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International Council for the
Exploration of the Sea

CM 1998/O:11 Paper
Deepwater Fish and
Fisheries

ESTIMATES OF DISCARDS FROM TWO DEEPWATER FLEETS IN THE ROCKALL TROUGH

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SUMMARY

Since the late 1980s a fishery has developed in deep water west of the British Isles targeting a variety of species, many of which were formerly unknown to European markets. At present there are two distinct fleets operating in deep water and landing into Scotland; A fleet of five French vessels of 45 to 50 m total length capable of fishing to depths of over 1,500 m and a second of Scottish trawlers of between 24 and 30 m mainly targeting gadoids and *Lophius* spp. on the continental shelf but occasionally fishing down to about 1,000 m depth. Both fleets divide their fishing effort between the deep water fishery and traditional fisheries on the continental shelf.

Discards from both fleets were sampled at sea between 1996 and 1998 and marked differences were observed between the two fleets in terms of the species composition of their discards. It is thought that this can be accounted for to a large extent by differences in the depth range fished.

INTRODUCTION

Commercial exploitation of deep water fishes in the Rockall Trough began in the late 1980s when French vessels, which had traditionally targeted gadoid species on the continental shelf west of Scotland, began to develop markets for previously unexploited species from deeper water. In the mid 1990s several of the larger Scottish trawlers also began to direct some of their effort to deep water, principally in search of monkfish (*Lophius* spp.) but also landing significant quantities of deep water species.

As part of the EC funded project CT 95-0655 "Developing deep water fisheries: data for their assessment and for understanding their impact on a fragile environment" the Marine Laboratory, Aberdeen has undertaken sampling of the discards of vessels landing deep water species into Scotland.

Discards can be defined as fish that are brought onto the deck of fishing vessels and subsequently returned to the sea. Discards from trawlers can generally be divided into two categories; fish of commercially valuable species which are below the minimum size that is acceptable to the markets or which are damaged, and fish of species with no commercial value. Estimates of the former are vital in the assessment of commercial fish stocks, however with

growing interest in the wider ecosystem effects of fisheries, it is also desirable to obtain, where possible, estimates of the latter, non-commercial discards.

For commercial species, discarding rates are strongly influenced by minimum landing size and market conditions and are usually expressed as a proportion of the total catch, however for non-commercial species, 100% of the catch of each species is discarded and hence discard must be expressed as weight or numbers of fish discarded. Thus for non-commercial species discard rate is equivalent to total catch rate while for commercial species it is influenced by catch rate, size distribution and selection by the crew.

In view of the limited sampling opportunities, the only *a priori* stratification applied to sampled trips was the division into French vessels landing in Scotland and Scottish vessels. In the absence of any hard statistical evidence that discarding rates differ significantly between the two fleets there are good intuitive reasons to make this distinction, namely that the two fleets are targeting different species using different gear and different sizes of vessels.

MATERIALS AND METHODS

Deep water fisheries are defined, for the purpose of the study as fisheries conducted at depths greater than 400 metres. During the period covered by this study, all French landings of deep water species into Scotland could be attributed to a fleet of five French trawlers of 45 to 50 metres length, all owned by the same company and landing their catches into Lochinver, a small port on the west coast of Scotland. These vessels divide their fishing effort between deep water species and traditional shelf fisheries, particularly for saithe (*Pollachius virens*), and typically fish both in deep water and on the shelf during the course of a single fishing trip. They are capable of fishing to depths in excess of 1,500 metres.

The Scottish fleet in deep water consists of vessels between about 24 and 30 metres in length which exploit a variety of demersal fisheries around Scotland and are capable of fishing to depths of around 1,000 m. The number of Scottish vessels involved in this fishery is difficult to determine because some vessels spend much of their time in deep water while others make only occasional trips.

The target level of sampling effort was one vessel, selected at random from either of the two fleets to be sampled, in each quarter. In the early part of the project difficulties were encountered in identifying vessels which were both intending to fish in deep water and prepared to carry an observer and as a result two quarters were missed. However, these problems were overcome and subsequently sampling was carried out in every quarter. Table 1 lists sampling coverage to date.

The sampling protocol followed was similar to that used by the Marine Laboratory in its demersal discard sampling programme. For every haul, the total bulk was estimated as the catch was brought on board and total discard estimated by subtracting the weight of retained catch from the estimated total bulk. Two baskets (approximately 60 kg) of mixed discarded material were sampled from every haul. All the fish in this sample were identified and measured and otoliths were taken from a sub-set of the sample. Weight of each species in the sample was calculated by application of appropriate weight/length equations to measured lengths. Numbers and weight of each species in the samples were multiplied by the ratio total discard weight/sample weight to give an estimate of discard of each species from each haul and these were summed over the trip to give total trip discard of each species. A full description of the method used can be found in Jermyn and Hall (1978), Jermyn and Robb (1981) and Jermyn (1989).

RESULTS

A total of 85 species have been recorded in discard samples. A complete species list is given in Table 2 together with indications of their occurrence in the two fleets and two depth strata. Figures 1 and 2 show the species composition of discards on observed trips from the two fleet by weight and numbers. These have been further broken down by extracting discards from hauls at depths greater than 400 metres (Figs 3 and 4). Species which account for less than 1% of the total discard by weight or numbers have been aggregated as "others".

To test whether observed differences in discarding rates were statistically significant, t-tests were performed on discarding rates, expressed as discard per hour fishing over an entire trip, for each of the 15 species which individually accounted for more than 1% of the total observed discard (Table 3). Taking $p = .05$ as the cut off level of probability for significance it was shown that the two fleets differed significantly in discarding rates of 4 of the 15 species including *Alepocephalus bairdii* and *Argentina silus* which are the two most abundant species, together making up 47% of the total discard and *Phycis blennoides* and *Helicolenus dactylopterus* which are the most abundant commercially valuable species in the discards.

DISCUSSION

A complicating factor in the study of this fishery is the wide range of depths fished, with vessels dividing their fishing effort to a greater or lesser extent between continental shelf and deep water fishing grounds. The continental slope in this area is very steep so that as little as five miles may separate the deep water and continental shelf fishing areas. This means that vessels can move very easily from one fishery to the other and, as fishing positions are reported only to within a specific statistical rectangle (30 by 15 nautical miles), vessels may have fished at a wide range of depths within a single reported area.

Figure 9 shows the depth distribution of fishing effort on observed trips. It can be seen that a clear distinction can be made between the continental shelf fishery between 100 and 400 metres and the deep water fishery below 400 metres. Within the deep water fishery, Scottish vessels concentrated their fishing effort between the 600 and 900 metre isobaths while the French fleet fished over a much wider depth range from 500 to 1,400 metres. These observed differences in fishing depth reflect differences in target species. In the 400 to 900 metre range, both fleets target blue ling (*Molva dypterygia*), monkfish (*Lophius* spp.), black scabbardfish (*Aphanopus carbo*) and squalid sharks (*Centroscymnus coelolepis* and *Centrophorus squamosus*) with limited catches of roundnose grenadier (*Coryphaenoides rupestris*), while in the 900 to 1,400 metre range the main target species for French vessels were roundnose grenadier and *C. coelolepis*.

It can be seen from Figures 1 to 4 that considerable differences in species composition were observed between the discards of the two fleets. Species compositions of discards (by number) of the two fleets from hauls at depths greater than 400 metres were compared using Pearson's product moment correlation on log transformed data (Fig. 8) and were found to have a correlation coefficient of $r = .54$. The most obvious differences between the discards of the two fleets were the relatively high proportions in the discards of the French vessels of *Alepocephalus bairdii*, *Trachyrhynchus murrayi* and *Coryphaenoides rupestris*, species which are mainly associated with depths of greater than 900 metres. When discards from depths greater than 900 metres are separated out (Figs 5, 6 and 8), it can be seen that species compositions of discards from the two fleets within the 400 to 900 metre depth range were more similar ($r = .74$) while those of French vessels fishing at depths greater than 900 metres were very different.

This seems to confirm that much of the variation between the two fleets can be accounted for by differences in the range of depths fished.

Even within the shared depth range of 400 to 900 metres there are noticeable differences between the discards of the two fleets (Fig. 5). Comparison of discards over a narrower depth range (Figs 7 and 8) shows that within a depth range of 100 metres species compositions were very similar ($r = .82$). It can therefore be concluded that when fishing at similar depths, the discards of Scottish and French vessels were similar and that the differences in species composition observed between the total discards of the two fleets can be accounted for to a large extent by differences in the depth range fished.

