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IFRO Report

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The Economics of a Landing Obligation: Short Term Impacts for the Danish Fishery of Implementing the EU Landing Obligation*

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Abstract
By 2015 The European Common Fisheries Policy Reform includes a landing obligation in some fisheries and over the next few years all EU fisheries will be facing the obligation to land all catches. In spite of that, there is a lack of theoretical as well as empirical analyses of the consequences of a landing obligation. The paper includes an empirical analysis of the landing obligation's impact on the Danish fishery in the short run. In the first part of the paper, we survey the fisheries economics literature for theoretical findings regarding behavioural aspects of a discard ban and we exploring gaps in our knowledge. A comprehensive analysis of the short term economic impacts of the discard ban for the Danish fleet under various assumptions regarding costs of handling previously discarded fish, prices obtained for them, selectivity, minimum sizes, and quota utilization is presented. Among other things, the analysis shows that the fisheries will suffer economic losses under the landing obligation if quotas are not increased with the historical discard rate. With quota top-ups however fisheries can experience economic gains which increase with reduced minimum sizes or by increasing selectivity.

Keywords: fisheries economics, bioeconomics, fisheries management, discard ban, landing obligation

Introduction
In 2013, the European Union's (EU) reform of the Common Fishery Policy (CFP) entailed a landing obligation (L.O.). A biological motivation for the L.O. is the encouragement of increased selectivity and the following effects on marine ecosystems in line with the CFP's goals. An ethical motivation for the L.O. is to reduce resource waste in that previously discarded fish that still cannot be avoided in the catch can be used for industry or consumption purposes. The L.O. is being implemented from 2015 and onwards starting with pelagic and industrial species as well as salmon in the Baltic Sea. From 2019 the L.O. covers all quota species in all areas. There are some exemptions to the L.O., e.g. related to survivability (EU, 2013).

The theoretical understanding of why discarding takes place and what can be done to alleviate it is well understood. However, knowledge is limited on the actual impacts of trying to regulate discarding through a landing obligation. By analyzing the short-run effects of the L.O. in the Danish fishery, this paper aims to add to the empirical knowledge of economic impacts of the L.O. The L.O. covers many species highly valuable in the Danish fisheries. The analysis makes use of the fishery's performance in 2013 as a baseline and then imposes the L.O., keeping the fishery patterns constant. The economic impacts are calculated as changes compared to the baseline for the average vessel in each vessel group. Under different assumptions about management regime, costs, prices, and behavior, different scenarios are analyzed. Medium or longer run changes, e.g. changes in fishing patterns and complex behavior nor biological impacts due to these changes are analyzed. Furthermore, full enforcement is assumed.

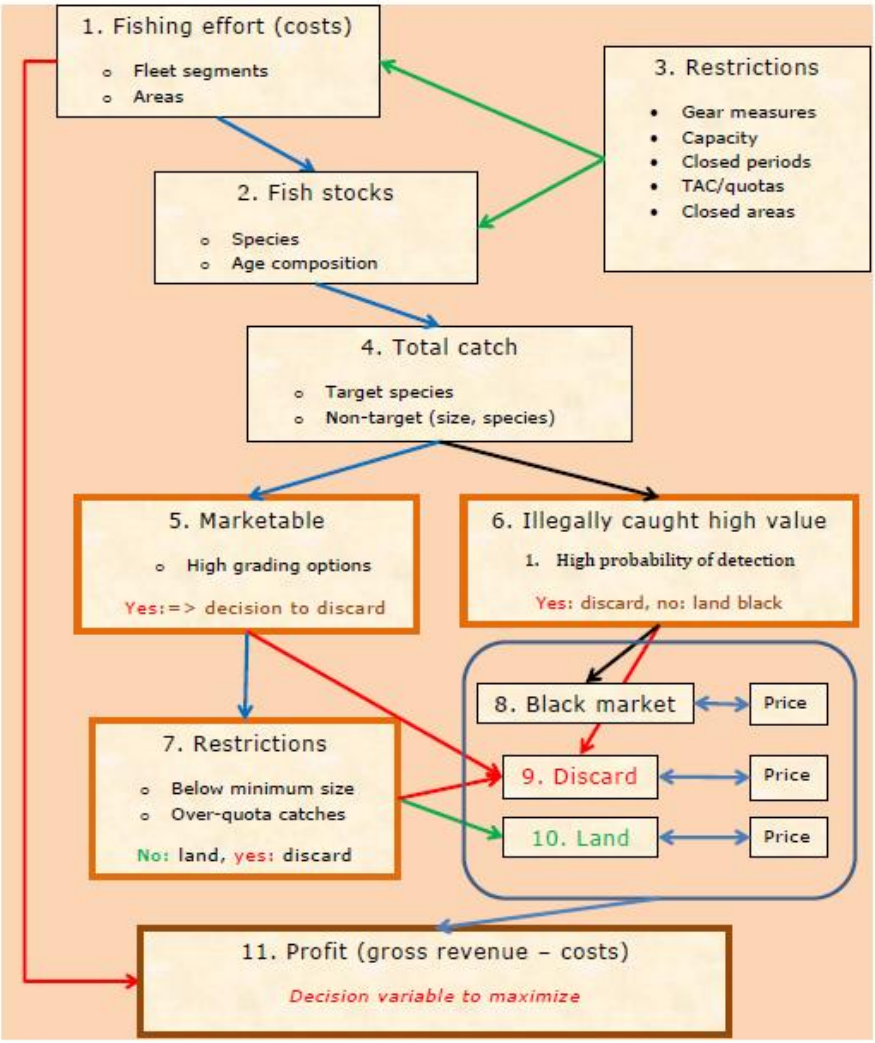
*Empirical findings in this paper are published in Ravensbeck et al. (2015). A short version of this paper can be found in the IIFET Conference Proceedings 2016.

