Chapter 6
Potential Economic Consequences of the Landing Obligation

Ayoe Hoff, Hans Frost, Peder Andersen, Raul Prellezo, Lucía Rueda, George Triantaphyllidis, Ioanna Argyrou, Athanassios Tsikliras, Arina Motova, Sigrid Lehuta, Hazel Curtis, Gonzalo Rodríguez-Rodríguez, Hugo M. Ballesteros, Julio Valeiras, and José María Bellido

Abstract To assess the likely economic outcomes to fishing fleets of the Landing Obligation (LO), bioeconomic models covering seven European fisheries, ranging from the North East Atlantic to the Mediterranean, have been applied to estimate the

A. Hoff (✉) · H. Frost · P. Andersen
Department of Food and Resource Economics (IFRO), University of Copenhagen, Frederiksberg C, Denmark
e-mail: ah@ifro.ku.dk

R. Prellezo
AZTI, Sukarrieta, BIZKAIA, Spain

L. Rueda
Centro Oceanográfico de Baleares, Instituto Español de Oceanografía, Palma, Spain

G. Triantaphyllidis · I. Argyrou
NAYS Ltd., Kallithea, Athens

A. Tsikliras
Laboratory of Ichthyology, School of Biology, Aristotle University of Thessaloniki University Campus, Thessaloniki, Greece

A. Motova · H. Curtis
Seafish, Edinburgh, UK

S. Lehuta
Ifremer, Fisheries Ecol & Modelling Unit, Nantes, France

G. Rodríguez-Rodríguez · H. M. Ballesteros
Fisheries Economics and Natural Resources Research Unit, Department of Applied Economics, Faculty of Economics and Business Administration, University of Santiago, Santiago de Compostela, A Coruña, Spain

J. Valeiras
Instituto Español de Oceanografía (IEO), Centro Oceanográfico de Vigo, Vigo, Spain

J. M. Bellido
Instituto Español de Oceanografía, Centro Oceanográfico de Murcia (IEO), San Pedro del Pinatar, Murcia, Spain

© The Author(s) 2019
S. S. Uhlmann et al. (eds.), *The European Landing Obligation*,
https://doi.org/10.1007/978-3-030-03308-8_6

economic performance of fleets before and after implementing the LO. It is shown that for most of the analysed fisheries, their economic outcome will be negatively affected in the long term by the LO, when compared to the expected outcome with no LO. Efficient mitigation strategies (exemptions, quota uplifts, improved selectivity, effort reallocation and others) may, for some of the analysed fisheries, reduce the negative economic effect of the LO. Moreover, the possibility to trade quotas, both nationally and internationally, may also reduce the economic losses caused by the LO. However, even with mitigation strategies and/or quota trade in place, most of the analysed fisheries are worse off under the LO than what could be expected if the LO was not implemented.

Keywords Costs and earnings · Discards · Economic repercussions · Fisheries management · Fleet adjustment

6.1 Introduction

Commercial fisheries in Europe are diverse, with fish being caught for varied purposes ranging from high-value species for human consumption to fish used for fishmeal and fish oil. Technological and biological interactions make it difficult to catch target species completely selectively. For almost a century, landings of immature fish have been prohibited by regulations. Discarding fish below a minimum conservation reference size (MCRS) has been mandatory in European waters since the adoption of the Common Fisheries Policy (CFP) in 1983. The CFP Landing Obligation (LO) of 2013 requires fish under the MCRS to be landed, with implementation being phased in from 2015 to 2019. Similarly, before 2013, it was forbidden to land species for which quota was exhausted, and discarding of catches at or above MCRS was therefore required, a logical practice in mixed species fisheries.

Many businesses expect significant short-term negative economic repercussions of the LO due to increased operating costs, decreased income from landings and underutilisation of quotas (Condie et al. 2014). However, the actual outcomes of the LO will depend on several factors, including (i) the management system in place, (ii) application of exemptions (e.g. *de minimis* allowance of discards up to 5%), (iii) interannual transfers, (iv) catch allowances of stocks without TACs, (v) quota adjustments and quota swaps/movements, (vi) application of selectivity measures, (vii) costs of landing unwanted catch, (viii) prices obtained for unwanted fish and (ix) compliance of the sector. It is hoped that short-term losses could be mitigated by longer-term gains, given the desired reduced pressure on fish stocks and anticipated increases in quota and catch rates.

This chapter considers economic outcomes for fleets by analysing possible economic effects of the LO for seven diverse European case studies comprising (i) UK and Danish North Sea demersal fisheries, (ii) the French demersal trawl fishery in the Eastern English Channel, (iii) the Spanish trawl fishery in the Bay of Biscay, (iv) the Spanish trawl fishery in the Cantabrian-NW region, (v) the Greek trawl and small-scale coastal fishery in the Thermaikos Gulf (Eastern Mediterranean) and (vi) the Spanish demersal trawl fishery in the Western Mediterranean. Common for all these fleets is that they have a history of substantial unwanted catches before the LO; therefore it can be expected that the LO would affect them substantially.

6.2 What Can the Literature of Economics Tell Us?

The literature tells us that fishers tend to use more fishing effort than socially optimal due to market failures such as the tragedy of the commons (Hardin 1968). An unregulated, open-access fishery leads to overexploitation of fish resources; therefore the EU has attempted to prevent this by use of total allowable catches (TACs), limited fishing effort, MCRS and technical specifications for fishing gears, closed areas and seasons, among other measures. However, in mixed fisheries, these restrictions may also, in some cases, encourage a ‘race to fish’ and may increase incentives to discard because low quotas of some species prevent full exploitation of species with higher quotas. Quotas may also increase incentives to high-grade (discard lower-value fish) to maximise profit.

Although the CFP has a common approach to managing the fishing opportunities of the European Union including rules of compulsory discard, the management and organisation of fleets differ between Member States. Therefore, the economic repercussions of the LO not only depend on the rules of the LO but also on the national management system to which fishing businesses are subjected.

When interest for the discard issue arose in the 1990s, four general types of factors that encouraged discarding were identified (FAO 1996b; Nordic Council of Ministers 2003): (i) *institutional*, e.g. management measures such as quotas, effort restrictions, minimum landing size of fish and mesh size regulations; (ii) *biological*, e.g. species interaction and characteristics of the fish (e.g. gender, and size); (iii) *technological* such as gear selectivity (e.g. prohibited gear, damage to fish); and (iv) *economic*, for example, price and cost relationships determined on the market and high-grading (discarding low-value fish, both regulated and unregulated) to maximise profit by using quota and room on-board for more valuable fish (Batsleer et al. 2015).

