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Mapping and Modelling the Incentives for a Landing Obligation in Scottish Demersal Fisheries

Fisheries Innovation Scotland Research Project No. FIS006

Final Report

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EXECUTIVE SUMMARY

Under the revised Common Fisheries Policy, a landing obligation (discard ban) will be introduced for all EU demersal fisheries from 2016. By 2019, a landing obligation is due to be in place for all quota species, i.e., all species subject to Total Allowable Catches (TACs).

Against this background, the aim of this FIS-funded project was to build a *vessel-level* discarding model for Scottish demersal whitefish and prawn (*Nephrops*) trawlers in order to investigate discarding behaviour under different assumptions about the costs and benefits of complying with the landing obligation. Depending on average daily catch rates and prices, the model predicts landings, discards and profits for fishing trips of varying lengths under different assumptions about the enforcement of a discard ban and penalties for illegal landings.

The study is designed to complement, rather than duplicate, other sectoral-level modelling and impact assessments of the landing obligation by focusing specifically on the behaviour of *individual* fishing vessels under a landing obligation for different species.

The model is informed by economic theory and is underpinned by a survey of demersal and prawn trawler skippers based in North East Scotland. Skippers were interviewed about their discarding behaviour and their perceptions about the likely impact of the landing obligation on their fishery. The model predicts levels of discards of different species in response to a variety of factors including market prices, quota prices and the size of the vessel's hold, in addition to the expected penalty costs of discarding at sea or landing fish without quota.

The model can be used to illustrate the difficulty of imposing a discard ban in a multispecies fishery when there are quota supply constraints for "choke" species as well as limits on the amount of storage space available in a vessel's hold or fish room. It clearly demonstrates how discarding needs to be perceived as a costly activity if a landing obligation is to be effectively enforced in practice.

The model is intended to be useful for fisheries policy makers and managers seeking to understand the incentive structure of a landing obligation at the individual vessel level, as well as fishing industry representatives wanting to examine the possible implications of the landing obligation for various types of fishing vessel under different policy scenarios.

1. INTRODUCTION

1.1 Project aims and objectives

The reformed EU Common Fisheries Policy contains a commitment to phase in an obligation to land all catches of quota species by 2019, beginning with the pelagic fisheries in 2015. Clearly, the landing obligation will create significant technical challenges in the areas of gear selectivity and monitoring and enforcement, for example. It is likely, however, that fishing selectivity will always be less than perfect and that, in the mixed demersal fisheries in particular, fishermen may be required to retain on board and land fish for which they either have no quota or no market (or both). At the same time, it is unlikely that enforcement of a landing obligation can ever be perfect. The quandary of a “discard ban” is then how to discourage discarding while not encouraging the exploitation of fish stocks beyond sustainable limits, for example by permitting over-quota landings or creating valuable markets for fish that would otherwise be discarded. Getting the economic incentives right, so that fishermen continue to have a disincentive to fish in excess of quota limits or to target undersize fish, presents a major challenge for policy makers and managers.

With a focus on the Scottish demersal fisheries, the central aim of this project is to enhance our understanding of the incentive structure of a landing obligation at the individual vessel level in order to inform managers seeking to implement measures which will, as far as possible, align the incentives of fishermen with the new policy objectives. Through a combination of modelling and survey work the research explores the nature and scale of the incentives for catching, landing and discarding fish in a multispecies quota fishery and the likely impacts of regulatory change.

The specific objective of the project was to map the economic incentives for catching (or avoiding), retaining on board and landing (or discarding) quota species in a mixed demersal fishery in order to model the incentive structure of a landing obligation. This was done using desk research and survey work to inform the construction of a discard simulation model for a typical fishing trip by a Scottish demersal trawl vessel (TR1 or TR2).

1.2 Background: the EU landing obligation

A landing obligation for EU fisheries is introduced by Article 15 of EU Regulation 1380/2013 establishing a revised Common Fisheries Policy (CFP). Under the landing obligation, all catches subject to catch limits (i.e., TACs) must be "retained on board the fishing vessels, recorded, landed and counted against the quotas". Article 15 provides for a gradual phasing in of the landing obligation, commencing in 2015 for the pelagic fisheries, in accordance with discard plans put forward by the EU Member States. For the demersal fisheries in the North Sea, the landing obligation is to be introduced from 1 January 2016 "for the species which define the fisheries" and by 1 January 2019 at the latest for all other species.

The Joint Recommendation by the North Sea Member States (the *Scheveningen Group*) for a discard plan for the North Sea proposes the following phased introduction for the main demersal (TR1) and *Nephrops* (TR2) trawl fisheries in ICES areas IIa and IV (the fisheries in the North Sea referred to in Article 15 as those for "cod, haddock, whiting, saithe" and for "Norway lobster").

(1) For demersal trawlers using nets with mesh sizes equal to or greater than 100mm (TR1 vessels):

2016	All catches of saithe (if deemed a saithe targeting vessel*), plaice and haddock to be landed. Any bycatches of Northern prawn to be landed.
2017	All catches of whiting*** and cod*** to be landed. Bycatches of sole and, in IIa and IV, *Nephrops* to be landed.
2018	Any bycatches of saithe to be landed.
2019	All catches of all quota species to be landed.

(2) For *Nephrops* trawlers using nets with mesh sizes of 80-99mm (TR2 vessels):

2016	In all areas, all catches of *Nephrops* and sole to be landed. Any bycatches of Northern prawn to be landed.
2017	All catches of whiting*** and haddock to be landed.
2018	Any bycatches of plaice, saithe and cod*** to be landed.
2019	All catches of all quota species to be landed.

* Vessels with average landings of at least 50% saithe over a reference period

*** Assuming cessation of the existing Cod Recovery Plan

Note that under a landing obligation, "all catches" and "bycatches" includes all fish *below* the minimum size which can legally be sold for human consumption (what used to be the Minimum Landing Size and is now the Minimum Conservation Reference Size or MCRS).

Article 15 of the CFP Regulation provides for various exemptions to the landing obligation, including species for which there is evidence of high survival rates after discarding, and so-called *de minimis* exemptions for species where there is evidence that increases in gear selectivity are particularly difficult to achieve or, in certain cases, where handling unwanted catches would result in "disproportionate costs". The Joint Recommendation for the North Sea includes proposals for a number of such exemptions, including a *de minimis* exemption for *Nephrops* below the MCRS caught by TR2 vessels, "up to a maximum of 6% of the total annual catches" of *Nephrops* caught by this gear in the North Sea (specifically areas IIIa, IV and EU waters of IIa). This requested exemption is made to "avoid disproportionate costs of handling unwanted catches for the gear concerned, due to the cost of disposing of *Nephrops* below MCRS". According to the Joint Recommendation, "the unwanted catches do not represent more than 5% of the total annual catch of that gear".

1.3 National management measures

Implementation of the landing obligation in the demersal fisheries will require adaption of existing national management and enforcement, as has been the case for the pelagic landing obligation.

Enforcement of the landing obligation will be the responsibility of the MMO in England and Wales and Marine Scotland Compliance north of the border. It is still far from clear, however, how the landing obligation (effectively an at-sea discard ban) will be enforced in practice. At the moment, it appears unlikely that on board camera (CCTV) surveillance will be a requirement for all demersal and *Nephrops* trawlers (as is currently the case for vessels participating in the catch quota scheme for cod) although it may be appropriate for larger vessels (both demersal and pelagic). Otherwise, data on the species/size composition of landings might be used to provide circumstantial evidence of discarding but this would seem to raise significant legal problems if used as an enforcement tool *per se*.

Under a landing obligation for a given species, catches of fish of that species below the MCRS will be required to be recorded in logbooks and landings declarations, as well as sales notes, although they cannot be sold for human consumption. All discards allowed under exemptions (such as the *de minimis* exemptions) must also be registered in the vessel's logbook.

Currently, existing catch composition rules in particular fisheries (such as the *Nephrops* fishery) continue to apply under the landing obligation, although catches in excess of catch composition rules must be landed and will be counted against a vessel's quotas.

With regard to quota management, it is anticipated that annual TACs, and hence national quotas, will in general be increased *pro rata* for species subject to the landing obligation, to reflect estimates of quantities of fish previously discarded that will now be expected to be landed. At the time of writing, both the principal UK Fisheries Administrations (DEFRA and Marine Scotland) are consulting on how these quota "uplifts" or "transfers" should be allocated. The main options under consideration (which differ in detail between England and Scotland) include allocation to POs *pro rata* based on vessels' existing FQAs, allocation based on current discard rates, and/or improvements in gear selectivity, and (in the case of DEFRA) diversion of additional quota to the inshore (under 10m) sector. The POs themselves will also have to decide how to manage any additional quota internally.

At the national level, UK positions on adaption of existing arrangements for quota banking/borrowing and interspecies flexibility (provided for under the CFP Regulation) are currently being developed in consultation with the industry.

2. ECONOMIC THEORY

3.1 Introduction

The EU landing obligation is essentially a discard ban and modelling the impact of the landing obligation on vessel behaviour is grounded in an economic analysis of discarding in fisheries, particularly multispecies fisheries subject to quota regulation. In this section we review the economics of discarding and illustrate some key points using a simple theoretical model.

3.2 A review of the economics of discarding

Economic theory predicts that a rational (profit-maximising) fisherman will discard any element of the catch that is not profitable to retain and land (Pascoe 1997). Another way of expressing this is to say that if the costs of retaining on board and landing any part of the catch are not exceeded by the benefits then that part of the catch should be discarded prior to landing. Strictly speaking, we should be talking here about *expected* costs and *expected* benefits since either or both are likely to be uncertain to a greater or lesser extent. This is particularly the case for costs associated with enforcement, where the likelihood of detection, apprehension and sanction may be significantly less than one. Hatcher (2014) discusses the economics of discarding in the context of regulatory enforcement. There may also be uncertainty about revenues, however, for example where fish is not already contracted for sale but is landed to auction (as is generally the case with demersal finfish species).

This very general characterisation of discarding would clearly cover a wide range of discarded material for which there is no market, including (in the case of bottom trawls) stones, weed and other debris, echinoderms and other benthic invertebrates, as well as a variety of unpalatable finfish species. In some fisheries it may also encompass the much less trivial discarding of bycatches of (usually) unmarketable species which have significant conservation value, including “charismatic” species such as seabirds and cetaceans (see, e.g., Abbott and Wilen 2009, Holland 2010). In the present context however, we are principally concerned with the discarding of commercial fish species which cannot be landed either for regulatory reasons or because there is a physical limit on the quantity of fish that a vessel can retain on board (see Anderson 1994, Arnason 1994, Pascoe 1997, Hatcher 2005, 2014). Ignoring any handling costs associated with bringing fish on board and then discarding it, the economic waste from discarding arises because (in general) discarded fish have low survival rates and there is a resultant loss to consumers both in the short term and in the longer term (to the extent that target fishing mortality is exceeded and stock abundance is compromised as a result). Uncertainty about discards and survival rates also creates considerable problems for fishery scientists and managers in the estimation and regulation of fishing mortality.

The problem of discarding in fisheries is greatly exacerbated by two particular characteristics of capture fisheries. The first is the nature of the harvest technology itself, which is inherently stochastic (see Herrera 2005) and, in the case of multispecies fisheries, generally exhibits a high degree of "jointness" in production (see Turner 1997, Singh and Weninger 2009). In simple terms, this means that it is hard for vessels to predict their catches of individual species from a single haul, trip, or even over the course of the year, and it is also hard for vessels in multispecies fisheries to catch one species without also catching other species. This creates difficulties in complying with regulatory limits on catches of particular species and in avoiding catches in excess of what can be stored in the vessel's hold or fish room. A good example of this problem is that of so-called "choke" species, where one or more quotas is in relatively short supply compared to the quotas for other species caught in the same fishery (e.g., Holland 2010, Hatcher 2014). Choke species cause early fishery closures or, perhaps more frequently, substantial discards as vessels continue to fish for other species.

The other factor that contributes to the discarding problem in fisheries is the difficulty (cost) of enforcing controls on individual vessels' catches at sea and hence the practical reliance on landings controls instead. This gives vessels the option of discarding fish at sea in order to comply with regulations at the landing site (Hatcher 2014). Indeed, prior to the implementation of the landing obligation, EU and national rules *require* vessels to discard catches which cannot legally be landed. If the EU landing obligation can be seen as a move from landings controls to catch controls, however, it is unclear how monitoring and enforcement will similarly be shifted from the landing site to the vessel.

The practice of "highgrading", referring to the substitution of lower value fish with fish of higher value in order to remain within quota or physical capacity limits (Copes 1986, Anderson 1994, Vestergaard 1996) is a type of discarding which frequently causes concern for fishery managers, although despite anecdotal evidence the extent to which highgrading is a significant problem in practice is not always well documented. The problem of highgrading is often associated in particular with ITQs as a management instrument, although economic theory would suggest that it is likely to be more of an issue for *non*-transferable quotas and physical capacity constraints (see Hatcher 2005). Even then, the perceived incentive to "save" quota for a later period (for example when fish prices are higher) needs to be set against the cost of actually catching more fish.

Economic analysis generally predicts that tradeable (transferable) quotas are likely to result in fewer, rather than more, discards, provided that quota markets are relatively frictionless and transparent (e.g., Sanchirico *et al*. 2006, Pascoe *et al*. 2010, Singh and Weninger 2015). Tradeable quotas, however, can only solve inefficient allocation of quota between vessels; they cannot solve fundamental imbalances between the total supply of, and demand for, individual species quotas in a multispecies fishery. The problem of choke species requires either an adjustment of total quota supplies (i.e., national quotas, in the EU context) or a shift in aggregate quota demands (through gear selectivity, for example) or both (see Hatcher 2014).

3.3 A simple economic model

Consider a hypothetical fishing vessel catching just two species of fish in a mixed demersal fishery. Denoting fishing effort by e (which we could measure in days, for example) and the unit cost of fishing effort by ϕ, we can write a *profit function* for a typical fishing trip as equal to

$$p_1[c_1e - d_1] + p_2[c_2e - d_2] - [r_1q_1 + r_2q_2] - \phi e - \gamma\big[[c_1e - d_1 - q_1] + [c_2e - d_2 - q_2]\big] \\ - \omega[d_1 + d_2] + \lambda\Big[L - \big[[c_1e - d_1] + [c_2e - d_2]\big]\Big] + \mu[E - e].$$

Here, p_1 is the ex-vessel price for landings of species 1 and c_1 is the catch per day of species 1, while d_1 represents the quantity of species 1 that is discarded prior to landing. Similarly for species 2. For each species, quota (denoted by q) can be leased in at a rental price r. Here, we implicitly assume that the vessel has no quota to begin with: this simplifies the equation somewhat and makes no significant difference to the analysis which follows. If fish is landed without quota, the vessel expects to pay a unit cost penalty γ. If a cost penalty can be imposed on the vessel for discarding, this is represented by the unit cost ω. These *expected* costs for regulatory non-compliance can be thought of as representing the product of the probability of detection and the unit fine if detected.

