The Feeding Ecology of Grey Gurnard, *Eutrigla gurnardus,* off the coast of Scotland.

Abstract

Until recently, little research had been conducted into the feeding ecology of grey gurnard (*Eutrigla gurnardus*), and the species' wider interaction with the ecosystems it inhabits. This study was carried out to address several questions that have recently arisen about the species. Mainly whether the grey gurnard population at Rockall Bank have been predating on the juvenile haddock to a degree that could cause the stock to decline. This was assessed by conducting a stomach contents analysis on a sample of grey gurnard caught on several trawls. The results of this were inconclusive, with only 3 stomachs containing potential haddock remains out of a total of 121 stomachs. However, these results do not completely disprove the hypothesis, as other factors may have influenced the low fish intake in these gurnard. Furthermore, the populations of grey gurnard from Rockall Bank and the Firth of Forth were compared to determine any differences in feeding ecology between the two. It emerged that the two populations were reasonably similar, with smaller size classes consuming less fish and proportionally more invertebrates, while larger size classes had a diet that was predominantly fish, with the fish prey consisting largely of sand eels. Finally, the influence of fish size on prey selection was investigated, with the result showing a clear correlation between increasing fish size and increasing prey mass, likely owing to the greater amount of fish prey that makes up a larger gurnard's diet.

Introduction:

Grey gurnard, *Eutrigla gurnadus*, is a demersal marine species that has a wide distribution throughout the North Atlantic and the North Sea (Vinogradov *et al.,* 2014; Floeter *et al.,* 2005). Until recently little research has focused on the grey gurnard and therefore little is known about population size and life history strategies (Vinogradov *et al.,* 2014). Russian fleets began a commercial fishery for grey gurnard in the North East Atlantic in 1999-2000 which increased research effort into the species (Vinogradov *et al.,* 2014). The emphasis of much of the grey gurnard research is on their feeding behaviour, mainly prey type and quantity but also acoustic patterns associated with feeding (Amorim & Hawkins 2005; Vinogradov *et al.,* 2014; Floeter *et al.,* 2005).

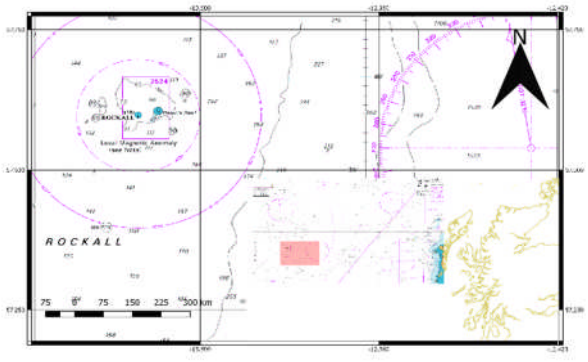


Figure 1: Location of Rockall Bank. Bottom right shows location in regards to rest of UK.

This study focuses on the feeding behaviour of two separate populations of grey gurnard off the coast of Scotland. The first population considered is found at Rockall Bank located 200 miles off the west coast of Scotland in the North East Atlantic. The second is found in the Firth of Forth area of the North Sea off the east coast of Scotland. Both areas are of economic interest to British fishing fleets (Newton *et al.,* 2008; Floeter *et al.,* 2005). Rockall Bank is fairly isolated and so management of fish stocks is difficult. The first major fishery in the area operated by British fleets was for cod, however in the 20th century haddock became of higher commercial interest (Newton *et al.,* 2008). In the 2000's, after some controversy regarding the UK's fishing limits, Russia and Britain were the main countries fishing in the area, with Scottish boats making up the bulk of the fleet (Newton *et al.,* 2008). Rockall Bank haddock is managed as a separate stock unit and due to hydrological conditions eggs or larval haddock from surrounding populations do not reach Rockall (Neat *et al.,* 2011; Newton *et al.,* 2008). In recent years there has been a decline in haddock catches in the Rockall area and therefore research into their wider trophic interactions, as well as possible life history causes has been conducted(Newton *et al.,* 2008). At Rockall haddock recruitment is highly variable from year to year so to try and encourage more reliable recruitment some areas of Rockall have been closed to all fishing activity to try and protect haddock nursery areas (Wright *et al.,* 2010).