Discarding originates primarily from non-selective catch and high-grading practices. These form the basis for the empirical and theoretical economic research that has been done regarding discarding over the last 20 years.

This research began in the 1990s (e.g. Flaaten and Larsen 1991; Frost 1996; Christensen 1996; Pascoe and Revill 2004). Empirical approaches also appeared in conferences and research programmes (FAO 1996a, b; Clucas 1997). In the FAO context, the economics of discarding can be found in Pascoe (1997) with an update in Kelleher (2005). The Nordic Council of Ministers (2003) investigated incentives to discard and options to reduce it. An EU Framework 7 project, NECESSITY, investigated options to reduce discarding by using increased mesh sizes or panels in fishing gear (Frost et al. 2007).

Alongside empirical research, theoretical work based on socio-economic modelling has developed. One approach concerns unwanted catch in open-access and individual transferable quota (ITQ)-managed fisheries (Ward 1994; Ward et al. 2012; Boyce 1996; Turner 1996, 1997). These analyses usually include two species (target and nontarget) and two fleets and deal with the optimal use and allocation of effort subject to a profit- (or resource rent-) maximising objective. In this context, bycatches of nontarget species constitute an endogenous externality, i.e. an outside impact influenced by fishers. In a simple situation where harvest of the target and nontarget species is in fixed proportions, fishing effort used to harvest target species can simply be scaled up and down to reach a first-best optimum. However, harvest of target and nontarget species may take place in variable proportions. Boyce (1996) compares maximisation of welfare in situations governed by open access and ITQs of harvesting two such species by two fleets. He finds that open access leads to excessive bycatches and that an ITQ system can only secure a first-best optimum if imposed on both target species and bycatches. Segerson (2007) extends this analysis to include stochastic bycatches and shows that neither landing fees nor ITQs on both target species and bycatches can secure an expected first-best optimum in which all market failures are corrected in an economically optimal way. A different approach to analyse bycatches is adopted in Abbott and Wilen (2009) where actual regulation, as opposed to estimated economically optimal regulation, is introduced. A given fishery is regulated with quotas for both target and nontarget species combined with limited entry programmes, and this actual regulation generates excessive bycatches and too short harvest seasons.

Another theoretical approach deals with high-grading. High-grading may occur for several reasons, e.g. to extend a quota that is nearly exhausted, to get the best value per tonne of quota or to make room on-board the vessel for more valuable fish. Arnason (1994) and Anderson (1994) show that a traditional ITQ system strengthens the incentive to high-grade. However, Turner (1997) shows that a value-based ITQ system (quotas measured in value instead of volume) secures a welfare optimal level of high-grading in a similar way that open access does. Under open-access or effort management, the distance between fishing grounds and ports of landing affects vessel operators' decisions about catching patterns; limited hold or processing capacity may be increased in the short term for high-priced fish through discarding of low-priced fish, and this discarding can thus pay for one or two more hauls per trip (turnaround cost) (see Vestergaard 1996). In the market policy of the CFP, the suppression of withdrawal prices in 2014 also constituted an incentive to discard, as the removal of a fixed minimum price increases the economic propensity to discard.

Analysing high-grading requires the inclusion of high- and low-priced fish. This can be done by including age-structured fish stocks in the model or simply dividing the stock in two parts: a low-priced and a high-priced part.

Fish sales prices relative to fishing costs also influence the incentives to discard: if the price of fish is lower than the costs of putting the fish on the market, then the fish should be discarded – at least from an economic point of view. However, it may pay to land fish even when handling costs are higher than the total value. That is, if costs of discarding are higher than the loss likely to be incurred by putting the fish on the market, then the fish should be landed.

When it is illegal to discard fish while incentives to discard remain, monitoring and control must be effectively invoked to offset incentives to discard (Sutinen and Andersen 1985; Nuevo et al., this volume). Also, social norms, trust and cooperation play a role (Sutinen and Kuperan 1999; Kraak and Hart, this volume). When it is difficult to monitor vessel operations at sea, vessel operators may decide not to comply with regulation. Jensen and Vestergaard (2002) consider discarding in a moral hazard context, i.e. when fishers hide their actions at sea; when these actions cannot be detected, repercussions are placed on them based on common elements such as estimated changes in target fish stocks.

To discourage non-compliance, measures are required to assist enforcement, including penalties, incentives to adapt to social norms, increased acceptance of management rules (Sutinen and Kuperan 1999; Kraak and Hart, this volume) and a governance structure which addresses diverging perceptions about the legitimacy of discarding in the first place (Fitzpatrick et al., this volume; van Hoof et al., this volume). In theory, a premium can be introduced, e.g. an increase in the price of fish that would otherwise be discarded because of a low price. It could also be invoked as a penalty placed on the (estimated) net benefit from discarding. In such a case, the vessel operator will include the benefit/penalty in their decision function. However, he/she will also consider the probability of being detected and the likelihood and size of any fine. If the risk of being detected and the penalty are low, fish will probably be discarded and vice versa.

6.3 The European Case Study Fisheries

Possible economic implications of the LO are presented through seven diverse European fishery case studies. Characteristics of each case are summarised in Table 6.1. Cases are divided into three groups: (i) demersal fisheries in the North Sea, West of Scotland and English Channel, represented by fleets from Denmark, the UK and France, (ii) Spanish Atlantic fisheries represented by the Basque mixed demersal fishery in the Bay of Biscay and the Galician trawl fleet in the Cantabrian-NW region and (iii) Mediterranean fisheries represented by two mixed demersal trawl fisheries from the Balearic Islands (Spain, Western Mediterranean) and the Greek trawl and small-scale coastal fishery in the Thermaikos Gulf (Eastern Mediterranean).