The penultimate term in this profit equation specifies an upper limit *L* on the vessel's total landings in any given trip, due to the physical capacity of the hold or fish room, while the last term places an upper limit *E* on fishing effort for a given trip (14 days for example). The symbols λ and μ are *shadow prices* and represent the value to the vessel of a marginal (very small) change in *L* and *E* respectively. If these constraints are not binding, λ and μ will take values of zero.

Technically, a profit function written like this, with constraints on some of the variables (such as total landings and effort), is called a *Lagrangian* function. The necessary conditions for maximising trip profits can then be found using differential calculus. Specifically, we differentiate the profit equation with respect to the variables that the vessel can choose (fishing effort, discards and quota leasing) in order to find the *first order conditions* which tell us how the vessel should make its choices in order to maximise profits.

The condition for a profit maximising choice of fishing effort *e* (assuming that *e* is less than *E*) is

$$p_1c_1 + p_2c_2 - \phi - \gamma[c_1 + c_2] - \lambda[c_1 + c_2] = 0.$$

The condition for optimal discards of species 1 is

$$-p_1 + \gamma - \omega + \lambda = 0,$$

similarly for species 2, while the condition for optimal leasing of quota for species 1 is

$$-r_1 + \gamma = 0,$$

again, similarly for species 2.

Taking the last of these conditions first, if we write the condition for the optimal choice of q_1 as

$$r_1 = \gamma,$$

this tells us that the vessel should lease quota for landings of species 1 as long as the quota lease price r_1 is less than the expected penalty for landing fish without quota (similarly for species 2). We can then substitute r_1 for γ in the condition for choosing the level of discards of species 1 to give

$$p_1 - r_1 + \omega = \lambda.$$

If the hold constraint is not binding, then λ is equal to zero and we can write this discarding condition as

$$p_1 - r_1 + \omega = 0.$$

This says that the vessel should discard fish of species 1 if the ex-vessel price, minus the quota price, plus the expected cost of discarding (if any) is equal to (or less than) zero. Otherwise, the fish should be retained on board. A similar condition applies for species 2. If the hold constraint *is* binding, so that fish needs to be discarded because there is no more storage space on board, then the equation

$$p_1 - r_1 + \omega = \lambda,$$

together with its counterpart for species 2, both defines the shadow price of the hold limit (λ) and dictates that fish should be discarded as long as its net value is less than the shadow price. When the hold is *just* full and there is no more fish to discard, the expression holds as an equality for either species 1 or species 2, depending on which has a greater net value and is therefore preferentially retained on board.

Finally, we can substitute r_1 and r_2 for γ in the condition for the optimal level of fishing effort to give

$$[p_1 - r_1]c_1 + [p_2 - r_2]c_2 - \phi = \lambda[c_1 + c_2].$$

The left hand side of this condition is the marginal value (increment to profit) of an additional unit of fishing effort. Assuming that the first constraint to bind is the hold constraint *L*, the right hand side of the condition is the shadow price of the hold constraint multiplied by the marginal catch (the catch per unit of effort). Essentially, this condition just says that the vessel should keep fishing until the hold is full, although it may be worth fishing on a bit in order to replace some of the lower value fish already on board with fish of higher value. The vessel should stop fishing when the extra profit from additional effort is no greater than the value of the least valuable catch already on board (which would need to be discarded in order to make room for more fish).

This very simple model clearly ignores a great many real-world complexities, including stochastic and uncertain catches, prices and costs, and it assumes only two species and no variation in fish grades and prices. It nevertheless exemplifies all the key economic decisions that a vessel operator needs to make with respect to discarding and landing in response to prices and costs, including the *expected* costs imposed as a result of regulatory enforcement.

We should recognise, however, that skippers may choose to behave in ways that are not strictly in accordance with economically rational decision-making. In particular, “respect for the law” and adherence to personal and social norms, for example, may result in compliance with regulations despite or even in the absence of effective deterrent enforcement (see, for example, Hatcher and Gordon 2005). We can, however, allow for voluntary compliance with regulations, including a discard ban, in the model by assuming an arbitrarily large shadow price or cost for non-compliance.

3. THE FIELD SURVEY

3.1 Survey design and methodology

Data on industry perceptions about the impending demersal landing obligation were collected using semi-structured questionnaires administered in face-to-face interviews. A total of 22 interviews were conducted with the skippers of Scottish TR1 and TR2 vessels fishing in the North Sea. Fieldwork was undertaken in North East Scotland during June - August 2015.

The survey was conducted in close liaison with the main Producers' Organisations (POs): the Aberdeen Fish Producers' Organisation (AFPO), the North East of Scotland Fishermen's Organisation (NESFO), the Scottish Fishermen's Organisation (SFO) and the Shetland Fish Producers' Organisation (SFPO). The Scottish Whitefish Producers' Association (SWFPA) and the Scottish Fishermen's Federation (SFF) were also consulted about the project. The POs all took a keen interest in the project and saw it as a useful adjunct to the ongoing work of the Scottish Industry Discards Initiative (SIDI). POs and association representatives assisted by providing contact details of skippers. SIDI fishery liaison officers were also able to suggest suitable skippers to interview.

Most interviews were conducted in Fraserburgh and Peterhead, which are the two main landing ports for North Sea TR1 and TR2 vessels. Those skippers that habitually consign fish to markets were contacted at their home ports, including Banff, Buckie and Whitehills.

A total of 22 skippers were successfully interviewed, representing 13 TR1 vessels and 9 TR2 vessels. A higher number of interviews were initially planned, but for various reasons it proved to be very difficult to arrange suitable meeting times with the skippers. In all, a further 10 skippers had agreed to participate in the study, but a suitable time to meet could not be found. Interviews generally lasted around one hour, although some were much longer.

The questionnaire was divided into five sections. Section A considers the reasons for discarding quota species, their relative importance and why the problem is thought to arise. Section A also addresses the extent to which possible solutions are perceived to exist, such as quota uplifts or easier quota leasing. Section B of the questionnaire deals with selectivity and the possibilities for reducing unwanted catch. Section C considers compliance and enforcement in relation to both existing landings controls and a discard ban. Section D addresses some implications of landing all catches of quota species under a landing obligation, including capacity constraints and the expected costs and benefits of landing fish that would otherwise have been discarded. A final section invites respondents to elaborate or to discuss any other issues relating to discarding and compliance with a landing obligation. A copy of the questionnaire is attached at Annex 1.

3.2 Results

3.2.1 North Sea whitefish trawlers (TR1 vessels)

Most of the TR1 skippers interviewed owned at least a part share in their vessel and owned at least some quota (i.e., FQAs) although all relied on quota leasing to some extent. All vessels were over 20m in length, either single rig or twin rig trawlers and including some pair trawls. The hold capacity of these vessels ranged from around 30 tonnes to 65 tonnes (based on 40kg per box). The main target species were cod, haddock, saithe and whiting. Hake, monk and ling were among other valuable species caught by these vessels. Three vessels, including one of the biggest whitefish boats landing into Peterhead, owned no quota at all, relying solely on leasing (which accounted for over 50% of their costs). All vessels were members of POs. Depending on which PO they belonged to, some skippers were fishing against individual quota allocations (topped up through leasing) and some were fishing from pools (also topping up through leasing). Most skippers were between 40 and 60 years old and had over 15 years' experience as a skipper.

A. Current reasons for discarding

All respondents cited a lack of quota as a reason for discarding and over 70% considered this the main reason for discarding. Either quota was too expensive in relation to fish prices or difficulties in sourcing quota to lease meant that marketable fish were discarded in order to "save" quota for more valuable catches. Most characterised this as "highgrading". Over 90% of skippers thought that a landing obligation was simply not compatible with the quota system, or at least not until quotas were more reflective of what was perceived as current stock status.

Skippers were extremely worried about "choke" species such as hake and particularly concerned that there appeared to be no proposals to deal with this problem. There was seen to be too much emphasis by regulators on selectivity as a solution to the discarding problem.

In relation to undersized fish, most skippers stated that they are currently fishing with big mesh sizes (often bigger than 140mm), and that any larger would lose too much of their target catch. Over half the skippers thought that there was little incentive for further gains in selectivity, suggesting that in the absence of any subsidy the costs were disproportionate. It was also pointed out that selectivity measures would not avoid small fish being retained in nets that were already half full. On the whole, though, skippers thought that selectivity measures and knowledge of grounds could avoid very large catches of undersize fish.

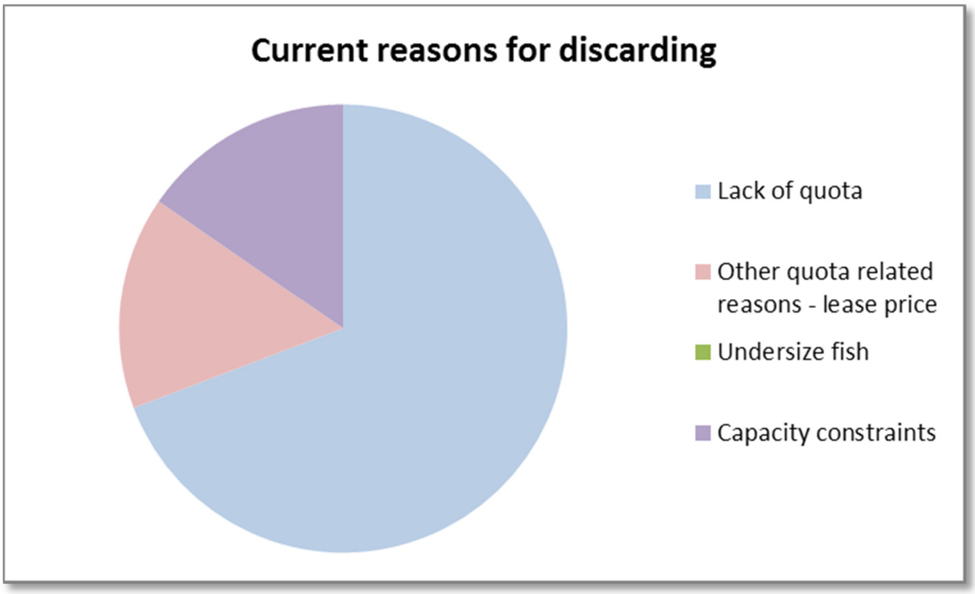

Fig. 3.1. Current reasons for discarding

Capacity (hold) constraints were seen as less of a problem currently given existing quota constraints although respondents thought they would be very significant under a landing obligation, due to the need to retain quantities of undersize fish.

Other reasons for discarding were given as low value fish or illegal catches (e.g., skates and rays) although on the whole the opinion was that the latter could be avoided.

Some skippers referred to the existing catch quota scheme (for cod). While this was seen as having reduced volumes of discarded fish, the additional quota awarded was not considered to have offset the costs of landing rather than discarding small fish.

Most respondents considered that there were potential solutions to high levels of discards, but that for most species zero discard levels would not be possible. This was largely attributed to the complex nature of the mixed fisheries in the North Sea and the low survivability of fish after being caught.

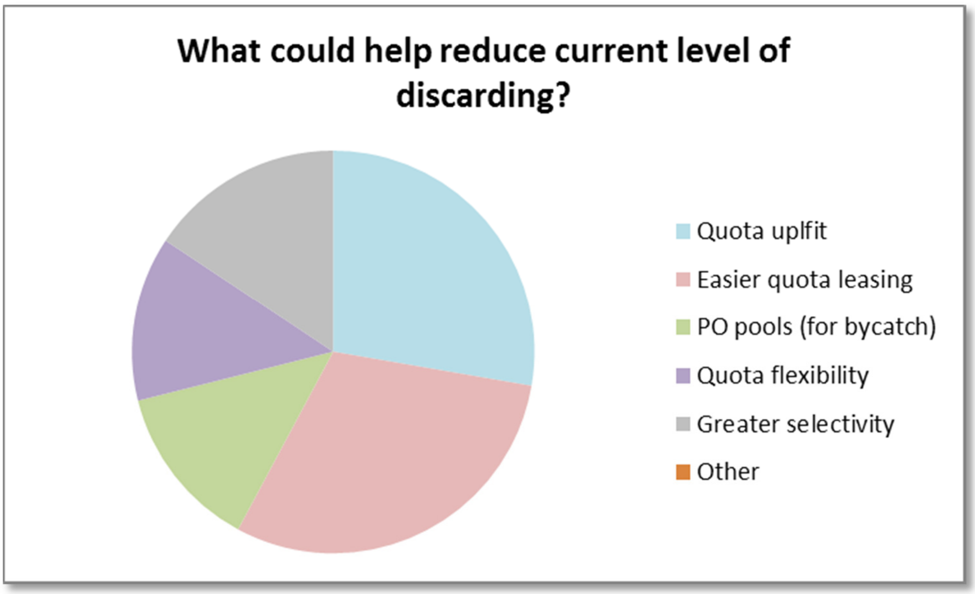

Fig. 3.2. Discard reduction measures

Quota uplift (or a "discard quota" as some skippers referred to it) was perceived as an overall increase in quota supply and many skippers thought this could put downward pressure on high lease prices, although it was recognised that the landing obligation itself would *increase* demand for quota. Some skippers were very concerned that they would be using significant amounts of their quota to land undersize fish for bait or meal, earning negative profits. There were also concerns about how the quota uplift would be allocated, whether *pro rata* with FQAs (would it go to those who don't need it?) or to sectors with high discard rates (rewarding discarding?). The lack of information about the likely size of the uplift was also mentioned, making it difficult to plan for the landing obligation.

Some skippers recognised that a quota uplift might not be the answer to the problem, simply increasing the overall scale of catches and landings across the board. In addition, even a significant uplift might not solve the problem of choke species.

Skippers were also concerned that the physical capacity of their boat would represent a real challenge to retaining discards. This would be the case for both smaller and larger vessels. This was linked to a general perception that the landing obligation would impose significant costs on the industry.

There was a reasonable consensus among the skippers who participated in the survey that the Scottish industry had made significant gains in terms of selective fishing. There was a general view that further increases in selectivity would require incentives in the form of aids or subsidies.

Overall, the two main solution areas identified were sufficient quota uplift, distributed in a fair and equitable manner (i.e., to those that most need it and only to active fishermen), and limited further gains in selectivity (with support, and provided there was no further loss of marketable fish).

Interspecies quota flexibility was identified by a few skippers as a possible partial solution to quota shortages. While this is already happening at PO level, the skippers thought it could be formalised more widely. There was a recognition, however, that there were potential dangers, for example skippers trading less valuable quota for more valuable quota, or simply increasing their quota for species for which market prices were currently high.

B. Options for selectivity and reducing unwanted catch

The TR1 skippers interviewed were keen to talk about gear selectivity and there was a general view that significant gains had already been made and that little more could be done without losing too many marketable fish. Again, many skippers said they were using bigger meshes than required by law. Most of the skippers were keen to point out that there was no such thing as a discard free net.

