is no binding output restriction for nephrops.

The first-order conditions of (9.11) when fishermen violate the regulative measures are:[27]

[26] The names nephrops and Norway lobster will be used interchangeable.

$$P_h - \frac{\partial C}{\partial h} - \pi_h F_h = 0 \tag{9.12}$$

$$P_t - \frac{\partial C}{\partial t} - \pi_t F_t = 0 \qquad 9.\ (13)$$

where $\frac{\partial C}{\partial h}$ is the marginal production cost of nephrops and $\frac{\partial C}{\partial t}$ is the marginal production cost of cod. Equations (9.12) and (9.13) state that the marginal revenue equal the marginal expected costs under profit maximisation. The marginal expected costs consist of the marginal production costs and the marginal expected value of the penalty when violating regulative measures.

(9.12) and (9.13) may be re-written as:

$$y_h = \frac{\partial C}{\partial h} \tag{9.14}$$

$$y_t = \frac{\partial C}{\partial t} \tag{9.15}$$

where $y_h = P_h - \pi_h F_h$ and $y_t = P_t - \pi_t F_t$. Thus, y_h and y_t is the marginal net revenue of lobster and cod, respectively, including the expected fine but not the production costs. We have information about all variables in y_h and y_t from the deliverable in WP2. Thus, y_h and y_t may be identified. In addition, information is also available on harvest of cod, nephrops and the stock size of cod, h, t and x_t. This implies that $\frac{\partial C}{\partial h}$ and in (9.14) and (9.15) can be estimated using traditional econometric procedures. We do, however, not have information about the functional form of the cost function. We therefore estimated the marginal costs based on six possible functionalities. These six models are defined below:

Model 1:

$$C(h,t,x_t) = f + ch + d\frac{t}{x_t} \tag{9.16}$$

where:

f is fixed costs

[27] The problem is only solved for violators since non-violators are irrelevant in this case.

c is variable cost of nephrops
d is a cost parameter associated with cod.

This cost function corresponds to a case where there is no interaction in the cost function between the harvest of nephrops and the harvest of cod. Based on the cost function in (9.16), the functions to be estimated (equation (9.14) and (9.15)) may be written as:

$$y_h = c \tag{9.14.1}$$

$$y_t = \frac{d}{x_t} \tag{9.15.1}$$

Model 2:

$$C(h,t,x_t) = f + ch^2 + d\frac{t^2}{x_t} \tag{9.17}$$

Again there is no interaction in the cost function between harvests of cod and nephrops. With (9.17), (9.14) and (9.15) become:

$$y_h = 2ch \tag{9.14.2}$$

$$y_t = \frac{2dt}{x_t} \tag{9.15.2}$$

Model 3:

$$C(h,t,x_t) = f + ch + d\frac{t}{x_t} + eth \tag{9.18}$$

Now there is interaction in the cost function between the catches of cod and nephrops. From equation (9.17) equations (9.14) and (9.15) are given as:

$$y_h = c + et \tag{9.14.3}$$

$$y_t = \frac{2d}{x_t} + eh \tag{9.15.3}$$

Model 4:

$$C(h,t,x_t) = f + ch^2 + d\frac{t^2}{x_t} + eth \tag{9.19}$$

Again there is interaction in the cost function between the catches of cod and nephrops. (9.14) and (9.15) are calculated as:

$$y_h = 2ch + et \tag{9.14.4}$$

$$y_t = \frac{2dt}{x_t} + eh \tag{9.15.4}$$

Model 5:

$$C(h,t,x_t) = f + ch + d\frac{t}{x_t} + et^2h^2 \tag{9.20}$$

And equations to be estimated are:

$$y_h = c + 2et^2h \tag{9.14.5}$$

$$y_t = \frac{d}{x_t} + 2eh^2t \tag{9.15.5}$$

Model 6:

$$C(h,t,x_t) = f + ch^2 + d\frac{t^2}{x_t} + et^2h^2 \tag{9.21}$$

and (9.14) and (9.15) are given as:

$$y_h = 2ch + 2et^2h \tag{9.14.6}$$

$$y_t = \frac{2dt}{x_t} + 2eh^2t \tag{9.15.6}$$

The dataset for the case study, in particular for the enforcement effort and penalties for violations, are based on all landings from Kattegat and Skagerrak containing either nephrops or cod from 2005 and 2006. We thus have cross-sectional data over years. Since we would like to regard to differences in time we include a yearly dummy, *A*. The value of the dummy is zero in 2005 and one in 2006. In the equations for nephrops (9.14.x) *fA* is included and in the equations for cod (9.15.x) *gA* is included.

We apply the probability of being detected as defined in section 9.2. In the data set, which forms the basis for defining the probability of being detected, we also have information about the catches of nephrops and cod and the fines. The fines in the data set are, however, not directly allocated to violations of nephrops and cod regulative measures, respectively. Therefore we make in indirect allocation of the fines for different types of violation based on the catch composition. For the main part of the violators the catches consist of either cod or nephrops alone and in these cases it is easy to allocate the fines to different types of violations. When a violator catches both cod and nephrops we allocate with 50% of the fine to each type of regulative measure.

An overview over the estimation results of equations (9.14.x) and (9.15.x) is given in Table 9.2.

Table 9.2. Estimation results for cost parameters in the cost of harvest function.

Parameter estimates (*t*-value)	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
c	23.54 (0.47)	- 0.003 (-0.04)	53.96 (0.8)	0.1 (0.63)	-50.05 (-0.32)	0.06 (0.47)
d	-883350 (-1.56)	-1617.5 (-2.23)	-830345 (-0.57)	4514 (0.76)	-174007 (-0.96)	6306.5 (1.27)
e			-0.11 (-0.72)	-0.65 (-0.96)	0.01 (0.56)	0.01 (0.45)
f	-81.93 (-1.18)	-212.79 (-2.01)	-33.92 (-0.39)	33.34 (0.05)	-377.4 (-1.24)	-413.94 (-1.42)
g	-41.2 (-0.6)	-40.66 (-0.52)	-84.08 (-0.56)	77.93 (0.13)	-301.93 (-1.24)	159.95 (0.33)
R^2	0.04 and 0.01	0.15 and 0.12	0.04 and 0.01	0.37 and 0.42	0.29 and 0.24	0.42 and 0.38
Breuch-Pagan test	2.56	4.17	2.13	3.14	4.13	5.14
White test	5.46	6.13	6.14	8.19	7.97	6.13

With respect to model 3-6 we have used simultaneous equation estimations so that a common value of *e* is generated for both first-order conditions. For all models the Breuch-Pagan and White tests are so low that there is no problem with heteroscedasticity. For all estimated parameters in all models the variance inflation is below 10, which implies absence of serious multi-collenarity problems. For model 1, 2, 3 and 5 the value of *d* becomes negative while the value of *d* is positive in model 4 and 6. A negative value of *d* means that costs will decrease when more cod is harvested, which is an unlikely situation. This implies that we prefer model 4 and 6 because a positive value of *d* is what we will expect according to theory. Model 4 and 6 also generate the largest R^2 and the highest *t*-values so based on these criteria they also perform best. Summarising the above estimation, then the two models for further application can be written as follows:

Model 4:

$$y_h = 2*0.1*h - 0.65t + 33.34*A \;\; \mathrm{R}^2 = 0.37 \qquad R^2{=}0.37 \tag{9.22}$$
$$(0.63) \quad (-0.96) \; (0.05)$$

$$y_t = 2*4514t/11795 - 0.65h + 77.93*A \ \mathrm{R}^2 = 0.42 \qquad R^2{=}0.42 \tag{9.23}$$
$$(0.76) \qquad (-0.96) \quad (0.13)$$