Theory

The theoretical framework for analyzing the effects of a landing obligation lies within the literature of discarding behavior; see e.g. Anderson (1994), Arnason (1994), and Vestergaard (1996). Discarding certain catches may take place for various reasons and can be linked to bycatch or high-grading, see e.g. Frost et al. (2015); bycatch cannot be avoided completely in an imperfectly selective fishery and may be discarded if illegal to land. High-grading is the decision to discard less valuable fish in favor of catching more valuable fish of the same species on the quota. Several factors can play a role in a fisherman's decision whether to land certain catches; catchability of target and non-target fish, distributions of species in catch, prices, costs of processing and discarding, distance from harbor to fishing area, stock effects, regulation type, as well as the probability and scale of legal punishment (Frost et al., 2015).

These factors feed into the decision making of the fisherman. The decision process is illustrated in the figure below. As described by Frost et al. (2015), the fisherman faces restrictions by policy-makers such as quotas or closed areas (box 3). With these restrictions in mind, he decides on a fishing effort (box 1) and obtains a catch which dependent on the species and age distribution (box 2) comprises of target and non-target species and sizes (box 4). Box 5 shows that with a marketable catch at hand the fisherman may choose to high-grade and thus discard some of the catch (box 9). Although not high-grading he may face restrictions on minimum sizes or have landed amounts above the quota (box 7) which may contribute to the choice to discard (box 9). If there are no such restrictions, the catch may be landed (box 10). Box 6 shows that the fisherman's catch may consist of illegally caught fish, e.g. above-quota catches, but if there is a low probability of legal punishment the catch may be landed and sold on a black market (box 8). If the probability of punishment is high, the catch may be discarded (box 9). These decisions will depend on the net income from legal and illegal catches and the probability of detection and the size of the fine. The potential income from boxes 8, 9, and 10 feed into the fisherman's profit maximization in box 11 together with the costs of fishing in box 1.

Figure 1. Behavior under restrictions



Source: Frost et al. (2015)

With the landing obligation, the previous discards in box 9 have to be landed and these achieve a lower price than wanted and marketable landings. This affects the fisherman's profit in varying degrees depending largely on the amount of previous discarding and whether the management system in box 3 is based on quota top-ups or write-offs. The profit maximization also depends on the costs of handling and landing previously discarded catch, whether the minimum sizes are reduced, and whether quota utilization of more valuable species can be improved.

Methodology

The economic impacts of the L.O. are calculated as changes against a baseline without a L.O. The baseline is the fishery as it was in 2013. The analysis locks the fishery patterns as they were in 2013 and the calculations are carried out as if the full L.O. is implemented at once on the fishery in 2013. Under the L.O. the fishermen thus continue their catch patterns, including where they fish, while facing a new management regime.

Changes are calculated for revenue, variable costs, profitability, wages and gross margin. Revenue is defined as landings value. Variable costs consist of fuel, ice, supplies, landings and sales costs. Profitability is the landings value minus the variable costs. Wages are assumed to be in proportion to the landed value and thus change with the change in revenue. The gross margin is the landings value minus variable costs and wages. As it is assumed that neither fixed costs nor fishery patterns change in the short run, these are not considered in the analysis.

Overall, without the L.O. landings equal catch minus discards. Under the L.O. landings equal catches. The analysis considers scenarios with a management regime of quota top-ups and situations without quota top-ups, i.e. landings of previously discarded fish are written off on the quota. Landings above the minimum size and thus aimed at human consumption are labelled marketable landings (ML). Under quota top-ups marketable landings ($ML^{N,Q}$) are simply the old amount of marketable landings (L^{O}), that is; $ML^{N,Q}=L^{O}$ since the quota has simply been increased with the former amount of discard. Without quota top-ups, marketable landings (ML^{N}) are reduced by the amount of previously discarded fish; $ML^{N}=L^{O}(1-dp)$, where dp is the discard percentage.

The analysis then explores what happens when assumptions change regarding handling costs, minimum sizes, and behavioral related to quota utilization and a of a 25 % avoidance of previously discarded fish. This is done while keeping the fishery patterns as they were in 2013 and under regimes of either quota top-ups or quota write-offs.

By assumption, vessels' behavior is driven by the species they have quotas for. Therefore, only landings data on quota species are directly included in the analysis and changes in landings of these species drive the economic results. Landings of non-quota species change in proportion to changes in effort and are thus indirectly included in the analysis. Changes in the amount of fish landed, be it quota or non-quota species, are assumed not to change prices obtained at harbor or at fish meal and oil factories.

Stock effects, technology changes, complex behavioral changes such as change of fishing area or quota purchases, imperfect enforcement nor choke species issues are considered in the analysis. Choke species are species which quotas are fished before those of the target species and therefore the fishery has to stop. This could for example be cod caught while targeting Norway lobster. Further, only demersal species and no pelagic or industrial species are considered in the analysis. Downstream effects are assessed by an input/output model, while long-term effects are assessed descriptively.

Data

The analysis made use of publicly available data for 2013 on Danish landings and quotas obtained through the AgriFish Agency and economic data obtained through Statistics Denmark. The year 2013 was chosen since this was the most recent year with final economic data in the database. The discard ratios per species based on vessel type and area has been estimated by DTU Aqua (see Ravensbeck et al., 2015).

Because of data limitations, only demersal species are considered. Demersal fisheries do indeed face issues regarding selectivity, e.g. minimum sizes, thus being impacted to a large degree by the landing obligation.

