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Ágrip

Í skýrslunni er fjallað um meðafla í úthafsrækjuveiðum (Pandalus borealis) norður af Íslandi og borin eru saman þrjú aðgreind tímabil. Á fyrsta tímabilinu (til ársins 1995) voru úthafsrækjuveiðar stundaðar án skilju og fisk landað með rækjuaflanum sem var þá ekki hátt hlutfall af heildaraflanum. Annað tímabil hófst þegar seiðaskilja (Nordmøre grid) var sett í gildi með reglugerð árið 1995 en þá hvarf allur meðafli í löndunartölum rækjubáta. Síðasta tímabilið hófst árið 2005 þegar leyfi var veitt fyrir notkun á yfirpoka sem var settur yfir sleppigat skiljunnar og safnaði hann fiskum sem ekki smaug í gegnum möskva hans. Það var hins vegar ekki skilda að nota yfirpokann. Áður en leyfi var veitt fyrir notkun yfirpokans fór fram prófun á virkni hans. Í þeirri prófun mátti sjá að magn fisks undir viðmiðunarlengd hækkaði ekki við notkun yfirpokans. Einnig kom í ljós að meðafli óæskilegra tegunda jókst lítið. Á því tímabili sem yfirpoki hefur verið í notkun hefur stofnstærð rækju lækkað og þorskstofninn stækkað sem olli því að hlutfall fiskafla í rækjuveiðum hækkaði. Þá var aftur farið að landa grálúðu, þorsk og nokkrum öðrum fiskitegundum og nú í hærra hlutfalli og með stærri hlutdeild í aflaverðmæti en á fyrsta tímabilinu þegar engin skilja var notuð. Með innleiðingu yfirpokans var ekki verið að gera fiskveiðistjórnun flóknari þar sem reglur sem snúa að notkun hans eru skýrar, en hinsvegar hefur innleiðingin orðið til þess að auka sveigjanleika og hagkvæmni veiðanna í heild.

Abstract

This report examines bycatch of the main commercial species in the offshore shrimp fishery (Pandalus borealis) in Icelandic waters. This fishery has gone through three distinct regulatory periods, which show clear differences in bycatch composition. Before 1995, bycatch landings from shrimp fisheries were common. The mandated introduction of the Nordmøre grid in 1995 prevented catching those bycatches as the gear then did not select all larger fish. Only after the voluntary use of a 135mm mesh collection bag over the grid escape was allowed, did bycatch landings resume. The allowance made for using the collection bag is the result of a trial undertaken in 2005, which showed that the number of commercial fishes under the minimum reference length (MRL) did not increase while using the collection bag; therefore, the gear did not heavily impact juveniles of commercial species. The effect on unwanted non-commercial species passing through the grid was also minimal. Now, due to the decline of the shrimp stock and an increase in the cod stock,

proportionally higher bycatch is observed in this shrimp fishery. As a result, the landings value of cod and Greenland halibut as bycatch to the shrimp fishery is higher compared to the time before the grid was mandated. From the perspective of improving fisheries management within Iceland, the addition of the collection bag does not create complications, and instead provides benefits of increased revenue and flexibility for shrimp fishers and increased efficiency in the fishery system as a whole.

Lykilorð: *Shrimp fishery, bycatch, Nordmøre, pandalus borealis, collection bag.*

Undirskrift verkefnisstjóra:	**Undirskrift forstöðumanns sviðs:**
	

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Introduction

Like in many countries, northern shrimp (*Pandalus borealis*) are fished with bottom trawls in Icelandic waters. This method can result in a large amount of bycatch, often composed of multiple small-sized species or juvenile gadoids. To minimize unwanted bycatch, a Nordmøre grid (Isaksen et al., 1992) has been mandatory for the offshore shrimp fishery in Icelandic waters since 1995 (Sjávarútvegsráðuneyti, 1995). The grid allows fish that cannot pass through the bars to escape through an opening at the top of the grid. The main reason the grid was made mandatory in 1995 was a high capture rate that year of juvenile redfish *Sebastes* sp. as bycatch (as well as small Atlantic cod, *Gadus morhua,* in some cases) (Schopka, 2007). In Iceland, a grid with a minimum bar space of 22 mm was used for the offshore shrimp fishery, although in other northern countries spacing of 19 mm is more common. The 22 mm bar spacing aimed to exclude all commercial fish species larger than 20 - 30 cm, such as cod or Greenland halibut *Reinhardtius hippoglossoides*, from the catch, and did so effectively. Before the grid regulation, bycatch landings from the offshore shrimp fishery reached hundreds of tonnes every year. Once the grids were mandatory, bycatch landings dropped to zero.

However, in the early 2000s, the TAC for offshore shrimp declined relatively fast (MFRI, 2018a), so in 2005, the industry requested an experimental trial using a collection bag over the exit opening of the Nordmøre grid. The goal was to justify this gear modification could be used to collect larger sizes of commercially valuable fish that otherwise escaped from the gear, with minimal impacts to juveniles and non-commercial species. The main incentive for using the collection bag was to make the fishery more profitable in times of low shrimp quota and landings, as a long-standing discard ban, and general fishing permits allowed revenue to be gained from 'bycatch' species. Due to favourable results from a trial using a collection bag with a mesh size of 135 mm, an allowance was mandated for the offshore shrimp trawlers to use a collection bag with 135 mm mesh size (inside measure) in July 2005 (Sjávarútvegsráðuneyti, 2005). However, this gear modification was not put into commercial use until the year 2008, when the shrimp fishery revived from close to no activity.