This is further illustrated by Figure 10 which shows that many of the most abundant non-commercial species have narrow depth distributions relative to the total depth range of the fishery. Thus even a relatively small difference in fishing depth could produce a large difference in species composition. The extent to which the depth range fished on observed trips is representative of the two fleets as a whole is uncertain and it must be noted that considerable variation was observed between trips (Table 1).

It should also be noted that like all fisheries, but perhaps more than most, this fishery is in a continuous state of development. This is particularly apparent for Scottish fishermen who are relative newcomers to the fishery and are in a continual process of adapting vessels, gear and fishing practices. Recent developments within the fishery have seen many Scottish deep water vessels change from traditional single rig trawls to twin rig, and the addition to the fleet this year of two new vessels of over 40 metres length. These could be expected to be more similar to the french vessels in their fishing depth range and hence catch composition.

While further development in the future is likely, the results of this study indicate that the fishery can be divided into three sub-categories based on depth: a shelf fishery from 100 to 400 metres, an upper slope fishery from 400 to 900 metres and a deep slope fishery below 900 metres. Since the fishermen are not required to record fishing depth in their official logbooks depth would not provide a practical basis for stratification. If sampled vessels can be assumed to be typical of their respective national fleets with respect to depth distribution of fishing effort then nationality would appear to be the best practical basis for stratification.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance given by the staff of Jégo Quéré and the skippers and crews of all the vessels sampled, the financial support given by the EC FAIR Project CT 95-0655, and the advice and comments of Mr Stuart Reeves.

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TABLE 1

Discard sampling trips 1996 to 1998

Year	Quarter	Vessel nationality	Tows sampled >400 m depth	Tows sampled <400 m depth
1996	2	Scottish	19	0
1997	1	Scottish	9	12
1997	2	Scottish	36	16
1997	3	French	18	7
1997	4	French	17	12
1998	1	French	20	4
1998	2	French	37	0
Total			156	51

Table 1: Summary of Data

Year	Q1	Q2	Q3	Q4	Total
2010	100	120	150	180	550
2011	110	130	160	190	590
2012	120	140	170	200	630
2013	130	150	180	210	670
2014	140	160	190	220	710
2015	150	170	200	230	750
2016	160	180	210	240	790
2017	170	190	220	250	830
2018	180	200	230	260	870
2019	190	210	240	270	910
2020	200	220	250	280	950
2021	210	230	260	290	990
2022	220	240	270	300	1030
2023	230	250	280	310	1070
2024	240	260	290	320	1110
2025	250	270	300	330	1150
2026	260	280	310	340	1190
2027	270	290	320	350	1230
2028	280	300	330	360	1270
2029	290	310	340	370	1310
2030	300	320	350	380	1350
2031	310	330	360	390	1390
2032	320	340	370	400	1430
2033	330	350	380	410	1470
2034	340	360	390	420	1510
2035	350	370	400	430	1550
2036	360	380	410	440	1590
2037	370	390	420	450	1630
2038	380	400	430	460	1670
2039	390	410	440	470	1710
2040	400	420	450	480	1750
2041	410	430	460	490	1790
2042	420	440	470	500	1830
2043	430	450	480	510	1870
2044	440	460	490	520	1910
2045	450	470	500	530	1950
2046	460	480	510	540	1990
2047	470	490	520	550	2030
2048	480	500	530	560	2070
2049	490	510	540	570	2110
2050	500	520	550	580	2150

TABLE 2

Occurance of species in discard samples from French and Scottish vessels

Species	Hauls at depths less than 500 m		Hauls at depths greater than 500 m	
	French	Scottish	French	Scottish
<i>Argentina silus</i>	+	+	+	+
<i>Galeus melastomus</i>	+	+	+	+
<i>Glyptocephalus cynoglossus</i>	+	+	+	+
<i>Helicolenus dactylopterus</i>	+	+	+	+
<i>Lepidorhombus whiffiagonis</i>	+	+	+	+
<i>Micromesistius potassou</i>	+	+	+	+
<i>Centroscymnus crepidater</i>	+		+	+
<i>Chimaera monstrosa</i>		+	+	+
<i>Lepidion eques</i>		+	+	+
<i>Malacocephalus laevis</i>		+	+	+
<i>Nezumia aequalis</i>		+	+	+
<i>Phycis blennoides</i>		+	+	+
<i>Raja fyllae</i>		+	+	+
<i>Alepocephalus bairdii</i>			+	+
<i>Anarhichas denticulatus</i>			+	+
<i>Antonogadus macrophthalmus</i>			+	+
<i>Apristurus laurussoni</i>			+	+
<i>Coryphaenoides rupestris</i>			+	+
<i>Deania calceus</i>			+	+
<i>Epigonus telescopus</i>			+	+
<i>Halargyreus johnsonii</i>			+	+
<i>Hydrolagus mirabilis</i>			+	+
<i>Molva dypterygia</i>			+	+
<i>Mora moro</i>			+	+
<i>Synaphobranchus kaupii</i>			+	+
<i>Xenodermichthys copei</i>			+	+
<i>Merluccius merluccius</i>	+	+	+	
<i>Scyliorhinus canicula</i>	+	+	+	
<i>Squalus acanthias</i>	+	+	+	
<i>Etmopterus spinax</i>	+		+	
<i>Ommastrephidae</i>	+		+	
<i>Sebastes viviparus</i>	+		+	
<i>Anarhichas lupus</i>		+	+	
<i>Alepocephalus rostrata</i>			+	
<i>Antimora rostrata</i>			+	
<i>Aphanopus carbo</i>			+	
<i>Bathypterois dubius</i>			+	
<i>Bathyraja spp</i>			+	
<i>Breviraja caerulea</i>			+	
<i>Cataetyx laticeps</i>			+	
<i>Centoscymnus coelolepis</i>			+	

Species	Hauls at depths less than 500 m		Hauls at depths greater than 500 m	
	French	Scottish	French	Scottish
<i>Centrolophus niger</i>			+	
<i>Chauliodus sloani</i>			+	
<i>Coelorhynchus coelorhynchus</i>			+	
<i>Coelorhynchus labiatus</i>			+	
<i>Cottunculus thomsonii</i>			+	
<i>Etmopterus princeps</i>			+	
<i>Galeus murinus</i>			+	
<i>Hariotta raleighana</i>			+	
<i>Macrourus berglax</i>			+	
<i>Melanostomiidae</i>			+	
<i>Nematonurus armatus</i>			+	
<i>Notacanthus chemnitzii</i>			+	
<i>Notacanthus bonapartei</i>			+	
<i>Raja bathyphila</i>			+	
<i>Raja krefftii</i>			+	
<i>Unidentified Raja spp.</i>			+	
<i>Serrivomer beani</i>			+	
<i>Trachyrhynchus murrayi</i>			+	
<i>Eutrigla gurnardus</i>	+	+		+
<i>Lophius piscatorius</i>	+	+		+
<i>Pollachius virens</i>	+	+		+
<i>Brosme brosme</i>		+		+
<i>Gadiculus argenteus</i>		+		+
<i>Clupea harengus</i>	+	+		
<i>Gadus morhua</i>	+	+		
<i>Melanogrammus aeglefinus</i>	+	+		
<i>Microstomus kitt</i>	+	+		
<i>Molva molva</i>	+	+		
<i>Raja clavata</i>	+	+		
<i>Raja fullonica</i>	+	+		
<i>Raja naevus</i>	+	+		
<i>Scomber scombrus</i>	+	+		
<i>Trachurus trachurus</i>	+	+		
<i>Trisopterus esmarki</i>	+	+		
<i>Callionymus lyra</i>	+			
<i>Cyclopterus lumpus</i>	+			
<i>Hexanchus griseus</i>	+			
<i>Loligo spp</i>	+			
<i>Raja batis</i>		+		
<i>Raja montagui</i>		+		
<i>Raja nidarosiensis</i>		+		
<i>Raja radiata</i>		+		