Model 6:

$$\mathrm{y}_h = 2*0.06h - 2*0.010.596t^2h \ {-413.94}A \qquad R^2 = 0.42 \tag{9.24}$$
$$(0.43) \qquad (-0.45) \qquad (-1.42)$$

$$y_t = 2*6306.5t/11795 - 2*0.01h^2t + 159.95A \ \ R^2 = 0.38 \tag{9.25}$$
$$(1.27) \qquad (0.45) \qquad (0.33)$$

b) Social Benefit function

To determine the shadow price of landing undersized lobster, we build an economic model that can be used to estimate this shadow price. We set up the net profit function for Norway lobster and assume the representative fishermen maximise this:

$$\underset{h_L, h_I}{Max}(p_h(1-t)h_L + aP_h h_I - C(h_L, h_I) - \pi_h F_h h_I \tag{9.26}$$

s.t.

$$h_L \leq \underline{h} \tag{9.27}$$

where:

t is the income tax rate
h_L is legal catch of lobster
h_I is illegal catch of lobster
a is the share of illegal price compared to the legal price.
$C(h_L, h_I)$ is the cost function

Equation (9.27) is a constraint indicating that for the landings to be legal the regulatory measure for lobster cannot be exceeded. We are interested in the shadow price of a marginal increase in the binding regulatory measure, and this requires that the following Lagrange function be set up:

$$L = p_h(1-t)h_L + aP_h h_I - C(h_L, h_I) - \pi_h F_h h_I - \lambda(h_L - \underline{h}) \tag{9.28}$$

where λ is a shadow price for the regulatory measure. Assuming that the regulatory measure is set in an economically optimal way λ would be the shadow price we are interested in determining.

The first-order conditions for (9.28) are:

$$P_H(1-t) - \frac{\partial C}{\partial h_L} - \lambda = 0 \tag{9.29}$$

$$aP_H - \frac{\partial C}{\partial h_I} - \pi_h F_h = 0 \tag{9.30}$$

Equating the above two equations yields:

$$P_H(1-t) - \frac{\partial C}{\partial h_L} - \lambda = aP_H - \frac{\partial C}{\partial h_I} - \pi_h F_h \tag{9.31}$$

a = 0.5 and t= 0.5 is reasonable to assume. Assuming, further, that the marginal cost of legal and illegal landings are identical, which would be the case under cost minimisation, we might write (9.31) as:

$$\lambda = \pi_h F_h \tag{9.32}$$

With respect to π_h and F_h we can use the average values in 2005 and 2006. This would make it possible to identify the shadow price. This procedure yields:

$$\lambda = 7.57 DKK \tag{9.33}$$

which is the shadow price for undersized nephrops.

In a similar model the shadow price of cod could be determined. With a = 0.5 and t= 0.5 the shadow price for cod is 14.98 DKK.

Summarising the information from the above sections we are now able to define the social benefit function. This section sketches a private and social optimum and argues that there is sufficient information to solve these problems with the estimations in previous sections. It is important to notice that the social benefit function is constructed with the aim of optimising the benefits to the society using the enforcement effort as the control variable. The social benefit function is therefore a merger of the optimum from the private benefits from fishing, the costs of enforcement which should be maximized with respect to the two types of enforcement effort (dock side inspections and boardings) under the two response functions from the private benefit function.

In order to derive the social optimum we begin with the private profit maximisation problem in equation (9.11). Our aim is to find the harvest response functions for cod and nephrops:

$$\underset{h,t}{Max}(P_h h - P_t t - C(h,t,v_t) - \pi_h(x_h)F_h(h-\underline{h}) - \pi_t(x_t)F_t(t-\underline{t})) \quad . \tag{9.34}$$

The first-order conditions are:

$$P_h - \frac{\partial C}{\partial h} - \pi_h(x_h)F_h = 0 \tag{9.35}$$

$$P_t - \frac{\partial C}{\partial t} - \pi_t(x_t)F_t = 0 \tag{9.36}$$

In (9.35) and (9.36) we have information about P_h, P_t, F_h and F_t. In addition we know $\frac{\partial C}{\partial h}$ and $\frac{\partial C}{\partial t}$ from section 9.4 and $\pi_h(x_h)$ and $\pi_t(x_t)$ from section 9.2. Thus, we may specify the catches from a private response function:

$$t = T(x_t, F_t) \quad \text{(Cod response function)} \tag{9.37}$$

$$h = H(x_h, F_h) \quad \text{(Nephrops response function)} \tag{9.38}$$

These functions are obtained by solving (9.35) and (9.36) as two equations with two unknowns. The regulator assumes that the fishermen adopt optimal harvest behaviour and therefore follows the response functions as defined in (9.37) and (9.38). The regulator maximises the social welfare given as net-benefits from fishing minus the cost of applying enforcement and shadow costs subject to the fishermen's harvest response functions:

$$\underset{x_t, x_h}{Max}(P_h h - P_t t - C(h,t,v_t) - TC(x_t, x_h) - \lambda_h h - \lambda_t t) \tag{9.39}$$

s.t.

$$t = T(x_t, F_t) \tag{9.40}$$

$$h = H(x_h, F_h) \tag{9.41}$$

Where:

TC(x_t, x_h) are the total enforcement costs.
λ_h is the shadow price for lobster
λ_t is the shadow price for cod

Substituting (9.40) and (9.41) into (9.39), setting up an objective function and differentiating yields:

$$(P_h - \lambda_h)\frac{\partial H}{\partial x_h} = \frac{\partial TC}{\partial x_h} + \frac{\partial C}{\partial h}\frac{\partial H}{\partial x_h} = 0 \tag{9.42}$$

$$(P_t - \lambda_t)\frac{\partial T}{\partial x_t} = \frac{\partial TC}{\partial x_t} + \frac{\partial C}{\partial t}\frac{\partial T}{\partial x_t} = 0 \tag{9.43}$$

.

From above we know the response function and, therefore, $\frac{\partial H}{\partial x_h}$ and $\frac{\partial T}{\partial x_t}$. From section 4 we know the private cost function and prices and section 5 gives us information about λ_h and λ_t. Last, from section 3 we know the *AC*(x_t,x_h) and can thereby solve for *TC(x_t, x_h)*. Therefore, based on (9.42) and (9.43) we may calculate x_h and x_t which is then the optimal mix of enforcement divided into enforcement on violations on the nephrops regulatory measure and violations on the cod regulatory measure. This holds for the various specifications of *C(h, t, v_t)* and *TC(x_h, x_t)* as described in section 9.4 and 9.3, respectively. Equations (9.42) and (9.43) may also be interpreted as the marginal social benefit of different types of enforcement (dock side inspections and boardings). This would simply require the social benefit function in (9.42) maximized with respect to dock side enforcement effort (x_1) and boardings effort (x_2). In this case the fishermen's response functions would then depend upon probabilities of being apprehended if they exceed the nephrops and cod regulatory measures, respectively and are caught by a dock side or a boarding inspection. Altogether this yields two probabilities in each response function. It would, however, again imply the marginal social benefit of each type of enforcement is zero, and we could solve for the optimal mix of enforcement effort between different types of enforcement. In our case it would be the optimal mix of dockside inspections and boardings.

9.5.2 Enforcement cost function

In this section we calculate an enforcement cost function for the two different types of enforcement we operate with in this paper. In other words, we calibrate an average enforcement effort function for dock-side inspection (blanket 1) and boarding (blanket 2). With respect to costs of inspection we only have data for three years, see COBECOS deliverable WP2. This implies that we cannot rely on econometric methods when determining cost parameters. We, therefore, calculate cost parameters for one year based on The Danish Directorate of Fisheries (2006). Here we choose 2005 because for this year we also have data for enforcement effort as previously defined. We choose two specifications of the average cost function:

$$AC = sx \qquad \text{(model 1)}$$
$$AC = sx^2 \qquad \text{(model 2)}$$

Where

AC are the average costs of enforcement
x is the enforcement effort as defined previously
s is a cost parameter.

Note that we have chosen a formulation without fixed cost. This is necessary to assume in order to calculate s but is also a reasonable assumption. It corresponds to the case where inspection inputs are also used for other purposes and the fixed cost is allocated to these purposes.