All cases have different management systems on top of which the LO is imposed. However, all have a certain degree of MCRS regulation, and before the LO, it was compulsory to discard fish below MCRS, with a few derogations in certain pelagic

Table 6.1 Base characteristics of the European case study fisheries with respect to the type of fishery, its target species, a brief description of the management system and key reasons for discarding

	Fishery	Target species	Fleet	Management system	Reasons for discarding
North Sea, West of Scotland, Eastern English channel	Danish North Sea demersal fishery	Cod, plaice, hake, haddock, sole and Norway lobster	Netters and trawlers, with length groups from 12 to 40 metres	TACs allocated in ITQs, MCRS	Quota utilisation optimisation Fish below MCRS High-grading
	UK mixed demersal fisheries in the North Sea, West of Scotland and area 7	73 main UK stocks targeted by different fleets in different areas. Pelagic species and non-quota species representing around 58% of value and 75% of weight landed by UK fleet are excluded	All UK active vessels grouped in 99 producer organisation fleet segments	TACs allocated in fixed quota allocation units that can be pooled within a PO, traded by vessel owners, or can be leased by other vessels in the same or other PO, MCRS	Quota utilisation optimisation Fish below MCRS High-grading
	French demersal fishery in the Eastern English Channel	Sole, scallops, whiting, cephalopods, cod, red mullet, sea bass and plaice	Bottom trawlers, mixed trawlers and trawl-dredgers, with length groups from 12 to 40 metres	TACs, MCRS, seasonal closures for scallops and effort limitation	Quota utilisation optimisation Fish below MCRS High-grading
Mediterranean	Spanish demersal fishery in Western Mediterranean	Four different fishing tactics are used, depending on the main target species (Palmer et al. 2009): (1) shallow shelf (striped red mullet), (2) deep shelf (European	Mixed demersal trawl	MCRS and other technical measures	Hake below MCRS High-grading Discard of low-value species

(continued)

Table 6.1 (continued)

	Fishery	Target species	Fleet	Management system	Reasons for discarding
		hake), (3) upper slope (Norway lobster) and (4) middle slope (red shrimp)			
	Greek demersal trawl and small-scale fishery in the Thermaikos Gulf	Mainly hake and red mullet (also surmullet and deep-water rose shrimp)	Bottom trawlers and small-scale coastal vessels using gill nets and trammel nets	Spatial and temporal restrictions, MCRS, other technical measure	Hake and red mullet below MCRS High-grading
Spanish fishery in the Atlantic	Spanish mixed demersal trawl fishery in the Bay of Biscay	Pair trawlers: mainly hake. Otter trawlers: hake, megrims, horse mackerel, blue whiting, mackerel, rays, red mullet, seabass, squids and cuttlefish	Pair and otter trawlers using different métiers	The fleet is managed with fishing rights, TACs and Total allowable Effort, together with mesh and MCRS limitations	Quota utilisation optimisation Fish below MCRS
	Spanish demersal trawl fishery in the Cantabrian-NW region	Hake, megrim, anglerfish, blue whiting, horse mackerel and mackerel	Otter bottom trawlers (average length 28 metres)	The fleet is managed with fishing rights and Total allowable Effort together with mesh and minimum landing size limitations	Quota utilisation optimisation Fish below MCRS

fisheries. Under the LO, it has become obligatory to land these fish, but they cannot be sold for human consumption. On top of this new obligation to land small fish, the North Sea, West of Scotland and English Channel fisheries are regulated by TACs, in some cases combined with effort regulation and technical conservation measures. While TACs are set at the European level, national quotas (i.e. fixed shares of the TACs) are managed differently by the Member States. They are managed as ITQs in Denmark, are distributed between producer organisations (POs) and vessel owners in the UK in a system that is essentially a quasi-ITQ system and are distributed between POs in France. Swaps and quota exchanges are allowed between organisations in the UK and France. The Atlantic Spanish fisheries are regulated with Total Allowable Effort (Prellezo et al. 2016) and TACs. The Mediterranean fisheries are regulated through technical gear specifications and MCRS for the main target species, temporal and spatial closures and other technical measures (Stergiou et al. 2016).

Demersal fishing activities in the North Sea, West of Scotland and in the English Channel have highly mixed catches of species, and therefore it is not possible to fully catch all quotas at the same time in the year, leading to either underutilisation of quota or discarding of fish for which quotas are exhausted first. Under the LO, the risk of a choke situation, i.e. having to stop fishing when the quota of a low-quota stock is exhausted, is a great concern to managers and vessel operators alike (Ulrich et al. 2011). This is especially expected to be a problem for French vessels, operating with fixed quota shares within producer/fishery organisations, while this problem may be less severe for UK and Danish fleets, where quota trade may mitigate the problem to some extent. For Spanish demersal fisheries in the Bay of Biscay, mackerel and horse mackerel are discarded because of low-quota allocations, i.e. to optimise quota utilisation of other species, while hake is primarily discarded because of being below MCRS. Thus, in these fisheries choke situations may also be an issue. In the Mediterranean fisheries, discarding is primarily due to fish below MCRS and to high-grading. As such, all cases face lower revenues under the LO given that previously discarded fish of low value and below MCRS must now be landed, combined with increased handling costs of these unwanted catches.

6.3.1 Mitigation Strategies

Given the different challenges that the selected fishing fleets face under the LO, different scenarios have been analysed, mainly addressing (i) how fleets will respond given the threats faced and (ii) how economic losses can be reduced through mitigation strategies most relevant for that fleet. Table 6.2 gives an outline of the scenarios analysed for each case study.

In all case studies, the economic situation was analysed for the fleet, given the current management system (cf. Table 6.1), i.e. if the LO had not been implemented (named ‘business as usual’). This scenario is used as a first benchmark when analysing the effects of the LO. In all case studies the full implementation of the LO with no exemptions was also analysed, i.e. the economic situation for the fleets given their current management system with the LO superimposed. This is a second benchmark against which the effects of introducing mitigation strategies are compared. Application of full implementation in the case study models was based on different assumptions for each case study:

Table 6.2 Scenarios analysed for the European case study fisheries

	North Sea, West of Scotland and English Channel			Spanish Atlantic fisheries		Mediterranean fisheries	
	Denmark	UK	France	Bay of Biscay[1]	Cantabrian-NW	Spain (W. Med)	Greece (E. Med)
Business as usual (no LO)	■	■	■	■	■	■	■
Full LO implementation, no exemptions	■	■	■	■	■	■	■
De minimis	■			■	■		
Year Transfer				■			
Mesh size selectivity				■		■	■
Effort reallocation[2]/Flexibility	■		■		■		
Quota adjustment		■	■				
Decrease minimum landings size	■						
Catch allowance for stocks with zero TACs		■					
Vessel effort movements between métiers		■					
Quota movement (swaps)		■					