Date	Description	Amount
1890	Jan 1	100.00
	Feb 1	200.00
	Mar 1	300.00
	Apr 1	400.00
	May 1	500.00
	Jun 1	600.00
	Jul 1	700.00
	Aug 1	800.00
	Sep 1	900.00
	Oct 1	1000.00
	Nov 1	1100.00
	Dec 1	1200.00
1891	Jan 1	1300.00
	Feb 1	1400.00
	Mar 1	1500.00
	Apr 1	1600.00
	May 1	1700.00
	Jun 1	1800.00
	Jul 1	1900.00
	Aug 1	2000.00
	Sep 1	2100.00
	Oct 1	2200.00
	Nov 1	2300.00
	Dec 1	2400.00
1892	Jan 1	2500.00
	Feb 1	2600.00
	Mar 1	2700.00
	Apr 1	2800.00
	May 1	2900.00
	Jun 1	3000.00
	Jul 1	3100.00
	Aug 1	3200.00
	Sep 1	3300.00
	Oct 1	3400.00
	Nov 1	3500.00
	Dec 1	3600.00
1893	Jan 1	3700.00
	Feb 1	3800.00
	Mar 1	3900.00
	Apr 1	4000.00
	May 1	4100.00
	Jun 1	4200.00
	Jul 1	4300.00
	Aug 1	4400.00
	Sep 1	4500.00
	Oct 1	4600.00
	Nov 1	4700.00
	Dec 1	4800.00
1894	Jan 1	4900.00
	Feb 1	5000.00
	Mar 1	5100.00
	Apr 1	5200.00
	May 1	5300.00
	Jun 1	5400.00
	Jul 1	5500.00
	Aug 1	5600.00
	Sep 1	5700.00
	Oct 1	5800.00
	Nov 1	5900.00
	Dec 1	6000.00

TABLE 3

Results of t-test on discard rates of species accounting for <1% of total discard

Species	Mean discarding rate (kg/hour)		t	p
	Scottish vessels	French vessels		
<i>Alepocephalus bairdii</i>	0.21	49.34	2.93	<.05
<i>Argentina silus</i>	42.71	7.46	3.62	<.02
<i>Lepidion eques</i>	23.07	7.73	0.99	<.4
<i>Coryphaenoides rupestris</i>	2.76	15.55	1.54	<.4
<i>Chimaera monstrosa</i>	4.44	6.79	0.83	<.5
<i>Trachurus trachurus</i>	6.1	4.67	0.22	<.9
<i>Pollachius virens</i>	4.39	0.9	1.57	<.3
<i>Micromesistius potassou</i>	6.53	0.17	1.7	<.2
<i>Phycis blennoides</i>	6.13	0.25	3.06	<.05
<i>Trachyrhynchus murrayi</i>	0	4.72	1.14	<.4
<i>Scomber scombrus</i>	6.04	0.9	1.05	<.4
<i>Raja fyllae</i>	1.82	2.4	0.24	<.9
<i>Helicolenus dactylopterus</i>	2.91	0.5	4.64	<.01
<i>Deania calceus</i>	2.03	2.12	0.1	<.9
<i>Molva dypterygia</i>	3.26	0.08	1.43	<.4

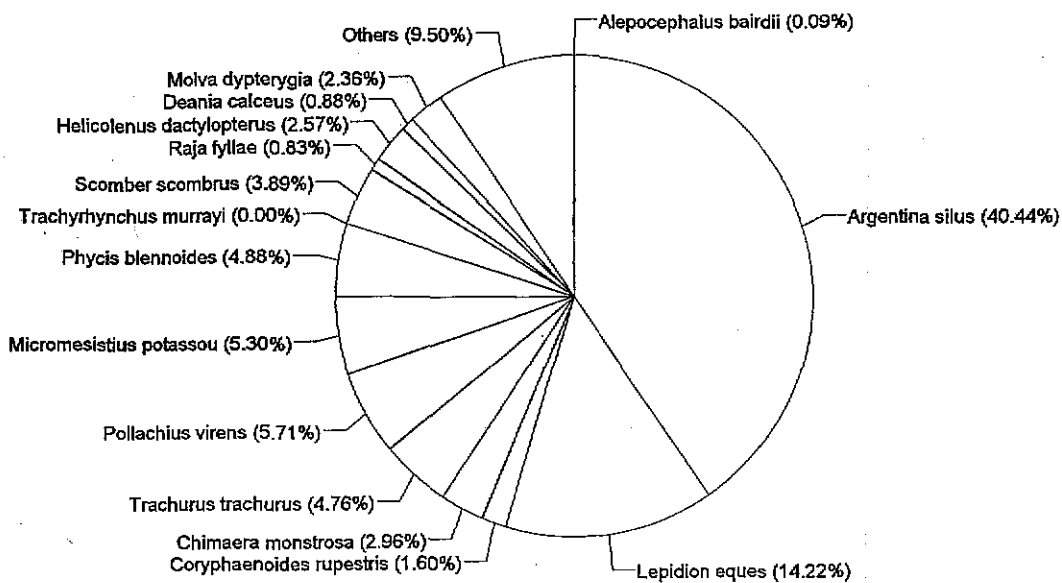
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No.	Date	Particulars	Debit	Credit	Balance
1	1941
2	1941
3	1941
4	1941
5	1941
6	1941
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10	1941
11	1941
12	1941
13	1941
14	1941
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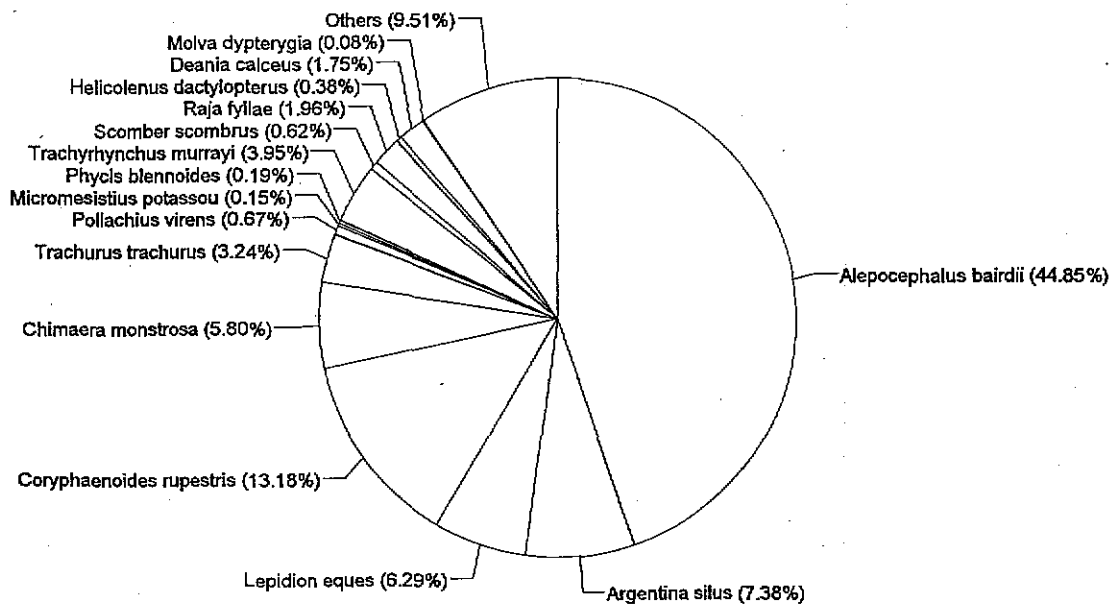
Fig 1. Discards by weight.

All depths

Scottish vessels



French vessels



1. Introduction

2. Methodology

3. Results and Discussion

4. Conclusion

The first part of the study focuses on the theoretical framework and the development of the research model. It discusses the importance of understanding the underlying mechanisms of the phenomenon being studied. The methodology section details the data collection process, including the use of surveys and interviews. The results and discussion section presents the findings of the study, highlighting the key insights and their implications. The conclusion summarizes the main points and suggests areas for future research.