For dock side inspection and boarding we have data for the enforcement effort, x. This variable is calculated as the mean value of the enforcement effort defines above. We also have data for AC for dock-side inspection and boarding. AC is defined as the cost per inspection. Note that AC may be overestimated for boarding because other control exercises than boarding is included in the number. This problem is solved by making sensitivity analysis on *s* for boarding.

With information on the average costs and the enforcement effort level, *x*, we can calculate s in all three models, see Howitt (1995) and Jensen and Vestergaard (2002) for others applications of the same method for calculating parameters. The results are shown in Table 9.3.

Table 9.3. Calculation of the cost parameter.

	Dock side inspection		Boarding	
	Model 1	**Model 2**	**Model 1**	**Model 2**
s	58403	1502782	1242012	30410903

Figure 9.3 illustrates the estimated cost functions.

Figure 9.3. Enforcement cost functions for dock side inspections and boardings.

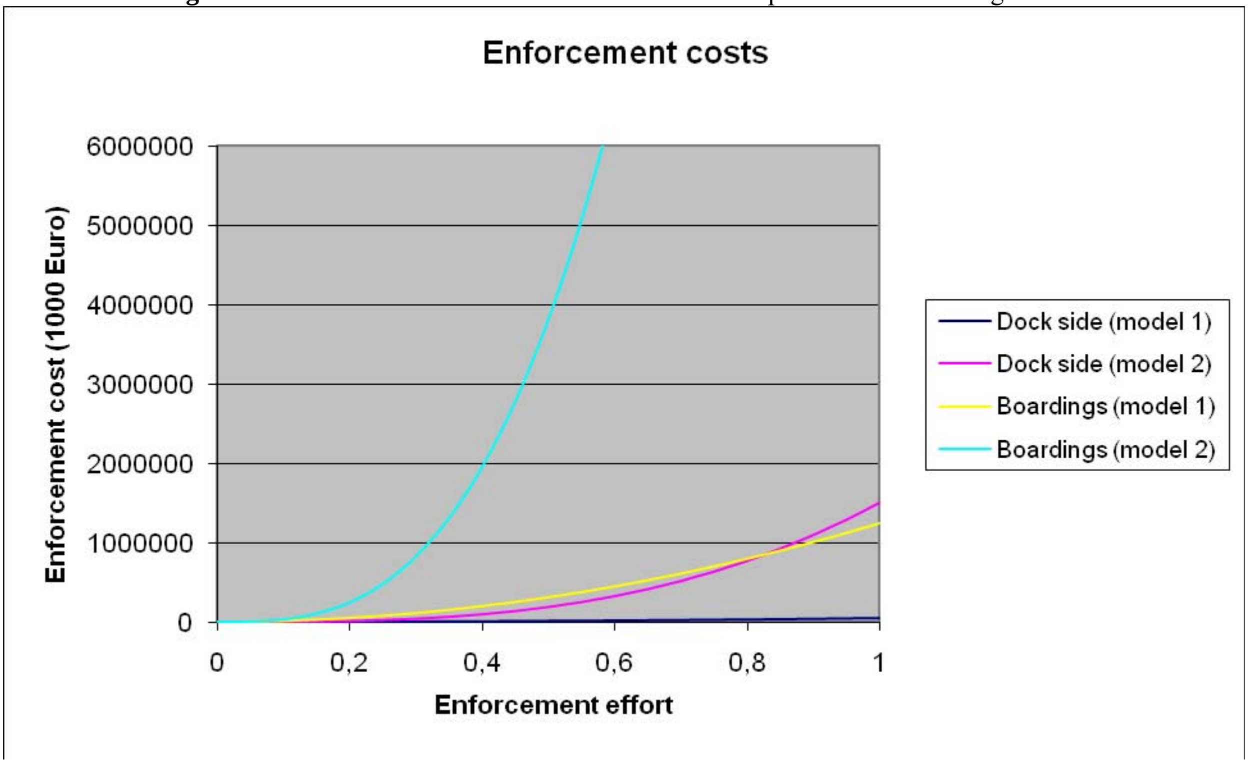

Figure 9.3 indicates the large uncertainty that there is on the cost of enforcement since there is a large span between the estimated costs functions for the same type of enforcement. The figure also indicates that there is more uncertainty on the cost of boardings than on the dockside inspections, which is explained by many other tasks also being assigned to the control vessels such as rescue obligations, own maintenance, shipping line, personnel administration and other tasks appointed by the Directorate of fisheries. The above figure

also shows that generally boarding inspections are more expensive that dock side inspections.

9.5.3 Probability of penalty function

With respect to models we estimate two different models:

$$y = a + bx \quad \text{(model 1)} \qquad (9.44)$$
$$y = a + b \ln x \quad \text{(model 2)} \qquad (9.45)$$

where:

y is the probability of being apprehended
x is enforcement effort
a,b are parameters to be estimated.

Equations (9.44) and (9.45) are estimated for both dock side inspections and boardings. The data set for control data contains cross-sectional data for both 2005 and 2006. It is, therefore, reasonable to include a yearly dummy variable in the estimation not to disregard differences over time. Including the dummy equations (9.44-9.45) become:

$$y = a + bx + cD \quad \text{(model 1)} \qquad (9.46)$$

$$y = a + b \ln x + cD \quad \text{(model 2)} \qquad (9.47)$$

Where:

D is a yearly dummy variable with value 0 in 2005 and value 1 in 2006

c is the parameter to be estimated.

The statistical program “Eviews 6” with its estimations techniques is applied for estimation. Table 9.4 summaries the results.

Table 9.4. Estimation results for two different types of enforcement-probability functions.

	Dock side inspections		Boarding	
	Model 1	**Model 2**	**Model 1**	**Model 2**
a	-0.01 (-2.39)	0.52 (5.59)	-0.01 (3.49)	0.76 (5.45)
b	1.00 (38.5)	0.13 (5.06)	0.99 (28.26)	0.19 (4.72)
c	-0.01 (-1.78)	-0.06 (-1.30)	-0.002 (-1.20)	-0.116 (-1.16)
R^2	0.98	0.51	0.98	0.76
Breuch-Pagan test	1.2	3.2	2.3	1.8
White test	2.00	2.05	1.4	1.04

Table 9.4 yields the estimation results for the parameters *a*, *b* and *c* in the enforcement probability function, the *R*-squared, the Breusch-Pagan test and the White test for all three types of models for dockside inspections and boardings, respectively. The numbers in brackets under each estimate are the *t*-tests.

With respect to both dock side inspections and boarding the Breuch-Pagan and White test shows that there is homoscedasticity. Thus, we can use OLS in the estimations. The variance inflation is, in all cases, below 10, therefore we have no problem with multi-collenarity.

From the *t*-tests for both dock-side inspection and boarding it is seen that both the *a* and *b* parameters are significant. However, the parameter in front of the dummy variable, *D*, is insignificant but excluding the dummy variable would significant reduce R^2. Therefore, *D* is included. The R^2 is relatively high so the models perform well.

With respect to the choice of model, model 1 for both dock-side inspection and boarding yields a very high R^2. However, *b* is in all cases close to one and because (0.9999; 0.9999) is included in the estimation, there is with a linear model an almost one to one relation between effort and probabilities. In other words, the estimated *b* parameters is governed by the (0.9999; 0.9999) observation. Therefore, we exclude model 1 and use model 2 in the following analysis. We do so despite the fact that model 1 yield a higher R^2. Figure 9.4 depicts the two types of enforcement probability functions.

