for birds
for people
for ever

Net loss – seabirds gain?

Implications of fisheries management for seabirds scavenging discards in the northern North Sea

Net Loss – Seabirds Gain?

Implications of Fisheries Management for Seabirds Scavenging Discards in the Northern North Sea.

S.A. Reeves and R.W. Furness

S.A. Reeves[1]
FRS Marine Laboratory
PO Box 101,
Victoria Road
Aberdeen,
AB11 9DB
UK

R.W. Furness
Institute of Biomedical and Life Sciences
Graham Kerr Building
University of Glasgow
Glasgow
G12 8QQ
UK

(*r.furness@bio.gla.ac.uk*)

[1]Current Address :
Danish Institute for Fisheries Research, Charlottenlund Slot, DK-2920 Charlottenlund, Denmark.
Email : sar@dfu.min.dk

Abstract

The North Sea is important both for fisheries and for seabird populations. Current fishing practices in the northern North Sea fishery for cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) lead to substantial wastage of undersized haddock and whiting which are discarded and thus available as a food supply for seabirds. The North Sea has important populations of scavenging seabirds, for which discards and offal, especially of haddock and whiting, are an important food source. When considered as a proportion of the biogeographic population, the North Sea is particularly important for great skuas (*Catharacta skua*) and great black-backed gulls (*Larus marinus*). Fishery management measures which alter the availability of discards and offal in the North Sea may thus have an impact on the region's seabird populations.

This report addresses the fisheries and seabirds of the North Sea with the aim of identifying likely impacts of recent and future fishery management measures on seabird populations. The roundfish fisheries, particularly for haddock and whiting, are discussed with special reference to discarding and offal production, and how these activities might be affected by changes in fishery management measures. The status of the relevant seabird populations is reviewed, with particular emphasis on recent studies of seabirds and discards. The likely impact is evaluated of possible future management measures on the availability of discards and offal, and the knock-on effect this might have on seabird populations.

Mainly as a result of reduced roundfish stocks, recent production of discards and offal has been at relatively low compared to the last 25 years, and further declines in discard production are likely as a consequence of measures intended to make fishing gears more selective and to reduce fishing effort. Better gear selectivity is likely to lead to a particularly marked reduction in the availability of small discards, which are important for the smaller scavenging seabird species, although offal production may increase.

Scavenging seabird populations in the North Sea are large, and there are indications that this may be due to the ready availability of fishery waste as a food source. A reduction in discards is therefore likely to have consequences for seabird populations, although this will to some extent depend on the availability of other prey. The precise impacts are difficult to predict, but are likely to be most severe on the smaller scavenging seabirds (notably great skua and certain gulls). Breeding populations may decline and predation by great skuas on other seabird species may increase. The management implications of these potential changes are discussed, both for the seabirds and the fishery.

Net Loss – Seabirds Gain? Implications of Fisheries Management for Seabirds Scavenging Discards in the Northern North Sea

Summary and Recommendations

1. Current fishing practices in the North Sea roundfish fishery lead to substantial wastage of undersized fish which are discarded and thus available as a food supply to seabirds. Over 1975-1999, vessels fishing for haddock *Melanogrammus aeglefinus* for human consumption in the North Sea are estimated to have discarded 39% and 44% respectively of their catch in weight of haddock and whiting *Merlangius merlangus*.

2. This report concentrates on recent and future production scenarios for discards and offal of haddock and whiting, since these are the main species taken by scavenging seabirds, and the potential impacts of these changes on these birds. Particular attention is paid to the availability of small discards (25cm or less) which are an important food source for the smaller scavenging seabird species.

3. To make these projections, detailed models are described of both the exploited fish population and processes such as gear selectivity and discarding which may be affected by fisheries management actions, with special reference to the Scottish demersal fleet. Quantities of haddock and whiting discarded are estimated from Scottish sampling data for 1975 -1999. Fisheries management considerations use information up to 2000.

4. Quantities of discards and offal generated by fishing vessels have been at a relatively low level in recent years, reflecting the reduced abundance of stocks of haddock and whiting.

5. Future fisheries management measures, particularly better gear selectivity (notably the introduction of a square-meshed panel into the codend of trawl nets) and to a lesser extent reduced fishing effort (projections are based on a 20% reduction), are likely to lead to a further reduction in the quantities of haddock and whiting discarded. There is likely to be a particularly marked reduction in the availability of small discards.

6. However, assuming the continuation of current gutting practices, any measure which reduces discards will also tend to result in an increase in offal production, as a greater proportion of fish would survive to be caught at a size at which they would be gutted at sea.

7. It has been estimated that North Sea seabirds consume about 600,000 tonnes of prey annually, including ca 100,000 tonnes of discards and ca 70,000 tonnes of offal.

8. Populations of scavenging seabird species in the North Sea showed a ten-fold increase over 1900-1990, and the ready availability of discards and offal is likely to have contributed to this increase.

9. Some of these seabird populations are of international conservation importance. The British Isles hold 58% of the world population of the great skua *Catharacta skua,* and over 70% of the world population of both northern gannet *Morus bassanus* and the subspecies *graellsii* of the lesser black-backed gull *Larus fuscus*. Almost the entire west European population of the great-black-backed gull *Larus marinus* is thought to winter in the North Sea.

10. Given the relatively high population of scavenging seabirds, the reduced availability of discards is likely to have consequences for their populations, although this will depend to some extent on the availability of other food sources, notably sandeels.

11. The effects of such a food shortage are difficult to detect and predict for two related reasons: (a) seabird censuses concentrate on breeding populations and non-breeders may, for several years, fill breeding vacancies that arise; (b) because of delayed maturity typical of seabirds, breeding adults usually represent less than 50% of the total number of birds, so responses at the population level lag behind changes in environmental conditions.

12. However, in the long term, the effects of reduced discards are likely to be reduced breeding populations of the species affected, and of other seabirds on which they may prey.