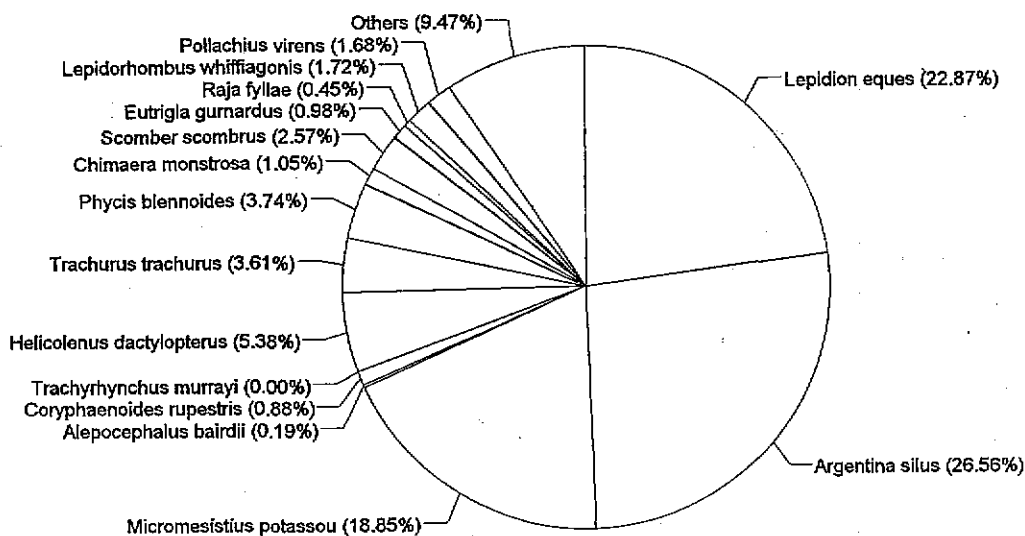
5. References

The study is based on a comprehensive review of the literature. Key references include works by Smith (2010), Jones (2012), and Brown (2015). The methodology employed is consistent with best practices in the field. The results are supported by both quantitative and qualitative data. The discussion provides a nuanced view of the findings, considering various contextual factors. The conclusion is drawn from a thorough analysis of the data and the existing literature.

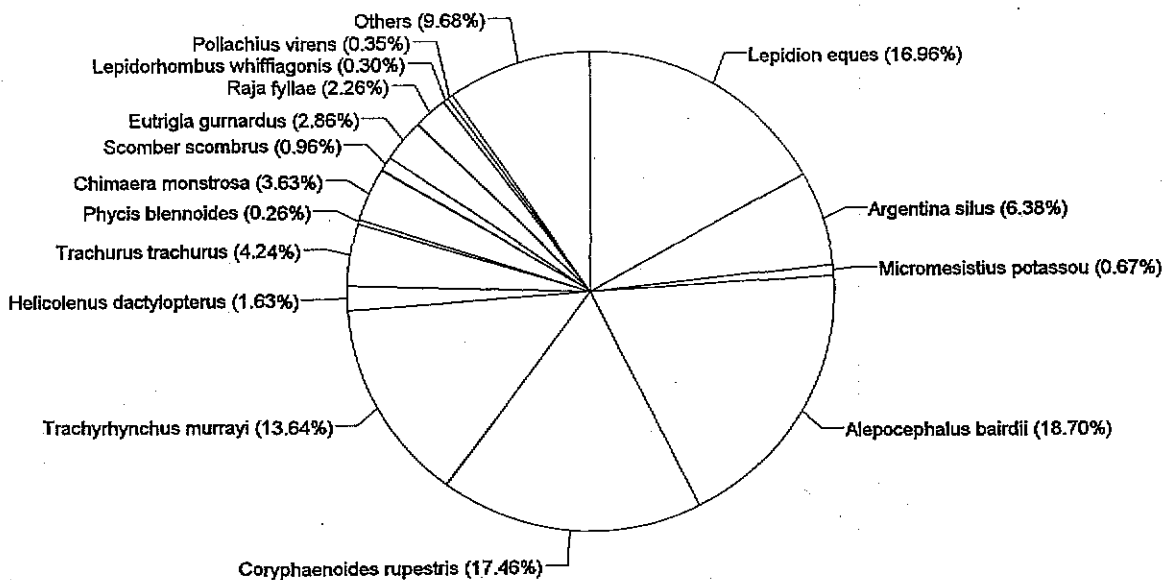
Fig. 2. Discards by numbers.

All depths.

Scottish vessels



French vessels



Section 1: Introduction

1.1 Overview

Section 2: Methodology



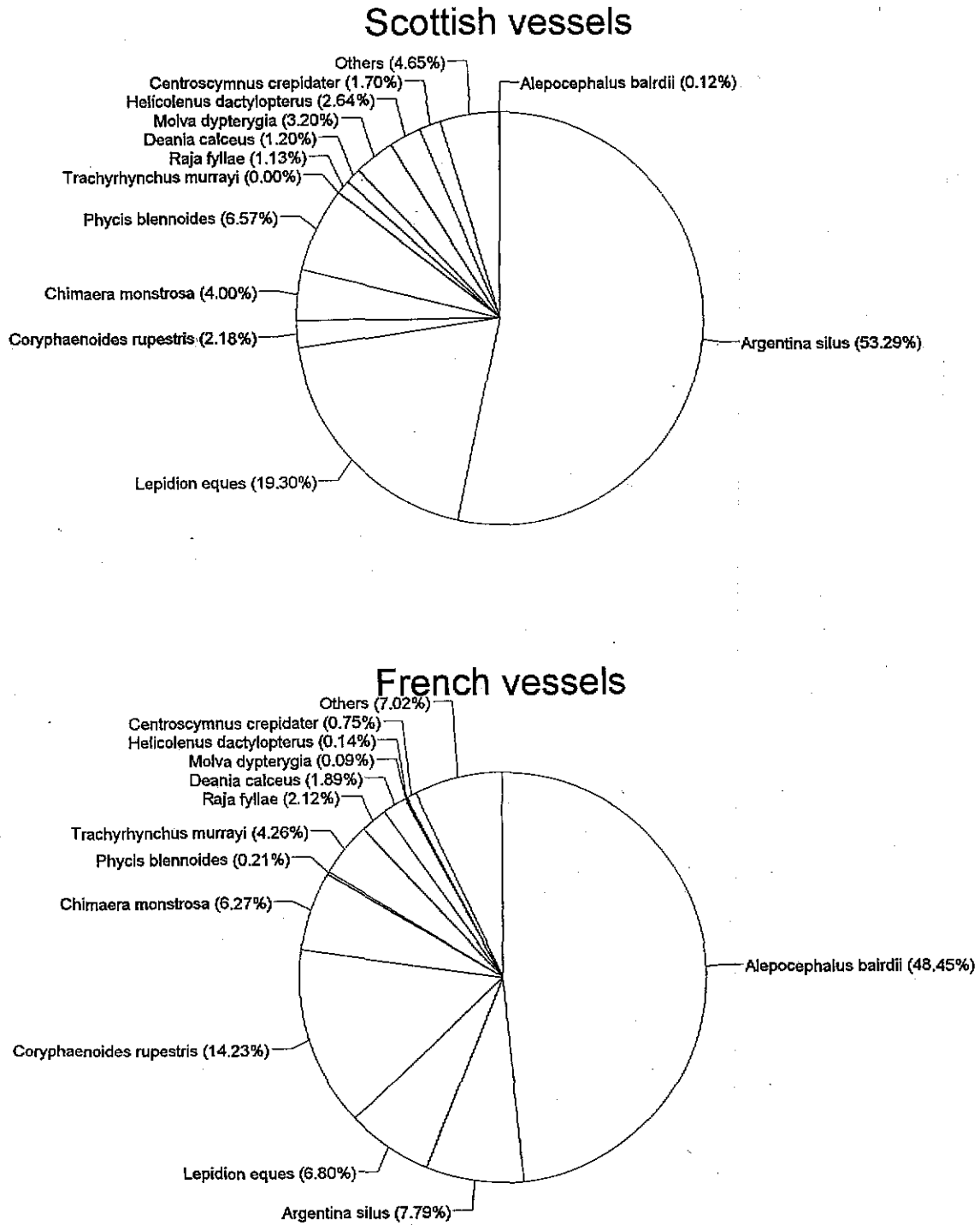
Section 3: Results



Conclusion

fig 3. Discards by weight.