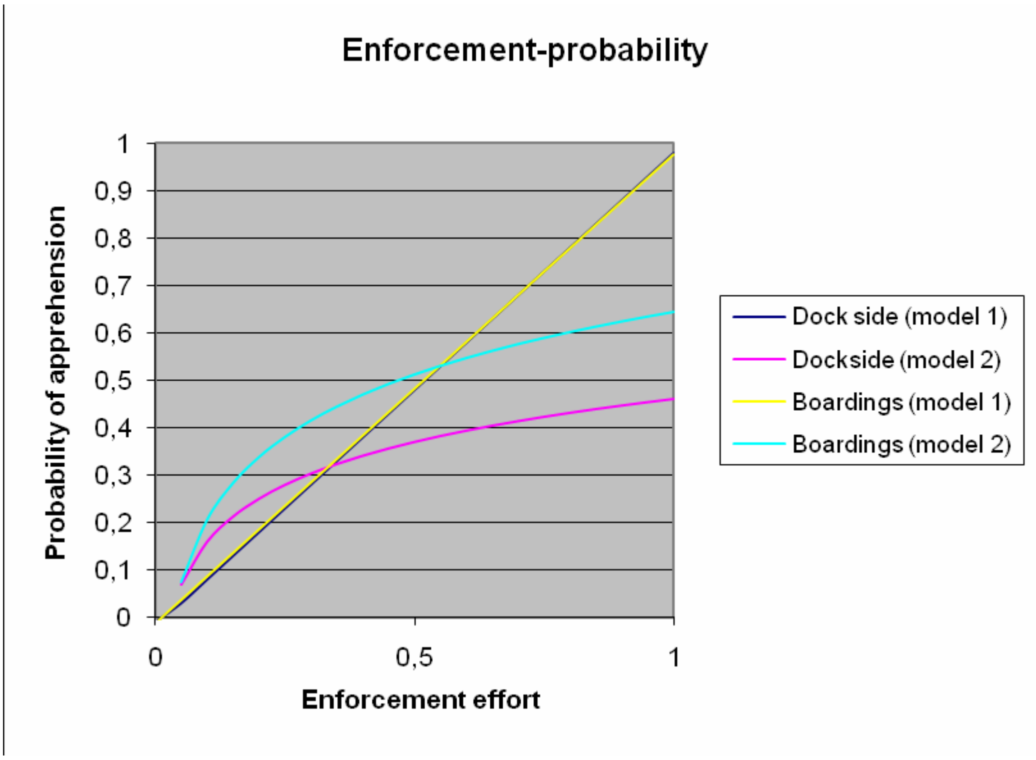

Figure 9.4. The enforcement-probability functions for doc side inspections and boardings.

It appears that full enforcement effort (enforcement=1) does not yield a probability higher than around 70 %. This can be explained by that even though a vessel have made a violation and it is inspected with a certain type of inspection we cannot be sure that the violation is revealed and afterwards apprehended. In addition very high levels of enforcement effort are unrealistic, and it will never be possible to induce such high levels. Therefore, the lower part of the curve are the most importanat ones.

9.6 Conclusions

This paper aims at presenting the first steps in the application of the theory on fishery enforcement from the COBECOS project to a specific case, namely the case of Norway lobster trawl fishery in Kattegat and Skagerrak. To apply the theory of fisheries enforcement we need to estimate and determine different functionalities relevant for the application of the COBECOS code. In this paper we start by defining how to convert data from our case into enforcement data between zero and one as necessary for the COBECOS code. We then estimate 1) the enforcement effort and the probability of apprehension function, 2) the enforcement effort and enforcement cost function, 3) the fishermen's private benefit function, 4) the shadow value of the two biomasses cod and nephrops and finally 5) the social benefit function.

During our setup we recognize challenges that are general to the whole setting and some challenges that are related to our specific case and the available data. The general challenges are primarily connected to determining the enforcement probability. Among these challenges are

- The actual enforcement effort is not a random variable, but merely a targeted enforcement towards previous violators or based on biological sustainability issues. We have not found a way to overcome the non-randomization of the enforcement effort, and we therefore recognise that the problem is there, but we do not deal with it.
- In our data set the only information about violators available is that we only know violators that are also apprehended. Violators that are not apprehended are not represented in our data set. This leads to, together with the above-mentioned targeted enforcement that the information about violators may be biased.
- We found it difficult to define what enforcement effort is. It could be number of man hours, fuel costs, number of inspections, or others. We do need a link between the enforcement effort and probability of being apprehended and since we have only cross sectional data over 2005 and 2006 we are not able to make a time series analysis. We have, therefore, decided to settle on the number of inspections since this is the most accurate measure that we have on an individual level even though we are aware that not two inspections are similar.
- To be able to apply the COBECOS software in our next step we need to rescale the enforcement between zero and one. Now one is a measure of controlling each and every harvest.
- It is only a very little percentage of all landings that are actually controlled. Out of the controlled landings are even fewer violations. Therefore the enforcement effort relative to the number of landings is very low and similarly the probability of apprehension is very low. This means that data are concentrated for very low values of enforcement effort and for very low values of probability for apprehension. For estimating the enforcement probability function, we therefore use extrapolation.

We also experienced some more case specific data problems:

- As mentioned under the more general issues we have only cross sectional enforcement data for each landing from Kattegat and Skagerrak with cod or nephrops from the years 2005 and 2006. We were therefore forced to find the enforcement effort and the probabilities of apprehension on an individual level. We added a dummy to identify the year. We are therefore not able to identify any development in the enforcement effort or the probability of apprehension over time.
- Our data set for enforcement cost had very limited information. We had only average enforcement cost over a 3 year period. We therefore had to rely on a positive mathematical programming method introduced by others (Howitt 1995, Jensen and Vestergaard 2002). We are aware that our cost of enforcement function is encumbered with a great deal of uncertainty, and sensitivity analysis on this function is of great importance.
- There exists no stock assessment of nephrops. We can therefore not include the nephrops stocks in the private cost of harvesting function. We have, however, been able to calculate the shadow value of biomass based on an alternative economic model with a binding regulatory measure. By this the nephrops stock will still be represented in the social benefit function.
- The binding regulatory measure for nephrops is the minimum landing size. We have to redefine this regulatory measure in our benefit functions such that it is converted into a TAC.

The paper estimates the functional forms that are now ready to apply in the COBECOS software for finding the optimal mix of enforcement effort.

10. (Western) Channel Fisheries

10.1 Authorship and affiliation

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10.2 Introduction

The UK Western Channel fisheries predominantly target a multitude of demersal fish stocks in the Western Channel (ICES sub-area VIIe). In this case study the UK component comprises mainly English vessels fishing out of South West ports. This case study focuses specifically on one of the most valuable stocks, that is, VIIe sole and the associated fleets that target sole (the South West beam trawl fleet). The fishery for VIIe sole is a demersal mixed species fishery, and there is traditionaly a high level of mis-reporting of sole (specifically mis-reporting of landings to area VIId). Based on the availability of economic data this case study focuses on English beam trawls >221kw. These large vessels (typically greater than 24m) of which there are about 37 active vessels in 2008 are predominantly based in two ports (Newlyn and Brixham).

There have been moderate declines in effort (days fished) over the period 2000-2005. Although not totally distinct the fleet that fish out of Brixham rely more heavily on VIIe sole and cuttlefish in the Western Channel, whereas large beamers that fish out of Newlyn fish in deeper water (ICES area VIIh) for part of the year targeting monk and megrim. In this case study the >221kw fleet is split into <30m and >30m, as data (for the year 2005) for these two fleets are presented separately in a report (SEAFISH, 2007).

A management plan was agreed for VIIe sole in 2007. Council Regulation (EC) No 509/2007 establishes a multi-annual plan for the sustainable exploitation of VIIe sole. Years 2007-2009 are subject to a recovery plan, with subsequent years being subject to a management plan. More recently a days at sea restriction was imposed on towed gear and in 2005 vessels were allowed to fish for a maximum of 20 days in a calendar month. There are mesh size restrictions for beam trawlers of 80mm and a minimum landing size of sole of 24cm. The responsible department for enforcement is the Marine and Fisheries Agency. Quota management in the UK is mostly delegated to Producer Organisations. However, VIIe sole is a shared stock and as such overall management responsibility is at the EU level. The Marine and Fisheries Agency (MFA - UK) have provided data on enforcement effort.

A dynamic bio-economic simulation model of the SW beam trawl fleet was specified and parameterised. The profit under various future scenarios can be estimated as well as the shadow value of biomass. The social benefit can thus be computed if the shadow value of biomass has been estimated. The cost-enforcement effort relationships have been defined and the theoretical probability of penalty function estimated based on a consideration of the enforcement data.