13. The effects will be most pronounced amongst the smaller scavenging species which prefer small discards, *ie* great skua and most gull species (but notably herring gull *Larus argentatus* and lesser black-backed gull).

14. Northern gannet and great black-backed gull which can handle larger discards are less likely to be affected, likewise northern fulmar *Fulmarus glacialis* which is more dependent on offal than discards (though recent declines in haddock and whiting catches have already reduced offal availability).

15. The impacts of reduced discarding are likely to be most evident in Orkney and Shetland which support high breeding populations of scavenging seabirds and which are close to waters yielding the highest catches of roundfish.

16. Shortage of discards for great skuas is likely to lead to prey-switching including increased predation by this species on other seabird species such as black-legged kittiwake *Rissa tridactyla*, Atlantic puffin *Fratercula arctica*, European storm petrel *Hydrobates pelagicus*, Leach's petrel *Oceanodroma leucorhoa*, red-throated diver *Gavia stellata*, common eider *Somateria mollissima*, and even great black-backed gull. The incidence of such killing, which is possibly the most serious implication of fisheries management actions for seabird populations, will probably be a function of both sandeel and discard abundance.

17. Discarding is extremely wasteful of valuable fishery resources and disruptive of the North Sea ecosystem, so measures to further reduce or even to eliminate discarding should be encouraged even though they may have serious short- and medium term implications for seabird populations.

18. Studying the implications for seabirds of changes in the production of discards and offal will assist in forecasting likely changes in seabird populations and in devising more sensitive management for the conservation of affected species. In particular, there is a clear need for further research into interactions between scavenging seabirds and other wildlife (see 12, 16, above) so that the impacts of changes in discarding patterns on the overall seabird community can be better understood and possibly also managed.

Implications of fisheries management measures for scavenging seabird populations in the Northern North Sea

The main part of this Report is Section 1 which gives an overview of the work, including a general description of the models and data used to estimate the effects of possible fisheries management actions on the availability of discards and offal to seabirds. Section 2 gives a much more detailed technical description of these models. These sections are followed by an extensive reference list which places particular emphasis on recent studies of seabirds and discards. Annex 1 contains a Glossary giving brief definitions of some of the fisheries management terminology used in the Report.

Section 1

1.1 Introduction

The waters of the North Sea sustain large populations of a number of seabird species. The same waters also support large scale commercial fisheries. These two facts are related as some of the North Sea's seabird species are scavengers which feed extensively on offal and fish discarded by fishing vessels, and whose populations have expanded as a result. Hence these seabird species are, to some extent, dependent on a food supply which is only available through the activities of fishing vessels in the North Sea. As a consequence, any fishery management action which restricts the activity of fishing vessels in some way may also have consequences for these seabird populations. By drawing together information on both the fisheries and the seabird populations, this study considers the possible effects which management of some of the main North Sea fisheries may have on the area's seabird populations.

We will first review the context, namely fisheries and seabirds in the North Sea. We will identify the fisheries which are most important in terms of discard and offal production, and consider how the activities of these fisheries make discards and offal available to seabirds, and how current and future fisheries management may influence these activities. Turning to the seabirds, we will review the importance of the North Sea for seabirds and highlight the species of most concern. We will then review the exploitation of fishery waste by seabirds, with particular reference to the North Sea.

Having established the context, we will then document the approaches we have used to assess how future changes in fisheries management may affect the availability of discards and offal, and how these changes may affect seabird populations. We will then discuss the results of these analyses and attempt to draw conclusions about the implications of possible fisheries management measures for seabird populations.

1.2 Context - Fisheries and seabirds in the North Sea

1.2.1 North Sea fisheries

The fisheries in the North Sea include fisheries directed at pelagic species (*eg* herring, *Clupea harengus* and mackerel, *Scomber scombrus*) and industrial fisheries taking species such as Norway Pout (*Trisopterus esmarkii*) and sandeel (predominantly *Ammodytes marinus*). However, these fisheries tend not to generate very large quantities of discards or offal, so here we focus only on demersal fisheries. The principal demersal fisheries in the North Sea can be broadly categorised as a roundfish fishery targeting mainly cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and to a lesser extent saithe (*Pollachius virens*); and a flatfish fishery where the principal target species are plaice (*Pleuronectes platessa*) and sole (*Solea solea*). The fishery for Norway Lobster (*Nephrops norvegicus,* sold as 'scampi') also takes a bycatch of roundfish species and can generate substantial discards of these species, so it is here considered as a component of the roundfish fishery. The main roundfish fishery takes place in the northern North Sea, whereas the flatfish fishery is focussed in the southern North Sea. Both fisheries generate substantial quantities of discards and offal but this is less of a feature of the flatfish fishery. In addition, discarding has been less well studied in the flatfish fishery, so here we consider only the roundfish fishery. Furthermore, as numbers of cod discarded are much lower than those of haddock or whiting, only the latter two species are considered here.

1.2.2 Fishing activity and the availability of discards and offal

In the context of the North Sea roundfish fisheries, discarding typically arises from the discrepancy between the size of fish which are retained by the fishing gear in use and the size of fish which may be legally landed or which the market will accept. It can thus be seen to have two components: the selectivity of the fishing gear, which determines the size composition of the catch, and the sorting process on the deck, which determines whether individual fish are either retained or discarded.

In the North Sea, haddock and whiting are caught predominantly in towed gears such as trawls and seines where the catch is retained in a mesh bag at the rear of the net which is known as the codend.

The selectivity characteristics of these gears are largely determined by the construction of the codend and the section of the net it is attached to (known as the extension). Increasing the mesh size of a codend tends to make it more selective by allowing more small fish to escape. However, other aspects of the codend's construction also influence its selectivity, for instance using a thicker twine results in a less selective codend as the meshes are less open. Reeves *et al* (1992) estimated the selectivity of gears in general use by Scottish trawlers and seiners and concluded that they were highly unselective. It would appear that nets are typically rigged so that they retain all fish of a marketable size. The mixed-species nature of the North Sea roundfish fishery means that a net rigged to retain the smallest marketable size of whiting will inevitably also retain haddock and cod which are substantially smaller than the legal minimum sizes for these species.