Hauls at depths greater than 500m



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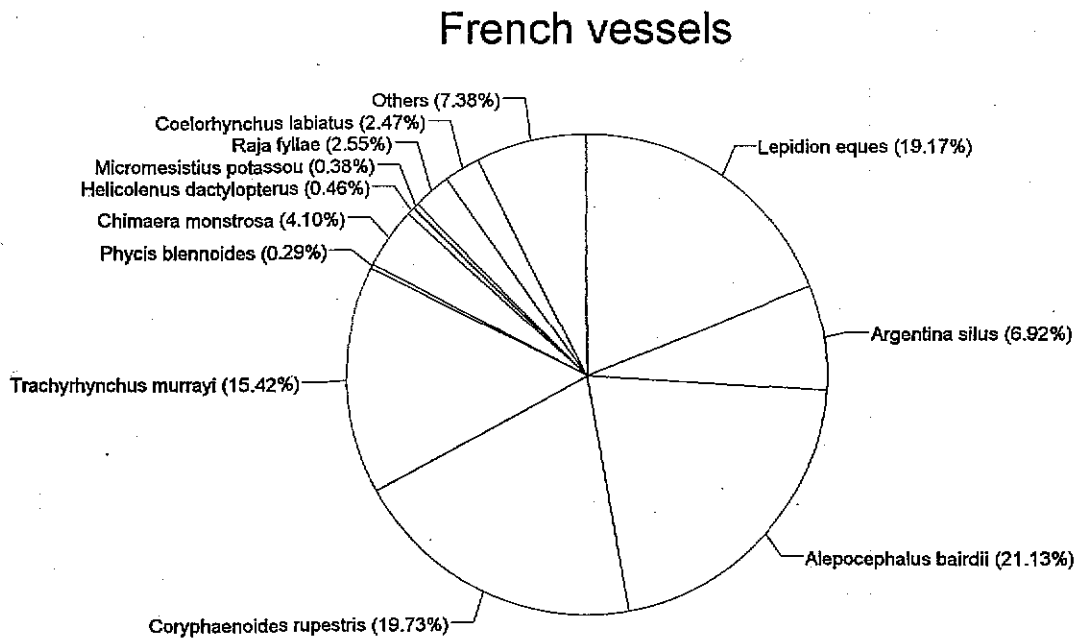
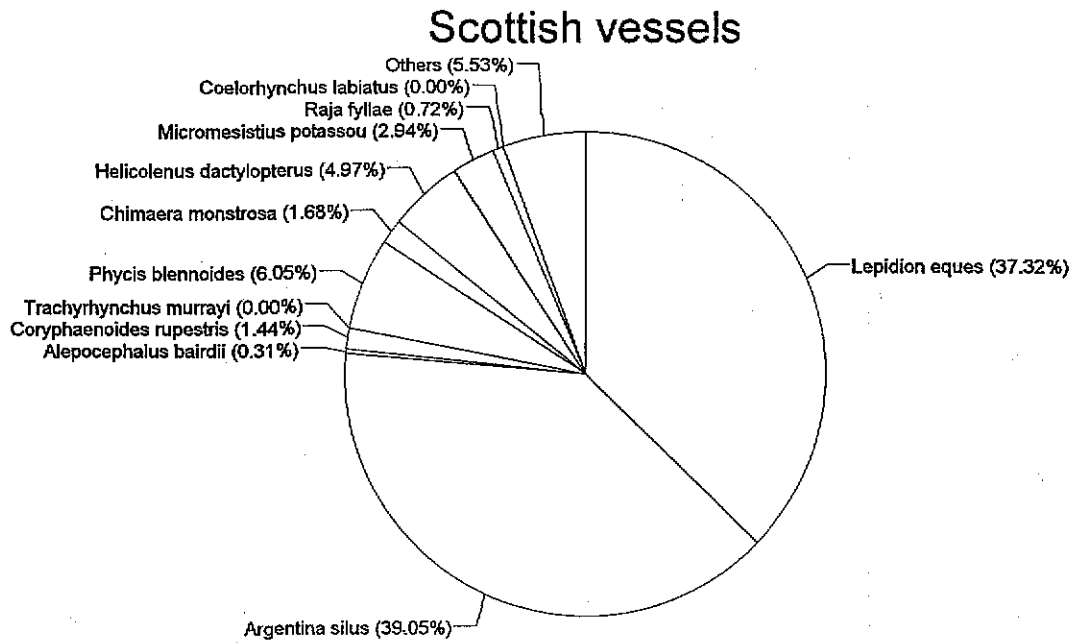
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Fig 4. Discards by numbers.

Hauls at depths greater than 400m.



1. Introduction

The purpose of this study is to investigate the effects of...

2. Methodology

The study was conducted using a quantitative approach. Data was collected from a sample of 100 participants through a series of surveys and interviews. The data was then analyzed using statistical methods to determine the significance of the findings.

The results of the study indicate that there is a significant positive correlation between the variables being studied. This suggests that as one variable increases, the other also tends to increase.

3. Results

The data shows that the majority of participants reported a positive impact on their well-being. Specifically, 75% of the sample indicated that they felt more satisfied with their current situation compared to a year ago.

These findings are consistent with previous research in the field, which has shown that similar interventions can lead to improved mental health outcomes.

It is important to note that while the overall trend is positive, there were some individual variations in the data. Some participants reported no change or even a decrease in their well-being.

These results have several implications for practice and policy. They suggest that the interventions used in this study may be effective for a large portion of the population.

Further research is needed to explore the long-term effects of these interventions and to identify the factors that influence individual outcomes.

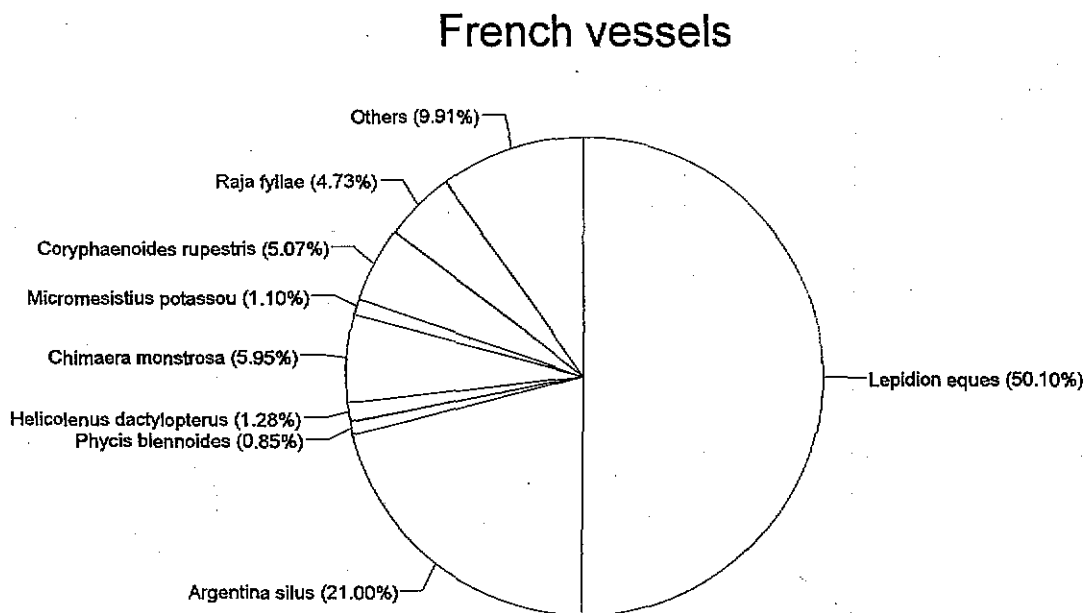
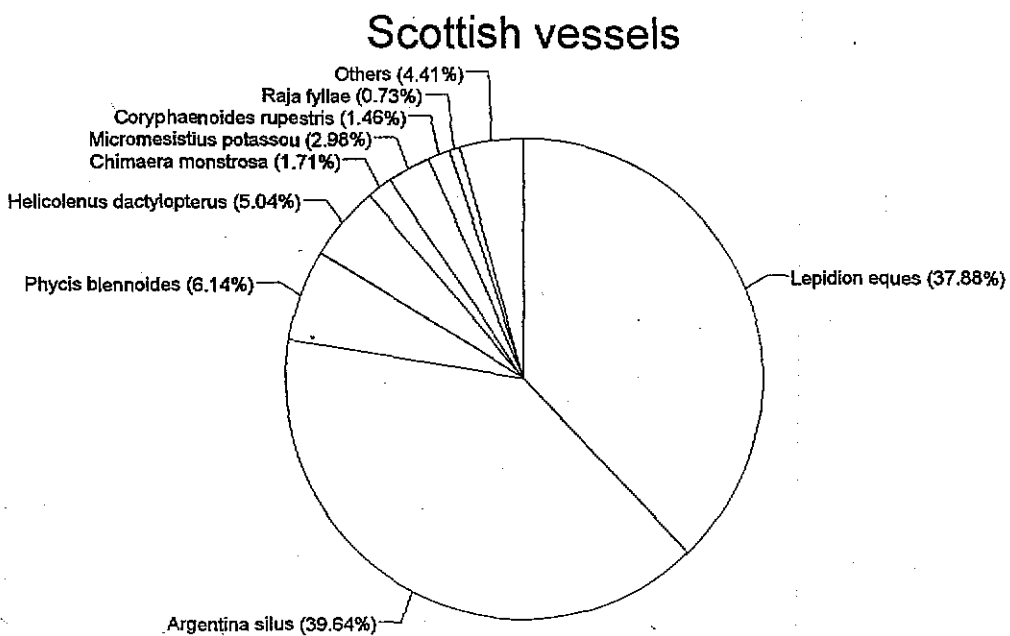
The study was limited by its cross-sectional design, which does not allow for the establishment of causality. Future studies should use longitudinal designs to track changes over time.