10.3 Description of the enforcement system

The responsible department for management in England and Wales is the Department of Environment, Food and Rural Affairs; with the Marine and Fisheries Agency (an agency of DEFRA) responsible for enforcement and collection of data. Quota management in the UK is mostly delegated to Producer Organisations. However, VIIe sole is a shared stock and as such overall management responsibility is at the EU level. It is suspected that substantial quantities of sole caught in VIIe have been reported to two rectangles in VIId in order to avoid quota restrictions. Corrections for this misreporting were first made during the 2002 WG, but misreporting to other areas has been more difficult to identify. In addition, black landings are likely to have occurred to various degrees since quotas became restrictive in the late 1980s. The MFA are aware of these black-landing and mis-reporting and have implemented various exercises to specifically target fishing vessels identified as potentially mis-reporting (identifications are based on outliers in reported CPUE in log-books). Only inspections at sea (Royal Navy) or at port (Port Inspections) can identify actual infringements which relate to differences in catch in hold versus that noted in logbook.

10.4 Data used

The Marine and Fisheries Agency (MFA - UK) have provided data on enforcement effort for England and Wales (port inspections, navy and aerial surveys for 2005 and 2006). There is also a limited data set from 1999-2007 that is specific to the fleets in the case study that provide a time series of enforcement effort for each of the enforcement types where infringements specific to this case study (VIIe sole) can be identified.

10.5 Estimation of theoretical relationships

10.5.1 Benefit function.

a) Private Benefit function

The estimation of the private benefit function within fishery enforcement general model is based on those presented by Arnason (Memos, WP2). Private benefits form fishing are given by:

$$B(q,x) = p \cdot q - c \cdot \frac{q^2}{x}, \qquad (10.1)$$

where q represents landings, p is the price of landings and x the biomass level. In the function c is a cost parameter. The parameter estimates are presented in Table 10.1, which also indicates their source. The estimate of the cost parameter was not obtained from the bio-economic model as it is includes the costs and revenues from all the stock targeted by beam trawlers, rather this estimate is based on the assumption that the costs are 5% less than the amount obtained for total revenue. The private benefits versus harvest (including the optimal fisher response harvest) are shown in the next figure.

Table 10.1. Parameter estimate – private benefit function

Parameter	**Value**	**Source**
p - price	£7000 per tonne	Landings database (from logbooks)
c – cost parameter	£6650 (per tonne)	Estimate (see text for explanation)
x - biomass	3500 tonnes	ICES Working Group (ICES 2007)

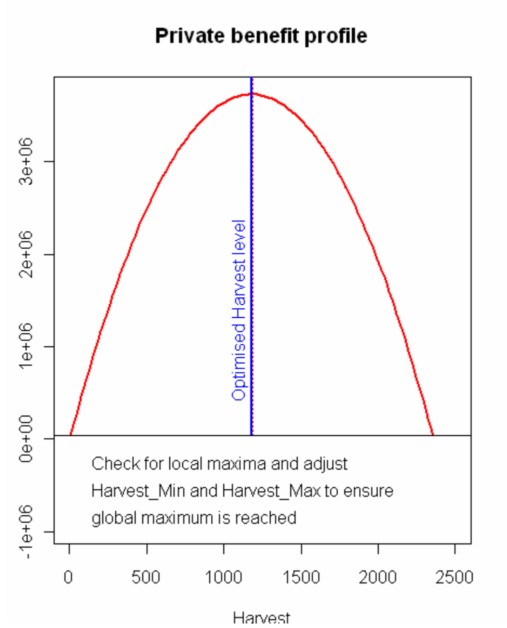

Figure 10.1. The Private Benefit function (benefits versus harvest). In this case only illegal harvest.

b) Social Benefit function

The estimation of the social benefit function within fishery enforcement general model is based on those presented by Arnason (Memos, WP2). Social benefits form fishing are given by:

$$B(q,x) - \lambda \cdot q - C(e). \quad , \tag{10.2}$$

where λ is the appropriate shadow value of biomass. In order to estimate the shadow value of biomass, a dynamic bio-economic simulation model of the SW beam trawl fleet was specified and parameterised. The biological component is a forward projection of VIIe sole output from the ICES assessment (XSA – assessment, WGSSDS 2007). The economic component as such includes the two main fleets (<30m and >30m English beam trawl fleet), that is, their estimated costs based on effort (days at sea) and revenue (sole and other stocks). The estimate of the shadow value of biomass is 2872 per tonne. The cost of enforcement (C(e)) estimates are provided below. The social benefits versus harvest (including the optimal fisher response harvest) are shown in

Figure **10.2**.

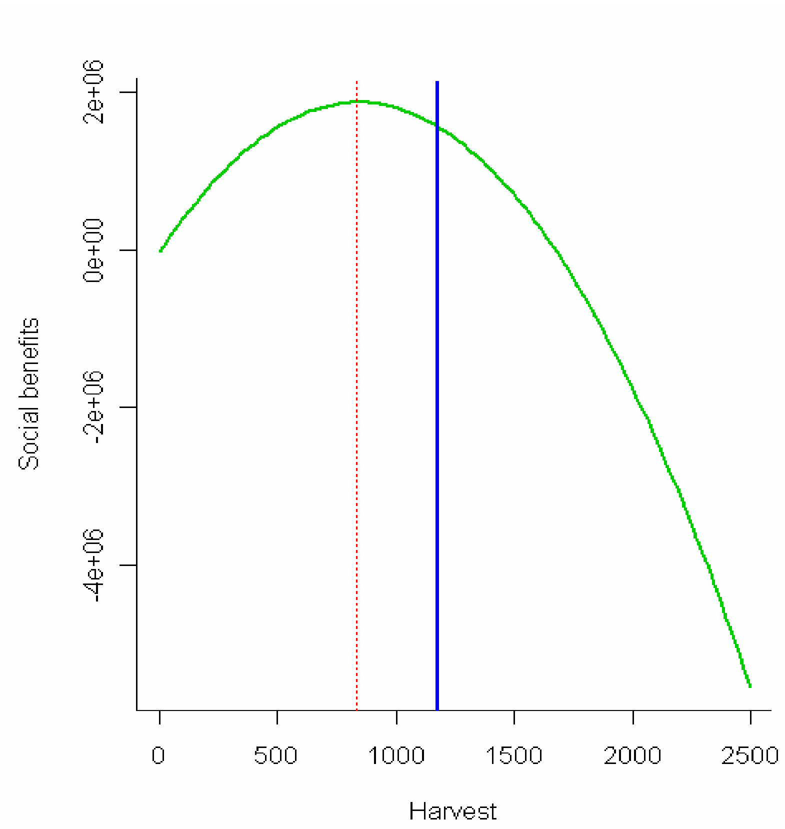

Figure 10.2. The Social Benefit function (benefits versus harvest). In this case only illegal harvest.

10.5.2 Enforcement cost function

The cost-enforcement effort relationships have been defined (based on cost estimates, see MFA Business Plan 2007/8). The estimates for total surveillance budgeted was £6.2 million (MFA Business Plan 2007/8). This final estimate of this value spent approximated the original budget. The budget was dependent on the predicted total of expected sea inspections coast-wide, normally in the region of 1400 inspections. Thus the unit cost per inspection could be estimated (as £4525 per inspection).

In order to estimate the specific costs for sea inspections for the main port in this case study, the number of inspections (average of about 60 per year) could be multiplied by the unit cost. These estimates of number of inspections *x* unit cost are regressed against normalised effort (which is the number of inspections/total number of trips in each year)(see

, which shows the model fitted relationship using the COBECOS software).