Notes: [1]Quota adjustments assumed in all LO scenarios for the Bay of Biscay

[2]Effort reallocation can be seasonal and between fleets (the Danish case) and spatially (the French case) or more efficient effort use (the Cantabrian-NW case)

- In the Danish North Sea demersal case, fish below MCRS must be landed, with gradual implementation from 2016 to 2019 depending on species.
- In the UK mixed demersal fleets, each vessel in a PO has its initial quota available, and by 2019 no demersal species below MCRS can be discarded. The LO is implemented gradually towards 2019 depending on the fish stock.
- In the French mixed demersal case, vessels in métiers are forbidden to continue fishing as soon as the quota of one of their target stocks is reached, and fishing effort is then allocated between the remaining métiers. Fish under MCRS are landed but cannot be sold (price set to zero).
- In the Bay of Biscay Basque mixed demersal trawl case, the fishing activity of a given métier is stopped when the most binding quota share is reached.

- In the Galician mixed trawl case, all catches of species subject to TACs or MCRS must be landed.
- In both Mediterranean cases, a 10% increase in daily variable costs and one more crew member on-board are assumed to reflect the extra effort needed to bring ashore unwanted catches. Three full implementation scenarios were examined for the Greek case (Eastern Mediterranean) based on varying discard rates: (i) 5% increase of daily costs, no extra crew member; (ii) 10% increase of daily costs, 10% extra crew (the original full implementation scenario); and (iii) 20% increase of daily costs, 20% extra crew (based on the discard rates reported in the literature). The reason for the extra full implementation scenarios was that, according to official reports (DCF 2016), the percentage of hake and red mullet discards in Greece had dropped to less than 5% since 2013; thus, this case differs substantially from initial estimates that were based on the literature (e.g. Tsagarakis et al. (2014)).

The analysed mitigation strategies (see Table 6.2) are different for each case, reflecting the specific challenges each fleet faces when the LO is introduced.

In the UK, Danish and French cases, the focus is on maximising quota utilisation. For the Danish demersal fishery, the effect of introducing a 5% *de minimis* exemption is analysed. In addition, economic effects of lowering the MCRS for cod (making it possible to sell some fraction of cod below the previous MCRS) are analysed. For the UK North Sea and West of Scotland mixed demersal fleets, a number of mitigation strategies are analysed: (i) allowance for catching and landing species with zero TAC; (ii) as scenario (i) but with quota adjustment to all TAC species; (iii) as scenario (ii) but with the possibility to reallocate effort to other areas of operation to better utilise producer organisation (PO) quota; (iv) as scenario (iii) but with quota reallocation allowed within the UK to maximise use of quotas; and (v) as scenario (iv) but with international and national swaps at the level of the baseline year incorporated and UK end of year quota reallocated to PO fleets in need of quota. The French mixed demersal fishery in the English Channel case focused on (i) quota adjustments for sole, plaice, cod and whiting and (ii) assuming that fishers can shift to fish in other areas.

The choke situation and having to land fish below MCRS are also issues in the Spanish Atlantic cases. Thus the focus is on quota utilisation optimisation and on fishing gear selectivity. For the Spanish Bay of Biscay mixed demersal fishery, the focus is on investigating the economic effects of implementing (i) 5% *de minimis* exemption, (ii) inter-year quota flexibility, (iii) combining *de minimis* and inter-year flexibility and (iv) selectivity changes for the pair trawlers, given the single-species nature of their catches (90% hake), assuming a change in minimum mesh size from 100 mm to 120 mm. For the Spanish demersal trawl fishery in the Cantabrian-NW region, the focus is on (i) 5% *de minimis* exemption and (ii) effects of improved selectivity, e.g. through effort reallocation or non-compliance, assuming this will reduce unwanted catches by 50%.

The two Mediterranean cases focus predominantly on selectivity issues, given their high catches of unwanted species and fish below MCRS. For the Spanish demersal trawl fishery around the Balearic Islands (Western Mediterranean), several selectivity possibilities for hake are analysed: (i) no fishing mortality for hake at age 0, (ii) no fishing mortality of hake below MCRS (by decreasing the fishing mortality of age 1 individuals by 10%) and (iii) no fishing mortality of immature individuals (through modification of age-selectivity parameters).

For the Greek demersal trawl and small-scale coastal fishery in the Thermaikos Gulf (Eastern Mediterranean), three selectivity scenarios are applied to both hake and red mullet: (i) no fishing mortality at age 0, (ii) no fishing mortality below MCRS (by additionally decreasing the fishing mortality of age 1 individuals by 10%) and (iii) no fishing mortality for hake and red mullet at ages 0 and 1 through modification of age-selectivity parameters.

6.3.2 The Model Tools

The analyses were done using different bioeconomic models constructed for the geographical areas of the case study fleets (Table 6.3). Given the level of detail and complexity of each model, model descriptions are not provided in this chapter but can be found in the references listed in Table 6.3. All but one of the models are dynamic, evaluating the development of fleet capacity, economic performance and effort, together with stock dynamics, during the period 2015–2025. The exception is the analysis of the Spanish trawl fishery in the Cantabrian-NW region, which is based on input-output models.

6.4 Results

Analyses of the economic consequences of implementing the LO include two parts, firstly the economic outcome under the LO relative to the outcome if the LO had not been introduced and secondly the LO mitigation scenarios benchmarked against the LO scenario with no exemptions or other mitigation strategies included. These results differ depending on whether they are evaluated in the short or long term. Short term is defined as a period in which only variable inputs can change (e.g. fuel and crew) but not fixed inputs such as vessels, equipment and gear, while in the long term, all inputs can change.