The study presented in this report illustrates the results of the experimental trial. It also shows how offshore fishery operations have changed over time in response to modifications in gear restriction regulations. In this report, the offshore shrimp fishery is analysed by using logbook and survey data to compare three periods of operations under different gear restrictions: 1) before using grids, 2) when only grids were used and 3) while using grids with collection bags.

Material and Methods

This report draws its conclusions from three separate analyses: 1) an examination of an experimental fishing trial conducted in 2005, 2) an analysis of reported catches in logbook data, and 3) an investigation of bycatch quantities from annual shrimp surveys conducted by the Marine and Freshwater Research Institute of Iceland (MFRI).

Fishing trial: A trial of a collection bag in 2005

A fishing trial was performed on board the shrimp stern trawler Andey ÍS-440, a 45-meter-long vessel with 1325Hp. The trial took place from the 16th to 21st of February 2005. Ten hauls were taken in the "Skagafjörður Deep" ("Ormagryfjan") (Figure 1) at depths from 460 to 612 meters where the bottom temperature was near 0°C. Towing time was generally 10-11 hours, with the collection bag always in place over the sorting grid.

A conventional shrimp trawl (3800 meshes in circumference) with a door spread of 54 meters and headline height of 15 meters was used. A Nordmøre grid with 22 mm bar spacing was placed in front of the codend as required by regulation. In addition, a collection bag made with 135 mm mesh (the opening of mesh, 145 mm full length of the mesh) was mounted over the sorting grid's exit (Figure 2), with the intention of retaining fish of commercial value. The collection bag was designed from a drawing by Wileman et al. (1996) who had suggested the design based on selection trials (Wileman et al., 1996; Figure 4.2.6.2).

For each haul, the number of individuals for all fish species were counted. For Greenland halibut, cod and some other species, length measurements from both the codend and the collection bag were taken. The shrimp catch, and main fish species total weight was estimated by the fishermen at sea and the total catch weighed when landed. Furthermore, a subsample of shrimp was length measured from the codend.

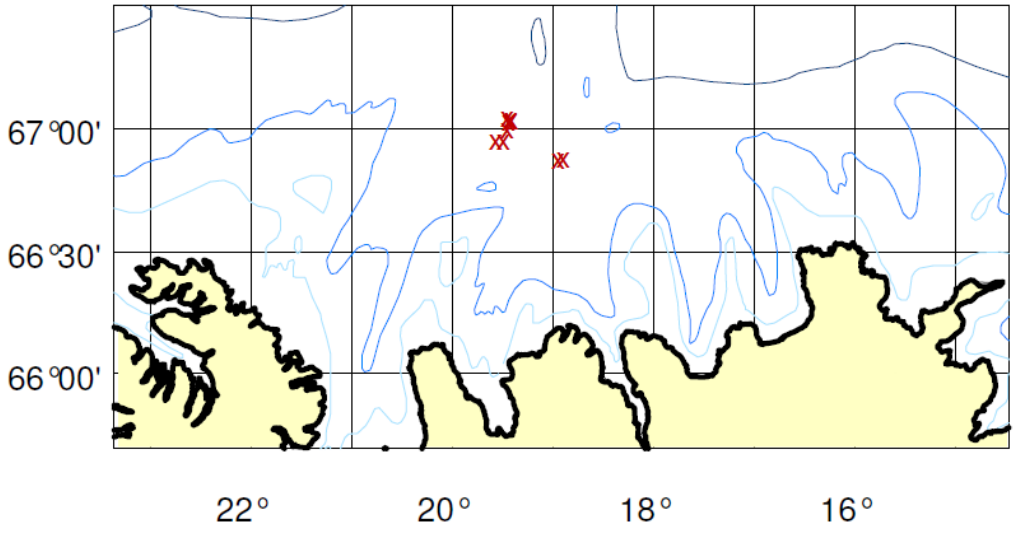

Figure 1. Study locations in the "Skagafjörður Deep" ("Ormagryfjan") north of Iceland. Depth contours at 100, 200 and 1000 m are shown.