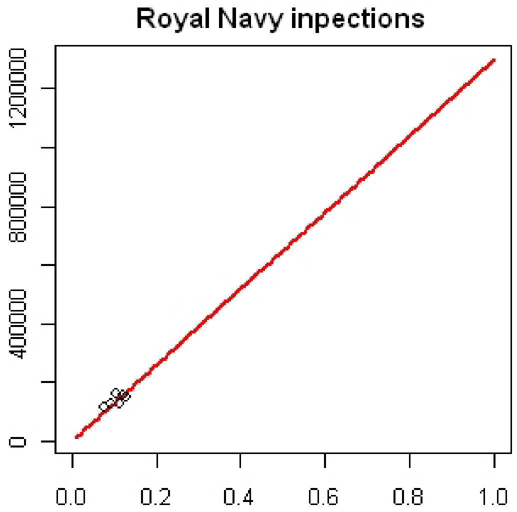

Figure 10.3. The estimated costs of at sea inspections versus enforcement effort.

The estimates for total port inspections are not directly available. Although the beam trawl fleet fish out of two ports, the mis-reporting (VIIe sole to VIId) is only mainly associated with one of the ports. The regional costs are the two ports were budgerted to be £522k (MFA Business Plan 2007/8). In addition there are rent costs and non-pay costs. As the staff levels at the two ports are roughly equal it was assumed that the budget for one of the ports was in the region of £250k.

The marginal costs per inspection are presented in the MFA report (£19 per inspection)(MFA Business Plan 2007/8). These underestimate the true marginal costs and more probably represent a short-run average cost. More recent estimates of cost per inspection are avalaible in the draft of the Marine Bill (a value of £176 per inspection). Therefore, a fixed cost of £200k was assumed to represent the costs of the admistration and effforcement team at the head-quarters (HQ) in London, and the regional administration costs.

In order to obtain a cost of enforcement versus enforcement effort, the number of inspections per year were multiplied by the unit costs and fixed cost. The estimates were plotted against the nomalised efforcement effort data (which is the number of inspections/total number of trips in each year). To obtain the bounds on the relationship the assumption was made that if every vessels was inspected (as currently about a quater are) it would roughly triple the total cost at the port (£750k) as additional staff would be employed and existing would undertake more inspections per year.

At the lower end of the scale of the relationship reducing the port inspections by half could be undertaken by a single inspector (with support staff), including the same rent and reduced non-pay costs. (Figure 10.4, shows the model fitted relationship using the COBECOS software). Both of these relationships were used as input to the estimation of the private and social benefit functions. The fine for each inspection type is £25000. This is based on recent sanctions.

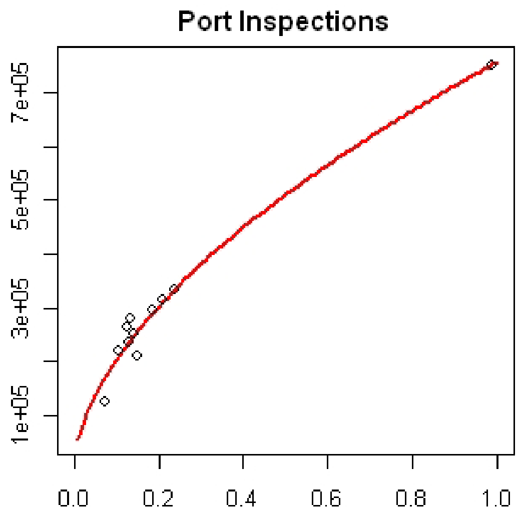

Figure 10.4. The estimated costs of at port inspections versus enforcement effort

10.5.3 Probability of penalty function

For each enforcment type (Port inspection and Royal Navy – inspections at sea) data on enforcement effort from 1999 to 2007 for beam trawlers landing into the main port were collated (see Figure 10.6). The recent (2007) inspection rate for the port is in the region of 23.6 percent of the trips by beam trawlers. The inspection rate at sea for this specific fleet is 17.3%.

There is a no available information or data from surveys to indicate to what degree the quality of the enforcment has improved or violations have increased in either the case of port inspection or inspection at sea (Royal Navy). Hatcher and Gordon (2005) undertook an extensive study on the port concerned in order to evaluate the factors influencing compliance.

The objective in this analysis was to estimate a relationship between probability of detecting a violation (infringment of regulations relating to VIIe sole at a specific port) versus enforcement effort. The MFA have set coastwide targets for the *no. of fisheries offences detected as a % of inspections on land and sea* (the targets as performance indicators are 4% and 13% respectively). In this case study, the estimates are higher in the case of land/port and lower in the case of sea (15% and 10% respectively).

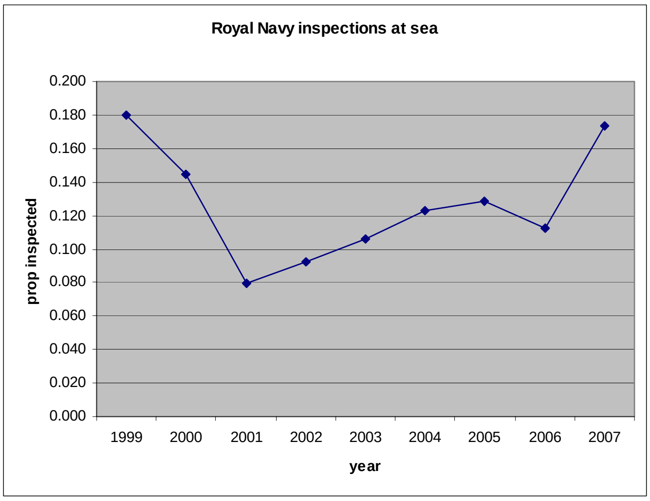

Figure 10.5. The percentage of inspections at sea over the lst few years – Royal Navy (data are specific to the beam trawl fleet and the main port in the case study)

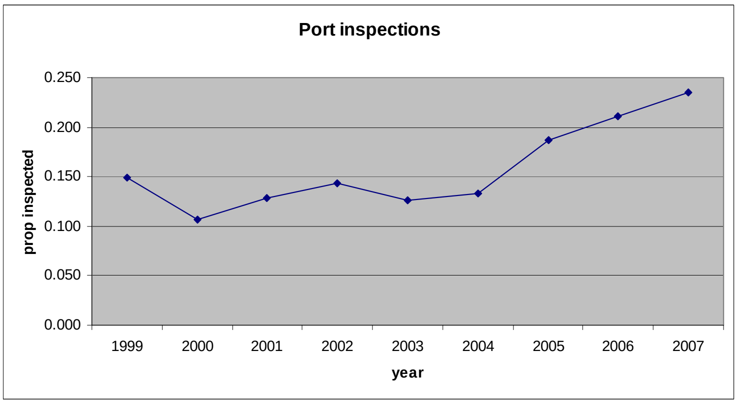

Figure 10.6. The percentage of inspections at port over the lst few years (data are specific to the beam trawl fleet and the main port in the case study)

A theoretical relationship for probability of detection of a violation was specified for each enforcement type (see

and Figure 10.8). These were obtained by considering the data (number of port inspections per year) shown in and Figure 10.6, and the average number of offences detected as a % of the number of inspections. These data only range over the lower values of enforcement effort (e.g. 0.05 – 0.25) for both enforcement types thus an assumption had to made with regard to the shape to fhe functional form at higher enforcement effort. The use of the logistic functional form for the relationship seems more reasonable as the exponential functional form (other studies, e.g. Arnason) imposes a very steep slope at the origin which is thought to not be situation in this case study.