The landed but previously discarded fish, that is fish below the minimum size for consumption, is assumed to supply the fish oil and meal industry, obtaining a price of DKK 2/kg (Marine Ingredients, 2015). The price of transportation to the fish oil and meal plant has been estimated to DKK 1/kg by COWI (2015). Thus previously discarded fish obtain a sales price of DKK 1/kg.

Vessel data in the database is at the level of length or gear group. Only non-specialized vessels at commercial activity levels[1] are included. Specialized fisheries target e.g. mussels and are managed by licenses and not individual transferrable quotas (ITQs) as the rest of the Danish fishery. The analysis is thereby carried out for 19 segments and for the North Sea fleet, Baltic Sea fleet, and Skagerrak/Kattegat fleet, as well as the Danish fleet as a whole.

To have an overview, the table below shows the economic performance of the fishery as it was in 2013 by fishing area and in total. As explained in the methodology section, the economic impacts are calculated as changes compared to this baseline situation.

Table 1. Economic performance of the Danish fishery in 2013.

	DKK 1,000[1]			
	Baltic Sea	**Kattegat/ Skagerrak**	**North Sea**	**Total**
Revenue	278,135	493,440	1,745,283	2,516,858
Variable costs	84,373	58,182	442,961	585,515
Wages	61,155	42,651	366,602	470,408
Gross Margin	132,607	392,607	935,720	1,460,935

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark

The North Sea accounts for the largest share of revenue and costs. Kattegat/Skagerrak has almost twice the revenue as the Baltic Sea, but has lower costs, reflecting the high value species such as Norwegian lobster caught in Kattegat/Skagerrak.

Scenarios

To illustrate the impacts of the L.O. under possible management regimes and fisher behavior, the analysis is carried out for several different scenarios. The economic impact is calculated as changes from a baseline scenario: the fishery in 2013 without the landing obligation (scenario 0).

As can be seen in table 1 below, scenarios with quota top-ups are labelled A-scenarios and scenarios without are labelled B-scenarios. A-scenarios thus entail the crowding out of more valuable consumption landings by previously discarded fish that now take up part of the quota.

Scenarios A1 and B1 consider the imposition of the L.O. directly on the fishery as it was in 2013, without and with quota top-ups, respectively. Scenarios A2 and B2 are like A1 and B1 although with an additional cost of handling and landing previously discarded fish that need to be brought into harbor. A1, A2, B1, and B2 thus illustrate the situations in which no further management change takes place except the L.O. itself.

Scenarios A3 and B3 are like A1 and B1 although with increased minimum sizes of cod and Norway lobster in some areas. This means that a quantity of previously discarded cod and Norway lobster above the new minimum size but below the old minimum size can obtain a consumption price instead

[1] The Department of Food and Resource Economics classify commercially active vessels according to earnings. In 2012, the minimum earnings for being categorized as a commercial vessel was DKK 270,000.

of the price for fish meal and oil purposes. These scenarios thus illustrate the effect of the L.O. combined with a management measure to reduce potential economic adversity of the new policy.

Further, under-utilized quotas are observed across species and areas. An increased utilization and thus landings revenue could reduce the negative economic consequences in face of the L.O. Therefore, an additional scenario without quota top-ups, A4, incorporates increased quota utilization. This scenario thus illustrate the imposition of the L.O. with no further management changes, but where behavioral changes initiated by fishers themselves can reduce negative economic impacts.

Additionally, two scenarios called C1 and C2 resemble scenarios A1 and A2 but assume a behavioral change that reduces discard rates by 25 %. Scenario C2 is only calculated for the Danish fleet as a whole. These scenarios thus exemplify situations without additional management measures in which fishermen themselves find ways to reduce landings of previously discarded fish. This could for example take place by changing fishing time and place. The table below provides an overview of the scenarios:

Table 2. Scenarios

Scenario	Description	Explanation
0 scenario	Basis scenario: The Danish fishery in 2013 is used as basis for comparison	2013 situation with discard for different segments and fishing areas
Scenario A1	2013 situation without quota uplift and therefore a reduction of landings and effort **(Effort reduction)**	Reduction of catch value, the landings of previously discarded fish replace some of the wanted catch. Effort reduction (reduction in variable costs) in proportion to the reduction in catch
Scenario A2	As scenario A1 and additional costs of handling former discard onboard **(A1 + handling costs)**	Increased variable costs caused by costs of handling a more mixed catch. This can be viewed as a "Worst Case Scenario"
Scenario A3	No quota uplift and therefore an effort reduction but a part of landed discard can now be sold for consumption **(A1 + new minimum sizes)**	2013 situation, no quota uplift, but where the part of landed discard which was previously between the old and new minimum sizes will be sold for consumption (lowest price class)
Scenario A4	No quota uplift and therefore effort reduction, but with improved quota utilization (≤ TAC). **(A1 + improved quota utilization)**	2013 situation, no quota uplift, but the quota utilization increases when the previously discarded fish is included in the quota
Scenario B1	2013 situation with quota uplift and no reduction in effort **(Quota uplift)**	Landings = Previous landings + Estimated landed discard
Scenario B2	Quota uplift no effort changes but additional costs of handling former discard onboard **(B1 + handling costs)**	Increased variable costs caused by costs of handling a more mixed catch.
Scenario B3	Quota uplift and a part of former discard can now be sold for consumption purposes **(B1 + new minimum sizes)**	2013 situation, with quota uplift, but where the part of former discard which was previously between the old and new minimum sizes can be sold for consumption purposes (lowest price class)
Scenario C1	2013 situation with behavioral changes **(A1+behavioral changes)**	C1 is like A1, but a change in behavior is assumed which reduces unwanted catches (former discard) by 25 %
Scenario C2	2013 situation, with quota uplift and behavioral changes **(B1+ behavioral changes)**	C2 is like B1, but a change in behavior is assumed which reduces unwanted catches (former discard) by 25 % (C2 is only calculated for the total fishery)