Generally, some short-term negative economic effects of the LO can be expected. The main reasons for this are (i) the choke species issue for fisheries regulated with quotas, whereby catch of some species is constrained once catch of another species has reached its total quota, (ii) that landing of unwanted fish below MCRS and of low market value will replace landings above MCRS and of high value and (iii) the higher costs created by landing instead of discarding. The scale of these short-term losses is case-specific. In the long term, choke situations and displacement of vessels to other areas are expected to reduce fishing pressure, leading to biomass increases and thus improved fishing possibilities. However, ensuing economic improvements

Table 6.3 Model tools applied to evaluate the consequences of the LO for European case fisheries

	Fishery	Model
North Sea, West of Scotland, Eastern English channel: Mixed demersal	Danish North Sea demersal fishery	Fishrent: A bioeconomic profit maximisation model integrating, and allowing feedback between, the economy and the biology of the fishery (Frost et al. 2013)
	UK mixed demersal fisheries in the North Sea, West of Scotland and area 7	SEAFISH: Based on the Fishrent structure, the SEAFISH simulation model is developed to analyse the activity of the total UK fleet (Mardle et al. 2017)
	French demersal fishery in the Eastern English Channel	ISIS-Fish: A spatialised operational simulation model which simulates the dynamics of fish populations and fleets of the mixed fisheries in the Eastern Channel (Pelletier et al. 2009; Lehuta et al. 2015)
Mediterranean	Spanish demersal fishery in the Western Mediterranean	MEFISTO (Mediterranean Fisheries Simulation Tool): A bioeconomic fisheries simulation model with an age-structured biological component (Lleonart et al. 2003, https://mefisto2017.wordpress.com/)
	Greek demersal fishery in the Thermaikos Gulf (Eastern Mediterranean)	
Spanish Atlantic fisheries	Spanish mixed demersal trawl fishery in the Bay of Biscay	FLBEIA: A management strategy evaluation model coupling economic, biological and social dimensions; it shares economic structure with Fishrent but with an age-structured biological component (Garcia et al. 2017)
	Spanish demersal trawl fishery in the Cantabrian-NW region	Input-output analysis: Based on input-output tables for the Galician Fishing and Preserved Fish Sectors 2011 (García-Negro et al. 2016), the function of production of the fleet was recalculated considering the LO and the biological data obtained from IEO (Spanish Institute of Oceanography) campaigns

will differ for individual fleet segments and vessel businesses, depending on catch composition and on whether TACs increase proportionally when biomasses increase. If the latter is not the case, the choke situation may be enhanced.

Here we present a single year view of the economic outcome of the LO for the considered fisheries in 2025 assuming that the LO has been fully implemented (Table 6.4). The exception to this is the Cantabrian-NW case that represents a static view of the impact of the LO in an average year (based on 2014–2016) in the

Table 6.4 This table displays the economic outcomes in 2025 for the LO scenarios relative to the scenario assuming no LO (business as usual)

Mitigation measures[3]	North Sea, West of Scotland and English Channel			Spanish Atlantic fisheries		Mediterranean fisheries	
	Denmark	UK	France	Bay of Biscay	Cantabrian-NW	Spain (W. Med)	Greece (E. Med)
Full LO implementation, no exemptions	P [yellow]	R [red]	R [red]	P [yellow]	P [red]	P [red]	P [yellow]
De minimis	P [yellow]			P [red]	P [red]		
Year Transfer				P [yellow]			
Mesh size selectivity				P [yellow]		P [green]	P [green]
Effort reallocation[2]	P [yellow]		R [red]		P [red]		
Quotaadjustment		R [red]	R [red]				
Decrease minimum landings size	P [yellow]						
Catch allowance for stocks with zero TAC		R [red]					
Vessel effort movements between metiers		R [red]					
Quota movement (swaps)		R [red]					

For most scenarios the economic outcome is measured as the total profit in 2025 for the included fleets, while for the UK and French cases, the economic outcome is measured in total revenue for the included fleets. Results at a glance: total economic result (profit='P', revenue='R') in 2025 with LO implemented relative to the business-as-usual case (no LO)

Note: [1]For the Spanish Cantabrian-NW case, the results represent the expected outcome in 2017 given the assumed scenario
[2]Effort reallocation can be seasonal and between fleets (the Danish case) and spatially (the French case) or more efficient effort use (the Cantabrian-NW case)
[3]Yellow indicates less than 5% change, red indicates more than 5% decrease and green indicates more than 5% increase

scenarios considering full implementation and *de minimis*, while the scenario considering flexibility is a longer-term view, assuming a 50% reduction of catches in the long term given improved effort reallocation or other means. Whether 2025 corresponds to a long term will, to some degree, depend on the specific case study, i.e. on whether adjustments are ongoing in the given fleet or whether equilibrium is reached. Theoretically, a better measure of impacts would have been the net present value (NPV) covering the whole period from 2015 to 2025. However, not all models included in the present synthesis are able to provide NPVs over that period, and it has therefore been chosen to present the outcomes for 2025 alone.

In 2025, four of the seven case studies are expected to be negatively affected by the LO, when no exemptions are assumed (see Table 6.4). The exceptions are the Danish North Sea demersal fleet, the Spanish Bay of Biscay fleet and the Eastern Mediterranean fleet. The reasons for the expected economic losses are increased daily and crew costs (Western Mediterranean case), the industry being unable to process the previously discarded fish, and lost landings value due to cessation of fishing after choke situations (the UK and French cases). The assumption of constant TACs in the French case probably exacerbates the problems and results in overly pessimistic scenarios. For the Danish case, where choking on low-quota stocks is the greatest concern, possible negative economic consequences of the LO are reduced through (i) quota trade under the ITQ system in place and (ii) seasonal effort flexibility. In the Spanish mixed demersal fleet in the Bay of Biscay, possible economic losses are reduced by the effects of choke situations reducing mortality and increasing stock size, i.e. under full implementation of the LO, other fleets face choke situations and cease fishing before catching quotas of other stocks, such that the target species stock size increases in the long term, thus increasing catch possibilities (Prellezo et al. 2016). In the Eastern Mediterranean case study, the percentage of discards for hake and red mullet that are officially reported is below 5% for trawlers and even lower for netters (DCF 2016). For that reason, the full LO implementation scenario will result in very low increase (< 5%) in the daily costs and will not necessarily require an extra crew member to handle the extra catch.