Once the catch has been taken aboard, the fish are then sorted and a proportion of the catch is discarded. For the principal commercial species, this discarding process generally involves a choice by the fishers such that fish below a certain size are discarded, and fish above that size are retained. Stratoudakis *et al* (1998) described this threshold size as the DL50, or the length at which 50% of the fish caught are discarded. They found that the DL50 tended to reflect the legal minimum landing size but that there were also differences *eg* between inshore and offshore areas, with more larger fish being discarded in offshore areas. In addition, the discarding practice for whiting was dependent to some extent on the amounts of the other, more valuable, species in the catch. For haddock, there was some indication that the size at discarding increased in response to more restrictive quotas, in order to retain quota for the larger, more valuable fish - a process known as 'high grading'. However, it is most unusual for the whole catch of a species to be discarded for quota reasons. On occasions the whole catch of whiting may be discarded, particularly if there are good catches of cod and haddock in the same haul (Stratoudakis *et al*, 1998), but this is connected more with the relatively low value of the species than with quota restrictions.

The quantity of discards is to a large extent determined by the size composition of the exploited fish population. Haddock and whiting are relatively slow growing and can take three to four years to reach a marketable size, hence large numbers are caught and discarded before they reach these sizes. Overall population size is also an important factor. Haddock, and, to a lesser extent, whiting can show considerable variations in year class strength (*ie* the number of young fish entering the population each year), so the numbers of fish discarded can also vary accordingly. Cod are naturally a larger, faster growing and less abundant species than haddock or whiting, hence the numbers of cod discarded are much lower than those of haddock and whiting. Very few of these discarded fish survive, so these discards represent a considerable waste and a loss to the fishery.

Offal is generated when fish are gutted at sea and the resultant guts and waste are discharged into the sea. Only fish from the retained portion of the catch are gutted, but most of these are gutted at sea. In some cases, economic considerations may mean that only larger individuals of lower-value species will be gutted.

1.2.3 Fisheries management and the availability of discards and offal to seabirds

Fisheries management seeks to limit the activities of fishing vessels in order to conserve the fish stocks which the vessels are exploiting. Broadly speaking this is done through a combination of measures which affect the overall amount of fishing effort, (*eg* limits on the total amount of fish which may be landed) and technical conservation measures (TCMs) which affect the size of fish which are caught (*eg* regulations on minimum landing size of fish and on minimum mesh size of the fishing gear). Both of these approaches will affect the relative availability of discards and offal to seabirds. Any measure which reduces the overall fishing intensity will mean that on average fish will live longer before they are caught, resulting in a larger average size in the catch and thus fewer undersized fish to be discarded, but more larger fish to be gutted. The intention of technical measures is to make fishing gears more selective by allowing more small fish to escape, so again the overall result should be a reduction in the number of discards together with an increase in the mean size of the catch.

In the North Sea, it is the demersal fishery for roundfish which represents the most important source of discards and offal for seabirds. The principal management measures in place for the fishery are annual TACs (Total Allowable Catches, *ie* annual limits on the quantity of each species that may be landed) and regulations on minimum landing size for each species and on the minimum mesh size which may be used in constructing the codend.

Scientific advice on the management of North Sea fisheries is formulated by the Advisory Committee for Fishery Management (ACFM) of the International Council for the Exploration of the Sea (ICES). The ACFM advice is then used as the basis from which TACs are negotiated for the following year. The 1999 ACFM advice for both haddock and whiting implied that the fishing intensity on these stocks should be reduced by at least 10% for haddock, and at least 20% for whiting. While this advice may only be partially reflected in the TACs, these figures do give an indication of the likely extent of short-term changes in fishing intensity.

Historically, attempts to regulate the selectivity of towed fishing gears in the North Sea have only imposed restrictions on the minimum mesh size which may be used, and current regulations dictate that vessels fishing in the directed roundfish fishery should use a mesh size of at least 100mm. As noted in Section 1.2.2, other aspects of codend construction can also influence the selectivity of the gear, and this is reflected in the most recent EC technical regulation on fishing gears (European Council Regulation 850/98), which came into force in January 2000. This regulation imposes limits on twine thickness and on the maximum number of meshes around the codend. These measures will have little effect on the selectivity of current codends which already conform to these constraints. The regulation also allows for the optional introduction of square mesh panels into the top of 100mm mesh codends. These measures, with additional restrictions on twine thickness, became mandatory for UK vessels during the summer of 2000. In addition, the 2000 ACFM advice for North Sea cod stated that a rebuilding plan should be implemented in order to rebuild the spawning stock. It is likely that further changes in technical measures will be implemented as part of this rebuilding plan, including the introduction of a minimum mesh size of 120mm in the North Sea roundfish fishery.

1.2.4 Populations of scavenging seabirds in the North Sea

The British Isles hold many internationally important seabird colonies. Partly because of their long coastlines and many cliff-bound islands, the numbers of seabirds in the British Isles are higher than in most other countries in Europe. In this study, we focus on scavenging seabirds whose populations are particularly concentrated in the North Sea. We define 'scavenging' seabirds in the North Sea context as those species identified by Camphuysen *et al*. (1995) as feeding extensively on offal or discarded fish behind fishing vessels in the North Sea. Population estimates for these species are given in Table 1.1, while Table 1.2. gives the estimated seasonal peak numbers for these species in the North Sea. Figure 1.1 shows the areas mentioned in the text and tables. In terms of the importance of the North Sea populations, the most relevant species are great skua *Catharacta skua* and great black backed gull *Larus marinus*.