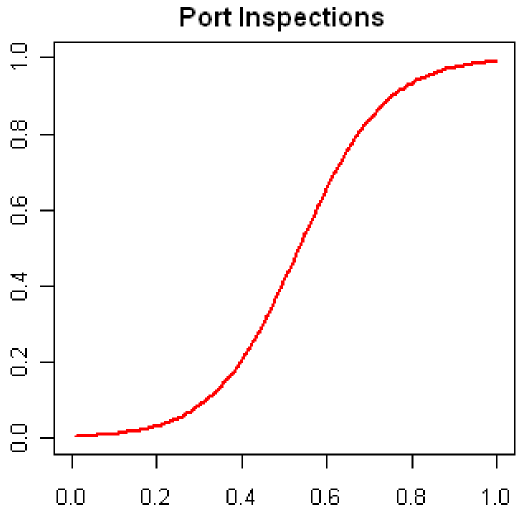

Figure 10.7. The probability of detection of a violation versus enforcement effort (Port Inspections)

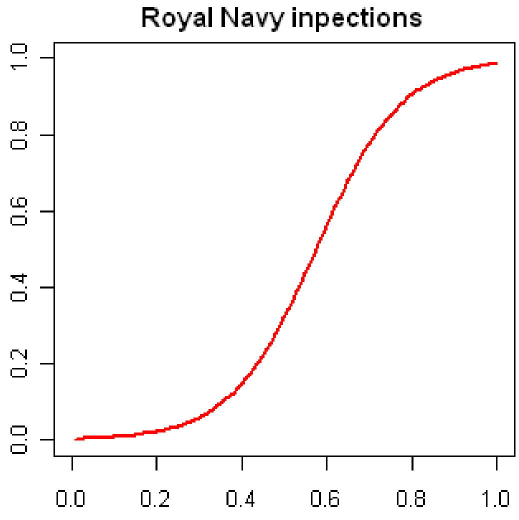

Figure 10.8. The probability of detection of a violation versus enforcement effort (Sea Inspections)

Due to the small difference in the average number of offences detected as a % of the number of inspections the relationships for port inspections and sea inspections differ; however these are not clear on visual inspection.

10.6 Conclusions

Due to the complexity of this case study (a mixed fishery that targets many species) the estimates of the fisher response to enforcement effort need to be put in context. As the fleets are regulated via output controls (TAC) any strict enforcement regime will result in discarding of fish not necessarily a reduction in fishing mortality. The assumption in this model is that higher enforcement levels do modify the behaviour of the fleets such that they reduce fishing effort in VIIe. Furthermore, the enforcement effort (and all associated costs) are not stock specific. In this case study, only VIIe sole and violations linked to this stock are considered; however the enforcement agency (MFA) is concerned with the management and enforcement of all of the marine species. Therefore, considering these uncertainties any results must be evaluated with this in mind. The determination of an optimum is to be commended; however at this stage the results must be considered to be preliminary. The exercise of determining optimal enforcement via the use of these theoretical models has been useful as it highlights the key factors that need to taken into account (e.g. fines) and the consequences of uncertainty (e.g. future stock levels based on recruitment).

Part II Comparison and conclusions

1. Comparison between case studies

Among the case studies there are considerable differences in the amount of data available. In addition to the reduced length of the time series, in partly due to the process of introduction of the control measures, there are intrinsic difficulties to finding data for this type of study. On the one hand enforcement is only realised by governments and therefore data will be collected on their own criteria with no other source of information than governments themselves. On the other, there is a clear challenge in trying to quantify the amount of illegal activity to cover the different concepts in the model.

Three cases (France, South Georgia and the Dutch beam trawlers) have a series of around ten years of enforcement data. The Icelandic case lays in between with a 5 year long time series. But for the rest of the cases there are only two or three years available. This can in some cases entail problems of lack of variability in the data

For most cases, the management measures whose application had to be assured by the enforcement process were related to catch (ITQs or other types of quotas) and technical measures (mesh sizes, landing sizes), together with temporal and spatial restrictions. The models include generally landing and mesh size restrictions. There is however an exception, as the South Georgia case study is also based on a dichotomy between licensed and unlicensed (thus illegal) vessels.

A table with the main characteristics of each case study may be seen on Table 11.1.

Table 11.1 Main characteristics of each case study

	N Hke	B.Saint-Brieuc	S Georgia	Ligurian	Norway	Iceland	Netherlands	Kattegat	SW UK
Data series	2005-2007	1991-2007*	1995-2007	2005-2007	2003-2005	2001-2006	1996-2006	2005-2006	2005-2006 1999-2007*
Management measure	TAC	non transferable effort quotas	individual vessel seasonal catch quota (set no. of licenses)	-temporal restr -spatial restr	quota violation area closure gear incorrect use	-harvest control -mesh size	-quota -mesh size	-landings undersized lobster -cod quota excess	TAC
Enforcement measures	inspection at sea	-air inspections -inspections at sea -port inspect.	-VMS -sea patrols (FPV, no.days &trip length)	-landings inspections -inspections at sea	-inspections at sea -port inspect. -processing co. inspections	-landings inpsections -mesh size inspections	-inspections at sea -port inspection -Transport, wholesale inspections	-dockside inspections (no.) -boardings (no.)	-inspections at sea -port inspection
Species analysed	hake	scallops	toothfish	hake striped mullet shrimp, others	cod	cod	sole plaice	cod lobster	sole
Quality of estimations	p(sanction): R2=0.9587 p value (model)= 3.601e-09		highlysignificant *γ=2.2e-03* *(SD=7.5e-06)* *χ = -1.9e-07* *(SD=3.4e-08)* residualSE					emforc.cost model 4: R^2=0.37 model 6 R^2 = 0.42	

			=0.015.						
Use of software	COBECOS + R (scenario simulations)	COBECOS	R (sample building)	COBECOS	COBEC OS	Matlab ©	COBECOS[v1] (enforccement-cost relation)	NECESSITY (shadow value)	COBEC OS

***** Not all data series have the same duration, see text for details

These differences among the case studies raise a variety of issues that affect the use of the models presented.

There are cases that present difficulties because of their lack disaggregation of the enforcement effort and costs not being disaggregated by management tool. In theses cases, an overall efficiency of the control system can still be analysed (see for example Ligurian sea CS).With more disaggregated data however the additional interest would be to check the interactions between various enforcement options. This could help in the further step of defining a mix of enforcement tools to be applied in a specific context, but even before that, it still contributes to show whether one enforcement tool is actually reinforcing the effect of another one or on the contrary both are working on the opposite direction.

Cases with particular modelling of the phenomenon of illegal fishing inside the enforcement framework are also shown. Examples of this are how this phenomenon is included in the model: as part of the biomass modelling, (eg Ligurian CS) as part of the social benefit function (eg South Georgia).

Regarding the probability of penalty there are some slightly different approaches. Starting from the basic theoretical models, different sets of assumptions have been made (eg North. Hake CS) or simulations have been employed to approximate the size of the probability by spatial and temporal coincidence (South Georgia CS).

With respect to the social benefit function the concept of shadow value has also received different treatment depending on the amount of data and the conceptualization of the model, with variations in the case studies for South Georgia and Kattegat, (with material from NECESSITY). These variations inside the approach reflect the complex reality of the enforcement process, with special emphasis on its data requirements. Another clarification is needed for the sign of the shadow values. For example, the case studies of Northern hake and Icelandic Cod calculate negative shadow values (ie decreases in NPV due to reductions of stock originated by one extra unit of catch in the present) while the Kattegat and Skagerrak nephrops case study sets them in the opposite way (ie effect of a 1 unit decrease in catch). Both of these procedures are symmetric in their interpretation and do not pose any comparability problems. An exception occurs for the scallops fishery in the Saint Brieu case study, with a negative shadow value due to the relative abundance of the biomass in recent years.

For the social benefit function also, the South Georgia fisheries include the revenue from the sale of illegal catch. This does not occur in the other cases and it should be considered as it may counteract, at least partially, the costs of enforcement.

Finally the private benefits some case studies as the Ligurian and Tyrrhenian sea consider inside the calculations the unauthorised fishing activity (both in the catchability and the biomass) as well as violation of selectivity restrictions (reflected on the intrinsic growth rate of the biomass), which may not be comparable to the other case studies but still shed some light into the functioning of the control syste,.

A comparative table of the main results from the case studies may be seen on Table 11.2.