Results

Overall, fleet segments with higher discard rates are the most affected by the L.O., i.e. small and medium-sized trawlers. The results show a clear divide with respect to the effect of quota write-offs or quota top-ups on economic performance as seen in the A- and B-scenarios respectively. Quota-top ups allow fishermen to maintain their previous revenue while obtaining additional revenue from the sale of below minimum size fish to the fish meal and oil industry. A L.O. with quota top-ups may therefore benefit the fishermen. If on the other hand, the L.O. was to be implemented by writing off previously discarded fish on the quota, these will crowd out more valuable target fish and revenue and profitability losses are observed.

A reduction of the minimum sizes of cod and Norway lobster also reduces losses compared to a situation of quota write-offs with no additional management measure. Further, a behavioral change of increased quota utilization where possible can reduce the economic losses for some segments. A (technically imposed) behavioral change reducing discard percentages by 25 % can also alleviate negative effects. New minimum sizes improve earnings and profitability in the B-scenarios compared to the baseline as well as compared to the L.O. with no further measures.

Norway lobster, cod, and plaice in Kattegat, the Baltic Sea, and Skagerrak respectively affect results the most as these are highly valuable catches but at the same time have high discard rates for some segments and in some areas.

Further, the assessment of activity impacts on the fishery and downstream industry shows that the L.O. could increase activity if implemented with quota top-ups, while it would decrease activity if implemented without.

Tables with overall and partial results are presented below. The scenarios are listed to the left and downwards. Economic impacts are presented in either DKK 1,000 or in percentages compared to the baseline; the economic situation in 2013, and are listed horizontally for each scenario. For the overall and area specific results, physical impacts are presented; landings of previously discarded fish as well as changes in marketable landings, i.e. landings for human consumption. For vessel group specific results only the amount of landings of previously discarded fish are presented.

The table below shows the overall scenario results for the entire Danish fishery calculated as changes compared to the baseline scenario. Implementing the L.O. without quota top-ups, as seen in the A-scenarios, forces fishers to reduce effort. Here, the more valuable marketable landings are crowded out by less valuable landings of previously discarded fish now being sold to the fish meal and oil industry at a lower price. The L.O. implemented with no further management measures decreases effort and thus revenue and gross margin by 7 and 9 %, respectively. When taking into account the increased handling and landing costs, the revenue and gross margin decreases by 7 and 10 % respectively compared to the baseline. New minimum sized as well as increased quota utilization reduces economic losses. New minimum sizes in A3 reduce both revenue and gross margin by 4 % while increased quota utilization decreases revenue and gross margin by 3 and 4 % respectively. In these scenarios, the ratio between marketable and more valuable landings and previously discarded fish is increased compared to A1 and A2.

Scenarios with quota top-ups (B-scenarios) illustrate that increasing quotas with the previously discarded amounts benefits fishers in tackling the L.O. The economic impact is almost neutral in scenarios B1 and B2 with increases in revenue of 0.4 %. Gross margins increase by 0.6 % in B1 whereas taking into account increased handling costs in B2 reduces gross margin by 1 %. It can even bring about a slight increase in revenue and gross margin if minimum sizes are reduced, by 3 and 4 %

respectively. Behavioral changes reducing discard rates by 25 % will help reduce losses compared to A1 and A2, while the effect is almost neutral in compared to B1 and B2. The effects seen for the whole Danish fleet, however, cover differences between fishing areas and fleets, as explained in the following.

Table 3. The Danish fleet

	DKK 1000[1] or %				*Ton*	
	changes in					
Scenarios	**Δ Revenue**	**Δ Gross Margin**	**Δ Revenue**	**Δ Gross Margin**	**Δ Discard landings[2]**	**Δ Marketable landings**
A1: Effort reduction (no quota adjustment)	-168,815	-127,792	-7%	-9%	-3,896	-8,541
A2: A1 + handling costs	-168,815	-147,554	-7%	-10%	-3,896	-8,541
A3: A1 + new minimum sizes	-92,719	-65,272	-4%	-4%	-5,891	-6,328
A4: A1 + increased quota utilisation	-69,356	-58,270	-3%	-4%	-1,689	-2,469
B1: Corresponding quota adjustment	10,769	8,435	0.4%	0.6%	0	0
B2: B1 + handling costs	10,769	-20,490	0.4%	-1%	0	0
B3: B1 + new minimum sizes	73,349	64,997	3%	4%	-4,084	6,685
C1: A1 + behavioural changes (25 % less discard landings)	-126,613	-95,845	-5%	-7%	-5,614	-6,406
C2: B1 + behavioural changes (25 % less discard landings)	6,822	5,209	0.3%	0.4%	-3,947	0

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

The table below show partial results for the fisheries in the Baltic Sea. Here, reductions in revenue and gross margin of 9 and 8 % take place in scenario A1 while handling costs in A2 increase losses in gross margin to 14 %. The discard rates for cod and plaice are rather high in this area while the gross margin is smaller than in other areas, so that an increase in costs causes larger reductions in gross margin. The B-scenarios show that quota top-ups can benefit the fisheries in the Baltic Sea compared to the baseline especially if there are no additional handling costs or in the case of new minimum sizes.