Table 1.1 Numbers of breeding pairs[1] of scavenging seabirds in different defined areas

Data for Britain and Ireland, Europe, Biogeographical population, and World total, from Lloyd et al. (1991) based on counts during the 1980s. Data for North Sea coasts within ICES areas from Hunt and Furness (1996) based on the same 1980s data sets.

Species	Britain and Ireland	Britain & Ireland numbers as % of Biogeogr. total	Europe	Britain and Ireland numbers as % of European total	World total breeding pairs for species	European numbers as % of world total	Biogeographical total	North Sea ICES IVa (west)	North Sea ICES IVa (east)	North Sea ICES IVb (west)	North Sea ICES IVb (east)	North Sea ICES IVc
Northern fulmar	571,000	7.6%	5,840,000	9.8%	20,000,000	29%	N. Atlantic; 7,540,000	294,000	0	12,600	36	700
Northern gannet	187,700	71.4%	223,.600	83.9%	263,200	85%	N. Atlantic; 263,000	21,700	0	22,100	0	0
Great skua	7,900	58.1%	13,600	58.1%	13,600	100%	World; 13,600	7,300	4	0	0	0
Black- headed gull	233,000	14.1%	1,200,000	19.4%	1,700,000	71%	Europe to Urals; 1,650,000	3,500	36,900	16,000	53,800	19,300
Mew gull	71,400	13.5%	488,000	14.6%	580,000	84%	Europe to Urals; 530,000	15,800	43,200	100	6,500	7,800
Lesser black-backed gull	88,500	71.4%	187,000	47.3%	not known	-	*L.f.graellsii*; 124,000	2,600	25,500	2,200	15,800	3,300
Herring gull	206,000	21.9%	978,000	21.1%	1,900,000	51%	*L.a.argenteus* and *L.a.argentatus*; 940,000	41,800	34,000	40,500	96,300	24,500
Great black-backed gull	23,400	16.7%	83,100	28.2%	200,000	42%	NE Atlantic; 140,000	9,900	14,500	31	1	0
Black-legged kittiwake	544,000	17.2%	1,740,000	31.3%	7,000,000	25%	*R.t.tridactyla*; 3,170,000	206,600	3,000	200,000	3,300	2,600

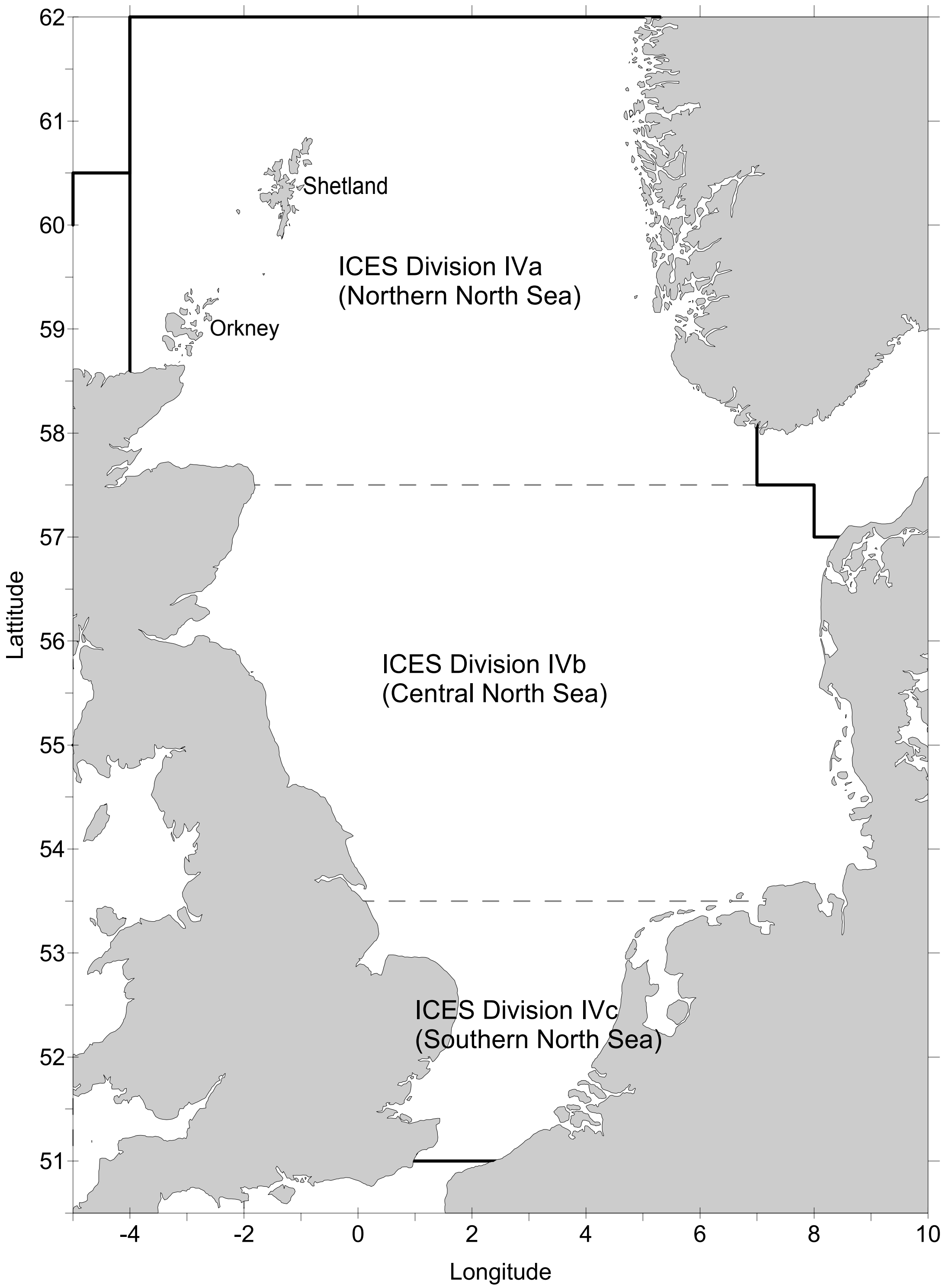
[1] Estimates for northern fulmars are occupied sites.