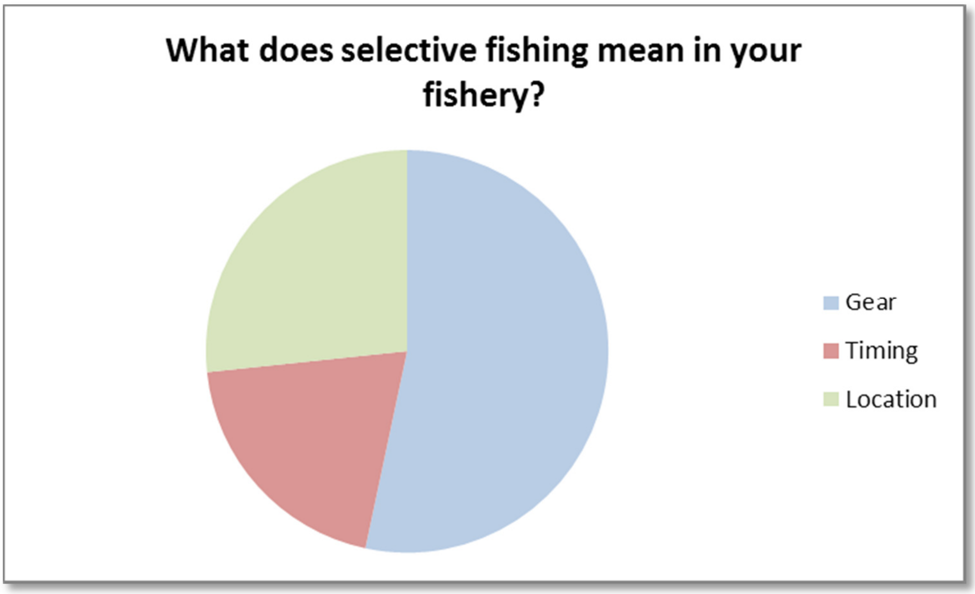

Fig. 3.3. Selective fishing options

Skippers referred to the different selectivity trials that they have been involved in over the years and the gains and success these had brought in terms of reducing levels of unwanted catch. However, there was a feeling that the landing obligation is the biggest thing to hit the industry since the introduction of quotas and they needed help to further reduce the level of unwanted catch. This might be in the form of subsidies to incentivise selectivity and help fishermen work with the landing obligation. Several skippers also pointed out that the industry has worked with (and around) other new regulations that they thought were unworkable and they will find a way of working with this one.

Selectivity was considered to be a function of geographical area and timing as well as gear design and use. Timing was considered to be an important factor. For example, haddock could be avoided by fishing in areas known for haddock abundance only during daylight hours (the fish are more active at night). Fishermen reported that they know areas to avoid, or times or seasons, in order to reduce catches of certain species. Again, skippers were keen to point out that the industry was already very selective in terms of where they fish, times of day and year, etc.

C. Costs of non-compliance

Only one skipper said that he thought that a landing obligation could be complied with. This was a skipper who considered that he had sufficient quota to be able to cope with landing all of his catch and had the capacity to store discards.

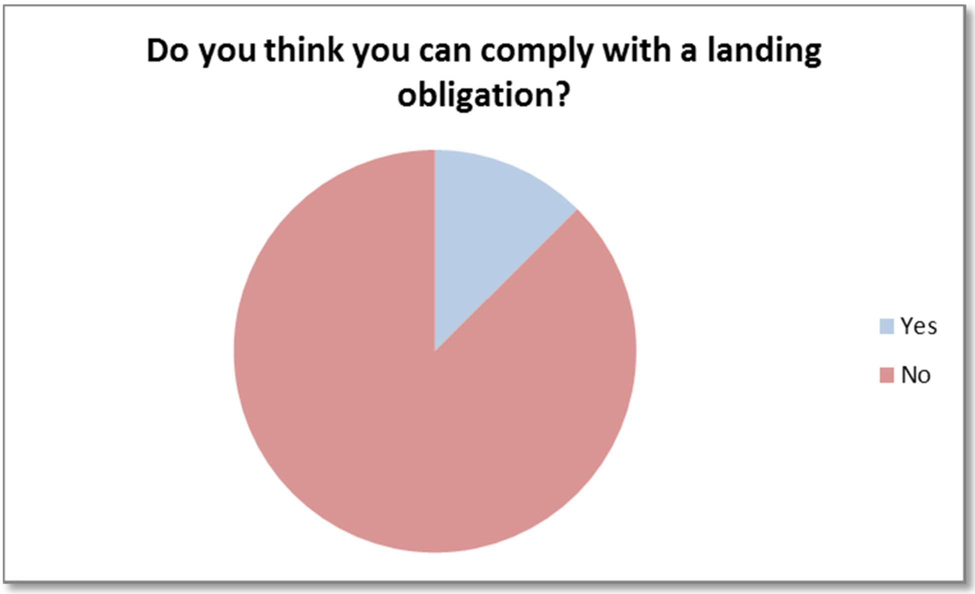

Fig. 3.4. Compliance with a landing obligation

Most skippers were not very keen to talk about the costs of non-compliance in the sense of landing illegally: black fish had been a big problem for the industry in the past, but illegal landings were considered to be almost non-existent today. All the skippers interviewed said that they would report anyone landing black fish. Skippers also pointed out that black landings would be very difficult now, particularly given the registration of buyers and sellers regulations and e-logbooks. All of the skippers thought the chance of being caught landing illegally would be greater than 1 in 5. This was not considered likely to change under a landing obligation.

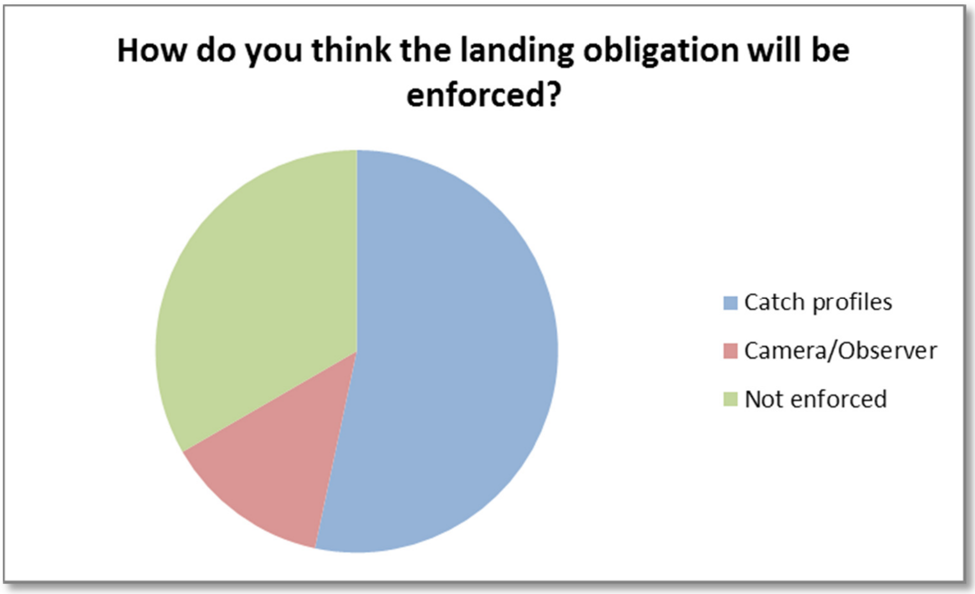

Fig. 3.5. Enforcement of a landing obligation

Skippers were very concerned about enforcement of the landing obligation. There was a general view that Marine Scotland did not have the resources to put cameras on board all boats (and actually observe the footage). Further, they anticipated strong opposition to cameras (as in the pelagic fleet) unless they were also installed in other EU fleets such as those of France and Spain, which was thought unlikely to happen.

There was also some concern regarding proposals to monitor the activity of "reference" boats fishing in similar areas in order to identify boats reporting fewer discards than expected. It was pointed out that there might be several plausible reasons why discrepancies could occur, for example the difference between fishing 200mm and 300mm square mesh panels, other differences in net design, fishing cleaner grounds, etc.

Most of the skippers didn't think that the landing obligation would lead to illegal landings, but rather, given the perceived lack of enforcement, discarding will simply have to continue (unless the quota uplifts were sufficient to allow for the landing of all discards). In general, it was not thought that vessels could comply with a landing obligation. Some skippers reported that they probably had enough quota and room on their boat to retain 10-15% of the fish that might previously have been discarded. However, for some species, e.g., hake, the lack of quota was a real concern. Other boats that rely heavily (or entirely) on leasing quota were seen as less well placed to be able to comply, particularly given current high lease prices and the uncertainty regarding the distribution of any quota uplift. Some skippers also pointed out that the real problems will be faced by the TR2 vessels, especially those with limited quota holdings.

In summary, there was a general feeling of impossibility and that if the discard ban was enforced the fleet would spend most of the time tied up in the harbour.

D. Landing all the catch

For the skippers interviewed vessel capacity ranged from 700-1500 boxes and quota holdings ranged from zero to almost 100% of their target catch. These were the two most important factors thought to affect the ability to retain and land all of the catch. The possibility of incorporating landing discards into their business model was generally seen as limited. Again, the main concern was the low value of "discard" landings and the impact on profitability.

All the skippers understood that undersize fish could only be sold for fishmeal or creel bait and the costs associated with transport, etc., would be the responsibility of the skipper. There was a perception amongst some respondents, however, that "over quota" fish above the legal size limit was also barred from human consumption and this was thought to be wrong in principle. There was clearly some confusion, at least in our sample, about the legality of landing fish without quota.

3.2.2 North Sea prawn trawlers (TR2 vessels)

Nine interviews were conducted with skippers of TR2 boats. Four had retained the option on their licence to change gear and operate as a TR1 vessel during 2015, although they interviewed in their capacity as TR2 skippers. All of the interviews were conducted in Fraserburgh at the quayside. Prawns (i.e., *Nephrops*) were the main target species for all the skippers interviewed. The four skippers with TR1 flexibility owned quota and the other five did not.

The skippers that were interviewed were keen to discuss the landing obligation and considered that having to land discards would affect them more than the TR1 vessels (as did the skippers of TR1 vessels). In 2016, prawn vessels will be required to retain and land all catches of prawns. Skippers did not foresee this to be much of a problem as they tend to do this now. However, by 2019, they will also have to land all catches of quota species.

A. Current reasons for discarding

The Scottish TR2 fleet is diverse in terms of size, catching ability and the flexibility to switch between gears and target whitefish stocks. Some of the smaller boats (< 20m) that do not own quota, and do not have a whitefish licence, earn little or no profit when prawn fishing is poor (for example, in 2013 and also in 2015). Boats that are larger (> 20m), which own quota and a TR1/TR2 licence are better placed to cope with years of poor prawn fishing. However, the primary target species of a TR2 vessel is prawns and while the fleet is diverse, the nature of the target species restricts their activity to specific areas and times of year. Given the lack of exclusive prawn grounds, the smaller mesh sizes required to catch prawns also result in bycatches of finfish, such as cod, haddock and whiting (depending on the fishing grounds). The amount of prawns caught varies from year to year, with some years such as 2013 recording very low catches. Skippers pointed out that their fishery is unpredictable, as is the rate of bycatch, especially when moving to new grounds (the first haul may produce only fish and no prawns).

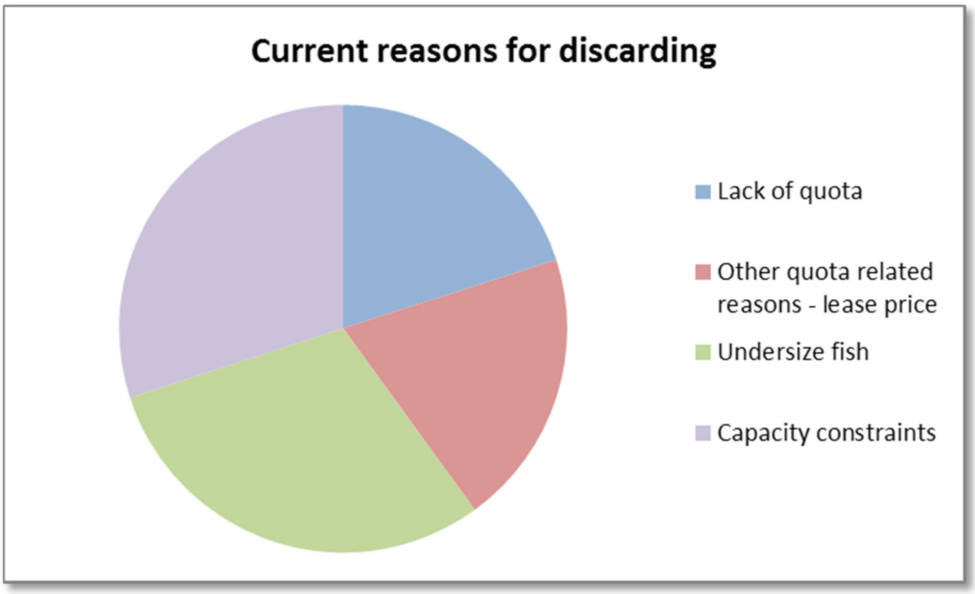

Fig 3.6. Reasons for discarding – TR2 vessels

Quota-related discarding here refers to bycatch of marketable size whitefish. Skippers differed in their views of their ability to land discards. While all skippers referred to lack of fish room space, some referred to having no quota and the prohibitive costs associated with leasing quota (especially for low value fish). For this sector, capacity constraints were a significant concern in the context of retaining and landing all bycatch. Many TR2 vessels are different in design to the larger TR1 vessels in that they tend to be shorter and deeper. Retaining fish that would have otherwise been discarded significantly reduces the space available to keep prawns. Smaller fish rooms mean less available space for the crew to sort and prepare the catch, as well as less room to store empty boxes and ice. For this reason, prawn vessels tend to make more frequent and shorter fishing trips. There were concerns about the extra costs associated with more frequent trips, as well as the cost implications of landing low value discards. Skippers were under the impression that fish not for human consumption would need to be prepared, iced and stored in the same way as fish destined for human consumption.

All the prawn skippers pointed out that "clean" prawn grounds exist only once fish have been cleared from the grounds. This means that the first haul often creates discards (of finfish), but subsequent hauls generate less discards.

Only around a third of the TR2 skippers cited undersize fish (i.e., prawns) as a specific reason for discarding. Currently, the skippers did not see discarding of prawns as an issue. The prawn quota is not considered to be restrictive and catches of undersize prawns are small. The challenge of the landing obligation for this sector will be the requirement to retain and land all of their bycatch by 2019. When asked about discarding under a landing obligation the skippers who owned quota for the key bycatch species (haddock and whiting) mostly considered capacity as their main limiting factor for retaining all bycatch. Those that did not own quota saw a lack of quota and high lease prices as a major concern (in addition to lack of capacity).