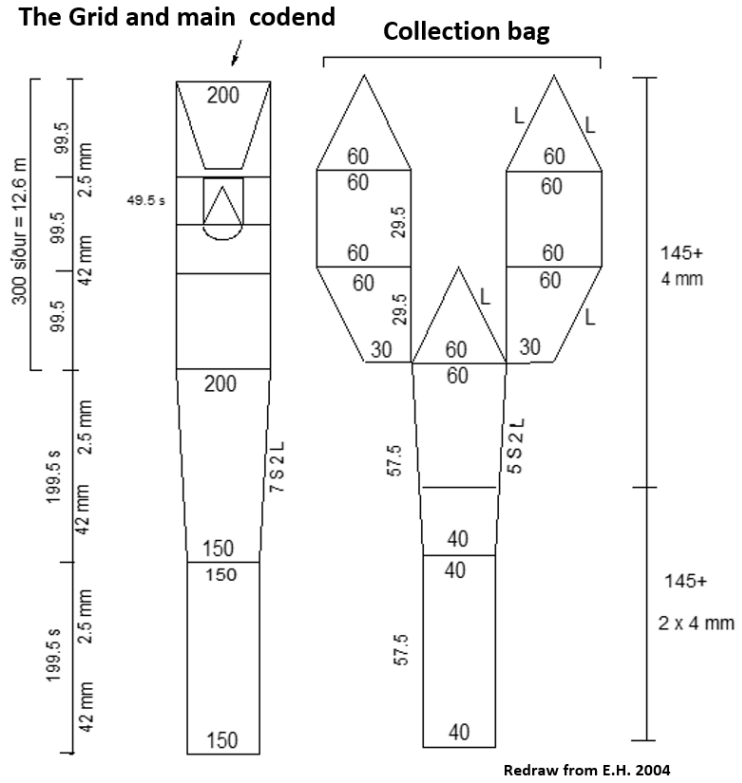

Figure 2. Layout drawing of the codend and collection bag. Mesh sizes are given in full mesh size, so that 145+mm is the same as approximately 135mm when measured inside, and 42+mm is approximately 37mm inside. Design *from a drawing by Wileman et al. (1996). Redraw with permission from Einar Hreinsson 2004.*

Logbook Data: Calculating the value of shrimp vs fish catch over time

The Icelandic logbook database contains mandatory registration of every fishing operation with information like time, location, effort and catch composition. These data were used to extract information on the annual catch composition by species in the offshore shrimp fishery.

Unfortunately, recording the use of collection bags is not required in the logbook entry. Therefore, direct analysis of catch composition with respect to usage of a collection bag could not be achieved. Instead, annual catch composition data were evaluated relative to three periods that differed based on legislation and changes therein:

- **-1994**: Prior to the year 1995 sorting grids were not mandatory.
- **1995-2008**: 22mm sorting grid was mandatory, collection bags were not used.
- **2008-**: 22mm sorting grid continued to be mandatory. Collection bags were allowed but not mandatory.

In addition to the catch composition, the relative economic value of the catch was estimated by using the following cod equivalent conversion factors for the catch by species:

Table 1. The 2018 exchange value of the main species in the shrimp fishery. Cod has a value of 1 and other species are calculated in comparison to cod by the economic value. This rate is used in the Icelandic ITQ system for the exchange of species between quota owners.

Species	***value***
shrimp	1.17
cod	1.00
G. halibut	2.43
other	0.50

These values reflect the current species “exchange value” in the Icelandic ITQ system and are used to implement a variety of other regulatory applications (Fiskistofa, 2018). They are designed to reflect relative economic value, as their calculation is based on the previous year’s price data. In this study, these exchange rates were used to convert the proportional contribution to a vessel’s catch of each species by weight into the proportional contribution of each species to the catch’s total economic value.

Data analysis: Catch composition in the annual surveys of offshore shrimp

During the annual shrimp survey, haul samples from fixed stations were taken with a standard survey trawl (Jónsdóttir, 2018). The annual mean catch rate by species per standardized tow duration was calculated using the 'smean.cl.boot' function from the Hmisc-package in the statistics program R (Harrell et al. 2018, RCoreTeam, 2014).

Results

Fishing trial

The catch composition from the trial 1995

There were ten hauls taken in the trial trip during a period of good weather. The collection bag over the exit of Nordmøre grid had no effect on the performance of the grid itself. As expected the main catch was shrimp in all hauls. Shrimp was only in the main codend where the catch ranged from 140 to just under 460 kg/h (Table 2). As is common in the shrimp fishery there were many small-sized fish mixed with the shrimp catch. A total of 27 species (Tables 2-4), both juveniles of commercially valuable species and other small-sized species. In the collection bag mostly larger species like cod, Greenland halibut and thorny skate (Amblyraja radiata) were found. A total of 18 species were identified in the collection bag (Tables 2-4). Four of those fish species were landed (cod, Greenland halibut, thorny skate and the spotted wolffish Anarhichas minor) and all came from the collection bag. The total weight of bycatch fish species was just under 6 tonnes (Table 3).

Table 2. The main catches at each tow station in kg, as estimated on board (not weighed).

Haul no. (tow duration)	Shrimp (kg/hour)	Cod (kg/hour)	Greenland halibut (kg/hour)
1. (9:18)	2500 (269)	150 (16)	50 (5)
2. (11:28)	3350 (292)	100 (9)	100 (9)
3. (8:45)	4000 (457)	850 (97)	250 (29)
4. (12:08)	2800 (231)	600 (49)	150 (12)
5. (11:05)	2800 (253)	100 (9)	100 (9)
6. (11:16)	2500 (222)	350 (31)	100 (9)
7. (11:25)	2300 (201)	150 (13)	100 (9)
8. (10:53)	2000 (184)	100 (9)	100 (9)
9. (10:06)	1400 (139)	100 (10)	70 (7)
10. (9:54)	2100 (212)	100 (10)	100 (10)
Sum of total	25.750	2600	1120

Table 3. Catches (in kg) of the main landed species. Shrimp are shown in two size classes, small shrimp with more than 200 individuals per kg and larger shrimp with less than 200 shrimp per kg. Total catch was weighed at certified landing stations.