Table 1.2 Estimated seasonal peak numbers of scavenging seabirds in the North Sea

The figures given are peak numbers of various scavenging seabird species that were present in the North Sea over the period of the Seabirds at Sea Database reported in Tasker *et al*. (1987) (fieldwork from 1983-86). These estimates were presented, and discussed, in Furness (1992).

Species	Period of peak numbers in North Sea	Overall seasonal peak no. present in North Sea during 1983-86
Northern fulmar, *Fulmarus glacialis*	September-October	3,300,000
Northern gannet, *Morus bassanus*	March-April	160,000
Great skua, *Catharacta skua*	late summer	no estimate
Black-headed gull, *Larus ridibundus*	January-February	no estimate
Mew gull, *Larus canus*	November-March	no estimate
Lesser black-backed gull, *Larus fuscus graelsii*	September	122,000
Herring gull, *Larus argentatus*	November-December	1,600,000
Great black-backed gull, *Larus marinus*	October-December	700,000
Black-legged kittiwake, *Rissa tridactyla*	February	2,000,000

Figure 1.1 The North Sea showing areas mentioned in the text



The world population of the great skua is only 13,600 breeding pairs (Table 1.1). Britain and Ireland hold 58% of this breeding population, and over 50% of the world population breeds within the north-western North Sea, almost all within the islands of Shetland and Orkney. The world population of great black-backed gull is around 200,000 breeding pairs (Table 1.1), but counts indicate that as many as 700,000 birds may visit the North Sea in winter. This estimate seems high relative to the estimated 83,000 breeding pairs in Europe, but the birds visiting the North Sea in winter are thought to include almost all west European great black-backed gulls and probably also some Russian birds. The total also includes immature birds which comprise roughly 50% of the population.

Apart from the above species, the British Isles also hold high proportions of the breeding populations of other scavenging seabird species, (*eg* over 70% of the world populations of both northern gannet *Morus bassanus* and the subspecies *L. f. graellsii* of lesser black-backed gull). Other species including black-legged kittiwake *Rissa tridactyla* and herring gull *L. argentatus* scavenge within the North Sea at certain times of year. Black-headed gulls (*Larus ridibundus*) and mew gulls (*Larus canus*) are rarely seen scavenging at fishing boats in summer or in the northern North Sea but are more frequent at fishing boats in the southern North Sea during winter (Camphuysen *et al*. 1995). All 'scavenging' seabirds will take natural foods as well as offal or discards, and in general, scavenging at fishing boats forms a greater part of their feeding during winter than during the summer breeding season (Tasker & Furness 1996). This is evident also from the tendency for peak numbers of scavenging seabirds to occur in the North Sea during winter (Table 1.2). The most abundant scavenging species in the North Sea is northern fulmar *Fulmarus glacialis*, but the population in Britain and Ireland (over half a million occupied sites) represents less than 3% of the world population of this widespread species.

All of the above species feed extensively on offal or discards in some parts of the North Sea at some times of year. However, it is the particular concentration of internationally important populations of great skuas and great black-backed gulls in the north-western North Sea, where the bulk of the fishing effort for roundfish species also takes place, which makes these two species of most immediate concern here.

1.2.5 Seabird exploitation of discards and offal

North Sea seabird species differ in the extent to which they exploit discards and offal as a food source and also in the extent to which these food sources are available to them. Northern fulmars feed more on offal than on discards and tend to be behaviourally dominant and thus successful in obtaining offal in this manner. Northern gannets have a high success rate in obtaining discards; they are able to swallow even large discards (see below) and are able to take fish in competition with smaller scavenging seabirds. Great black-backed gulls can swallow larger discards than those taken by herring gulls or great skuas (see below), and often obtain a high proportion of these.

Of the fish species considered here, seabirds find whiting slightly easier to swallow than the same length of haddock, because haddock have a relatively greater maximum girth and are not as easily squashed during swallowing. It is probably the girth of the fish that mainly determines how long it takes a seabird to swallow it (Hudson 1989) and therefore determines both the maximum size that can be swallowed, and the handling time of fish that can be swallowed but may be stolen by other seabirds while they are being handled (Hudson and Furness 1988, Hudson 1989). Nevertheless, length and girth are closely correlated and most work has been based on relationships with discard length, hence only length is considered in this report. Current discarded haddock are predominantly in the size range 22-33 cm in length. Current discarded whiting are predominantly 23-31 cm long.

Although most scavenging seabirds in the North Sea will attempt to swallow fish up to 33 cm in length (Camphuysen *et al*. 1995), mew gulls rarely swallow discards more than 16 cm long, black-legged kittiwakes rarely swallow discards more than 19 cm long, northern fulmars rarely swallow discards more than 24 cm long, lesser black-backed gulls rarely swallow discards more than 25 cm long, herring gulls and great skuas rarely swallow discards more than 28 cm long, whereas great black-backed gulls take discards up to at least 35 cm long and northern gannets take discards up to at least 40 cm long (Camphuysen *et al*. 1995). Thus mew gulls and black-legged kittiwakes are already largely excluded from swallowing current sizes of discarded haddock and whiting in the North Sea. Northern fulmars, lesser black-backed gulls, herring gulls and great skuas may be progressively excluded from being able to swallow discards if the sizes of discards increased much from the current distribution, but great black-backed gulls and northern gannets might gain from an increase in discard size that would make a higher proportion of discards available to them but unavailable to smaller scavenging seabirds.