Another suggestion for the decline in haddock is that increasing numbers of grey gurnard are predating on juvenile haddock reducing the numbers reaching adult stocks. The aims of this study are firstly to assess the likelihood that grey gurnard are responsible for the decline in haddock at Rockall Bank and secondly to compare the feeding behaviours of two different populations of grey gurnard. Thirdly to assess whether size has any influence on prey selection of grey gurnard. To do this stomach contents analysis was carried along with various measurements taken from the fish.

Methods:

The Rockall Bank investigation was carried out by the vessel MFV *Carina* BF803, which left Kinlochbervie harbour on 16 May 2015 and carried out trawls over the course of 5 days using Carina standard demersal trawl gear with a 20mm internal binder fitted. During this time 24 stations were sampled with one haul of 30 minutes carried out at each station. The maximum depth was 220m, daily start time was 06.00 with all trawling completed by roughly 23.30 each night. See figure 1 for the shoot and haul locations of each trawl. On tows that recorded both haddock and gurnard, stomach samples were taken from one grey gurnard of each size class and frozen for later analysis. The number and lengths of haddock and grey gurnard were also recorded.

The Firth of forth samples are part of a longer running project that has information from 2009 onwards. Due to this along with stomach samples from a number of species, including grey gurnard, intestine, liver and gonad samples were also collected to assess energy reserves and age as well as diet. These samples were also frozen for later laboratory analysis.

Laboratory analysis of most recent samples collected from 2015 at Rockall Bank and 2013 Firth of Forth samples was carried out from the 27 July 2016. The frozen stomach samples were recovered from the freezer 8 samples at a time to prevent decomposition of stomach contents once defrosted. Every individual fish was given its own unique identification number to aid in recording the data properly. The stomachs were cut open from the oesophageal opening and the contents examined to the lowest possible taxonomic resolution and then weighed on a Mettler Toledo BD202 balance to the nearest 0.01g and recorded (see figure 2). If the stomach contained multiple prey types, such as fish and invertebrates, they were also weighed individually. For the Firth of Forth samples collected in 2013, the nematode parasites around the stomach and intestines were removed and weighed. The stomach mass was then analysed using the above procedure along with the contents of the intestines being recovered and weighed. Finally for the Firth of Forth samples, the gonads and liver were allowed to defrost before being weighed within their respective bags so as to include all the wet weight associated with them. The statistical software R (version 3.02.1, R Development Core Team 2015) was then used to create the scatter plots and boxplots shown in the results section.

A)

B)

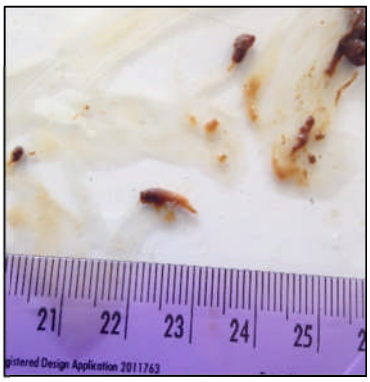


Figure 2

A) Shows empty gurnard stomach
B) Shows crustacean removed from Rockall Bank grey gurnard

Results

A total of 824 gurnard stomachs are considered in this study with 256 being dissected in July/August 2016 the rest are from previous studies carried out in the Firth of Forth. Of the 824 stomachs 20% were empty, 35% contained fish prey remains; 31% contained invertebrate prey and 14% contained both types of remains. Of the Rockall Bank samples the majority of the grey gurnard contained invertebrate prey remains and the few that did contain fish material were Sandeels (see Figure 4.1 and Table 1). Fish remains make up a larger mass of the stomach contents despite the number of fish containing invertebrates or fish being nearly the same. The main species found in grey gurnard stomachs was sandeels (*Ammodytes marinus*) there was also a number of crustacean species such as squat lobster (*Galathea squamifera*) and other smaller species. Finally there were also a number of cephalopod beaks removed from the stomach samples.