Shrimp (>200pcs/kg)	Shrimp (<200pcs/kg)	Cod	Greenland halibut	Thorny skate	Spotted wolffish
2853	18646	3080	1090	1752	29

The use of the collection bag increased the number of landed, commercially viable groundfish significantly. However, only two of those species were recorded as originating only from the collection bag (spotted wolffish and plaice *Pleuronectes platessa*). Just over half the total number of cod were caught in the collection bag, as well as almost all Greenland halibut and thorny skate (over 90%, Table 4). Small-sized fish were mainly found within the main codend after going through the grid, including juveniles of redfish species, the greater silver smelt *Argentinus silus* and the long rough dab *Hippoglossoides platessoides*.

Table 4. Commercial groundfish species (total number of individuals) from all hauls in each codend and proportion in each codend.

	Numbers			Rate (%)	
Species	**Main codend**	**Collection bag**	**Total**	**Main codend**	**Collection bag**
Cod	1202	1694	2896	41,05	58,5
Greenland halibut	23	811	834	2,8	97,2
Haddock (Melanogrammus aeglefinus)	1		1	100	
Golden redfish (Sebastes norvegicus)	112	18	130	86,2	13,8
Norway redfish (Sebastes viviparus)	16		16	100	
Demersal beaked redfish (Sebastes mentella)	4		4	100	
Spotted wolffish		7	7		100
Greater silver smelt	93		93	100	
Plaice		3	3		100
Long rough dab	555	73	628	88,4	11,6
Thorny skate	104	1582	1686	6,2	93,8

There were not many pelagic species in the catch, only herring (*Clupea harengus*), capelin (*Mallotus villosus*) and lumpfish (*Cyclopterus lumpus*). They are believed to enter the trawl while setting or hauling in, but might also in some cases enter the trawl at the towing depth. All herring and capelin were only in the main codend as their size allows them to pass the grid (Table 5). The mesh size in the collection bag is also large enough for those species to escape. The lumpfish, however, have no possibility to pass through the grid or the 135 mm meshes in the collection bag, and are therefore caught there, but never seen in the main codend.

Table 5. Commercial pelagic species (total number of individuals) from all hauls in each codend and proportion in each codend.

Species	In numbers			Rate (%)	
	Main codend	*Collection bag*	*Total*	*Main codend*	*Collection bag*
Herring	*68*		*68*	*100*	
Capelin	*507*		*507*	*100*	
Lumpfish		*13*	*13*		*100*

Non-commercial fish species (i.e., with no economic value) are very common in all northern shrimp fisheries. These are in most cases small-sized species who easily pass through the grid systems, including Nordmøre grids with 22 mm bar spacing. This was supported by the results of the 2005 trial, in which hundreds of individuals of seasnail and eelpout were found in every haul and mainly in the main codend. Only a few of those species were in the collection bag (Table 6), two of which were mainly recorded in the collecting bag (northern wolffish and arctic skate).

Table 6. Non-commercial fish species* (total number of individuals) from all hauls in each codend and proportion in each codend.

Species	*Numbers*			*Rate (%)*	
	Main codend	*Collection bag*	*Total*	*Main codend*	*Collection bag*
Northern Wolffish		*1*	*1*		*100*
Arctic cod	*2377*		*2377*	*100*	
Silver rockling	*186*		*186*	*100*	
Longfin snailfish	*12446*	*1*	*12447*	*100*	
Gelatinous seasnail	*1573*	*2*	*1575*	*99,9*	*0,1*
Montagu's seasnail	*327*	*1*	*328*	*99,7*	*0,3*
Mailed sculpin	*70*		*70*	*100*	
Atlantic poacher	*1089*		*1089*	*100*	
Arctic eelpout	*682*	*3*	*685*	*99,6*	*0,4*
Esmark's eelpout	*313*	*3*	*316*	*99,1*	*0,9*
Longear eelpout	*1196*	*1*	*1197*	*99,9*	*0,1*
Vahl's eelpout	*613*		*613*	*100*	
Doubleline eelpout	*8688*	*11*	*8699*	*99,9*	*0,1*
Pale eelpout	*994*	*1*	*995*	*99,9*	*0,1*
Lanternfish	*207*		*207*	*100*	
Lancet fish	*85*		*85*	*100*	
Arctic skate	*1*	*106*	*107*	*0,9*	*99,1*

**Latin names of the species in this table is given in Appendix I.*

Length distribution of main species

The target species in the trial trip, northern shrimp, composed most of the catch. It's average carapace length distribution mostly ranged from 12 to 22 mm, with a few individuals reaching up to 28 mm (Figure 3).