Compared with how the case study fisheries would have evolved without the LO, the LO implemented with mitigation measures is, in some cases, expected to make the fisheries equally or better off in 2025. This is so for the Danish North Sea demersal fishery, as the ITQ management system makes it possible for the fleets involved to avoid choke situations through quota trade and seasonal effort flexibility. For the Spanish demersal fishery in the Bay of Biscay, interannual quota flexibility (with a limit of 10% of the initial quota) and increased selectivity (assuming an increase in minimum mesh size from 100 mm to 120 mm) also limit the possible negative economic effects of the LO. However, the application of the *de minimis* exemption has a negative effect in the long term. The application of the *de minimis* exemption increases the fishing mortalities compared to the case with no LO and the harvest control rule will then reduce the advised TAC for the next year (which then happens every year). Thus, the penalty imposed, given increased fishing mortalities, is higher than the flexibility gained by the exemption itself.

Increased selectivity also makes the fishery better off for the Spanish fishery around the Balearic Islands (Western Mediterranean) and for the Greek trawl and small-scale coastal fishery in the Thermaikos Gulf, especially if the catch of immature hake individuals is totally avoided, which raises the profit in 2025 above what could be expected without the LO.

At a glance Table 6.4 shows that for most of the analysed fisheries, their economic outcome will be negatively affected in the long term by the LO. But the possibility to trade quotas, both nationally and internationally, and for some fleets increased selectivity and/or year-transfers may mitigate this effect.

Under the LO, a key question is to what degree the overall negative economic outcome can be avoided through appropriate mitigation measures. Table 6.5 shows the economic outcome in 2025 in the mitigation strategy scenarios for each of the analysed fisheries, relative to the expected situation in 2025, assuming full implementation of the LO with no exemptions.

Half of the mitigation strategies analysed do not significantly improve the economic outcome relative to full implementation of the LO with no exemptions (see Table 6.5). This is the case for the Spanish trawl fishery in the Bay of Biscay when

Table 6.5 Results at a glance: total economic result (profit='P', revenue='R') in 2025 with mitigations relative to full implementation of the LO with no mitigations

Mitigation measures[3]	North Sea, West of Scotland and English Channel			Spanish Atlantic fisheries		Mediterranean fisheries	
	Denmark	UK	France	Bay of Biscay	Cantabrian-NW	Spain, (W. Med)	Greece (E. Med)
De minimis	P			P	P		
Year Transfer				P			
Mesh size selectivity				P		P	P
Flexibility (effort reallocation)	P		R		P		
Quota adjustment		R	R				
Decrease minimum landings size	P						
Catch allowance for stocks with zero TAC		R					
Vessel effort movements between métiers		R					
Quota movement (swaps)		R					

Note: [1]For the Spanish Cantabrian-NW case, the results represent the expected outcome in 2017 given the assumed scenario
[2]Effort reallocation can be seasonal and between fleets (the Danish case) and spatially (the French case) or more efficient effort use (the Cantabrian-NW case)
[3]Yellow indicates less than 5% change, red indicates more than 5% decrease and green indicates more than 5% increase

inter-year quota transfers and increased mesh size selectivity are introduced. Likewise, the *de minimis* exemption in the Spanish fishery in the Cantabrian-NW region does not lead to an increased economic result compared to when no exemptions are applied. In parallel with this, applying the *de minimis* exemption leads to a reduced economic result for the Spanish demersal fishery in the Bay of Biscay, because increased fishing pressure leads to higher mortality and reduced hake and megrim stocks and thus reduced fishing possibilities. Likewise, for the French fishery in the Eastern English Channel, applying increased flexibility through spatial effort reallocation leads to a decreased economic result compared to the LO with no mitigation strategies.

Mitigation strategies that do increase the economic outcome relative to the full implementation of the LO with no exemptions are (i) quota adjustments in the French demersal fishery in the Eastern English Channel, (ii) more efficient effort use leading to reduced unwanted catches in the Spanish fishery in the Cantabrian-NW region, (iii) increased selectivity in the Spanish fishery around the Balearic Islands (Western Mediterranean) and (iv) all mitigation strategies (quota adjustment, catch allowance for zero TAC stocks, vessel movements between metiers and quota swaps) considered for the UK fishing fleets, but the scale of changes depend on the fishing fleets concerned (North Sea and West of Scotland).

Thus, at a glance, Table 6.5 shows that for the analysed fisheries, the most effective mitigation strategies depend on both the fishing fleet and the management system in place. Model structure and the assumptions applied in the models may also influence the results, but all models have been calibrated and tested against the actual situation in each case study. It is thus believed that the relative results provided in each case study are good indicators of the effects of the LO and applied mitigation strategies.

6.5 Summary and Policy Recommendations

To assess the likely fleet economic repercussions of the Landing Obligation, bioeconomic models covering seven European fisheries have been applied to estimate the economic performance of fleets before and after implementing the LO. The selected fisheries cover different species compositions and fishing technologies and different management systems ranging from the North East Atlantic to the Mediterranean.

When the four groups of factors that encourage discarding, i.e. institutional, biological, technological and economical, are combined, the main issues to address are (i) that certain stocks cause a choke species situation for some fleets; (ii) landings of small or damaged fish, which have low market values; and (iii) illegal high-grading as a consequence of the two former issues when vessel operators seek to maximise their profits. Consequently, it is important to improve catch selectivity through gear changes, changes to fishing patterns and effort reallocation and to apply management measures that decrease effects of choke situations, such as enabling quotas to be traded or reallocated. Finally, the use of price measures (deemed value) that consider the differences between market prices and the social value of the fish should be considered to reduce the relative benefits of high-grading (Pascoe 1997).

In the short term, when fleet structure has not adapted to the new situation, the introduction of the LO will generally result in decreasing profits for all selected fleets mainly because of choke situations constraining the catch of other species in TAC-regulated fisheries and because of lower catches of higher-value larger fish given the requirement to land undersize fish in MCRS-regulated fisheries. Obviously, this is of concern for vessel operators, who see the risk that their economic performance will deteriorate.

In the long term, economic repercussions will differ as the four factors mentioned above interact in different ways for each fishery and the type of management affects the options for businesses to adjust. In the Mediterranean, which is managed with MCRS and has a wide variety of species, the main anticipated issue is the cost of dealing with undersized fish which cannot be sold for human consumption and for which there is a lack of processing facilities to make it into fishmeal or other non-food products. This issue also applies to the northern fisheries, but here the choke issue also plays a role. Countries that have tradable quota systems, such as Denmark and the UK, can, to some degree, avoid or delay choke situations through quota trade. While trading is possible however, there are no mechanisms to ensure or require trading of quota units to mitigate choke situations. The choke issue could be more severe for stocks managed by non-transferable quota shares such as in France and Spain. Although long-term profits are expected to increase, some vessel businesses may not have the financial resources to overcome the severe economic losses predicted during the first years of implementation. Some governments might find it appropriate to implement measures to ensure that businesses do not fail as a result of short-term impacts of a fully implemented Landing Obligation.