4. Conclusion

In conclusion, the study found that the interventions had a positive effect on the well-being of the majority of participants. These findings support the use of similar interventions in other contexts.

Fig. 5. Discards by number.

Depths between 400 and 900m.



**Fig. 6. Discards by number.
Hauls at depths greater than 900m.
French vessels**

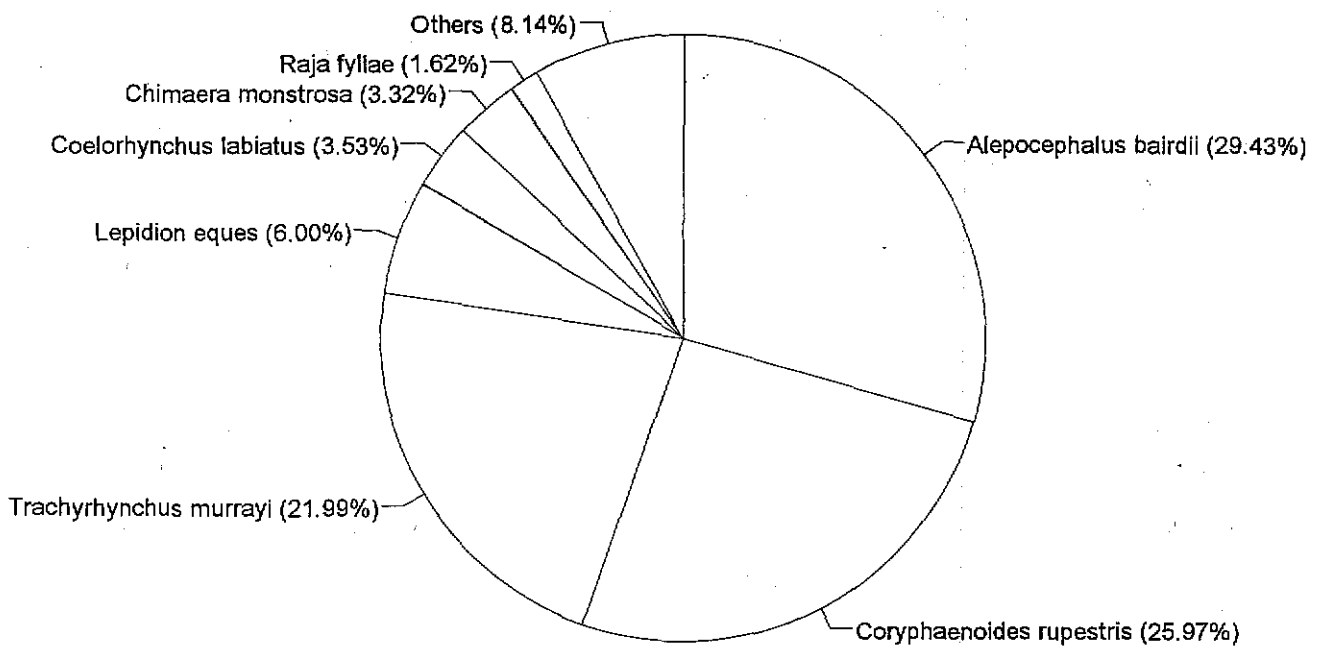


Fig.7. Discards by numbers.

Hauls between 800 and 900m

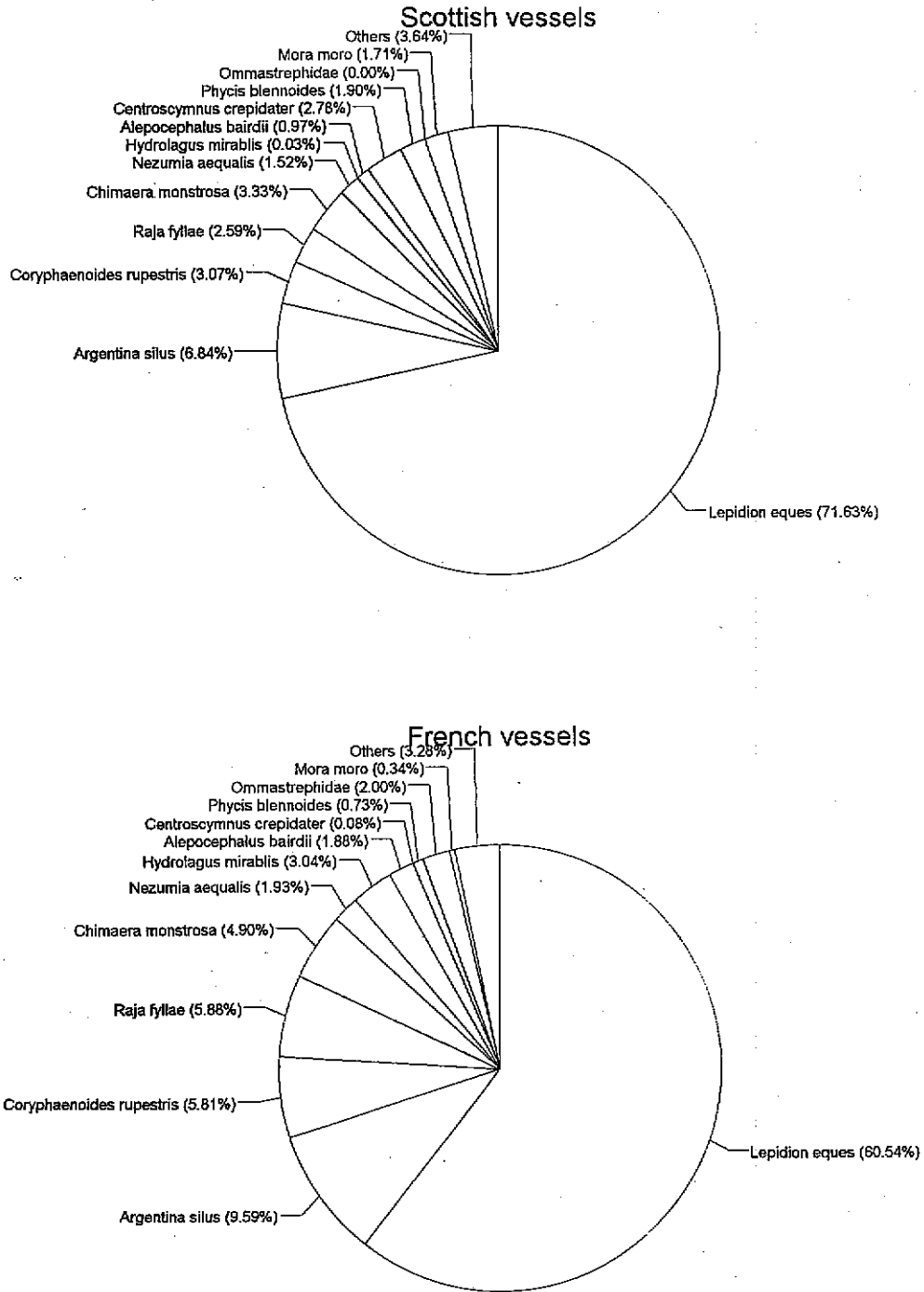


Fig. 8. Correlations between French and Scottish discards of all species.