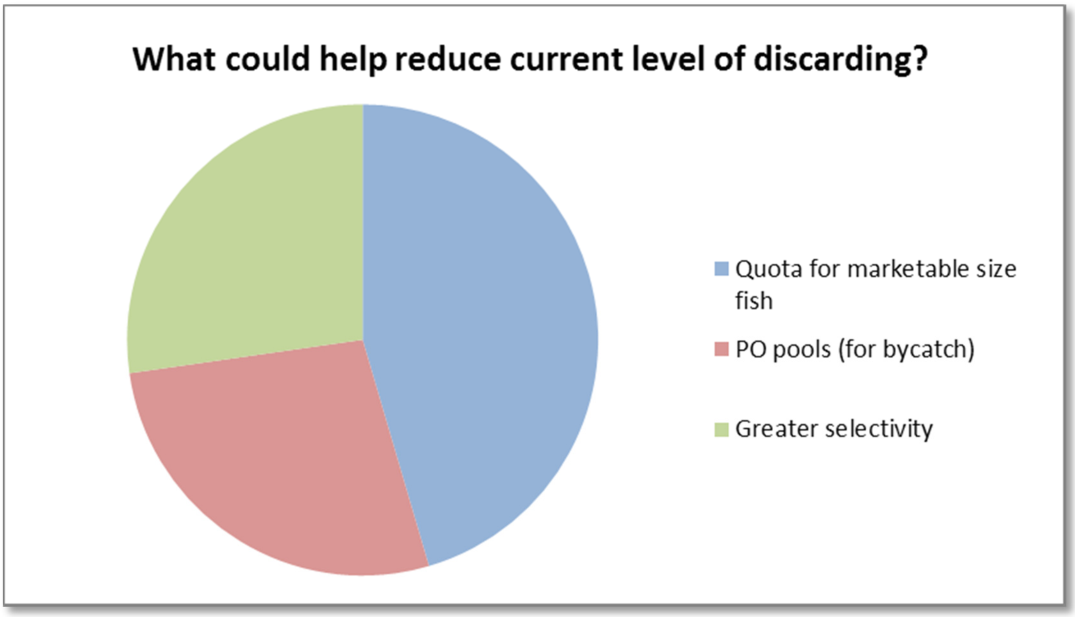

Fig. 3.7. Reducing discards – TR2 vessels

The small mesh sizes fished by the TR2 fleet do lead to discards of small (sometimes undersize) fish, but small mesh sizes are required for retaining marketable size prawns. Skippers discussed the various selectivity designs that have been trialled and their success. These skippers also felt that financial incentives or subsidies were required in order to further trial more selective gears. Selectivity for prawn boats is largely about gear type, it was pointed out, and there were few selectivity gains to be made from changing fishing areas or times.

The main issue in relation to quotas is that the prawn sector lacks quota for whitefish. While some boats retain licence flexibility, they have the quota to do so. Other vessels that did not invest in quota (perhaps investing in the boat instead) will face greater challenges under a discard ban. Again, most of the skippers were concerned about vessel capacity if they are required to retain all catches of whitefish.

B. Options for selectivity and reducing unwanted catch

Skippers referred to different gear designs, such as the Swedish grid, flip-flap panels, grids for selecting out fish and retaining prawns, and so on. As with the TR1 skippers, it was said that significant gains had been made over the last 10 years or so. Further improvements were seen as possible but requiring financial support, although the nature of the fishery meant that some bycatch of whitefish was inevitable. Those without quota pointed out that they would need to be perfectly selective in the absence of quota, which was impossible.

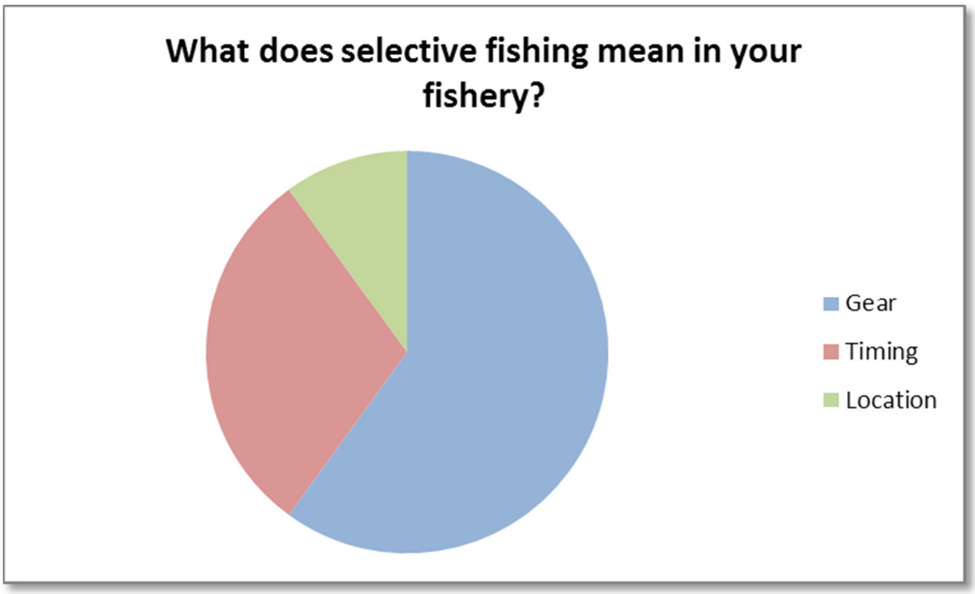

Fig. 3.8. Selective fishing – TR2 vessels

C. Costs of non-compliance

The views of the TR2 skippers on illegal landings were in general the same as those of the TR1 skippers. All of the skippers thought that the chance of being caught landing illegally would be greater than 1 in 5. Again, similarly to the TR1 skippers, they didn't perceive a change regarding illegal fishing once the landing obligation was in force.

There were also similar concerns about enforcement of the landing obligation by comparison with "reference" vessels. More of the TR2 skippers, however, considered that they might be able to comply with a landing obligation, specifically those who had invested in quota which could be used to land their whitefish bycatch. Those without quota did not think they could comply. Or if they had to lease in quota, they would end up making a loss.

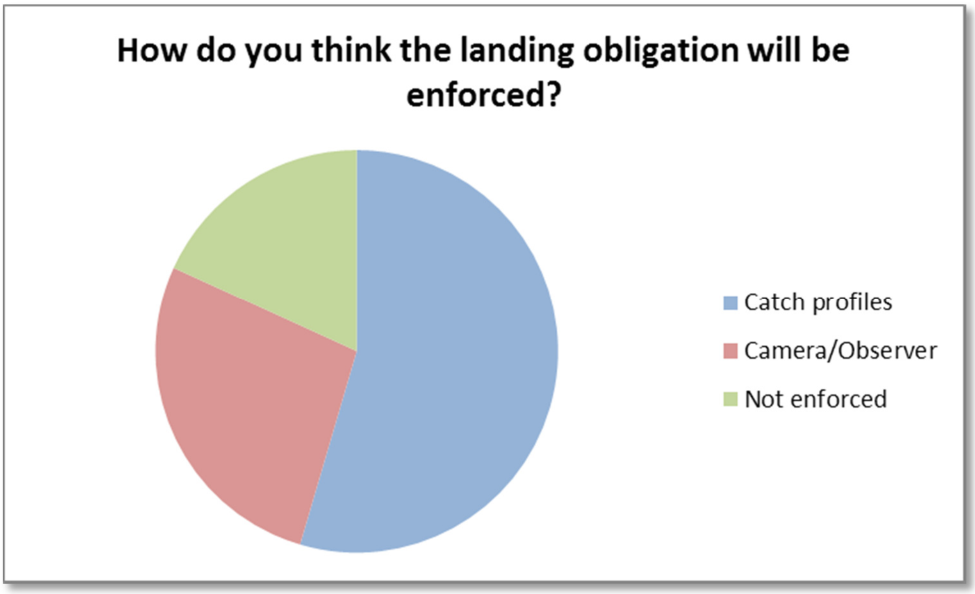

Fig. 3.9. Enforcement of the landing obligation – TR2 vessels

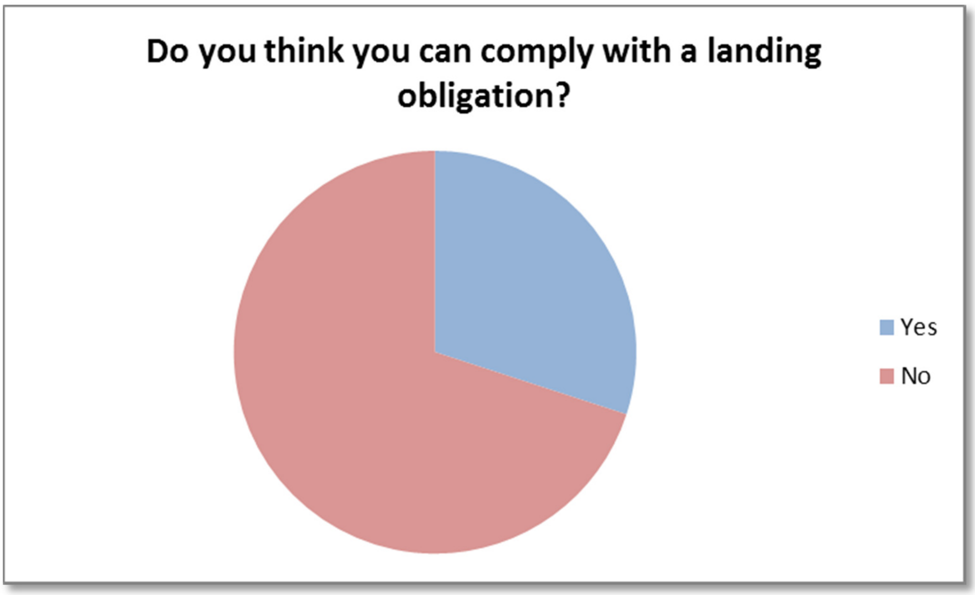

Fig. 3.10. Compliance with a landing obligation – TR2 vessels

D. Landing all the catch

The main concern for all the skippers interviewed was capacity. Larger boats have more fish room space (and some of the older prawn boats tended to have larger fish rooms). Concerns related to decreased trip lengths (as a result of a full fish room) and the impact on operational costs. This was the main concern for smaller boats (<20m). Small fish rooms and lack of access to quota (which means both not owning quota and the unaffordability of leasing quota) were the two main reasons stated for skippers feeling that they could not comply with a landing obligation. Skippers also pointed out that retaining their bycatch would have a greater impact on them than on the TR1 fleet. This is because their bycatch tends to contain more non-marketable fish (under the MLS) and skippers without quota would need to lease in quota to land fish of little or no value (or at potential net cost to them because of transport costs for discards destined for fishmeal). Two of the skippers interviewed, however, thought that they would be able to retain and land all their catch. These skippers had invested in quota for their main bycatch species.

4. THE LANDING OBLIGATION MODEL

4.1 Introduction

The FIS landing obligation model is designed to simulate the landing/discarding behaviour of a typical vessel for a particular vessel type and size category (e.g., North Sea TR1 or TR2). The model includes the most important species caught in terms of volume and/or value, but also includes other species which are of significance for the landing obligation, for example because they have been identified for introduction during the transition (phasing in) period, or because the UK has a relatively small quota for that species/stock. To keep the model as simple as possible, other species are aggregated into the category 'Others'.

This is an *economic* model. The model is parametrised using prices and costs as well as quantities since these are expected to be the main drivers of discarding behaviour. For a given set of parameters and assumptions, the model predicts discards, landings and trip profits for a fishing trip of between 4-12 days (TR1 vessels) or 1-7 days (TR2 vessels) in duration. Most importantly, the model assumes that the skipper of the vessel behaves *rationally* and seeks to maximise profits (i.e., maximise revenues and minimise costs) for each vessel trip. This is discussed in more detail in Section 4.3 below.

4.2 Model parameters and outputs

4.2.1 Catch rates

These are *average* total catch rates for the type of vessel in question, specified in kilogrammes per day. Total catch includes both legal size and undersize fish.

4.2.2 Percentages of large and small fish

In reality, for most species there are a number of size grades of fish offered for sale. In order to avoid making the model too cumbersome, however, the number of size grades is restricted to just two: small and large. The proportions of small and large fish are specified as percentages of the *total* catch of the species in question (i.e., including undersize fish).

4.2.3 Percentage of undersize fish

The proportion of fish caught below the Minimum Conservation Reference Size (MCRS) is expressed as a percentage of the *total* catch of the species in question.

4.2.4 Ex-vessel prices

The average ex-vessel prices received for landed fish of each size grade are expressed in pence per kilogramme. Ex-vessel prices for undersize fish (fish below the MCRS) are automatically set to zero unless there is a landing obligation in force for the species in question, in which case the ex-vessel price is the price entered in the model.

4.2.5 Daily fishing costs

Average daily fishing costs (£ per day) include fuel and other consumable items which can be attributed to the trip on a daily basis but do not include either crew wages or shares. Approximate average daily costs for different types and sizes of vessel can be obtained from Seafish statistics.

4.2.6 Hold (fish room) capacity

This is the total physical capacity of the vessel (in kilogrammes), i.e., the maximum quantity of fish that can be retained on board and stored in the vessel's hold or fish room. Clearly, any catch in excess of this must be discarded, whether or not a landing obligation is in force.

4.2.7 Quotas

The quotas set for each species represent the quantities of quota (in kilogrammes) that the vessel holds for the trip. Fish allocated to this quota does not require the leasing in of additional quota (or the payment of a penalty for landing fish without quota). The specification of quotas on a per trip basis is a significant problem for the model, however, as most vessels will either hold quota on an annual basis and/or be subject to quota limits on a monthly basis, depending on which PO the vessel belongs to. The alternative would be to specify the model on a monthly or annual basis but the hold/fish room constraint becomes meaningless in these contexts.

In order to retain the capacity constraint in the model, the current model is specified on a per trip basis, with the acknowledgement that this is not ideal for modelling quota constraints. Different approaches are available, however, depending upon the particular situation of the type of vessel under consideration:

(a) The trip quotas can all be set to zero. This would reflect the situation of a vessel leasing in all of its quota.

(b) The trip quotas can be set high enough that all catches are "covered" by the vessel's quotas and no leasing in of additional quota is required.

(c) In order to model a "typical" trip, a vessel's annual quota holdings (based on its FQAs) can be divided by the average number of trips per year and the trip quotas specified accordingly.

(d) Similarly, a vessel's monthly quota limits can be divided by the average number of trips likely to be undertaken each month.

4.2.8 Quota prices

Quota (lease) prices are specified in pence per kilogramme. The quota prices are applied to all catches/landings in excess of trip quotas in order for discarding and landing decisions to be made and for quota costs to be deducted in the calculation of trip profits. Thus quota prices are ignored in decision making with respect to catches/landings remaining within trip quota limits (see Section 4.3).

If quota is not available to lease for a particular species (completely inelastic supply), this can be simulated by specifying an arbitrarily large quota price. This will force the vessel to either land fish without quota or to discard (depending on the magnitude of the penalty for landing fish without quota). If the expected penalties for discarding and landing without quota are high enough, however, the vessel can be forced to buy quota at any price, although trip profits will then be negative. In effect, this implies a complete cessation of fishing.

4.2.9 Landing obligation

A landing obligation can be imposed for some or all of the species included in the model. The effect of imposing a landing obligation is that

(a) catches of undersize fish are counted against the vessel's trip quota for the species in question;

(b) landings of undersize fish are either included in the vessel's quota for the species in question or require additional quota to be leased in;

(c) landings of undersize fish are sold for the ex-vessel price specified in the model;

(d) instead of being automatically discarded, undersize fish are only discarded if it is profitable to do so, taking account of the expected discarding cost specified (see below).

In the case of prawn trawlers (TR2 vessels) a *de minimis* exemption can be selected for *Nephrops* (this has no effect if a landing obligation is not also selected for *Nephrops*). This allows discarding of prawns below the MCRS at zero cost. No upper limit on such discards is imposed as the *de minimis* ceiling (to be confirmed) is not expected to operate at the individual vessel level.