It has been estimated that seabirds in the North Sea consume about 600,000 tonnes of prey annually, including ca 100,000 tonnes of discards and ca 70,000 tonnes of offal (Tasker and Furness 1996). While it is evident that large quantities of offal and discards are both available and consumed (see also Camphuysen *et al*. 1995, Garthe *et al*. 1996, 1999), and that breeding numbers of scavenging seabirds on North Sea coasts increased at least ten-fold over 1900-1990 (Furness 1992), it is difficult to verify that these increases can be directly attributed to the provision of this food. Although it is difficult to prove this connection in the North Sea (see Section 1.3.2), studies in the western Mediterranean (Section 1.2.6) have indicated that populations of scavenging seabird populations there were sustained at an artificially high level by the availability of discards and offal, and it seems highly likely that a similar situation exists in the North Sea.

The increased food available through discarding and offal production could influence population size in a number of ways. It could have a direct effect on breeding success, though discard use in summer is generally less than in winter as scavenging seabirds tend to switch to natural foods (especially small lipid-rich fish) during the breeding season. As a result, increased availability of fish waste may be much less influential than variation in abundance of food-fish, although discards are fed to great skua chicks as a major part of their diet during growth.

Discards and offal may also affect breeding success indirectly, by improving body condition of scavenging seabirds during winter. This may also increase overwinter survival of scavenging seabirds, which could have a major influence on the rate of population growth. Hüppop & Wurm (2000) demonstrated that body condition of herring gull and great black-backed gull correlated with availability of discards near Helgoland, and they extrapolated to suggest that this would affect overwinter survival and hence population dynamics. A new research project funded by the EC (DISCBIRD) will investigate individual variation in body condition and breeding performance in relation to biochemical markers of the amount of demersal fish (presumed obtained as discards) in scavenging seabird diet.

Meanwhile, we infer by analogy with the changes observed in the western Mediterranean (see Section 1.2.6 below) that scavenging seabird populations in the North Sea are much larger at present than would be the case if fisheries had not been providing large quantities of offal and discards over many decades, and that changes in provision rates will alter these numbers through effects on various aspects of seabird demography.

1.2.6 Bibliography - Recent studies of seabird and discards

There has been a considerable amount of research published recently on discarding and implications for seabird populations or breeding biology. The Reference list attached to this report (and which includes a few sources not specifically cited in the Report) is intended to include as many relevant publications as possible, though it is inevitable that it will be far from comprehensive, especially given the difficulty of locating relevant papers in the 'grey literature' and various reports that are not abstracted in literature data bases. Much of the earlier work on these topics is discussed in Furness (1992).

The exploitation of discards as food by seabirds has been reported from many parts of the world, including Southern Africa (Abrams 1983, Ryan & Moloney 1988), the Falkland Islands (Thompson

1992, Thompson & Riddy 1995), Australia (Blaber & Wassenberg 1989, Blaber *et al*. 1995), New Zealand (Freeman 1997, Freeman & Smith 1998), the Gulf of St Lawrence (Chapdelaine & Rail 1997), the Mediterranean (Paterson *et al*. 1992, Castilla & Perez 1995, Oro 1995, 1996a,b, Oro & Martinez-Vilalta 1994, Oro & Ruiz 1997, Oro *et al*. 1995, 1996a,b, 1997, 1999, Arcos & Oro 1996, Ruiz *et al*. 1996, Oro & Pradel 1999, 2000), and Baltic Sea (Durinck *et al*. 1994, Scherp 1999, ICES 2000b,c).

However, the North Sea has been the focus of the earliest and the most detailed attention both for studies quantifying discard rates in different fisheries (Furness 1992, Reeves *et al*. 1992, Alverson *et al*. 1994, Evans *et al*. 1994, Garthe *et al*. 1996, Walter 1997, ICES 1998, Stratoudakis 1999, Stratoudakis *et al*. 1998, 1999), as well as for studies of the utilization of discards by scavenging seabirds (Dändliker & Mülhauser 1988, Hudson & Furness 1988, 1989, Hudson 1989, Berghahn & Rösner 1992, Furness *et al*. 1992, Camphuysen 1994, Garthe & Hüppop 1994, Walter & Becker 1994, 1997, Camphuysen *et al*. 1995, Garthe *et al*. 1996, 1999a,b, Tasker & Furness 1996, Camphuysen & Garthe 1997, Hunt *et al*. 1999, Tasker *et al*. 1999, 2000) and seabird dietary studies related specifically to use of discards as food (Hamer *et al*. 1991, 1997, Noordhuis & Spaans 1992, Thompson *et al*. 1995, Furness 1997, 1999, Ratcliffe *et al*. 1998, Phillips *et al*. 1996, 1997, 1999a,b).

The monitoring studies of North Sea seabird breeding numbers and breeding success (Walsh *et al*. 1991, 1992, 1993, 1994, 1995a,b, Thompson *et al*. 1996, 1997, 1998, 1999, Upton *et al*. 2000, Mavor *et al.* 2001) are more detailed than for any other region of the world, but there has been very little effort put into relating breeding biology of North Sea seabirds to the availability of discards and offal. The most detailed work on this important subject has been from Mediterranean studies, where it has been possible to relate seabird breeding performance to the opening and closure of the demersal fisheries that provide discards (Oro & Martinez-Vilalta 1994, Castilla & Perez 1995, Oro 1995, 1996a,b, Oro *et al*. 1995, 1996a,b, 1997, 1999, Oro & Ruiz 1997, Arcos & Oro 1996, Ruiz *et al*. 1996, Oro & Pradel 1999, 2000). Possible impacts of reduced discarding in the North Sea were examined by Furness (1992), in which there is a review of the evidence suggesting that seabird population sizes in the North Sea tend to be limited by food supply, and that there is considerable competition between seabirds for the supplies of discards and offal that have been available in recent years.