Table 1: Shows average stomach contents mass, fish prey mass and invertebrate prey mass for each location and year considered. (Fof= Firth of Forth)

Location and Year	Average Stomach mass (g)	Average Fish Prey Mass (g)	Average Invertebrate Mass (g)
Rockall Bank 2015	0.98	5.00	0.13
FoF 2009	0.95	1.34	0.20
FoF 2010	1.73	1.95	0.23
FoF 2011	0.22	0.45	0.19
FoF 2012	1.12	1.48	0.44
FoF 2013	1.04	1.30	0.57

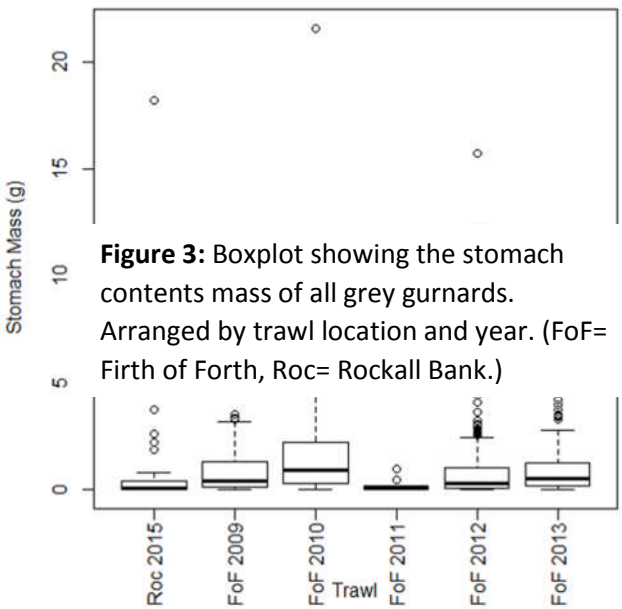
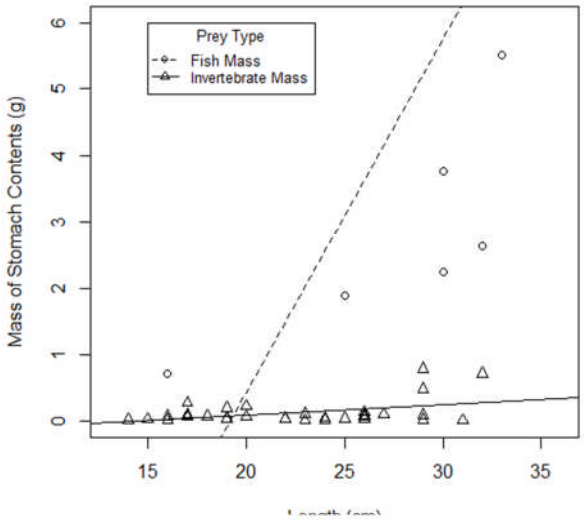


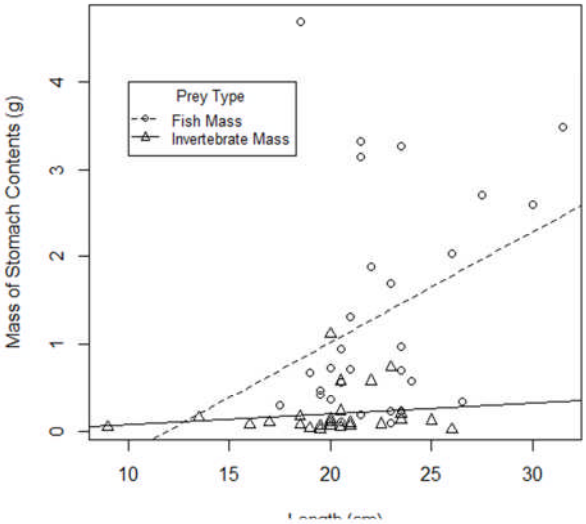
Figure 3: Boxplot showing the stomach contents mass of all grey gurnards. Arranged by trawl location and year. (FoF= Firth of Forth, Roc= Rockall Bank.)

The boxplot in Figure 3 shows that the mean stomach contents mass did not vary greatly between the years or geographical locations. The trawl carried out in the Firth of Forth 2011 did not contain many grey gurnard and the few that were caught most were empty or the stomach contents very low and hence a scatter plot was not drawn of this year (Figure 4). However, the FoF 2011 information was included in calculating the averages for each size class and prey type (Figure 4). The final aim of this investigation is to address whether the size of grey gurnard affects prey consumption.