4.2.10 Costs (penalties) for discarding

The discarding cost specified in the model is the expected unit cost (per kilogramme of fish discarded) incurred for discarding fish *if* a landing obligation is in force for the species in question. This cost is taken into account in decision making (retaining or discarding) but there is an option to include or discount the cost in the calculation of trip profit (see below). The discarding cost can therefore be interpreted in two ways:

(a) An expected cost actually incurred, on average, for each unit of fish discarded. This might be calculated as the expected (subjective) probability of being caught discarding fish multiplied by the expected unit cost that the vessel will have to pay in fines if caught and sanctioned. For example, if the expected probability of being caught and fined for discarding is 10% and the expected fine if caught is equivalent to £10 per kilogramme of fish discarded then the expected unit cost of discarding is £1 per kilogramme. This expected cost is then deducted in the calculation of trip profit to arrive at an average (expected) trip profit.

(b) A shadow cost or "psychic" cost for discarding, i.e., a cost which the vessel *responds to* as if it would be imposed even if it is not actually paid. A high shadow cost for discarding could be specified in order to simulate the behaviour of a vessel skipper who will comply voluntarily with the discard ban (landing obligation) even in the absence of effective deterrent enforcement. This cost is then discounted in the calculation of trip profit. Some care is then needed in interpreting the model results, however, as even with costly discarding there may still be an incentive to highgrade the fish already on board and this can suggest that longer trips are profitable even when they involve very high levels of discarding. In short, it may be necessary to deduct the cost in order to identify the "compliant" optimal trip length.

4.2.11 Costs (penalties) for landing fish without quota

Similarly, the expected (unit) cost of landing fish without quota can be thought of as the expected (subjective) probability of being caught landing fish without quota multiplied by the expected unit cost that the vessel will have to pay in fines if caught and sanctioned. This is a somewhat problematic concept as there is no such offence in law as "landing fish without quota" and a vessel landing fish in excess of current quota limits has little meaning on a per trip basis. A vessel landing fish which it has no intention of allocating against its own quota or covering with additional quota leased in from elsewhere would in practice need to hide the landings from both its PO and the authorities by not declaring those landings correctly in logbooks and landings declarations, which is a statutory offence.

Again, this cost can be modelled as an actual expected cost, to be deducted in the calculation of trip profit, or as a shadow cost, to be discounted in the calculation of profit. Here too, though, care should be exercised in interpreting the results, particularly when assessing the optimal (profit maximising) trip length.

Note that, for practical modelling reasons, the expected cost of landing without quota is not considered for landings within a vessel's own trip quota limits, but is considered when the vessel requires the leasing in of additional quota.

4.2.12 Landings

Landings by species and size are predicted by the model, as catches less the quantities discarded.

4.2.13 Trip profit

Trip profit (for trips of a given duration) is calculated as revenues from first sales of fish less fishing costs and quota lease costs, minus the expected costs of discarding (if counted) and the expected costs of landing fish without quota (if counted). It is assumed that fixed costs (boat costs), quasi-fixed costs (electronics and other equipment leasing, crew wages, etc.) and skipper/crew shares are paid from trip profits.

4.3 Model structure and assumptions

4.3.1 Model assumptions

The model assumes that the short run decision-maker (generally the vessel's skipper) behaves *economically rationally*, i.e., seeks to maximise revenues, and minimise costs, in order that profits for a trip of a given duration are maximised. Thus the model predicts that fish will be retained and landed only where it is profitable to do so, i.e., where the expected marginal profit is strictly positive. Similarly, fish for which the vessel does not hold quota will only be covered by the leasing in of additional quota where it is profitable to do so: if it is more profitable to land fish without quota then that is what the model will predict.

Voluntary compliance with a discard ban or with quota limits, i.e., compliance irrespective of deterrent enforcement, requires the specification of unit costs for discarding and for landing fish without quota which are high enough to ensure compliance, although these shadow costs can then be discounted in the calculation of trip profit (once the "compliant" optimal trip length is identified).

Note that if the quota price for a given species is *exactly* equal to the expected cost of landing fish without quota, quota will be purchased and the fish will be landed legally.

4.3.2 The structure of the model

Catches of fish are determined solely by the specified daily catch rates, the specified percentages of large, small and undersize fish and the trip duration in days. The model then determines which fish are retained for landing and the vessel's resultant revenues and quota leasing costs, taking account of the relevant prices and costs and the imposition of a landings obligation for one or more species.

The main structural features of the model can be summarised as follows.

(a) If the *landing obligation* box is checked for a particular species, fish of that species below the MCRS are counted against quota, i.e., counted against the vessel's trip quota (if any) or requiring quota purchase, or incurring a penalty for landing without quota.

(b) If the vessel has a non-zero trip quota for a particular species, fish of the more valuable grade (whether large or small) are counted against the quota first, followed by fish of the less valuable grade, followed by fish below the MCRS (if a landing obligation is in force).

(c) Fish are immediately discarded if they are below the MCRS and there is no landing obligation in force for the species in question. *Nephrops* below the MCRS are also discarded automatically if there is a landing obligation in force and the *de minimis* exemption is selected.

(d) Fish are immediately discarded if, in the case of fish included in the vessel's trip quota, the following condition holds:

> *The ex-vessel price plus the unit discarding cost (if any) is less than or equal to zero.*

(e) Fish are immediately discarded if, in the case of fish in excess of the vessel's trip quota, the following condition holds:

> *The ex-vessel price, minus the quota price*, plus the unit discarding cost (if any) is less than or equal to zero.*

*If the expected unit cost for landing fish without quota is less than the quota price, this cost is substituted for the quota price.

(f) If the hold (fish room) constraint binds, the least valuable fish on board are discarded first, followed by the next least valuable fish, and so on until all the excess fish has been discarded. Here the value of "over-quota" fish is the ex-vessel price minus the quota price (or the unit penalty for landing without quota if smaller). The value of "under-quota" fish is simply the ex-vessel price. The discard cost (if any) is not taken into account unless the species in question is subject to a landing obligation.

(g) In all cases, the discard cost is automatically zero unless a landing obligation is in force for the species in question.

(h) If a landing obligation is in force, fish below the MCRS can be sold for the ex-vessel price indicated. Otherwise, the ex-vessel price for undersize fish is zero (although in the absence of a landing obligation these fish are automatically discarded in any case).

(i) Expected discard penalties (under a landing obligation) and over-quota penalties are included in decision making but are only imposed as actual costs (deductions) in the calculation of trip profits if the appropriate boxes are checked. As an exception to this general rule, the cost of discarding *Nephrops* below the MCRS is always zero if the *de minimis* exemption is selected.

4.4 Model operation and screenshots

The model is built in Microsoft Excel (2013) and includes VBA programming. In order to run the model, open the appropriate Excel file (FISMODEL_TR1_v*n*.xlsm or FISMODEL_TR2_v*n*.xlsm, where *n* is the version number) and click on “Enable Content” if prompted to do so.

The *Front* page (sheet) displays a bar chart of trip profits for a trip of 4-12 days (TR1) or 1-7 days (TR2) as well as click buttons to launch control panels for *Catch Rates* (catches per day and percentages of large fish and fish below the MCRS) and *Prices* (ex vessel prices for fish of different size grades – large L, small S and undersize US). Clicking on the *Start* button launches the main control panel where all other parameters are specified.