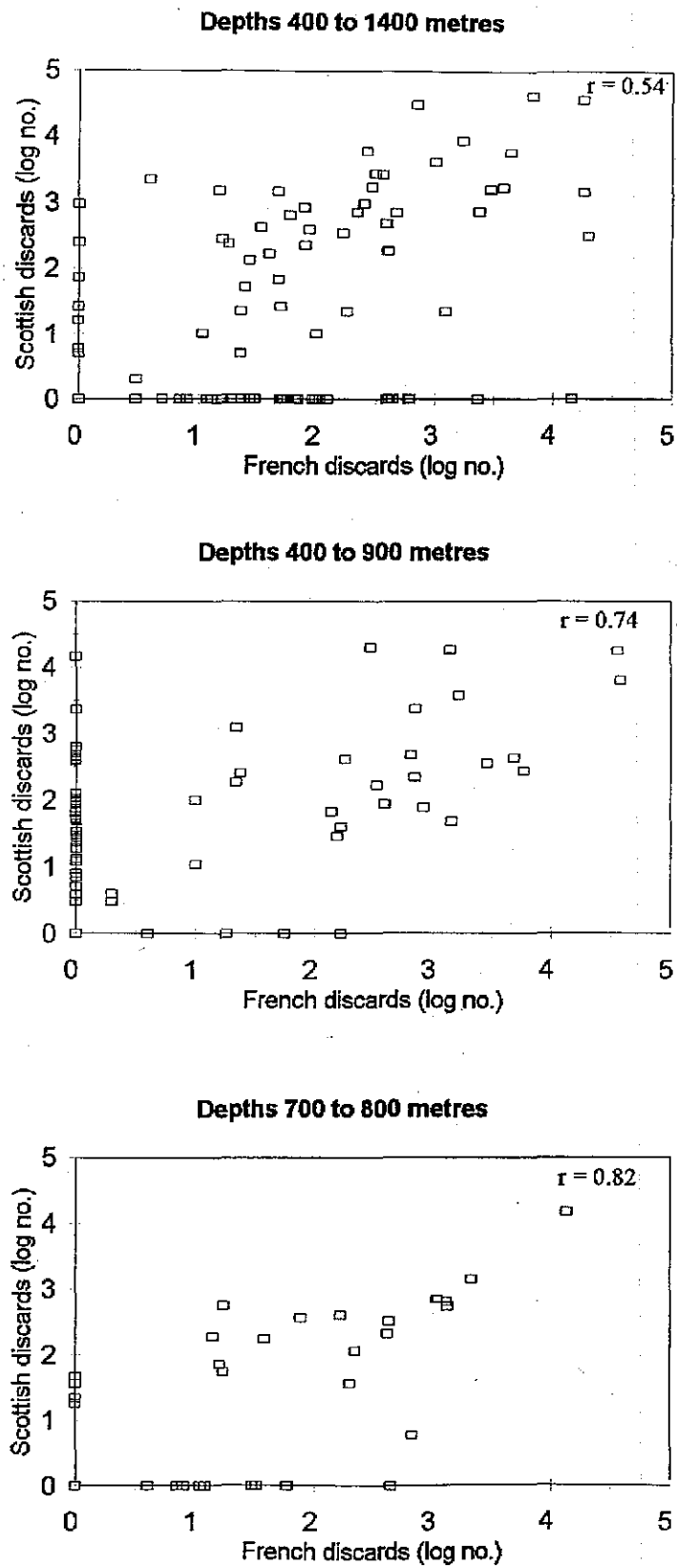
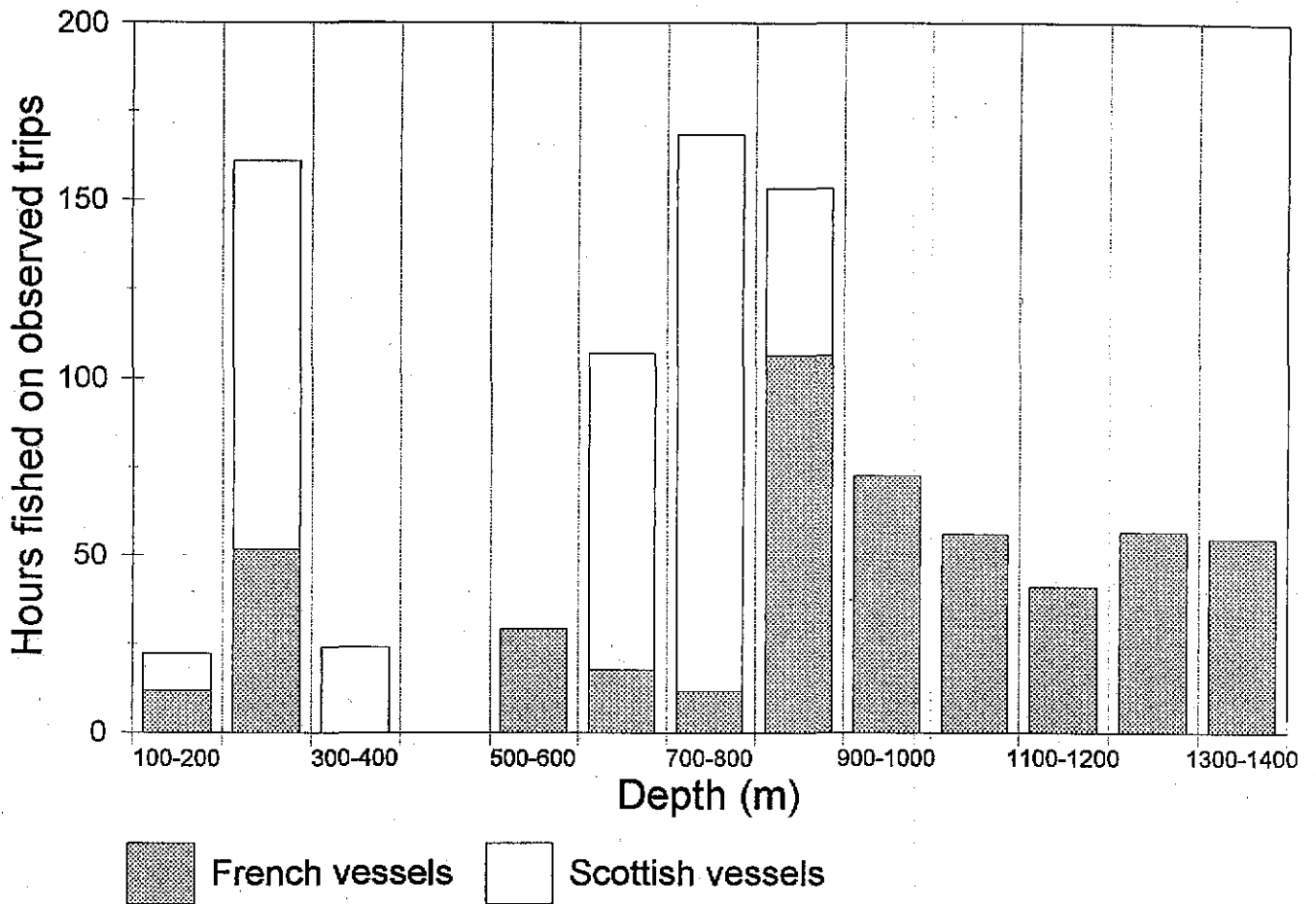


Fig 9. Depth distribution of fishing effort on observed trips.