Table 4. The Baltic Sea

	DKK 1,000[1] or %					*ton*			
	changes in								
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profit ability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**	**Marketable landings**
A1: Effort reduction (no quota adjustment)	-24,386	-7,711	-16,675	-6,187	-10,487	-9%	-8%	2,706	3,628
A2: A1 + handling costs	-24,386	0	-24,386	-6,187	-18,199	-9%	-14%	2,706	3,628
A3: A1 + new minimum sizes	-18,243	-7,711	-10,532	-4,145	-6,387	-2%	-5%	1,947	2,868
A4: A1 + increased quota utilisation	-4,258	-2,095	-2,163	-325	-1,839	-1%	-1%	3,401	743
B1: Corresponding quota adjustment	3,808	0	3,808	1,220	2,589	1%	2%	3,808	0
B2: B1 + handling costs	3,808	11,110	-7,302	1,220	-8,522	1%	-6%	3,808	0
B3: B1 + new minimum sizes	11,189	0	11,189	3,693	7,496	3%	6%	2,862	0
C1: A1 + behavioural changes (25 % less discard landings)	-18,290	-5,784	-12,506	-4,641	-7,865	-7%	-6%	2,030	2,721

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Table 5. Skagerrak/Kattegat

	DKK 1,000[1] or %					*ton*			
	changes in								
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profit-ability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**	**Marketable landings**
A1: Effort reduction (no quota adjustment)	-123,453	-7,742	-115,712	-9,262	-106,449	-25%	-27%	3,029	3,649
A2: A1 + handling costs	-123,453	0	-123,453	-9,262	-114,191	-25%	-29%	3,029	3,649
A3: A1 + new minimum sizes	-59,080	-7,742	-51,338	-5,769	-53,221	-12%	-14%	1,956	2,360
A4: A1 + increased quota utilisation	-64,486	-3,032	-61,454	-4,943	-56,511	-13%	-14%	4,463	1,560
B1: Corresponding quota adjustment	5,738	0	5,738	355	5,383	1%	1%	5,738	0
B2: B1 + handling costs	5,738	13,559	-7,821	355	-8,176	1%	-2%	5,738	0
B3: B1 + new minimum sizes	59,750	0	59,750	4,297	55,453	12%	14%	2,873	0
C1: A1 + behavioural changes (25 % less discard landings)	-92,590	-5,806	-86,784	-6,947	-79,837	-19%	-20%	2,272	2,737

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

The partial results for Skagerrak/Kattegat are presented above. Here, high rates of discarding of cod, Norway lobster, and plaice cause a decrease in gross margin of up to 29 %. If, however, new minimum sizes were introduced for cod and Norway lobster, important species in this area, the negative effects would be halved. If new minimum sized were combined with quota top-ups, the fleet would experience an increase in revenue and gross margin of 12 and 14 % respectively.

As seen below, the North Sea fleets are not as affected by the L.O. as the fleets in the Baltic Sea and Kattegat/Skagerrak. The economic impact is only slightly negative in the scenarios without quota top-ups, being between 1-2 % losses in gross margin and 1 % loss in revenue. The effect is neutral where quota utilization is increased as well as in the B-scenarios where quotas are topped up. Low discard rates in the North Sea is the explanation for this.

Table 6. The North Sea

	DKK 1,000[1] or %					***ton***			
	changes in								
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profit-ability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**	**Marketable landings**
A1: Effort reduction (no quota adjustment)	-20,976	-4,309	-16,668	-5,812	-10,855	-1%	-1%	1,138	1,264
A2: A1 + handling costs	-20,976	0	-20,976	-5,812	-15,164	-1%	-2%	1,138	1,264
A3: A1 + new minimum sizes	-15,396	-4,309	-11,087	-5,424	-5,663	-1%	-1%	974	1,100
A4: A1 + increased quota utilisation	-612	-651	39	-41	80	0%	0%	1,216	167
B1: Corresponding quota adjustment	1,223	379	844	379	465	0%	0%	1,223	0
B2: B1 + handling costs	1,223	4,636	-3,413	379	-3,792	0%	0%	1,223	0
B3: B1 + new minimum sizes	2,409	0	2,409	361	2,048	0%	0%	950	0
C1: A1 + behavioural changes (25 % less discard landings)	-15,733	-3,231	-12,502	-4,359	-8,143	-1%	-1%	853	948

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

In the following, results will be presented for the smaller vessels, 12-18m as well as for all vessels fishing with trawl.[2] From a coastal fishery and socioeconomic perspective the smaller vessels are particularly interesting when faced with the L.O. Based on their discard rates, equipment, and target species the trawlers face specific challenges under the L.O.

Below results are presented for gillnet and hook vessels between 12 and 15 meters. This is a rather large group, containing 22 vessels, although the actual changes in economic performance are modest. Relative changes in revenue and gross margin as a consequence of the L.O. are also modest

[2] All in all the analysis covers 19 segments. Results for all fleet segments can be seen in the report "Analyse af de erhvervsøkonomiske konsekvenser af discardforbuddet" (Ravensbeck et al., 2015, in Danish) or requested from the authors.

- and neutral when quotas are top-upped. Further, there are differences between fishing areas with the vessels that operate in the Baltic Sea most affected by the L.O.