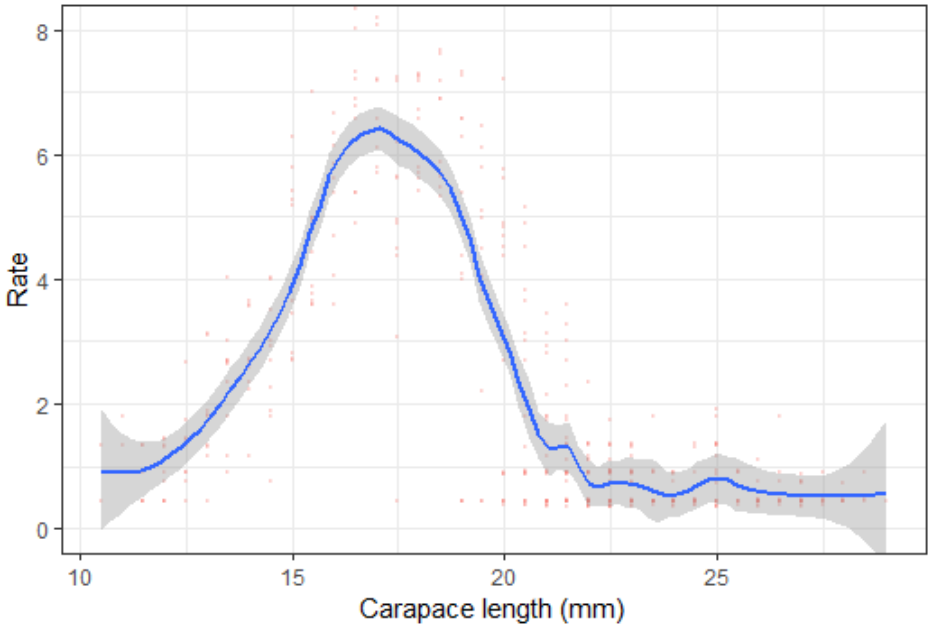

Figure 3. Shrimp catch composition by carapace length (mm). Small dots are the frequency of shrimp carapace length by the station. The line is smoothed average rate by carapace length with the grey area as the uncertainty limits between those 10 stations.

Length measurements were taken of the main commercial fish species in the catch, like cod and Greenland halibut. Cod smaller than 30 cm passed the 22 mm grids and were retained in the main codend where the average length of cod was 20.8 cm. In the collection bag, the cod were larger than 50 cm with a mean length of 65 cm and a maximum of 88 cm (Figure 4a). Only 23 Greenland halibut passed the grid system and were in the main codend. These were small Greenland halibut with an average 31 cm length and therefore of low economic value. In the collection bag, most of the Greenland halibut were larger than 40 cm with an average size of 53.7 cm and maximum size up to 78 cm (Figure 4b). Three redfish species were length measured (Figure 4c). Most of them (132 in total) were observed in the main codend. Individuals smaller than 17 cm passed the grid, leaving an average length in the main codend at 12 cm. In the collection bag, the smallest redfish recorded was 28 cm and the average length was 36.7 cm, but only 18 individuals in total were caught. For long rough dab, 422 individuals

were in the main codend with an average length of 17.8 cm. Fewer were in the collection bag (73 in total) with an average length of 35.8 cm (Figure 4d).

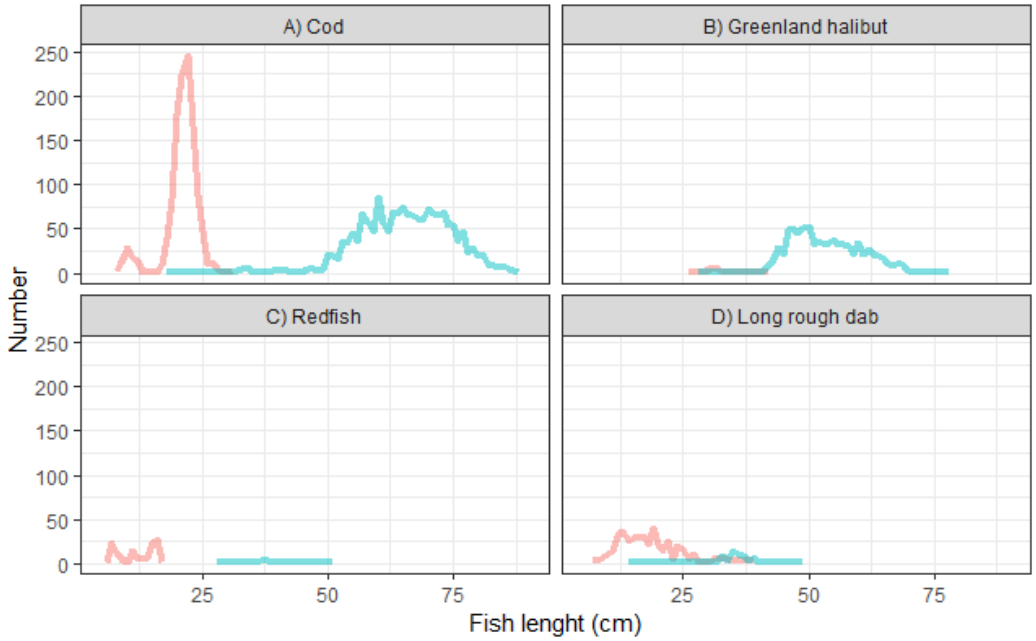

Figure 4. The total number of four main bycatch species by length summarized from all 10 tow stations. Red line, the main codend. Turquoise line, collection bag.