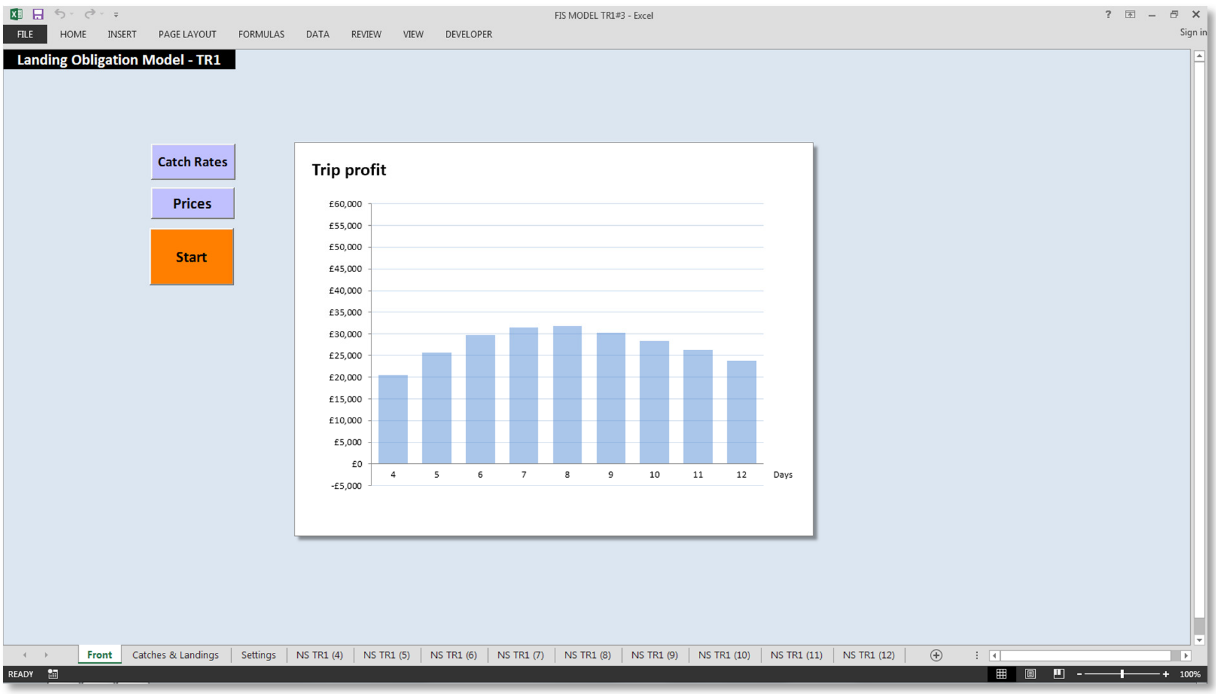

Fig. 4.1. Model front page

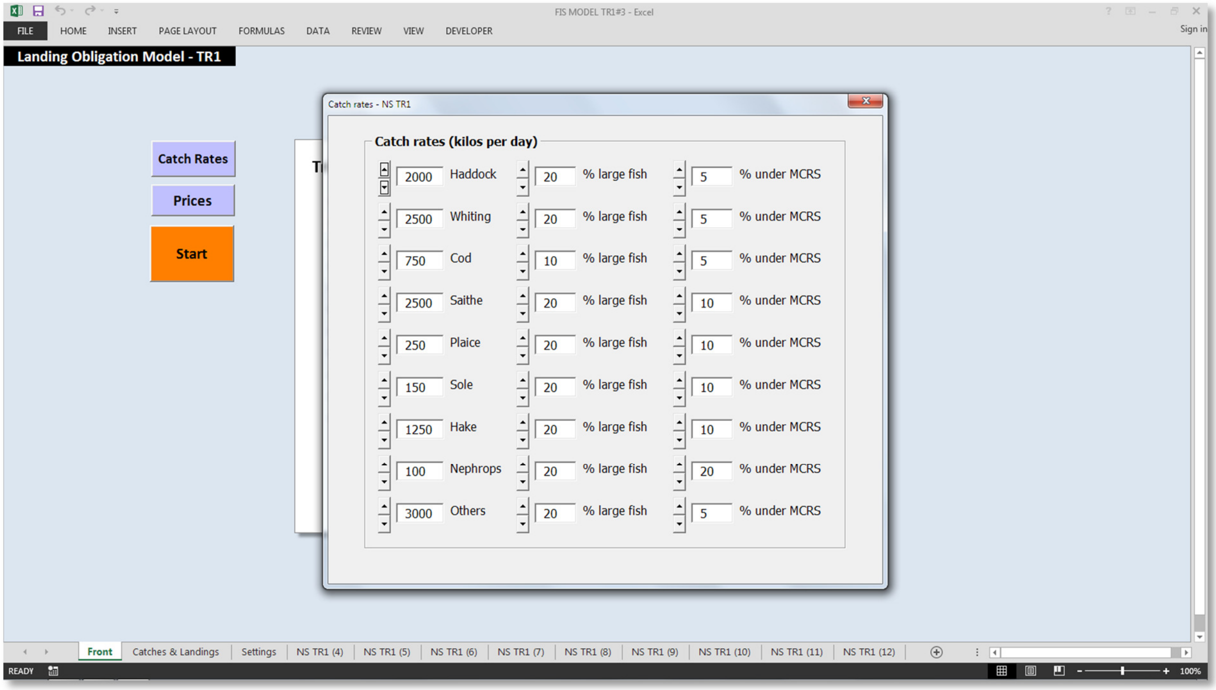

Fig. 4.2. *Catch Rates* control panel

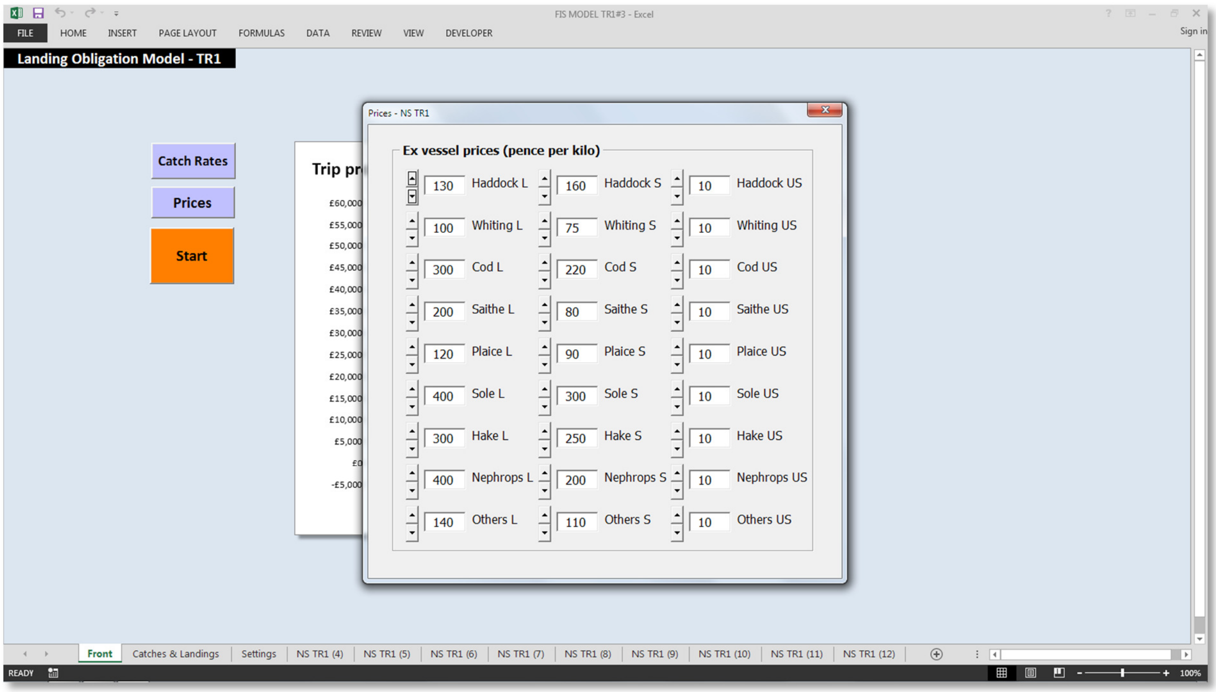

Fig. 4.3. *Prices* control panel

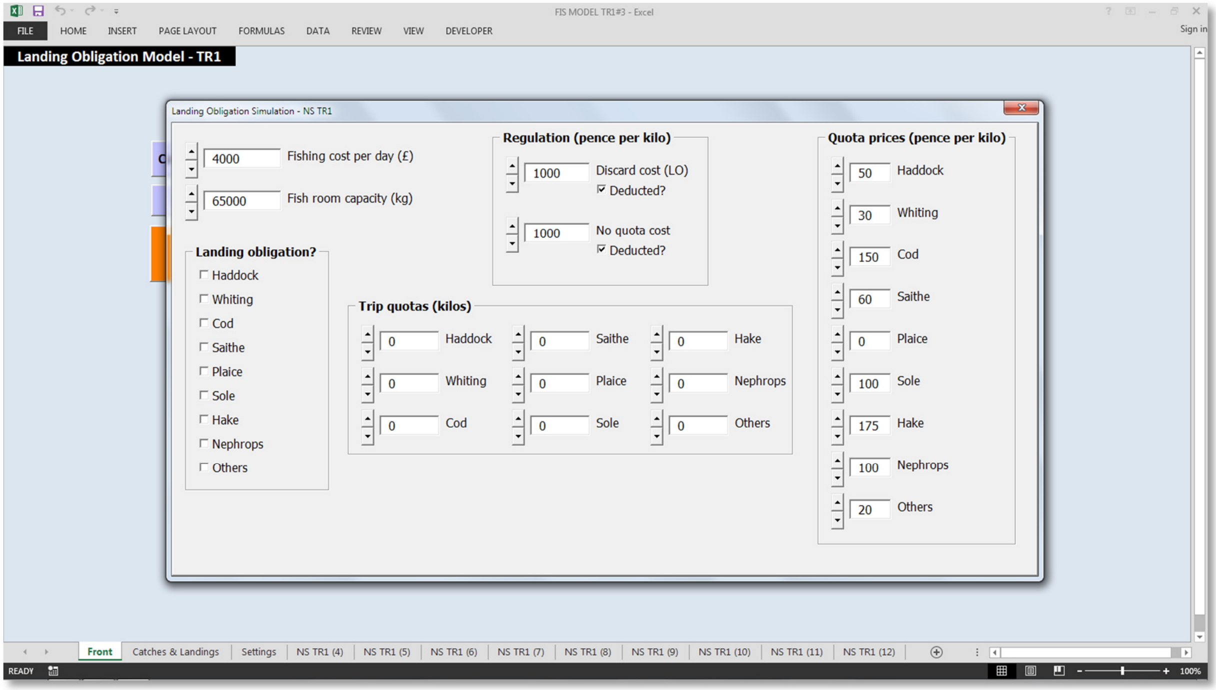

Fig. 4.4. Main control panel

The model results are updated immediately whenever any parameters are changed on any of the control panels. Note that large changes to some of the parameters can be cumbersome to make using the control panels (depending on the individual scroll settings). If required, large changes can be made directly on the *Settings* page, provided the cells highlighted in red are avoided. These changes will automatically update the settings shown on the relevant control panel (unless they exceed preset limits).

The *Catches & Landings* page displays bar charts of catches and landings (in kilogrammes) by species for trips of 4-12 days (TR1) or 1-7 days (TR2). Catches are shown in blue, landings in green. Darker shading at the tops of the bars indicates fish below the MCRS. Note: in the latest versions of the model this page also shows total discards (with discards below the MCRS shown by a darker area at the top of the bar).

Fig. 4.5. *Catches & Landings* page

The remaining pages, titled *NS TR1 (4)*, *NS TR1 (5)*, etc., contain the model calculations and should not be changed in any way (these pages will be protected in the final versions of the model).

4.5 A sample simulation

In order to illustrate the functioning of the model, we present a simulation of the impact of the landing obligation on an imaginary TR1 vessel.

Suppose we have a whitefish trawler with a fish room capacity of 40 tonnes (boxed and iced), costing an average of £2,000 per day to operate at sea. Assume that average daily catch rates and market prices are as shown in Figs. 4.6 and 4.7 respectively.

For simplicity, we assume that the vessel leases in *all* of its quota, and current quota prices are as shown in Fig. 4.8.

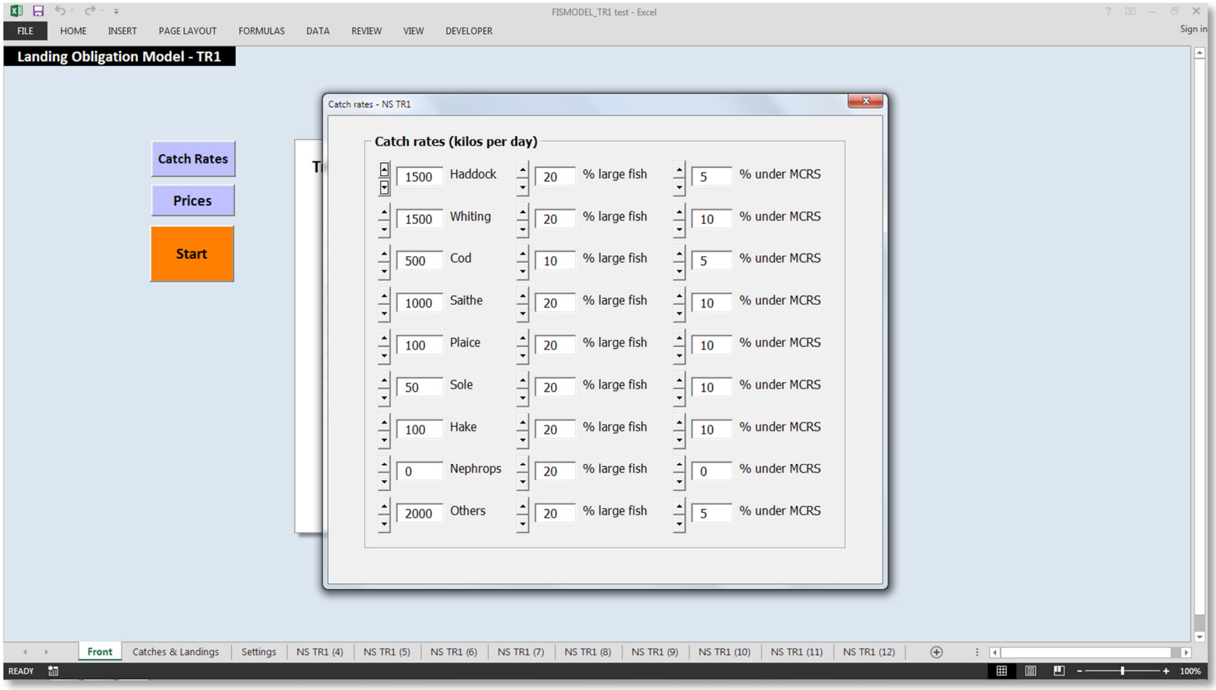

Fig. 4.6. Example: average catch rates

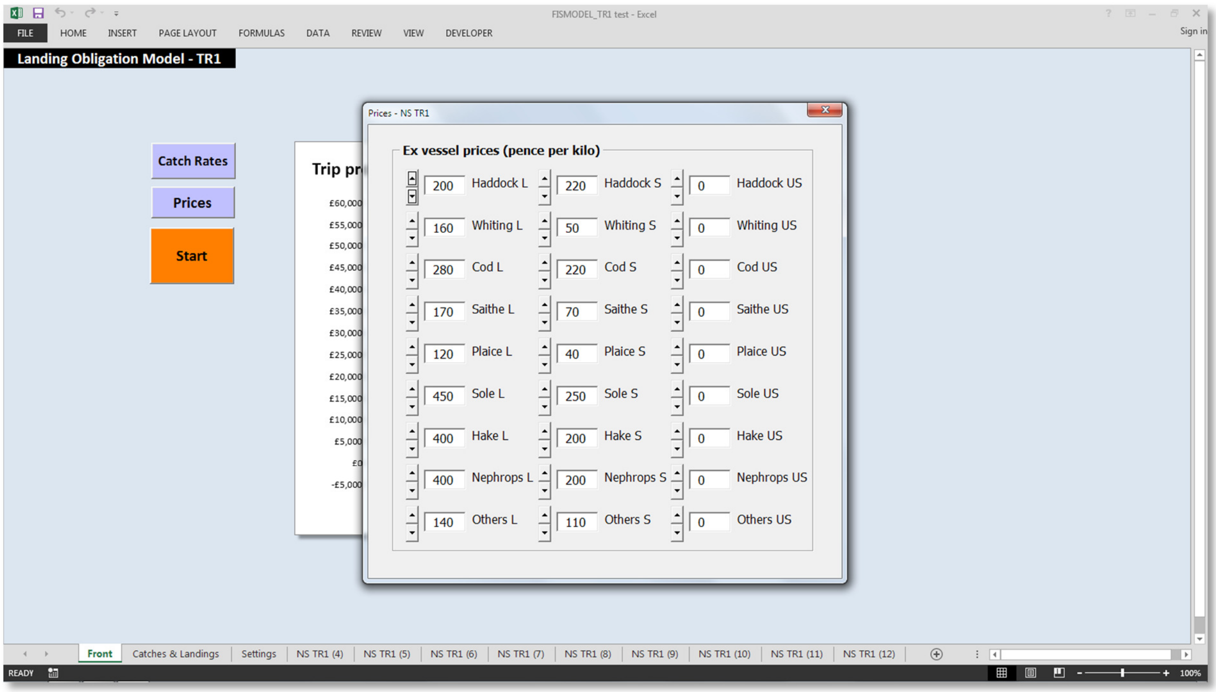

Fig. 4.7. Example: ex-vessel prices

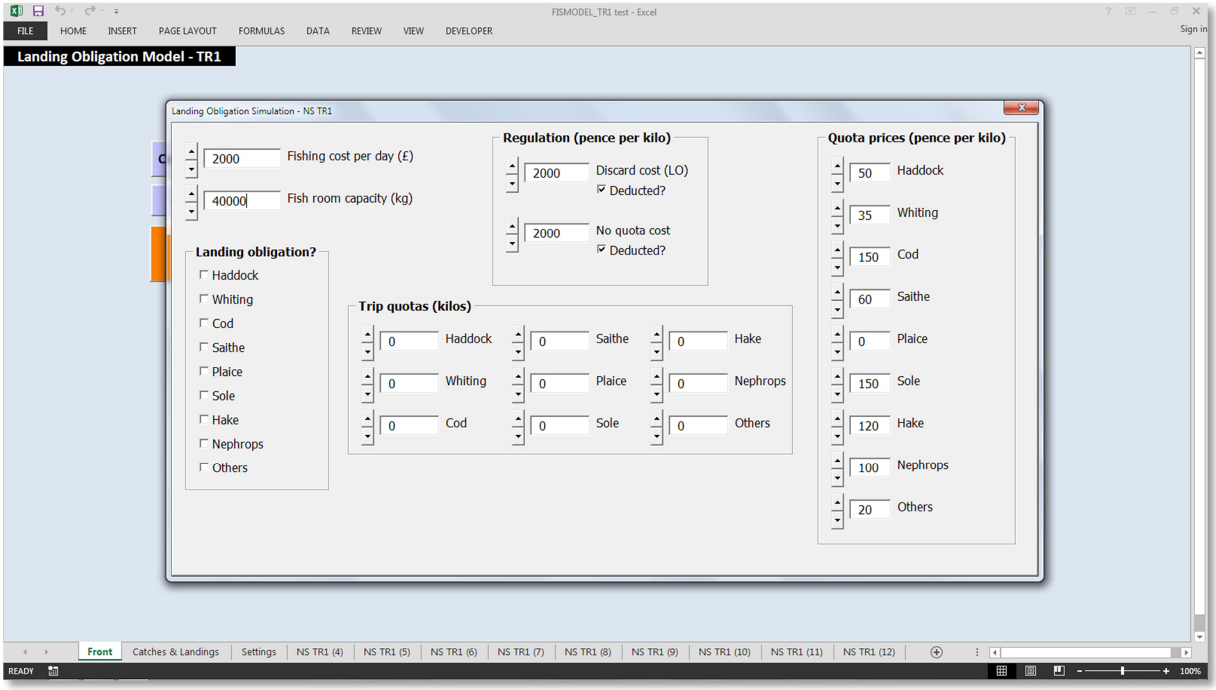

Fig. 4.8. Example: quota prices

In the absence of a landing obligation for any species in the catch, the profits results are as shown in Fig. 4.9. Profits are maximised at around £30,000 with a 10 day trip, although almost as much is made on a 9 day trip. The hold is actually filled on the 7th day, but it is profitable to fish for another 2-3 days and replace some of the fish in the hold with more valuable fish from the increased catch. All undersize fish is discarded, and we can see from Fig. 4.10 that there are also significant discards of marketable whiting, saithe and plaice. This is small fish which is of relatively low value (taking the quota price into account).