Table 7. Gillnet/Hook 12-15m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-648	-101	-547	-81	-466	-2%	-2%	34
A2: A1 + handling costs	-648	0	-648	-81	-566	-2%	-3%	34
A3: A1 + new minimum sizes	-515	-101	-414	-74	-382	-2%	-2%	30
A4: A1 + increased quota utilisation	-149	-28	-121	-15	-106	-1%	-1%	35
B1: Corresponding quota adjustment	37	3	34	5	28	0%	0%	37
B2: B1 + handling costs	37	108	-71	5	-77	0%	0%	37
B3: B1 + new minimum sizes	79	0	79	9	69	0%	0%	30
C1: A1 + behavioural changes (25 % less discard landings)	-486	-76	-410	-61	-349	-2%	-2%	26

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Below are the results for the vessels 15-18 meters long using gillnet or hooks. The segment obtains most of its revenue from the North Sea and where the largest absolute changes are felt, while the activities in the Baltic Sea experience the largest relative changes. The segment experiences slightly negative impacts on revenue (-2-0 %) and gross margin of (-3-0 %) in scenarios without quota top-ups and almost neutral effects in scenarios with top-ups. With increased quota utilization the segment can uphold its baseline economic performance as seen in scenario A4, while new minimum sizes can reduce the impact of the L.O. Behavioral changes reducing the catches of previously discarded fish by 25 % will have a neutral effect compared to a pure effort reduction as seen in scenario A1.

Table 8. Gillnet/Hook 15-18m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-1,291	-303	-988	-435	-553	-2%	-2%	69
A2: A1 + handling costs	-1,291	0	-1,291	-435	-856	-2%	-3%	69
A3: A1 + new minimum sizes	-913	-303	-610	-393	-217	-2%	-1%	56
A4: A1 + increased quota utilisation	-50	-52	1	-21	23	0%	0%	73
B1: Corresponding quota adjustment	76	24	52	29	23	0%	0%	76
B2: B1 + handling costs	76	334	-258	29	-287	0%	-1%	76
B3: B1 + new minimum sizes	181	0	181	44	137	0%	1%	56
C1: A1 + behavioural changes (25 % less discard landings)	-968	-227	-741	-326	-415	-2%	-2%	52

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Table 9. Danish seines/Gillnet/Trawl 12-15m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-5,578	-1,071	-4,506	-694	-3,812	-19%	-27%	359
A2: A1 + handling costs	-5,578	0	-5,578	-694	-4,883	-19%	-34%	359
A3: A1 + new minimum sizes	-3,520	-1,071	-2,449	-483	-2,302	-12%	-16%	265
A4: A1 + increased quota utilisation	-2,517	-183	-2,334	-206	-2,128	-8%	-15%	452
B1: Corresponding quota adjustment	512	8	504	85	419	2%	3%	512
B2: B1 + handling costs	512	1,530	-1,019	85	-1,104	2%	-8%	512
B3: B1 + new minimum sizes	2,264	0	2,264	308	1,956	8%	14%	367
C1: A1 + behavioural changes (25 % less discard landings)	-4,183	-803	-3,380	-521	-2,859	-14%	-20%	269

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

The table above shows the results for vessels that are 12-15 meters long and fishing with Danish seines, gillnet, or trawl. Scenarios A1 and A2 show a decrease in gross margin of 27 and 34 % respectively. New minimum sizes or increased quota utilization, in scenarios A3 and A4, would more than halve the losses in gross margin from the L.O. with no quota top-up compared to a situation with additional handling costs. The fleet segment would experience increases in revenue and gross margin in the case of quota top-ups alone and in combination with new minimum sizes. The fisheries

for important species such as Norway lobster in Kattegat/Skagerrak as well as cod and plaice in Skagerrak and the Baltic Sea are particularly affected by the L.O.

Table 10. Danish seines/Gillnet/Trawl 15-18m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-7,309	-959	-6,350	-1,090	-5,261	-21%	-31%	311
A2: A1 + handling costs	-7,309	0	-7,309	-1,090	-6,220	-21%	-36%	311
A3: A1 + new minimum sizes	-3,620	-959	-2,661	-719	-2,181	-11%	-13%	205
A4: A1 + increased quota utilisation	-5,244	-217	-5,027	-412	-4,615	-15%	-27%	422
B1: Corresponding quota adjustment	542	6	536	171	364	2%	2%	542
B2: B1 + handling costs	542	1,640	-1,098	171	-1,269	2%	-7%	542
B3: B1 + new minimum sizes	3,879	0	3,879	562	3,317	11%	19%	339
C1: A1 + behavioural changes (25 % less discard landings)	-5,482	-719	-4,763	-817	-3,945	-16%	-23%	233

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Results for the fleet of Danish seines, gillnet, or trawl between 15 and 18 meters are shown above. The segment experiences large negative impacts of the L.O. in the A-scenarios. New minimum sizes however can reduce the loss of revenue and gross margin to 11 and 13 % respectively, while increased quota utilization reduces losses in revenue and gross margin to 15 and 27 % respectively. New minimum sizes combined with quota top-ups brings about increases in revenue and gross margin of 11 and 19 %, respectively. A behavioral change reducing discard rates by 25 % can reduce the negative effects of the L.O. without quota top-ups to a 16 % reduction in revenue and 23 % reduction in gross margin compared to the baseline. Although the number of vessels is small (13) in this segment, it sees large absolute impacts of the L.O. as well as in relative terms.

Table 11. Danish seines 12-15m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-1,287	-321	-966	-31	-935	-15%	-15%	97
A2: A1 + handling costs	-1,287	0	-1,287	-31	-1,256	-15%	-21%	97
A3: A1 + new minimum sizes	-965	-321	-643	-31	-932	-11%	-15%	98
A4: A1 + increased quota utilisation	-520	-76	-444	-13	-431	-6%	-7%	109
B1: Corresponding quota adjustment	117	0	117	3	114	1%	2%	117
B2: B1 + handling costs	117	389	-272	3	-275	1%	-5%	117
B3: B1 + new minimum sizes	98	0	98	3	96	1%	2%	117
C1: A1 + behavioural changes (25 % less discard landings)	-966	-241	-725	-23	-701	-11%	-12%	73

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

The economic impacts of the L.O. on Danish seines between 12-15 meters are presented above. This segment operates mostly in Kattegat/Skagerrak. Revenue and gross margin decreases by 15 % each in the A1 scenario. With additional handling costs, the revenue loss is also 15 % while the loss in gross margin is 21 %. If the vessels reduce their catches of previously discarded fish as in scenario C1 losses in gross margin would be slightly reduced compared to A1. Increased quota utilization could reduce losses in revenue and gross margin by about a half compared to in A1. The segment experience modest benefits from quota uplifts although additional handling costs leads to a reduction in gross margin of 5 % as seen in scenario B2.