Commercial catch

Shrimp catches varied considerably over time, being much lower after 2004 (Figure 5A). In the period prior to 1995, before the mandatory sorting grid requirement, some bycatch of fish species was reported although their contribution to the total catch was low relative to the high shrimp catches (Figure 5B). In the period 1995-2007, when sorting grids were mandatory but no collection bags were in use, no fish bycatch was reported. With the commencement of collection bag usage in 2008, fish bycatch was again reported.

Given the relatively low shrimp catches in the most recent period, the contribution of fish bycatch to the total catch's value is quite significant: it accounts for nearly 30% (Figure 5C). This is relatively higher than in the period prior to the implementation of the grid (before 1995), when it accounts for generally less than 10% of the total catch's value.

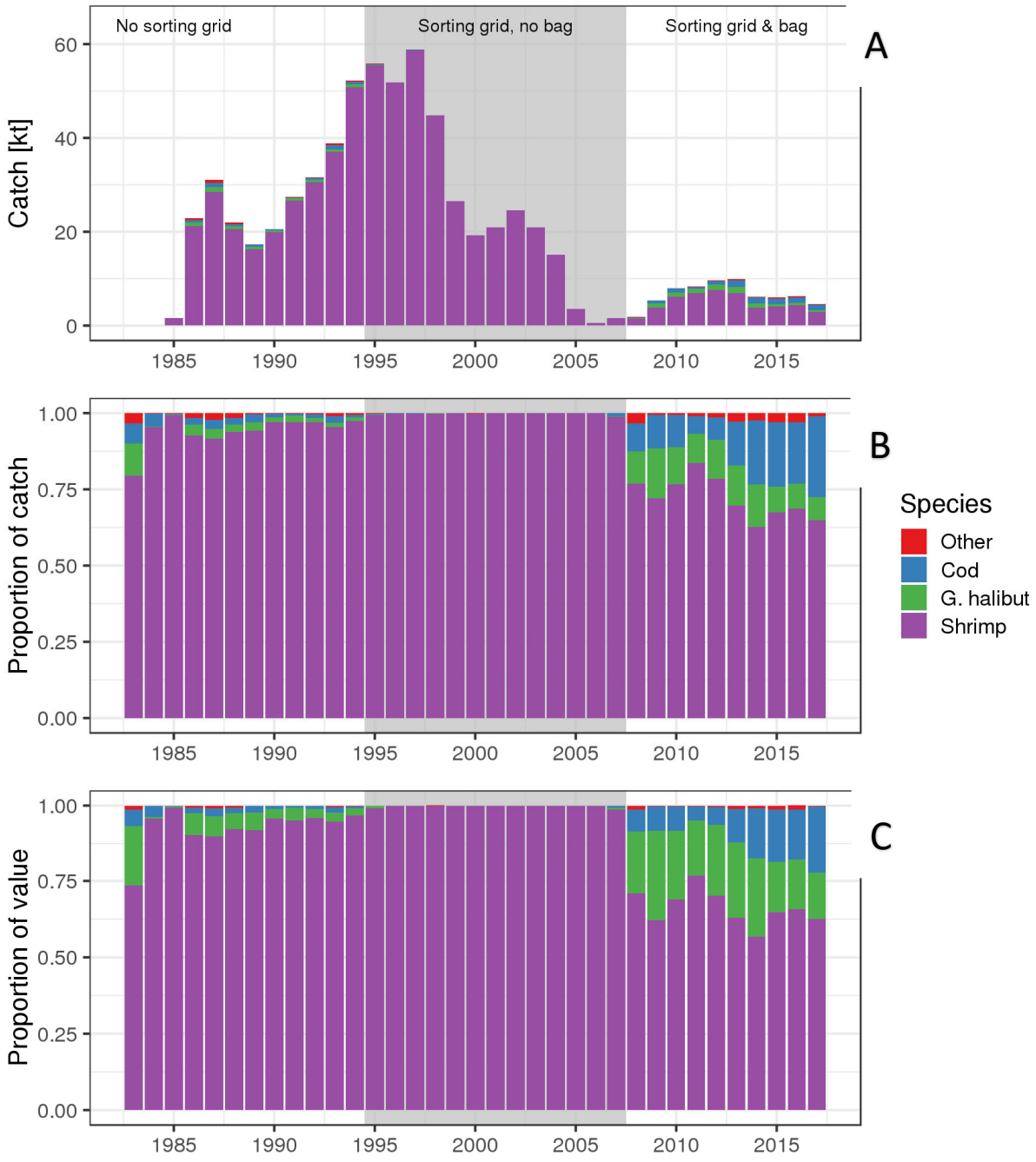

Figure 5. The top panel (A) shows the total catch in thousands of tonnes by years from the offshore shrimp fleet including bycatch. The centre panel (B) shows the proportion of total catch by year and species. The bottom panel (C) shows the proportion of total value between the species by year. The grey area in the centre of all figure panels indicates the period the sorting grid was mandatory, but no collection bag used. Shrimp are shown in purple, Greenland halibut in green, cod in blue and other species in red.