In addition, there is now growing evidence of the effects of reduced food supply causing dietary switching by great skuas in Shetland (Furness 1997, 1999, Oro & Furness submitted) and of this having immediate adverse effects on smaller seabirds that form the alternative prey of great skuas (Heubeck *et al*. 1997, 1999, Oro & Furness submitted). Similar predator-prey interactions involving scavenging seabirds have been reported in other areas of the world too, eg with gull predation on terns in the southern North Sea (Becker 1995) and Newfoundland (Howes & Montevecchi 1992, Regehr &

Montevecchi 1996), with large and small gulls in the Mediterranean (Oro & Martinez-Vilalta 1994), gulls and puffins *Fratercula arctica* in Newfoundland (Russell & Montevecchi 1996).

1.3 Assessing the implications of fisheries management measures for scavenging seabird populations

1.3.1 Assessing the effects of changes in fisheries management on discards and offal

The data and methods used to assess the possible effects of likely fishery management methods are documented fully in Section 2 of this Report. The intention of this section is to give a non-technical overview of the data and analyses.

To assess what effects a possible change in fisheries management may have, a number of different pieces of information are needed. For the change in technical conservation measures, information is needed on how selective current gears are, and how much this will change with the introduction of new gear regulations. In this case the gear regulations involve the introduction of square-mesh panels and other constraints on codend construction as noted in Section 1.2.3. Information on the selectivity of this gear is available from experimental trials on gear selectivity. It is also important to have information on the size and growth characteristics of the fish populations in order that the consequences for the population of the change in gear selectivity can be assessed. This information is available from routine sampling of the landings at fish markets and from sampling of discards at sea.

In addition to the change in management measures, the availability of discards and offal to seabirds will also be affected by any changes in the onboard processing of the fish. Information on the quantities and size compositions of discards is available from the Scottish discard sampling programme. In addition, a study using Scottish discard data (Stratoudakis *et al*, 1998) provides useful information on how discarding is influenced by factors such as catch rate, quota and minimum landing size. This same sampling programme is also a source of information on the size at which fish are gutted rather than landed whole. This is necessary to estimate offal production.

Once all this information is available, it is possible to use standard catch forecast models to predict what the quantities discards and offal will be for a given combination of technical measure, fishing effort and discarding practice. Here the quantities of interest are the total amounts of discards and offal, but also the total amount of 'small' discards as some seabird species can only handle smaller discards (see Section 1.2.5). For this purpose, we define 'small' discards as fish of less than 26cm in length, reflecting the maximum size of fish which can be handled by the smaller scavenging species. Because the fish populations will fluctuate naturally irrespective of the fishery management practices, the forecasts are done on a long-term or equilibrium basis to give an overall average result, which is not affected by this fluctuation. Further, it is most instructive to summarise the results as percentages relative to the baseline (*ie* a run with no change in fishery management or discarding practice). The results can then be put into context by comparing the baseline forecast number of discards with the historical trends in numbers discarded.

By making a number of different forecast runs using different combinations of technical measure, fishing effort and discarding practice, it is possible to determine which of these factors has the greatest effect on the supply of discards and offal. It is also useful to determine what effect any change in discarding practice would have on these results, bearing in mind that for haddock, at least, there has been a recent tendency to discard fish at a larger size. Such a change in discarding practice might also result from an increase in the legal minimum landing size (MLS) for either haddock or whiting, although no such changes are anticipated at present. To investigate the effects of all of these potential changes, runs were made assuming that square mesh panels were adopted by 0% and 100% of the UK fleet; that fishing effort was reduced by 0% and by 20%, and that the length at which 50% of fish are discarded (known as the DL50) was kept constant and increased by 2cm. This led to eight different scenarios for each species. To represent current gutting practices, it was assumed that all haddock which are landed are gutted at sea, but that only whiting greater than 35cm are gutted, with smaller fish being landed whole.

1.3.2 Assessing the effects of changes in the availability of discards and offal on seabird populations

In the context of the North Sea it is not straightforward to assess the possible effects of any changes in the availability of discards and offal. For instance, it would seem logical to look for effects of changes in discarding rates on seabirds by correlating changes in breeding numbers of scavenging seabirds in the northern North Sea with changes in amounts of fish discarded over the last 20 years or so. Unfortunately, for a number of reasons, such a simple approach is not appropriate. In short, the available seabird population data are sparse and refer only to the breeding component of the population which may be less than 50% of the total population. This large component of non-breeding birds means that there may be a considerable lag before the effects of any food shortage becomes apparent.

To expand on these points, the last complete published census of breeding seabird numbers in the British Isles was for 1985-87 (Lloyd *et al*. 1991). Trends in breeding seabird numbers since 1987 are not clear as for most species only some sample counts are available and these are not necessarily representative of the population as a whole. Another census, 'Seabird 2000' has recently taken place (1999-2001), but the results from this are not yet available. In addition, these censuses only measure seabird breeding numbers and thus do not necessarily reflect total population size. Non-breeders may fill vacancies that arise in the breeding component, such that breeding numbers remain relatively stable even during a period of rapid decrease in total population numbers.

A further complication is that responses of seabird populations will tend to lag behind changes in environmental conditions because seabirds show delayed maturity. Any effect mediated through breeding production will not become evident until several years later, when altered numbers of young birds recruit into the breeding population. If reductions in discarding were to affect breeding numbers, then we must bear in mind that most seabird populations in the North Sea have been increasing in recent decades. To reverse an increase is like changing the course of a supertanker - it takes time. The cohorts of young birds about to recruit into the population may have to be 'used up' before a decline in breeding numbers can begin. In the case of great skuas, some birds do not breed until they are more than 12 years old. The importance of this becomes more obvious when it is appreciated that in a typical scavenging seabird population the breeding adults represent less than 50% of the total number of birds. In other words the typical population contains more pre-breeding (immature) birds that cannot be censused than breeding birds that are counted. The pool of potential recruits may continue to maintain or even increase breeding numbers for many years after the demographics have shifted to values that in the long term will result in a declining breeding population.