Table 12. Danish seines 15-18m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-1,164	-310	-854	-98	-756	-11%	-10%	94
A2: A1 + handling costs	-1,164	0	-1,164	-98	-1,066	-11%	-15%	94
A3: A1 + new minimum sizes	-845	-310	-535	-89	-678	-8%	-9%	87
A4: A1 + increased quota utilisation	-561	-60	-501	-44	-457	-5%	-6%	107
B1: Corresponding quota adjustment	112	1	111	11	100	1%	1%	112
B2: B1 + handling costs	112	371	-259	11	-270	1%	-4%	112
B3: B1 + new minimum sizes	165	0	165	20	145	2%	2%	103
C1: A1 + behavioural changes (25 % less discard landings)	-873	-233	-640	-74	-567	-8%	-8%	70

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Above are the economic impacts on the Danish seine vessels between 15 and 18 meters. This fleet segment sees reductions in revenue and gross margin of 11 and 10 % respectively when the L.O. is introduced without quota top-ups. Additional handling costs in scenario A2 reduce the gross margin further. New minimum sizes would reduce losses only slightly compared to A1, whereas better quota utilization reduces losses of revenue and gross margin to 5 and 6 %. A behavioral change reducing catches of previously discarded fish, scenario C1, would reduce revenue and gross margin losses to 8 % each. Quota top-ups alone as well as combined with reduced minimum sizes would increase revenue and gross margin slightly although increased handling costs in scenario B2 reduce the gross margin by 4 %. The activities in the Baltic Sea and Kattegat/Skagerrak are the ones most affected by the L.O.

Tabel 13. Trawl 12-15m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-25,909	-2,004	-23,905	-2,629	-21,276	-28%	-48%	813
A2: A1 + handling costs	-25,909	0	-25,909	-2,629	-23,280	-28%	-52%	813
A3: A1 + new minimum sizes	-10,999	-2,004	-8,995	-1,328	-8,660	-12%	-19%	399
A4: A1 + increased quota utilisation	-11,227	-573	-10,654	-750	-9,904	-12%	-22%	1,275
B1: Corresponding quota adjustment	1,569	5	1,563	193	1,371	2%	3%	1,569
B2: B1 + handling costs	1,569	3,716	-2,147	193	-2,340	2%	-5%	1,569
B3: B1 + new minimum sizes	15,042	0	15,042	1,612	13,429	16%	30%	765
C1: A1 + behavioural changes	-19,291	-1,503	-17,787	-1,972	-15,816	-21%	-35%	610

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

The table above shows the economic impacts on trawlers between 12 and 15 meters. When implementing the L.O., this group is affected the most in relative terms. Here, revenue and gross margins are reduced by 28 and 48 % respectively. With additional handling costs in scenario A2, gross margin decreases by 52 %. New minimum sizes or increased quota utilization would approximately halve the losses. The L.O. combined with new minimum sizes would reduce gross margin by 19 % while the L.O. combined with increased quota utilization would reduce gross margin by 22 %. On the other hand, significant increases in earnings are seen if the L.O. is combined with both a quota top-up and new minimum sizes (scenario B3) with an increase in gross margin of nearly a third. C1 shows the effect of reducing the catch of previously discarded fish by 25 % which would assist in reducing the losses from 48 % loss in gross margin in A1 to a 35 % loss in C1.

Table 14. Trawl 15-18m

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-38,520	-1,780	-36,741	-3,103	-33,637	-22%	-37%	1,299
A2: A1 + handling costs	-38,520	0	-38,520	-3,103	-35,417	-22%	-39%	1,299
A3: A1 + new minimum sizes	-16,407	-1,780	-14,627	-1,588	-14,035	-9%	-15%	671
A4: A1 + increased quota utilisation	-16,819	-586	-16,233	-770	-15,463	-10%	-17%	1,995
B1: Corresponding quota adjustment	2,435	7	2,428	346	2,082	1%	2%	2,435
B2: B1 + handling costs	2,435	3,357	-923	346	-1,268	1%	-1%	2,435
B3: B1 + new minimum sizes	22,916	0	22,916	1,930	20,986	13%	23%	1,211
C1: A1 + behavioural changes (25 % less discard landings)	-29,026	-1,335	-27,691	-2,327	-25,364	-17%	-28%	974

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Economic effects for trawlers of 15-18 meters are shown above. The group experiences large losses in revenue of 22 % in scenarios A1 and A2. Losses in gross margin are 37 % in A1 while the increased handling costs in A2 decrease the gross margin further to 39 %. New minimum sizes or increased quota utilization in a situation without quota top-ups could reduce economic losses in terms of both revenue and gross margin by more than a half. The segment would on the other hand gain 23 % in gross margin if the L.O. was implemented with quota top-ups while revenue would increase by 13 % relative to a situation without the L.O.

The table below shows the economic impacts on the fleet segment between 18 and 24 meters fishing with trawl. This segment is one of the most affected segments in the analysis. The segment targets, among other species, Norway lobster but with discard rates as high as 55 %. The segment experiences reductions in gross margin of 29 and 32 % depending on whether increased handling costs are taken into account. New minimum sized or increased quota utilization would reduce the losses considerably. Reducing discard rates by 25 % would reduce losses more moderately. If the L.O. is implemented with quota top-ups, the segment sees small benefits, while additional handling costs in B2 reduces gross margin slightly. Quota top-ups combined with new minimum sizes would however increase revenue and gross margin by 8 and 15 % respectively.