4.1) Rockall 2015



4.2) FoF 2009



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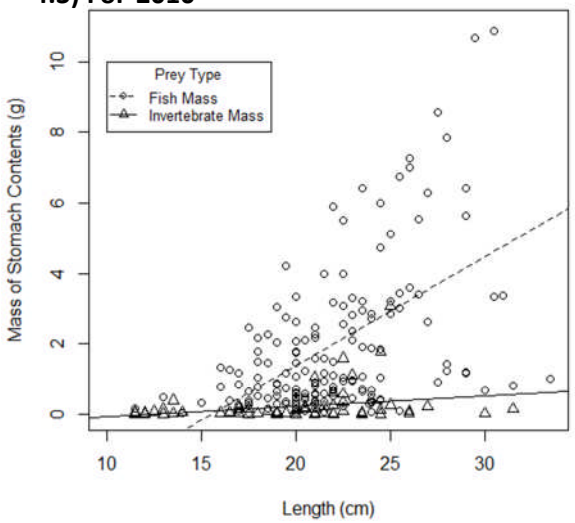
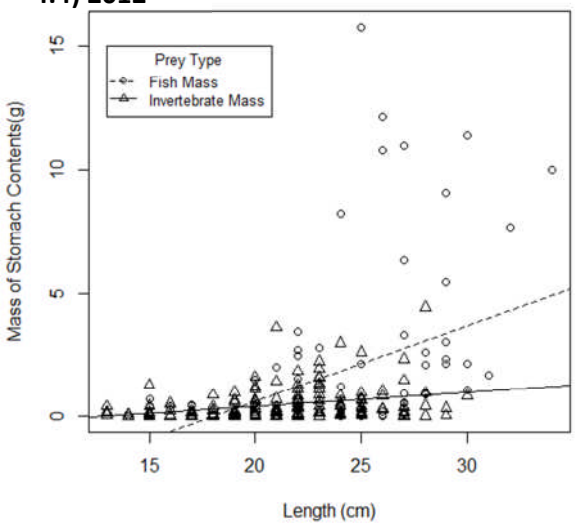


4.4) 2012



4.5) FoF 2013

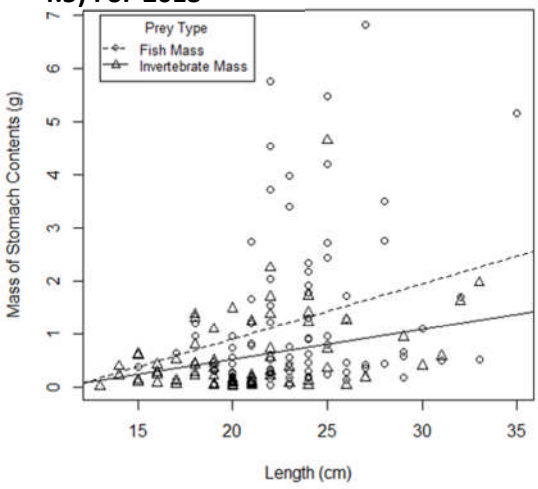


Figure 4: Scatterplots showing the relationship between length of grey gurnard and mass of each prey type found in the stomach. (Circles indicate fish prey, triangles invertebrate prey). 4.1) Rockall Bank samples with one outlier removed containing 18.8g of fish. 4.2) Firth of Forth 2009 samples. 4.3) Firth of Forth 2010 samples also with outlier of over 20g fish removed. 4.4) Firth of Forth 2012 samples. 4.5) Firth of Forth 2013 samples. All showing simple linear regression lines.

The scatterplots (Figure 4) show that in general the longer the fish the greater the mass of fish prey recovered from the stomach, this is consistent across all years considered. However the length of the fish does not seem to affect the amount of invertebrate prey within the stomachs as shown by the nearly

horizontal trend lines. There is a slight change in later years with the relationship between the longer fish and increased amount of invertebrate becoming more prominent.

Table 2 for numbers of gurnards within each size class containing fish remains, invertebrate remains, both or empty. In general large grey gurnard were more likely to contain fish prey and smaller fish were more likely to be empty or contain invertebrate prey. Table 2 also shows the average fish prey mass and average invertebrate prey mass found in each size class which is then plotted as a bar chart in Figure 5 shows the average mass of the two categories of prey type for each size class, with the fish separated into small (10-19.9cm), medium (20-24.9cm) and large (25-40cm). The results show that the percentage of large gurnards containing fish remains was higher (approximately 47%) than small gurnards with only ~20% containing fish remains.