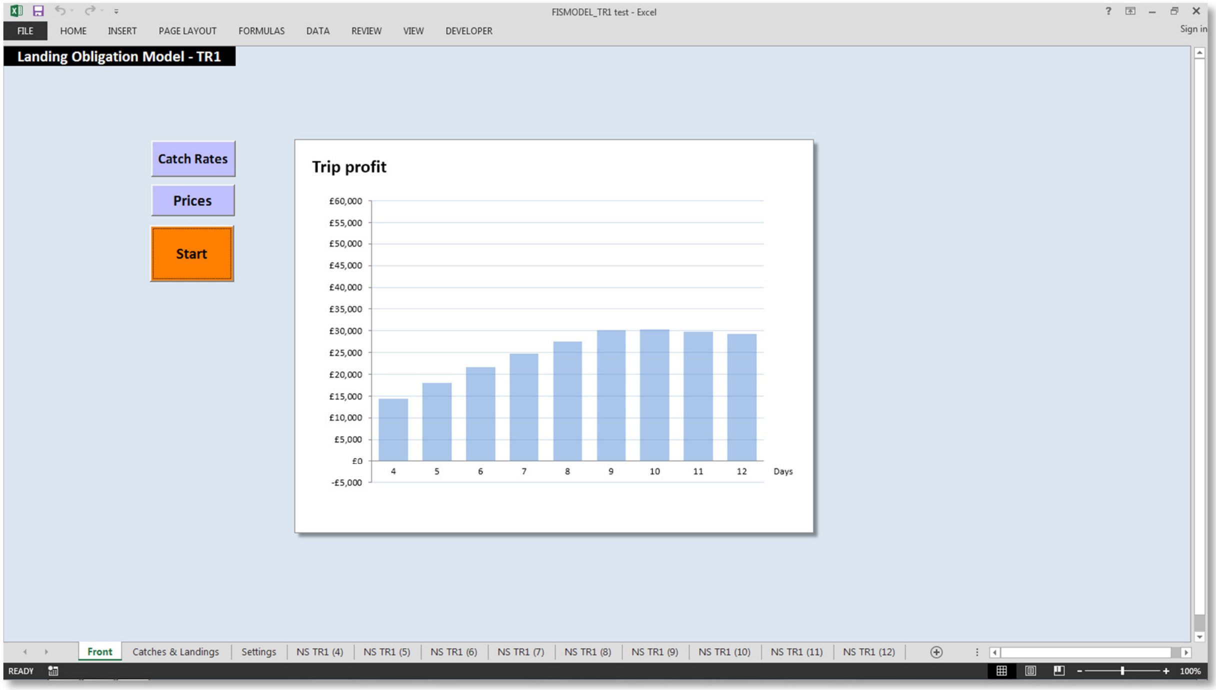

Fig. 4.9. Example: trip profits with no landing obligations in force

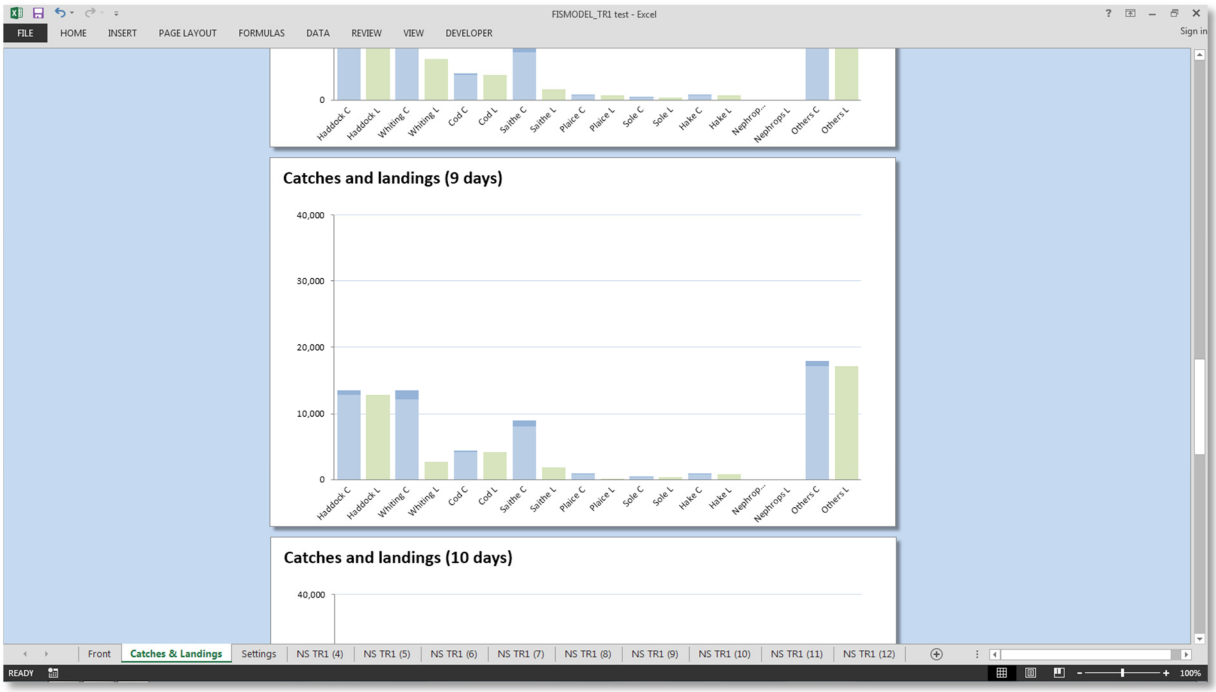

Fig. 4.10. Example: catches and landings with no landing obligations in force

Assume now that a landings obligation is introduced for haddock and plaice. We start with the assumption that discards, as well as over-quota landings, can be enforced with sufficient rigour that the expected penalty in each case is equivalent to £20 per kilo of fish discarded or landed without quota (see Fig. 4.11).

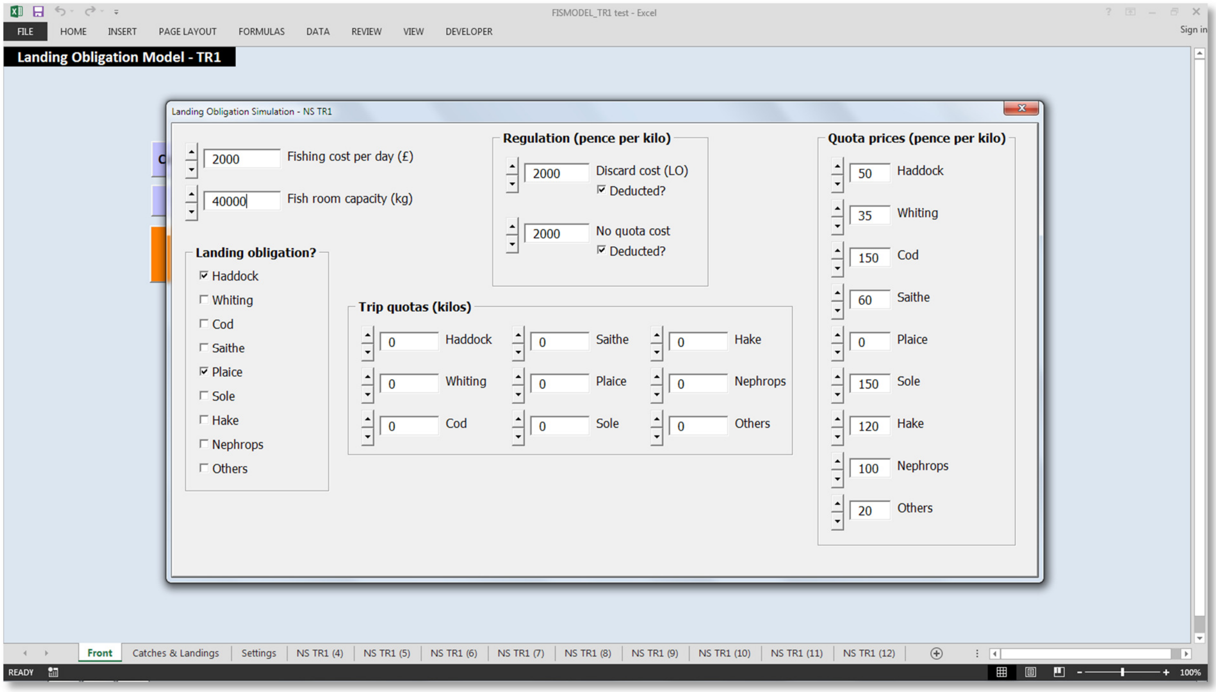

Fig. 4.11. Example: introducing a landing obligation for haddock and plaice

We can see from Fig. 4.12 that the impact on trip profits is relatively small. All haddock and plaice (including fish below the MCRS) is now landed, with quota, but the vessel has compensated by increasing discards of other species, namely whiting, saithe and cod (see Fig. 4.13).

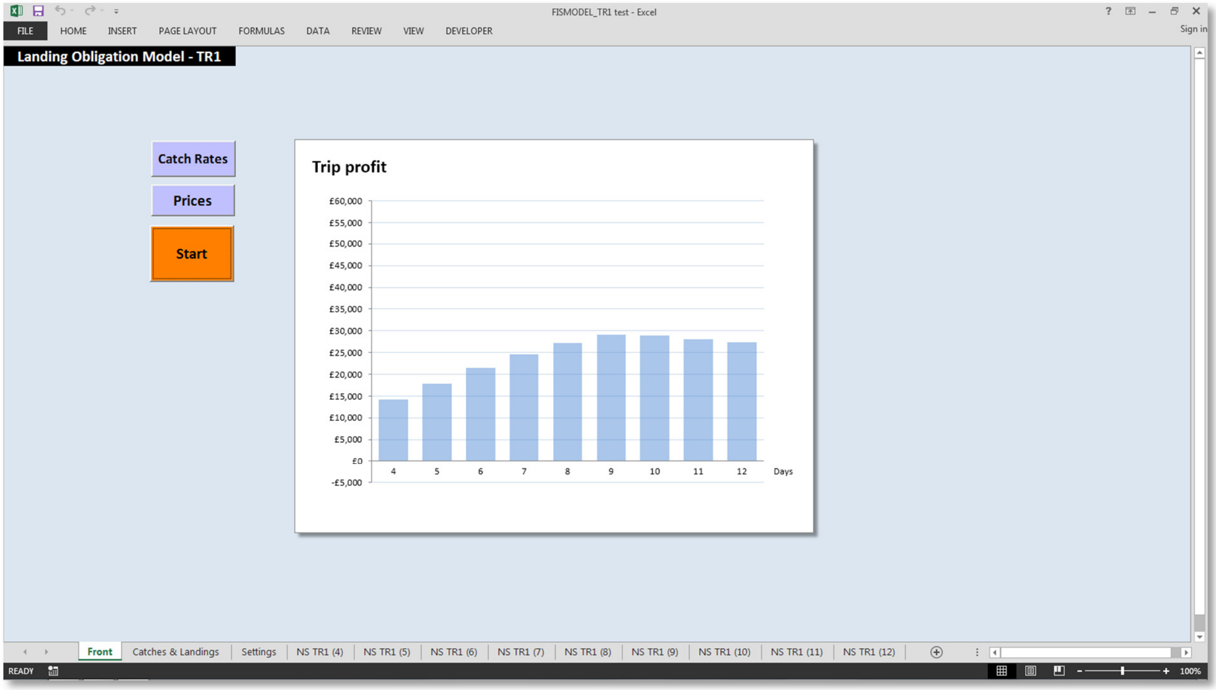

Fig. 4.12. Example: profits with a landing obligation for haddock and plaice

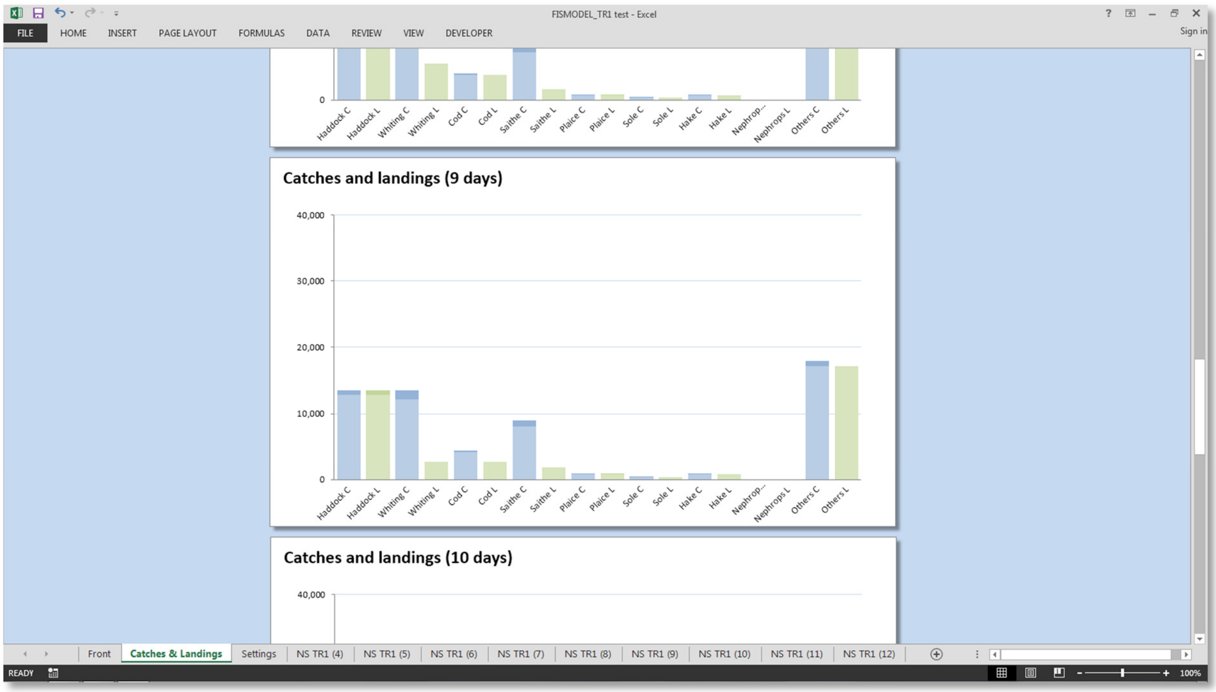

Fig. 4.13. Example: catches and landings with a landing obligation for haddock and plaice

Now we add whiting, cod, *Nephrops* and sole to the list of species subject to a landings obligation (although this vessel isn't actually catching any prawns). As we can see from Fig. 4.14 the impact is now more pronounced. Maximum trip profits are reduced to about £23,000 after just 7 days fishing. Beyond this, the vessel is discarding all other species, including more valuable fish, in order not to discard the protected species (see Fig. 4.15).

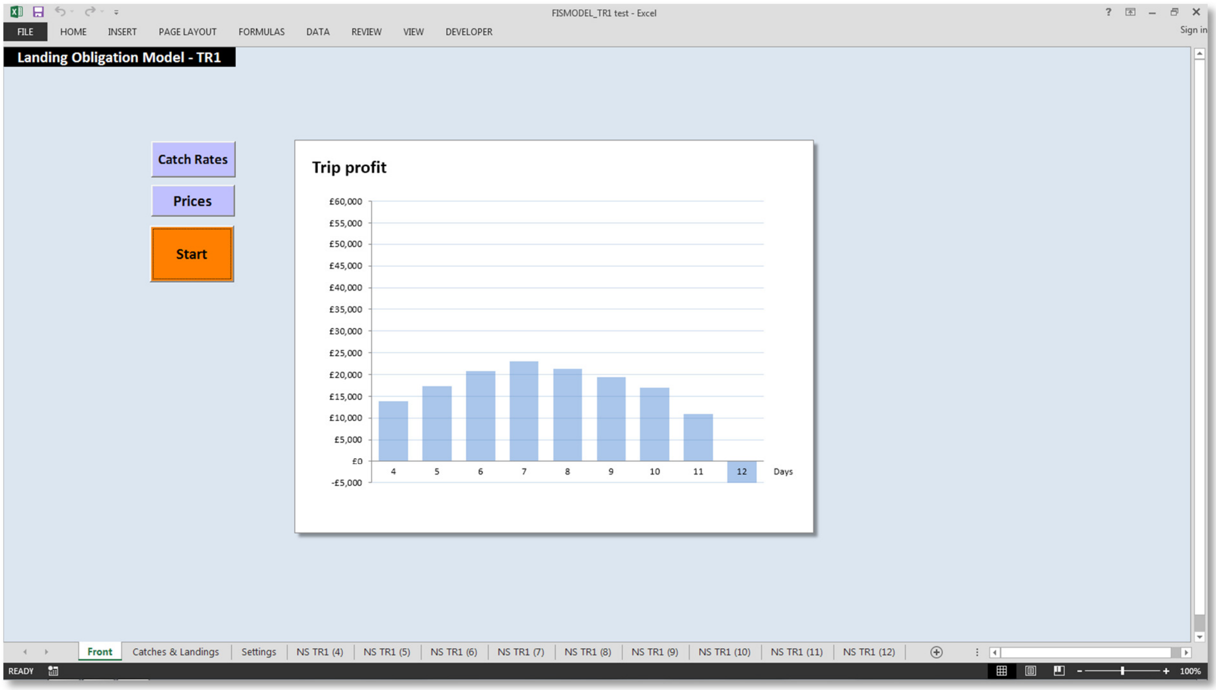

Fig. 4.14. Example: profits with a landing obligation for 6 species

Now we introduce the landing obligation for all quota species. Maximum profits are reduced to £17,000 after 5 days' fishing. The vessel would expect to make a loss beyond 6 days' fishing as discarding anything, we are assuming, incurs an expected cost in terms of fines for non-compliance with the discard ban.