Survey indices

Over the entire study period, the standardized catch per haul in the shrimp survey generally shows that the shrimp biomass has decreased over time while there has been a substantial increase of cod in the area covered by the shrimp survey (Figure 6). Prior to implementation of the sorting grid, cod was almost absent in the survey area. Cod abundance was somewhat

higher, although variable, in the period when sorting grids became mandatory, and then increased substantially during the period when using collection bags was practiced in the fishery.

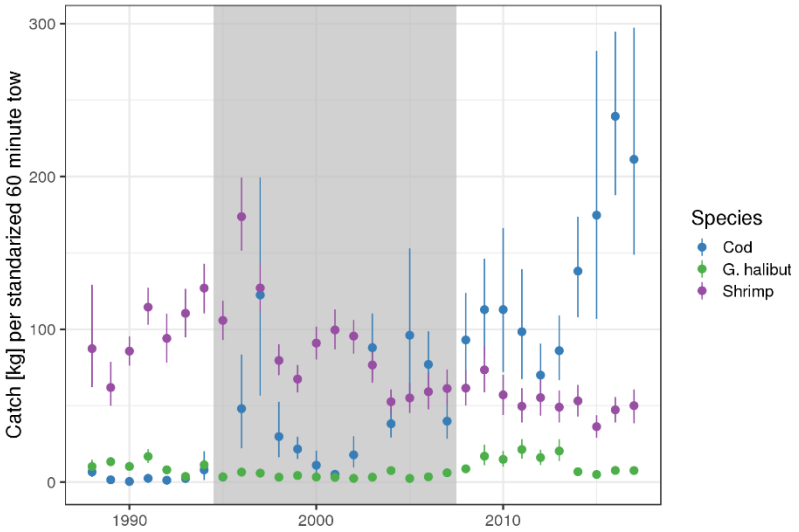

Figure 6. Results from the catch of standard 60-minute survey towing by year. The dots are estimated mean catch in kg of the dominant three species (cod=blue, Greenland halibut=green, shrimp=purple). The vertical lines are 95% confident interval of the estimated mean. The grey area covers the time interval when the sorting grid was mandatory to use but collection bags were not allowed. The sorting grid system was never used in standard survey trawling.

Discussion

Characteristics of the three time periods

The three different time periods show very different characteristics in terms of total volume of catch, the rate of bycatch as well as how regulations affected catch composition and value. In the period before the sorting grid became mandatory, there was an increase in shrimp catches and a rising number of vessels participating in the fishery (MFRI, 2018a). The added value of bycatch was of little interest at that point because the healthy shrimp catches sustained the industry. After the regulatory change requiring sorting grids was imposed in 1995 due to the high bycatch of juvenile redfish and gadoids, commercially viable bycatch became zero. In the early years after the sorting grid became mandatory, the shrimp catches were still high. However, with declining TACs for shrimp, economic pressure on the fishery started to mount.

By 2005 only a few vessels where left participating in the offshore shrimp fishery (MFRI, 2018a). At that time, an interest was aroused in increasing the economic viability of the shrimp fishery by retaining commercially valuable fish that were escaping through the sorting grid.

Retaining this commercial 'bycatch' would increase the catch weight and value while retaining the same unit of effort. After the allowance of collection bags, total fishing effort and TAC remained low, but fishery revenues have become roughly 1.8 times more valuable when the collection bag is used. Likely as a result, more vessels have re-entered the fisheries since using the collection bag was made legal. However, a direct relationship between the added value and increased participation is difficult to support with the existing data, as not all vessels use the collection bag. Nonetheless, if the TAC for shrimp remains low, increased revenue per unit effort through use of a collection bag can be an incentive for entering or remaining in the offshore shrimp fishery.

The experimental fishing trial in 2005

The trial was requested by the industry and there were no strong arguments against it, as there was no intention to undo benefits gained by the sorting grid in terms of a reduction in mortality of juveniles of commercially important species and other small-sized species. Cod and Greenland halibut had likewise been valuable bycatch species before the implementation of the grid. In addition, since they were the target species of a bottom trawl fishery using 135 mm codends in the same and nearby areas, the use of a cover over the grid with the same mesh size as used by the fish trawler was an easy choice to justify. The length distribution of species in the collection bag was similar to the length distribution expected from a 135 mm codend in the groundfish bottom trawl. The selectivity functionality of the collection bag mimics a groundfish bottom trawl codend used for targeting cod and Greenland halibut. Cod had an average length of 65 cm, with only a few individuals under the minimum reference length (MRL) of 55 cm. Equally, Greenland halibut had an average length of 53.7 cm, which was above the MRL of 50 cm. Redfish and long rough dab also had marketable landing sizes. The size classes between the juveniles that had passed through the grid and the fish retained in the collection bag where largely missing in the 2005 study, indicating that those individuals likely escaped through the meshes of the collection bag, as intended.