What defines the short and long term depends on the individual fisheries and how fast these are able to adjust to the new situation. It must be expected that the fleet structure will have adapted in ~10 years for most of the analysed fishing fleets, which is why it has been chosen to monitor the results in 2025 in the present context.

Mitigation strategies such as selectivity changes, *de minimis* exemptions and quota adjustments equal to previous discarded quantities could enable fishing businesses to increase profits with the implementation of the LO. But for the fisheries analysed in this chapter, the profits are generally lower than or equal to profit with no LO. For the North East Atlantic fisheries, regulated with TACs and quotas, a useful policy could be to further develop a system to mitigate the problem of choke stocks. Such a policy is already in place in the EU (cf. Frost 2010) through the annual setting of TACs, when single-species assessments show recommended total removals that are adjusted to take account of multispecies interactions and fleets' technological characteristics. Reducing differences between stock TACs and fleets' catch compositions could mitigate the choke problem and allow individuals, producer organisations or fleet segments to land and sell fish and decrease the inherent incentive to discard. However, this approach would also to some extent negate the purpose of the Landing Obligation, which is to encourage more selective fishing by creating incentives to avoid catching species with lower quotas. To create incentives to avoid catching fish below MCRS, price measures could be used to correct the difference between the sale price and the estimated social value of the fish. The difference must be sufficient to cover handling costs of landing the fish, and thus create an incentive to do so, but not high enough to incentivise targeting the fish beyond the quota, and vice versa to reduce prices for fish species with unused quotas.

Generally, the modelled economic outcomes for the seven selected fisheries under the LO suggest that fishing businesses may have incentives not to comply with the LO. Monitoring and enforcement are generally considered to be currently insufficient to motivate compliance. Therefore, high-grading and continuing to discard will still be an issue that must be addressed. The success of the LO is likely to require either larger investment in monitoring and enforcement or implementation of policies that create incentives for compliance or at least weaken incentives for non-compliance.

Acknowledgements This work received funding from the Horizon 2020 Programme under grant agreement DiscardLess number 633680 and from the LIFE+Environmental Program of the European Union under grant agreement iSEAS project, Ref. LIFE13 ENV/ES/000131. This support is gratefully acknowledged.

References

Abbott, J.K., & Wilen, J.E. (2009). Regulation of fisheries bycatch with common-pool output quotas. *Journal of Environmental Economics and Management 57*, 195–204.

Anderson, L.G. (1994). An economic analysis of high grading in ITQ fisheries regulation programs. *Marine Resource Economics 9*(3), 209−226.

Arnason, R. (1994). On catch discarding in fisheries. *Marine Resource Economics*, *9(3)*, 189−207.

Batsleer, J., Hamon, K.G., van Overzee, H.M.J, Rijnsdorp, A.D., Poos J.J. (2015). High-grading and over-quota discarding in mixed fisheries. *Reviews in Fish Biology and Fisheries*, *25*, 715–736.

Boyce, J.R. (1996). An economic analysis of the fisheries bycatch problem. *Journal of Environmental Economics and Management*, *31*, 314−336.

Christensen, S. (1996). Potential Bio-economic impact of reduced mortality of cod end escapees in the shrimp fishery in the Davis Strait. In A.V. Soldal (Ed.), *Bidødelighed i nordiske trawlfiskerier. Volum 2: Konsekvensudredninger*. Nord 1996:17. Nordic Council of Ministers, Copenhagen.

Condie, H.M., Catchpole, T.L., Grant, A. (2014) The short-term impacts of implementing catch quotas and a discard ban on English North Sea otter trawlers. *ICES Journal of Marine Science 71*, 1266–1276. doi: https://doi.org/10.1093/icesjms/fst187

Clucas, I. (1997). A study of the options for utilization of bycatch and discards from Marine capture fisheries. FAO Fisheries Circular No. 928 FIIU/C928. FAO, Rome.

DCF. (2016). On the Greek National Fisheries Data Collection Programme for 2015. Annual report, Directorate General for Fisheries, Ministry of Reconstruction of Production, Environment and Energy, Athens, Greece (p. 456).

FAO. (1996a). A global assessment of fisheries bycatch and discards and the technical consultation on reduction of wastage in fisheries (Tokyo, Japan, 28 October – 1 November 1996). Fisheries technical paper 339, Rome.

FAO. (1996b). Report of the technical consultation on reduction of wastage in fisheries. Tokyo, Japan, 28 October – 1 November 1996. FAO Fisheries report no. 547, Rome.

Fitzpatrick M., Frangoudes K., Fauconnet L., Quetglas A. (this volume). Fishing industry's perspectives on the EU Landing Obligation. In S.S. Uhlmann, C. Ulrich, S.J. Kennelly (Eds.), *The European Landing Obligation – Reducing discards in complex, multi-species and multi-jurisdictional fisheries*. Cham: Springer.

Flaaten, O., Larsen, N.-J. (1991). Sorting panels or normal trawl in cod fishery. An economic analysis. Working paper. University of Tromsø. (In Norwegian).

Frost, H. (1996). Economic impact of changes in by-mortality. In A.V. Soldal (Ed), *Bidødelighed i nordiske trawlfiskerier. Volum 2: Konsekvensudredninger*. Nord 1996:17. Nordic Council of Ministers, Copenhagen.

Frost, H., Boom, J.T., Buisman, E., Innes, J., Metz, S., Rodgers, P., Taal, K. (2007). Economic impact assessment of changes in fishing gear. NECESSITY. FOI report no. 194. Institute of Food and Resource Economics, Copenhagen.

Frost, H. (2010). European Union Fisheries Management. In R. Quentin Grafton, R. Hilborn, D. Squires, M. Tait, M.J. Williams (Eds.), *Handbook of marine fisheries conservation and management* (Ch. 35). Oxford University Press.