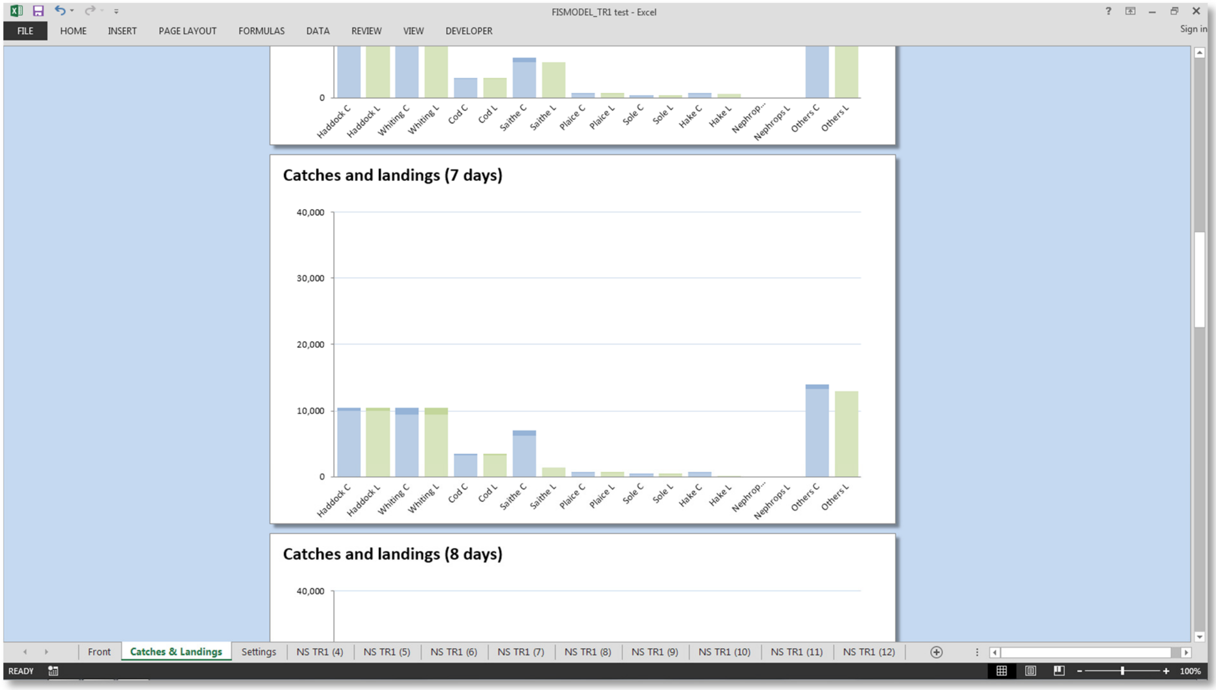

Fig. 4.15. Example: catches and landings with a landing obligation for 6 species

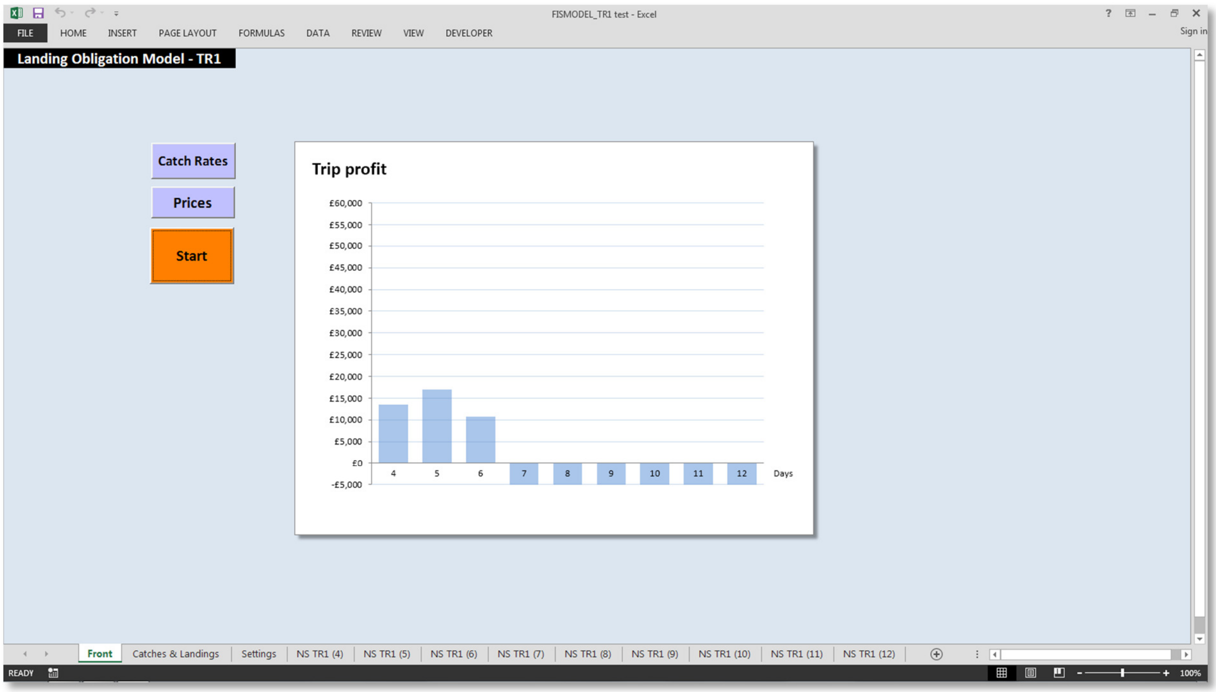

Fig. 4.16. Example: profits with a landing obligation for all quota species

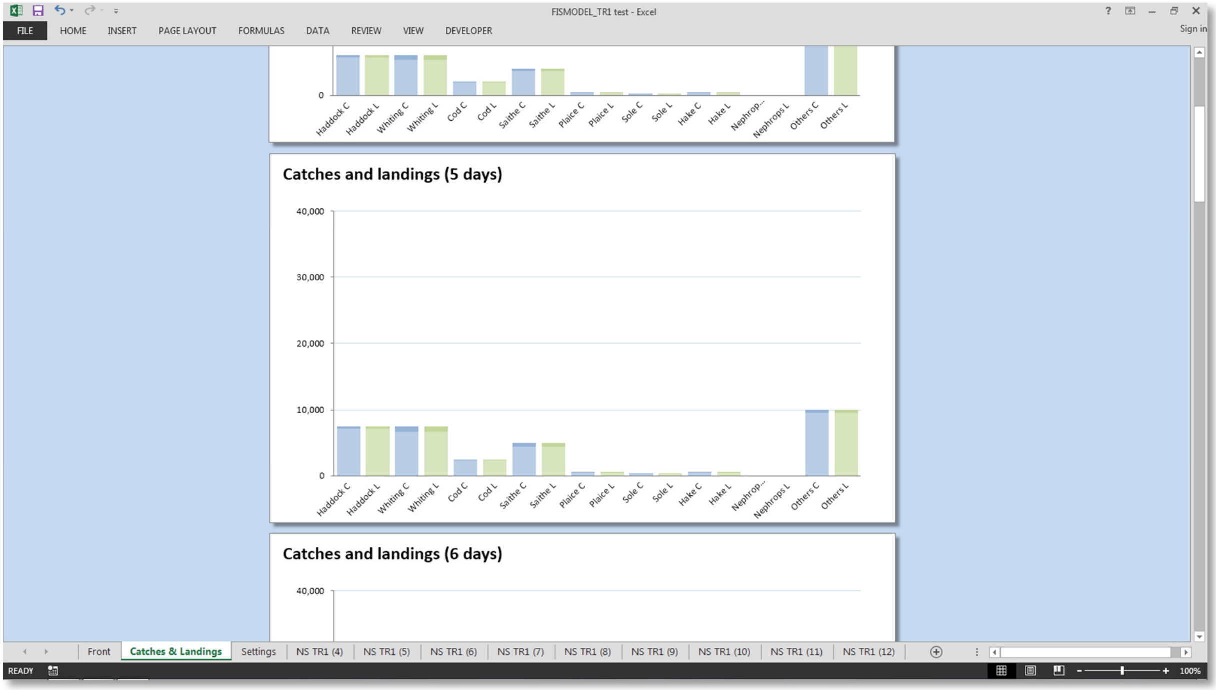

Fig. 4.16. Example: catches and landings with a landing obligation for all quota species

In this example, we have so far assumed that the vessel is able to source any amount of quota for any species at the stated quota lease price. All discards have either been of fish below the MCRS (for species not subject to a landing obligation) or necessitated by the vessel's physical capacity to retain fish. But what happens if quota for one species is not available, as in the case of a choke species, for example? We can simulate inelastic quota supply by specifying an arbitrarily high quota price.

Suppose we increase the quota price for hake to £30 per kilo. We could also increase the expected unit cost for over-quota landings to £30 just to get a clearer picture. Expected profits are now maximised at just over £7,500 from a 6 day trip. The vessel is now discarding *all* its catches of hake, simply paying the expected penalty for doing so. If expected penalties were much higher, of course, the vessel might not make any profit at all.

Let the hake quota price return to its previous level. What if the expected penalty for discarding under a landing obligation is in practice very low, even zero? Not surprisingly, reducing the discarding cost to zero results in the vessel behaving as if there are no landing obligations in force at all: catches, landings and profits are exactly the same as with no landing obligation.

So what, in this particular scenario, would the expected unit discard cost (penalty) need to be in order to deter discarding under a landing obligation? After 6 days' fishing, the vessel has not quite filled its hold but has discarded nearly 3 tonnes of undersize fish. To get these undersize discards down to zero, the expected discarding cost would need to be equivalent to at least £1.51 per kilo, but the vessel now has to discard the fish that there is no room for in the hold. Deterrence at this level will result in some discarding (some 500 kilos), but is high enough to make any further increase in effort unprofitable. Zero discards, i.e. no fishing effort beyond 5 days, would require the expected discarding cost to be at least around £8 per kilo.

5. DISCUSSION AND CONCLUSIONS

The FIS discard model, based on preliminary testing, provides a good prediction of the likely patterns of discards and landings for individual vessels with and without a landing obligation for some or all of the species included in the model. The specification and operation of the model appears to demonstrate a good fit with the experience and perceptions of the skippers interviewed in the survey. Any remaining "bugs" or omissions will be resolved as the model is tested further and revised versions of the model will be made available.

Given assumptions about the expected costs of discarding under a landing obligation and the expected cost for landing fish without quota, the model demonstrates the difficulties of implementing a discard ban for some or all species. For example, take the case of a "choke" species such as hake. If catches of hake are unavoidable, and the supply of hake quota is inelastic (simulated by entering an arbitrarily high quota price), then imposing a landing obligation for hake will result in either all hake discarded, or all hake landed illegally, or even no fishing once the quota is filled for the trip, depending on the relative magnitude of the expected costs for discarding and landing without quota. If the expected discarding costs are small (or indeed zero), as seems quite possible in practice, then all catches of hake will simply be discarded.

Similarly, the model can be used to demonstrate how imposing a landing obligation for all quota species in the prawn (TR2) fishery would result in fishing trips being severely curtailed because of limited space in the fish room, provided that discarding is expected to be costly. If the expected cost of discarding is actually zero, then again the landing obligation will demonstrably be ineffective.

In each case, the model shows that if discarding is perceived as costly, with inelastic quota supplies the result would be either illegal landings, or no fishing, depending on the relative costs of each option.

Clearly, the FIS model is sensitive to all the parameters used to calibrate the model. Use of the model requires calibration with representative catch rates, prices, etc., for the particular type and size of vessel of interest. Some preliminary calibration has been undertaken but this is necessarily limited and further calibration will be required by anyone wishing to run the model for a particular vessel scenario.

Some of the model limitations have already been discussed, and it is in the very nature of a model that there is a degree of abstraction from many of the complexities (and randomness) of the real world. A few points are worth elaborating on here, however.

Firstly, the model itself does not simulate any adaptive changes in fishing selectivity, although relative catch rates, proportions of undersize fish, etc., can easily be changed in order to reflect changes in catch composition.

Secondly, the limitations of the model with regard to vessels' quota holdings (based on FQAs and/or PO monthly limits) have already been mentioned. Including a hold (fish room) constraint in the model was considered to be important and this is incompatible with specifying the model on a monthly or annual basis (fishing costs are also problematic in this regard). The inevitable result is that either the model is run assuming that all quota has to be leased, or calculating the quota allowances or limits for a "typical" fishing trip based on an assumption about the average number of trips per year or per month.

Thirdly, there is a limit to the extent to which the model can simulate "highgrading" in the sense that the term is commonly used within the industry. In the model, if the vessel has a (trip) quota, the quota is filled first with the most valuable fish, then the least valuable, then fish below the MCRS (if there is a landing obligation in place for this species). This calculation is done for each trip, so if the trip is long enough the quota will be filled by only the most valuable fish. If the quota price is high enough (for example, because of inelastic supply), all less valuable fish will be discarded (depending on the expected discarding cost and the expected cost for landing without quota). To this extent, the model performs "highgrading". What the model cannot do, however, is model the "saving" of quota for hypothetical future trips, since the model runs on a single trip basis.

If the vessel has no quota, or has exceeded its trip quota, quota will be leased to cover any fish for which the ex-vessel price exceeds the quota price (provided it is not cheaper to land fish without quota). It is not possible to model "highgrading" in the sense of leasing quota only for the most valuable fish since this is not rational as long as the lease price is less than the ex-vessel price. There is no simple logical argument that can determine when the difference between the ex-vessel price and the quota price is of sufficient magnitude (although of course any arbitrary argument could, in principle, be constructed).

If the hold constraint binds, however, there is true “highgrading” of *all* the catch retained on board, in the sense that the least valuable fish is discarded sequentially until the hold is just filled. Again, this calculation is performed separately for a trip of each duration, so additional effort can profitably replace low value fish in an already full hold with additional catches of higher value.

Finally, given the relatively short timescale of this project, it is worth reiterating that testing of the model has not been exhaustive. Further model refinement and development is inevitable and can be undertaken once the model has been tested by others. Based on feedback from users, subsequent versions of the model could also include additional graphical or tabulated displays of results.

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ANNEXES

1. Survey questionnaire

2. Landing obligation model - North Sea TR1 vessel (FISMODEL_TR1_v*n*.xlsm)

3. Landing obligation model - North Sea TR2 vessel (FISMODEL_TR2_v*n*.xlsm)

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