Table 2: Number of grey gurnards in each size class and stomach contents group; fish prey, invertebrate prey, both types or empty

Size Class	Total with Fish remains Present	Total with Invertebrate remains present	Total with Both Present	Total empty	Fish Prey Mass Average (g)	Invertebrate Prey mass Average (g)
Small	54	116	31	65	0.23	0.1
Medium	148	103	61	69	0.65	0.19
Large	83	35	27	32	2.08	0.23

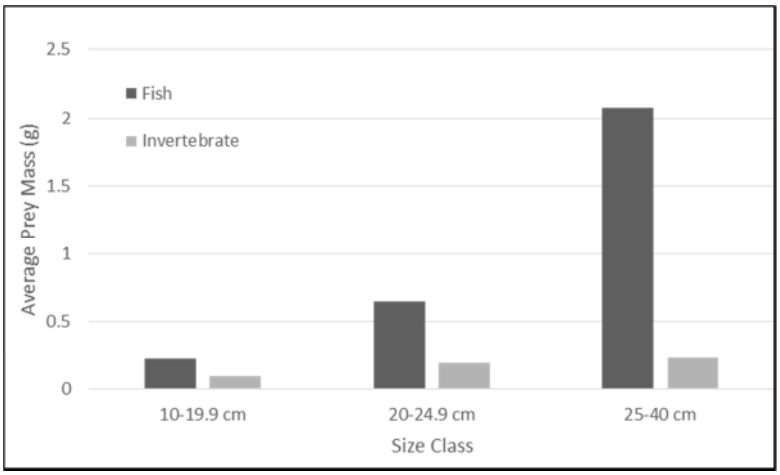
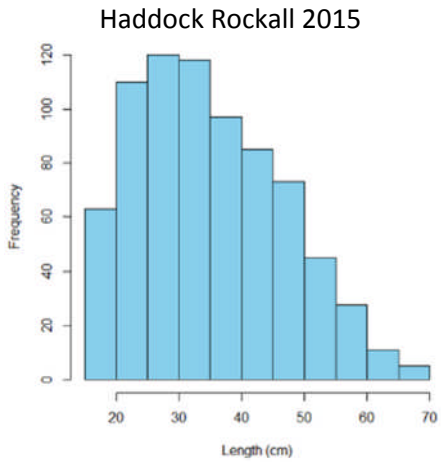
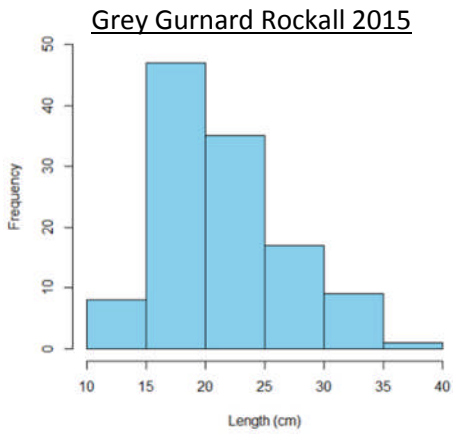


Figure 5: Bar chart showing average prey mass for all grey gurnards in the study separated into size classes. N= 824.

Figure 6: Length frequency histograms of all the grey gurnard and haddock caught in the 2015 trawls.