Frost, H., Andersen, P., Hoff, A. (2013). Management of complex fisheries: Lessons learned from a simulation model. *Canadian Journal of Agricultural Economics*, *6*, 283–307.

Garcia, D., Sánchez, S., Prellezo, R., Urtizberea, A., Andrés, M. (2017). FLBEIA: A simulation model to conduct Bio-Economic evaluation of fisheries management strategies. *SoftwareX*, *6*, 141–147.

García-Negro, M.doC., Rodríguez-Rodríguez, G., Ballesteros, H.M., Sálamo Otero, P. (2016). Táboas Input-Output da Pesca-Conservas Galega 2011. Consellería do Medio Rural e do Mar. Xunta de Galicia, Santiago de Compostela.

Hardin, G. (1968). The tragedy of the commons. *Science*, *162*, 1243–1248.

Jensen, F., & Vestergaard, N. (2002). Moral hazard problems in fisheries regulation: The case of illegal landings and discard. *Resource and Energy Economics, 24(4)*, 281–299.

Kelleher, K. (2005). Discards in the world's marine fisheries. An update. FAO fisheries technical paper no. 470. Rome, FAO (p. 131).

Kraak, S.B.M, & Hart, P.J.B. (this volume). Creating a breeding ground for compliance and honest reporting under the Landing Obligation: Insights from behavioural science. In S.S. Uhlmann, C. Ulrich, S.J. Kennelly (Eds.), *The European Landing Obligation – Reducing discards in complex, multi-species and multi-jurisdictional fisheries*. Cham: Springer.

Lehuta, S., Youen, V., Marchal, P. (2015). A spatial model of the mixed demersal fisheries in the Eastern Channel. In *Marine productivity: Perturbations and resilience of socio-ecosystems.* Proceedings of 15'th French-Japanese Oceanographic symposium, pp. 187–195.

Lleonart, J., Maynou, F., Recasens, L., Franquesa, R. (2003). A bioeconomic model for Mediterranean fisheries, the hake off Catalonia (western Mediterranean) as a case study. *Scientia Marina*, *67*, 337–351.

Mardle, S., Russel, J., Motova, A.. (2017). Seafish bioeconomic modelling – methodology report. Seafish Report No. SR702.

Nordic Council of Ministers. (2003). Report from a Workshop on discarding in Nordic fisheries. Editor: John Willy Valdemarsen, Fangstseksjonen, Havforskningsinstituttet, Bergen. Sophienberg Slot, København, 18–20. november 2002. TemaNord 2003:537. Nordic Council of Ministers, Copenhagen.

Nuevo, M., Morgado, C., Sala, A, (this volume). Monitoring the implementation of the Landing Obligation: Last Haul programme. In S.S. Uhlmann, C. Ulrich, S.J. Kennelly (Eds.), *The European Landing Obligation – Reducing discards in complex, multi-species and multi-jurisdictional fisheries*. Cham: Springer.

Palmer, M., Quetglas, A., Guijarro, B., Moranta, J., Ordines, F. Massutí, E. (2009). Performance of artificial neural networks and discriminant analysis in predicting fishing tactics from multispecific fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, *66*(2), 224–237.

Pascoe, S. (1997). Bycatch management and the economics of discarding. FAO Fisheries technical paper 370. FAO, Rome.

Pascoe, S., & Revill, A. (2004) Costs and benefits of bycatch reduction in European Brown Shrimp fisheries. *Environmental and Resource Economics 27*, 43–64.

Pelletier, D., Mahevas, S., Drouineau, H., Vermard, Y., Thebaud, O., Guyader, O., Poussind, B. (2009). Evaluation of the Bioeconomic sustainability of multi-species multi-fleet fisheries under a wide range of policy options using ISIS-Fish. *Ecological Modelling*, *220*, 1013–1033.

Prellezo, R., Carmona, I., Garcia, D. (2016). The bad, the good and the very good of the landing obligation implementation in the Bay of Biscay: A case study of Basque trawlers. *Fisheries Research*, *181*, 172–185.

Segerson, K. (2007). Reducing stochastic sea turtle bycatch: An efficiency analysis of alternative policies. Working paper, Department of Economics, University of Connecticut, Storrs.

Stergiou, K.I., Somarakis, S., Triantafyllou, G., Tsiaras, K.P., Giannoulaki, M., Petihakis, G., et al. (2016). Trends in productivity and biomass yields in the Mediterranean Sea large marine ecosystem during climate change. *Environmental Development, 17*(1), 57–74

Sutinen, J.G., & Andersen, P. (1985). The economics of fisheries law and enforcement. *Land Economics*, *61*(4)*,* 387−397.

Sutinen, J.G., & Kuperan, K. (1999). A socio-economic theory of regulatory compliance. *International Journal of Social Economics, 26*, 174−193.

Tsagarakis, K., Palialexis, A., Vassilopoulou, V. (2014). *ICES Journal of Marine Science 71*, 1219–1234.

Turner, M.A. (1996). Value-based ITQs. *Marine Resource Economics* 11, 59–69.

Turner, M.A. (1997). Quota-induced discarding in heterogeneous fisheries. *Journal of Environmental Economics and management*, *33*, 186−195.

Ulrich, C., Reeves, S.A., Vermard, Y., Holmes, S.J., Vanhee, W. (2011). Reconciling single-species TACs in the North Sea demersal fisheries using the Fcube mixed-fisheries advice framework. *ICES Journal of Marine Science*, *68*(7), 1535–1547.

van Hoof L., Kraan M., Visser N.M., et al. (this volume). Muddying the waters of the Landing Obligation: How multi-level governance structures can obscure policy implementation. In S.S. Uhlmann, C. Ulrich, S.J. Kennelly (Eds.), *The European Landing Obligation – Reducing discards in complex, multi-species and multi-jurisdictional fisheries*. Cham: Springer.

Vestergaard, N. (1996). Discard behavior, highgrading and regulation: The case of the Greenland shrimp fishery. *Marine Resource Economics*, *11*(4)*,* 247−266.

Ward, J.M. (1994). The bioeconomic implications of bycatch reduction devise as a stock conservation management measure. *Marine Resource Economics, 9*(3)*,* 227–240.

Ward, J.M., Benaka L.R., Moore C.M., Meyers S. (2012). Bycatch in Marine fisheries, *Marine Fisheries Review* 74, No. 2. United States Department of Commerce.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.