Table 15. 18-24m trawl

	DKK 1,000[1] or %							*ton*
	changes in							
Scenarios	**Δ Revenue**	**Δ Var. costs**	**Δ Profitability**	**Δ Wages**	**Δ Gross margin**	**Δ Revenue**	**Δ Gross margin**	**Discard landings**
A1: Effort reduction (no quota adjustment)	-39,307	-2,796	-36,511	-4,330	-32,181	-17%	-29%	1,414
A2: A1 + handling costs	-39,307	0	-39,307	-4,330	-34,977	-17%	-32%	1,414
A3: A1 + new minimum sizes	-20,754	-2,796	-17,958	-2,580	-17,151	-9%	-15%	919
A4: A1 + increased quota utilisation	-16,555	-1,080	-15,475	-1,518	-13,957	-7%	-13%	1,831
B1: Corresponding quota adjustment	2,230	61	2,169	268	1,901	1%	2%	2,230
B2: B1 + handling costs	2,230	4,509	-2,279	268	-2,547	1%	-2%	2,230
B3: B1 + new minimum sizes	18,417	0	18,417	2,024	16,393	8%	15%	1,262
C1: A1 + behavioural changes (25 % less discard landings)	-29,410	-2,097	-27,313	-3,248	-24,066	-13%	-22%	1,060

[1] €1 = DKK 7.5

Source: Own calculations based on Statistics Denmark, The AgriFish Agency, DTU Aqua, etc.

Overall, implementing the L.O. without quota-top ups (A-scenarios) will cause reduced revenues and profitability in the Danish fisheries. In that case, the fisherman has to replace target fish with previously discarded fish on the same quota. It will take fewer trips to fill the quota. Effort and therefore also variable costs are reduced. However, in the analysis it is assumed that non-target fish sell for a lower price than target fish for human consumption and thereby revenue is reduced. If it is assumed that handling and sorting non-target fish carries an additional cost, revenue and profitability decrease further. However, if minimum sizes on cod and Norway lobster are reduced, part of the previously under-sized and therefore discarded catch can be sold at consumption prices increasing revenue and reducing the overall losses from the L.O. Additionally, another scenario without quota top-ups but higher quota utilization analyses the effects of increasing utilization in order for the fishermen to better exploit the opportunities in their quotas. This would reduce losses from the L.O. The effect of this of course depends on the level of quota utilization in the starting point. In the absence of new minimum sizes or increased quota utilization, a technically imposed behavioral change reducing discard rates by 25 % alleviates losses.

If implementing the L.O. without quota top-ups but in combination with reduced minimum sizes or by fishermen increasing their quota utilization losses can be reduced considerably, some places by more than 50 %.

Increasing the quotas with the previously discarded amounts alleviates many of the potential losses and does under certain assumptions bring about economic gains for the fisheries. The latter especially refers to scenarios of reduced minimum sizes where previously discarded cod and Norway lobster can now be sold at consumption prices.

The areas most affected by the L.O. are the Baltic Sea and Kattegat/Skagerrak while the fisheries in the North Sea are less impacted. By vessel group, small and medium sized trawlers are the ones most affected by the L.O. Here, the decrease in revenue is on average 20 %, while the decrease in gross

margin is between 30 and 50 %. Trawlers overall are indeed the group most affected experiencing revenue decreases of between 17 and 28 % and decreases in gross margin between 27 and 48 %.

Because of high discard rates and highly valuable target catches for consumption, the fisheries for Norway lobster and cod in Kattegat as well as cod and plaice in the Baltic Sea and Skagerrak are affected the most by the L.O.

Discussion and future work

This paper analyzes the short-term economic consequences of the L.O. for the Danish fishing fleet. The analysis is carried out as if the full L.O. was implemented in 2013. The analysis assumes fixed fishery patterns, fishing prices, and fishing costs. Further, the analysis does not take into account changes in the fish stocks and possible changes in quotas in the Danish fishery. In the longer run, however, these assumptions do not necessarily hold. Therefore, dynamic analyses of impacts in the longer run are needed e.g. allowing stock effects and quota changes. For example, assuming full compliance with the L.O., the quota market will change as a consequence of the necessary complete matching by all vessels of all quotas to catch (Andersen et al., 2014).

Future work on the L.O. is linked to the EU project Discardless (www.discardless.eu) which aims to assess the impacts of stock effects, technology changes, complex behavioral changes as well as imperfect control and enforcement on discarding. The project is led by DTU-Aqua, while the Department of Food and Resource Economics at the University of Copenhagen leads the economics work package. Ongoing work includes an assessment of long-run impacts of the L.O. on Danish fisheries by Hoff and Frost (2016, forthcoming). This explores adjustments to changing quota availability for a range of different scenarios assuming different management measures under the L.O., including reduced minimum sizes and a de minimis exemption. Indeed, how the de minimis exemptions are interpreted and implemented affects how fisheries will perform under the L.O. This also relates to the issue of choke species in quota managed fisheries. A de minimis exemption could e.g. allow discarding of what would normally be a choke species. As discussed by Andersen et al. (2014), the L.O. and the choke species problem in particular will influence the quota market as catches have to be matched by quotas. Further analysis could look into how quota markets will develop under the L.O. Future work will also include the impact of various management systems in achieving efficient discard reductions, investments in more selective gear, and the impact of varying degrees of non-compliance.

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