Discussion

The initial aim of this project was to determine the extent of the trophic relationship between grey gurnard and haddock at Rockall Bank. However due to the fact that this type of stomach contents analysis has not been carried out at Rockall before it is difficult to properly address this aim. In the future it is crucial to obtain both a greater temporal range of samples and also the number of gurnard collected. From these results it seems unlikely that grey gurnard are the principal cause for the decline of haddock in recent years, of the 7 gurnard stomachs to contain fish remains 4 contained the remains of sandeels and the rest could not be determined. There are a number of possible reasons for such an inconclusive result however. Firstly, the time of year is a major factor influencing the feeding habits of grey gurnard at Rockall. Previous studies show that grey gurnard feed more heavily on fish prey in September whereas, in spring the major portion of their diet consists of euphausiids (Vinogradov *et al.,* 2014). Furthermore, the feeding intensity of Rockall grey gurnard was also shown to peak in April which again may explain why the majority of stomach samples collected in May 2015 were empty (Vinogradov *et al.,* 2014). In the North Sea grey gurnard is considered one of the 10 most dominant species in the area and therefore has begun to be studied in more detail to get a better understanding of its trophic interactions (Floeter *et al.,* 2005; Floeter & Temming 2005). In the North Sea it has been recorded that gurnard feed on a number of juvenile fish including whiting, cod and saithe along with sandeels. Juvenile haddocks have not been found to be a major prey item for grey gurnard in the North Sea and although the results for this study are not definitive, it does support the idea that grey gurnard are not a major source of mortality for juvenile haddocks (Floeter *et al.,* 2005). Previous studies have highlighted that Rockall haddock stock show large variation in recruitment year to year and this could be one of the causes for a decline in haddock (Newton *et al.,* 2008; Wright *et al.,* 2010). Another influencing factor is that when fish are caught in a trawl and hauled to the surface regurgitation of stomach material may occur (Staniland *et al.,* 2001). As the Rockall samples consisted only of the gurnards' stomachs, with the oesophagus being removed prior to freezing, potential haddock remains may have been lost.

The second aim of this study was to compare the feeding ecology of the Rockall grey gurnard to the population found in the Firth of Forth. The results show that the most recent year from the Firth of Forth, 2013, follows a similar pattern to that of Rockall Bank in that the larger gurnards contained more fish prey mass. Also as the years have progressed the amount of crustacean prey consumed by larger fish has increased in the Firth of Forth. There are a number of possible reasons behind this trend such as abundance of different prey types meaning it is more efficient to target one over the other. This could

have a seasonal component as the results shown here are only from spring. One large difference between the two populations was the presence of the parasite *Anisakis simplex* in the FoF stomach samples, which was entirely absent in the Rockall samples. A study by Levsen & Karl (2014) has investigated the occurrence of these parasites in gurnard populations in the North Sea, and hypothesised that they originate from one of the gurnards main food sources, the lesser sandeel (*Ammodytes marinus*). While the same species of sandeel is present at Rockall, it is possible that due to the geographical isolation of the species, *Anisakis simplex* has been unable to infect this population. However, a large number of the parasites were found in the intestines of the affected FoF samples, and as the Rockall samples consisted only of the stomachs, any present parasites may have been discarded before the samples were frozen.

The length of the grey gurnard was considered in relation to prey type. Over the years a number of studies have investigated the diet of grey gurnard with greatly varying results (Weinert *et al.,* 2010). Despite this variety in results from small scale studies grey gurnard show an ontogenetic diet shift from mainly invertebrate prey to fish prey once they reach a length of approximately 20cm (Floeter *et al.,* 2005; Floeter & Temming 2005; Weinert *et al.,* 2010). The results from this study follow the trend previously recorded that once grey gurnard attain the size of 20cm they consume more fish prey than invertebrate prey. The percentage of the stomach contents made up of fish prey remains is not that much greater in medium fish (77%) compared to small fish (70%) however in large gurnards the percentage is a lot higher at about 90%. The length frequency distributions (Figure 6) of haddock at Rockall bank show that there are individuals small enough to be consumed by the larger grey gurnard but it seems that gurnard favour invertebrates and sandeels. One study into prey preference of grey gurnard in the North Sea showed that at a certain predator size there is a shift back to a prey preference for relatively smaller prey such as invertebrates (Floeter & Temming 2005). This strategy can be explained from a bioenergetic perspective because as the predator increases in body size the energetic cost of fast burst swimming after larger fish prey becomes more costly and therefore the gurnards switch back to easier foraging for smaller prey such as crustaceans (Floeter & Temming 2005).

Conclusion

Based on the evidence gathered in this study, it would appear that the grey gurnard population at Rockall is not responsible for the declining haddock stocks, with no identifiable juvenile haddock being found in any of the sampled stomachs. However, differences in feeding at different times of year and the lack of regurgitated material from the samples mean that the original hypothesis cannot be completely ruled out, so more research into this area is recommended. Comparing the feeding ecology of the Rockall and Firth of Forth populations has shown the two areas to be similar, with similar prey mass to fish length relationships being shown across the two populations. Finally, it can be concluded that the size of the fish does influence prey selection in grey gurnard, with an increase in fish length leading to an increase in fish and invertebrate prey mass found in the stomach.

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