Table 11.2 Summary of model equations with examples of results

	Private benefit	Social benefit	Probability of penalty	Enforcement. cost
Northern Hake	*B(h,x)- π(e)·f·(h-h*) if h>h** *B(h,x)* *if h≤h**(1)	*B(h,x)-λ h - C(e)+ π(e)·f·(h-h*)* *if h>h** *B(h,x)-λ h - C(e)* *if h≤h** *shadow value:* 1229€/tonne	$\pi(e) = \frac{Infractions}{Inspections}$ (2) $\pi(e)$=0.022043Ln(e)	linear 1470€ per inspection
Bay of Saint-Brieu	$B(q,x)=p.q-C(q,x)$ $B(q,x)=p.q-\frac{c.q^2}{x}$	$B(q,x)=p.q-\lambda.q-C(e)$ $B(q,x) = p.q-(p-\frac{2.c.q}{x}).q-C(e)$ *shadow value:* λ = - 564 €/ton	*Π* air=0.214Eair+0.536locat+1.109 *Π* sea=0.091Esea+0.494locat+0.994 *Π* port=0.099Eport+0.492locat+0.996	linear VC=728€/trip air control VC=780€/contrrol at sea VC=232€/control at port
CCAMLR South Georgia	$B = h(p+l)-ec$ $B^{IUU} = h^{IUU}p^{IUU}(1-\Pi)-e^{IUU}c^{IUU} -$	$SB = \Pi(h^{IUU}p^{IUU}+f)+hp-e^{FPV}c^{FPV}-ec$ *shadow value* omitted (see p26, sect 4.5.1.b)	$\Pi = \gamma e+\chi e e^{IUU}$ *Π* =0.2-0.3.	linear: $C = e^{FPV}c^{FPV}$
Ligurian and Northern Tyrrhenian Sea	$B_i = R_i - C_i$.; $R_i = r_i(p_{i,1}L_{i,1}+p_{i,2}L_{i,2}+p_{i,3}L_{i,3})$;$L_{ij} = q_{ij}\left(1+\frac{V_q}{E}\right)E_iX_j$*	$SB{=}B{-}CC{+}\lambda_1(G_1(X_1){-}L_{,1}){+}\lambda_2(G_2(X_2){-}L_{,2}){+}\lambda_3(G_3(X$	$\pi(e_r) = 4.00\text{E-}06 * e_r$	linear $CC_1(e_1) = 3cc_1e_1$ linear cc1=cc2=33€, cc3=28€ per insp hour $CC_2(e_2) = 20cc_2e_2 + 15cc_3e_2$ $= (20cc_2 + 15cc_3)e_2$
Norwegian fisheries	NA	NA	function NA	function NA
Icelandic cod fishery	eq no.7 (Arnason et al 2008)	eq no.10 (Arnason et al 2008) *shadow value*:150 ISK/kg	eq no 5,6 (Arnason et al 2008)	eq no.9 (Arnason et al 2008)

(1) Following Arnason theoretical memorandum (2008 COBECOS.)

(2) All the detected infractions are sanctioned (see p23)

Table 11.2 (cont) Summary of model equations with examples of results

	Private benefit	**Social benefit[o]**	**Probability of penalty**	**Enforcement. cost**
Dutch beam trawl	$B = p_s \bullet q_s + p_p \bullet q_p + R_o - c \bullet \left(\frac{q_s}{\alpha_s \bullet X_s} \right)$ $- \pi(e) \bullet (f + R_t)$	$V = (p_s - \lambda_s) \bullet q_s + (p_p - \lambda_p) \bullet q_p + p_o \bullet q_o$ $- c\left(\frac{q_s}{\alpha_s \bullet X_s} \right)^{\frac{1}{\beta_s}} - (C_{port} + C_{sea} + C_{TW})$ *shadow value*: sole 8 €/kg plaice 1.50€/kg	Π port=0.191Eport+0.562locat+0.935 Π sea=0.029Esea+0.159locat+0.982 Π TW=0.098ETW+0.441locat+p.958	$C_{port} = c_{port} \bullet E_{port} + \overline{C}_{port} = 3.86 \bullet E_{port} + 0.012$ $C_{port} = c_{port} \bullet E_{port} + \overline{C}_{port} = 3.86 \bullet E_{port} + 0.012$ $C_{port} = c_{port} \bullet E_{port} + \overline{C}_{port} = 3.86 \bullet E_{port} + 0.012$
Kattegat & Skagerrak nephrops fishery	PB= $P_h h - P_t t - C(h,t,v_t) - \pi_h F_h (h - \underline{h}) - \pi_t F_t (t - \underline{t})$	$SB = p_h(1-t)h_L + aP_h h_I - C(h_L, h_I) - \pi_h F_h h_I - \lambda(h_L - \underline{h})$ shadow value cod:-14.98DKK shadow value nephrops: 7.57	$\pi(e) = p(V \mid C) \times p(C) =$ $\pi(e) = \frac{\text{\# Violations for specific v}}{\text{\# Landings for specific v}}$ (4)	$AC = sx$ linear $AC = sx^2$ quadratic $AC = 58403x$ dock $AC = 1502782x^2$ dock $AC = 1242012x$ board $AC = 30410903x^2$ board
UK South West fishery	$B(q,x) = p \cdot q - c \cdot \frac{q^2}{x}$ parameters: p= c= x=	$B(q,x) - \lambda \cdot q - C(e)$. *shadow value*: 2872€ per ton	(non linear, see p 125, 11.5.3) estim p(penalty) per land inspect=0.15 estim p(penalty) per sea inspect=0.10	4525pounds per sea inspection

(1) Following Arnason theoretical memorandum (2008 COBECOS.)

(2) All the detected infractions are sanctioned (see p23)

2. Conclusions

The limitations of the approach are centered on the importance given to data. Illegal activity is always hard to measure and so any data that can qualify the assumptions made or improve the simulation methodology would be useful. The importance of enforcement data is still considered low by the providers, and so great emphasis should be made on its importance and profitability.

Another limitation regards the characteristics of the fishery and the management system, as the potential value of the fishery and the capacity of the fisheries management system are a limiting factor at the time of obtaining benefits from the enforcement system

These limitations must not however hinder the relevance of the obtained results. Optimal enforcement and how it depends on the parameters of the situation is quite a complicated matter. Even in the relatively simple model of this paper, the optimal enforcement effort-mix responds in unexpected and quite possibly unforeseeable ways to alterations in the conditions. This suggests that, in general, simple enforcement rules are not going to work very well. In fact, it appears that due to the complexity of most real enforcement situations the most appropriate enforcement policy can hardly be located, even approximately located, without the assistance of the appropriate empirical model and computer code.

Limitations in terms of simulations also appear. Estimations of enforcement effectiveness are driven by the theoretical (parametrical) estimations and not by the observed data (see for example Figure 5.1). In that sense simulations of relatively high increases of enforcement effort should be carefully read.

Models can be used in a variety of contexts, as the theory has been proved generally applicable. The neeed and cost effectiveness of the enforcement data has been highlighted. Additionally, interactions between enforcement tools has been succesfully modeled and this is an important step towards selection of the best mix of enforcement tools, which is by itself an important contribution to management.

Overally it can be said that given the existing limitations, particularly on the availability of data, estimations of the theoretical relationships have been succesfull. It implies that WP5 is providing inputs enough to deal with the simulation and calibration workpackages.

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Appendix: Examples of calculated probability of penalty and enforcement cost specified functions:

Estimated probability of penalty function for the Dutch case:

Table 8.4. Parameters of the probability functions

	Asymptote	Location	Slope
Port inspections	0.935	0.562	0.191
Inspections at sea	0.982	0.159	0.029
Transport and wholesale inspections	0.958	0.441	0.098

Resulting probability of penalty equations:

p(penalty by port inspection)=0.191Eport+0.562locat+0.935

p(penalty by inspections at sea)=0.029Esea+0.159locat+0.982

p(penalty by inspections of transport & wholesale)=0.098ETW+0.441locat+p.958

Estimated cost of enforcement funstion for the Skagerrat case:

$AC = sx$ (model 1)

$AC = sx^2$ (model 2)

Table 9.1. Calculation of the cost parameter.

	Dock side inspection		**Boarding**	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Cost parameter s	58403	1502782	1242012	30410903

Resulting cost of enforcement equations

$AC = 58403x$ linear dock

$AC = 1502782x^2$ quadratic dock

$AC = 1242012x$ linear board

$AC = 30410903x^2$ quadratic board (no FC)