If the vessel has a quota for the species retained in the collection bag, there is nothing in Icelandic fishing regulations to suggest that the use of the collection bag should be prohibited, as long as catches are above the MRL. Furthermore, the collection bag seemed to have no effect on the shrimp catches themselves. The length distribution of shrimp observed in experimental trial fishing with the collection bag was in line with what would be expected from the trial area (Figure 3).

Unwanted non-value species like arctic skate, northern wolffish and lumpfish were found in the collection bag (Table 5 and 6). Those species don´t have a swim bladder and may have a

low mortality rate after discarding, but there are limited data to support this. It should be noted that if a trawler was trawling for cod and Greenland halibut in the same fishing ground, the likelihood for bycatch of large-sized non-value species would be similar, if not more, due to the faster trawling speed and larger trawls. Almost all other non-commercial fish species were in the main codend (Table 6) as they passed through the sorting grid. Therefore, the use of the collection bag would not change the bycatch species of the shrimp fisheries. Instead, it can be expected when using a collection bag with 135 mm mesh size to catch some proportion of individuals of most species entering the collection bag if larger than 25–30 cm, increasing up to almost all individuals if larger than 60 cm. However, individuals smaller than ~25 cm would almost all escape through the meshes of the collection bag. Fish smaller than 20-25 cm can penetrate the 22 mm bar distance on the sorting grids (Figure 4) and are retained in the codend of the shrimp trawl regardless of whether the collection bag is used or not.

The importance of bycatch for the shrimp fishery

The landed volume of bycatch was significantly higher in the last period when the collection bag was allowed, as compared to the first period when sorting grids were not mandatory (Figure 5). No bycatch was landed when sorting grids were mandatory, but the collecting bag was not yet permitted. Under current circumstances, the increased value of the total catch is of some importance to the fishing industry. The additional bycatch might, in some cases, maintain the shrimp fishery as profitable despite low shrimp biomass levels. The increase in cod bycatch in the last period is partly due to overall increased cod biomass levels observed in the annual shrimp survey (Figure 6). Alternatively, there is also a possibility that the fishermen now target fishing grounds where they can expect higher bycatch to make the trip more profitable, and the shrimp fishery more viable. However, potential increased bycatch targeting seems to be a minor factor in explaining higher bycatch rates when compared to the increased abundance of bycatch species.

Environmental effects and management resulting from the use of the collection bag

Revenue per unit effort has increased with the introduction of the collection bag. This increase in efficiency likely leads to a relative reduction in fuel and emissions as well as diminished pressure on benthic habitats. If the collection bag bycatch caught by the shrimp fishery were not allowed and instead caught by the groundfish fishery, it would take around 1000 hours of trawling, additional to trips already made to catch shrimp, to catch the 12kt of bycatch groundfish. This effort level assumes the average CPUE of 2017 as stipulated in the technical report on cod (MFRI, 2018b). Assuming a fuel consumption of 0.5 $^{l}/_{kg}$, the using collection bags saves around 600.000 l of fuel oil annually.

From the perspective of improving fisheries management within Iceland, the addition of the collection bag does not create complications, and instead provides benefits of increased revenue and flexibility for shrimp fishers and increased efficiency in the fishery system as a whole. As the mesh size for collecting valuable bycatch is modelled on the minimum mesh size on the fishery targeting those species, the same rules should apply to it. In area closures prohibiting those codends, the same reasoning should apply to the collection bag. Any changes in regulation concerning the minimum mesh size for in the main fishery should also apply to the collection bag. The bar space of the grid could be reduced to the North Atlantic standard of 19 mm, reducing unwanted bycatch further. Making the collection bag mandatory for all vessels possessing quota for valuable bycatch species could also be considered.

It is assumed that the collection bag does not affect the grid and grid angle. Observation and empirical data are, however, not available. A change in grid angle could lead to more shrimp passing above the grid through the escape opening and subsequently through the large meshes of the collection bag. This, in turn, would reduce overall shrimp catches, lower the CPUE and potentially negate gains made by collecting valuable bycatch. However, if expected catches of shrimp would be below par when using the collection bag, the experienced fleet would have made this fact known, so it is unlikely in this case. However, the rigging and design of the system could be further improved to ensure increased selectivity and ensure that selectivity parameters remain constant over the entire tow length.

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Appendix

Appendix I. Latin name for non-commercial species showed in table 6.

English name	*Latin name*
Northern Wolffish	*Anarhichas denticulatus*
Arctic cod	*Boreogadus saida*
Silver rockling	*Onogadus argentatus*
Longfin snailfish	*Careproctus reinhardti*
Gelatinous seasnail	*Liparis fabricii*
Montagu's seasnail	*Liparis montagui*
Mailed sculpin	*Triglops murrayi*
Atlantic poacher	*Leptagonus decagonus*
Arctic eelpout	*Lycodes reticulatus*
Esmark's eelpout	*Lycodes esmarki*
Longear eelpout	*Lycodes seminudus*
Vahl's eelpout	*Lycodes vahli*
Doubleline eelpout	*Lycodes eudipleurostictus*
Pale eelpout	*Lycodes pallidus*
Lanternfish	*Myctophidae spp*
Lancet fish	*Paralepis coregonoides*
Arctic skate	*Amblyraja hyperborea*

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