GENERAL AND SPECIAL INVESTIGATION OF
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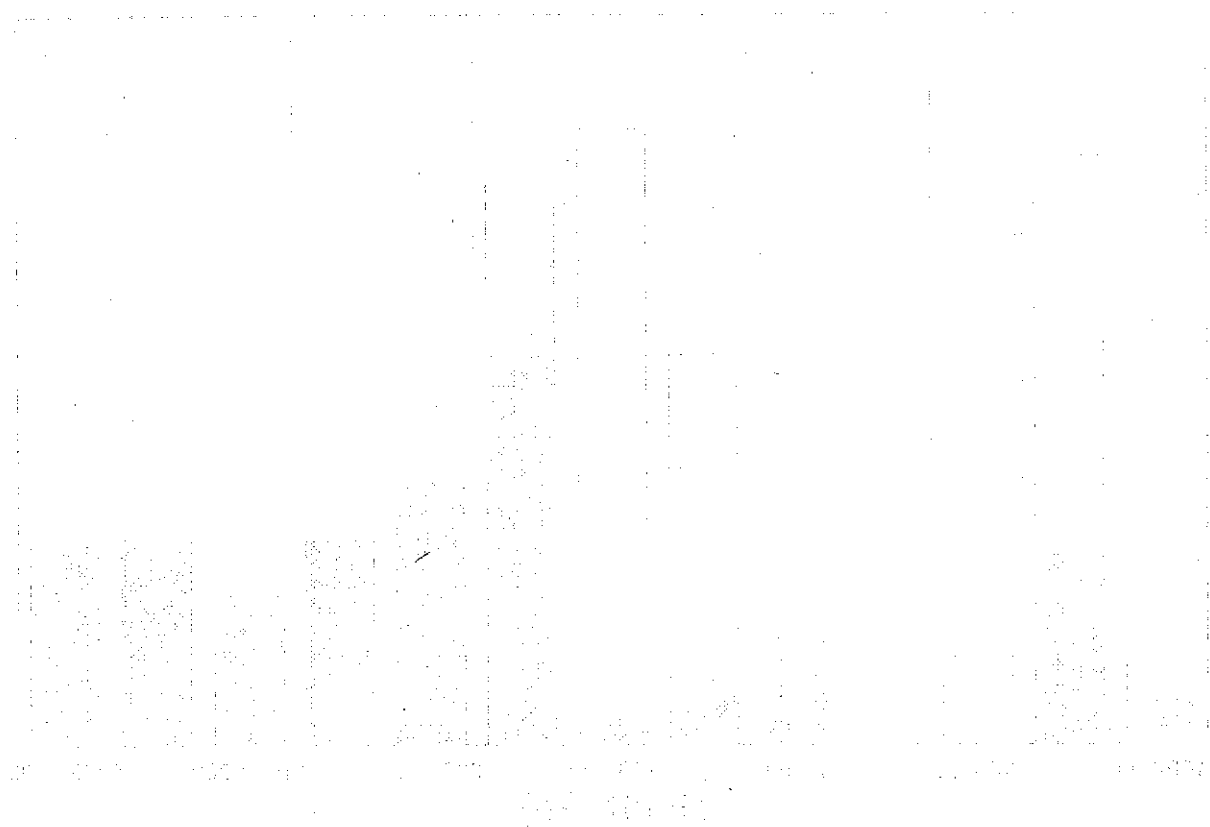
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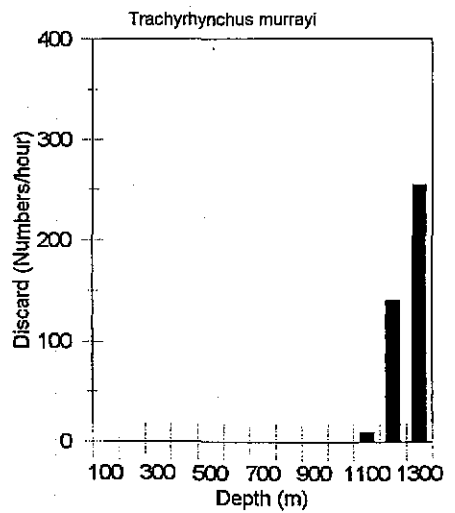
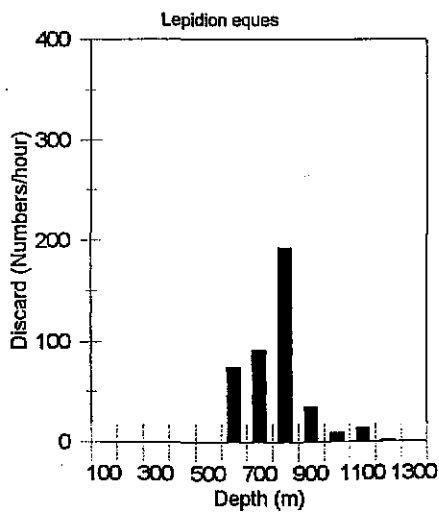
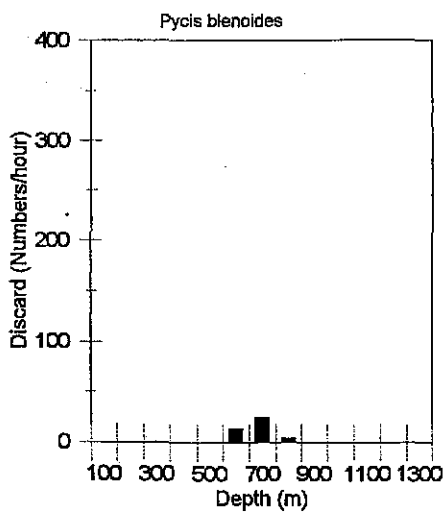
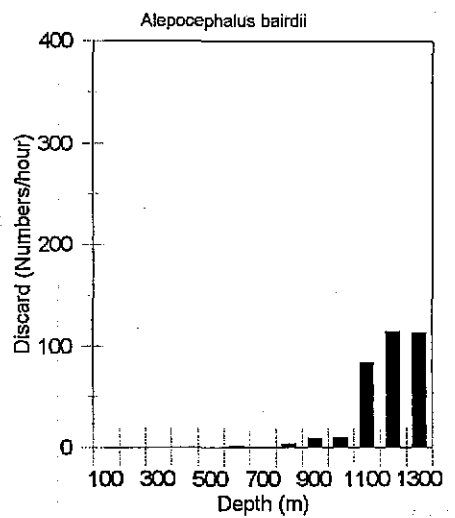
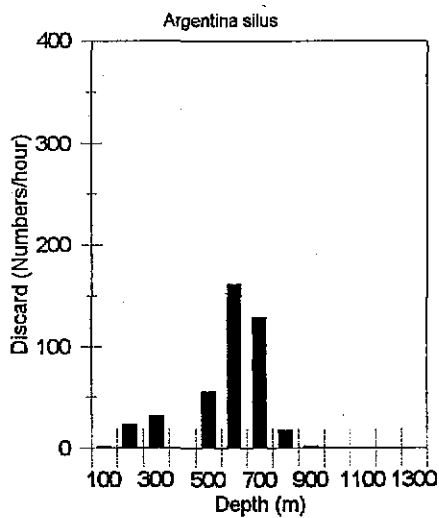
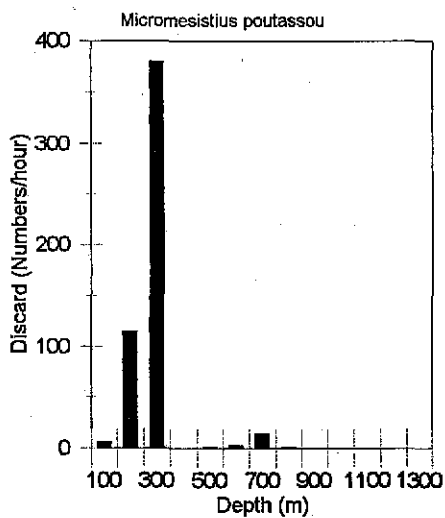
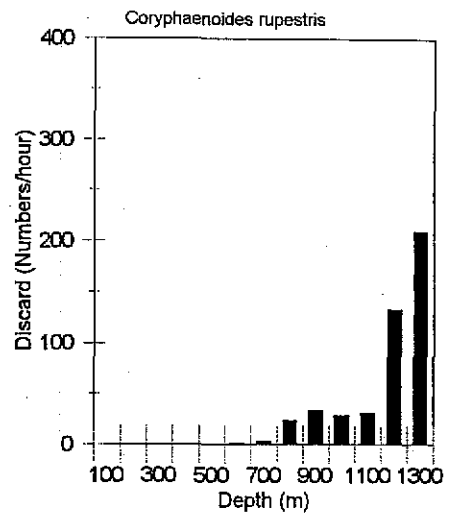
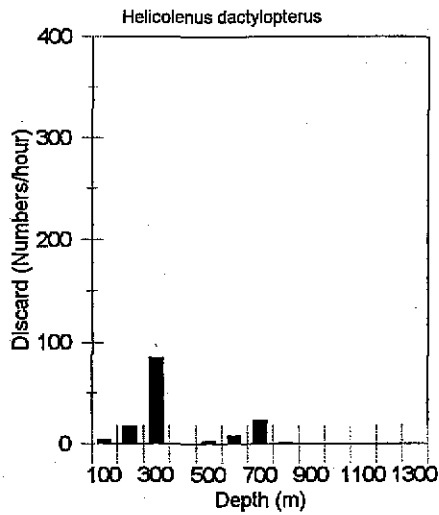
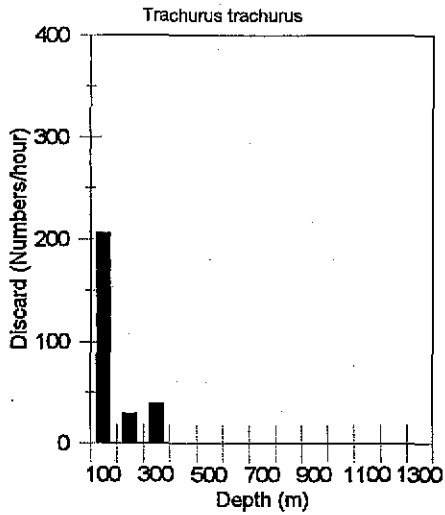
1957

RECORDS SECTION



GENERAL INVESTIGATION SECTION

Fig 10 Discarding rates of the 9 most abundant species. Fleet data combined.



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