It is possible that breeding success of scavenging seabirds might be more clearly and immediately responsive to reductions in discard rates, but the fact that scavenging seabirds feed more on natural foods, particularly sandeels (*Ammodytidae*), while breeding and rely more on discards in winter suggests that breeding success may not be very responsive to discard rates and may more often be affected by variations in the abundances of the preferred natural foods. Immature survival through the winter might be the most useful parameter to relate to discard rates, but immature survival rates are difficult to measure, rendering this approach impractical at present. Also, the lag in seabird response could mean that effects of reduced discarding in the northern North Sea may eventually be seen in terms of breeding numbers in other geographical areas. For example, great black-backed gulls wintering in the northern North Sea include birds that breed in Arctic Norway and Russia.

The complex nature of the potential population responses to any food shortage, together with the limited data available to detect these responses, mean that it is not possible to make any quantitative estimates of the likely effects of a reduction in discards and offal on seabird population sizes.

However, by using the available information on recent changes in seabird populations, and on discard and offal production, it is possible to make a more qualitative assessment of what the likely effects of changes in food availability may be. This is addressed in the Section 1.5 below.

1.4 Results - Past trends and likely changes in availability of discards and offal

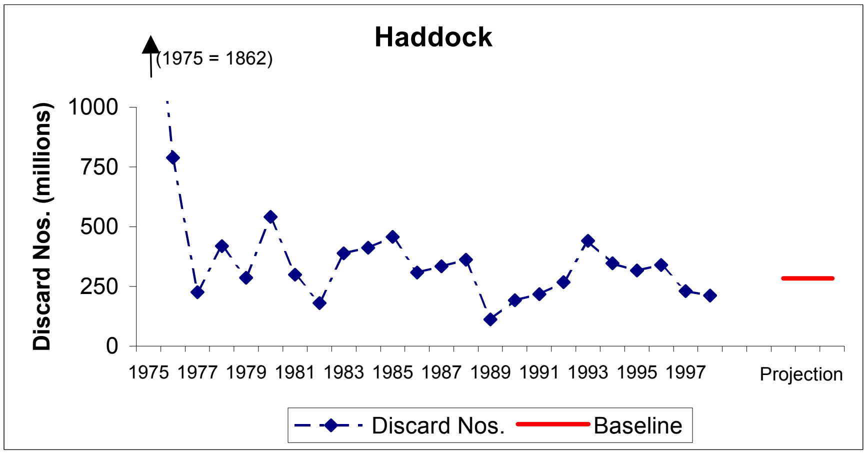
Before focussing on how future management measures are likely to change the relative availability of discards and offal, it is first useful to look at how these quantities have changed in the past. Estimates of quantities discarded are available from Scottish sampling back to 1975. Combining estimates for haddock and whiting (Figure 1.2), the total number of discards has tended to fluctuate without obvious trends, although there has been a clear decline since about 1993. This decline reflects in particular the decline in the whiting stock rather than any change in discarding practice, as discarding rates have varied without any obvious trend over this period. The baseline forecast indicates that without any change in management, the recent relatively low level of discarding will tend to continue. The numbers of discards less than 26cm in length have also tended to be at a low level in recent years (Figure 1.3), again reflecting mostly the low recent recruitment to the whiting stock. As in Figure 1.4.1, the forecasts indicate that this low level is likely to be maintained. Similar trends are also observed for offal production (Figure 1.4), with the recent relatively low level indicated to continue.

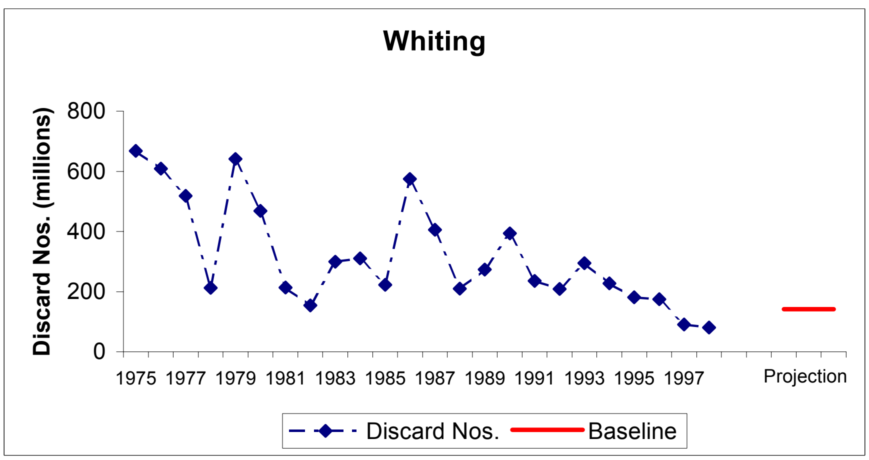
The discard data used in this study cover the period from 1975 to 1998. In 1999, the haddock stock in the North Sea spawned a very strong year class. This led to very high numbers of haddock being discarded in subsequent years, purely due to the abundance of fish from this one year class. This high discarding will continue until the majority of fish of this year class have grown larger than the minimum landing size. It can be seen here that such natural variation in the abundance of young fish is important in determining the availability of discards to seabirds. However, the effective implementation of fishery management measures would still reduce the relative availability of discards by ensuring that fewer undersized fish were caught and discarded in the first place. Indeed, the technical measures introduced by the UK during 2000 were to some extent prompted by the need to reduce wastage of the 1999 year class of haddock (Ferro & Graham 2000).

Apart from the influence of the one exceptional haddock year class noted above, it is clear from past trends in discard and offal production, and from the baseline projections, that recent levels of both discards and offal have been relatively low and that this situation is likely to continue even if no changes in fishery management are implemented. From this baseline position it is instructive to consider one ‘most likely’ management scenario and contrast this with the baseline.

Figure 1.2 Numbers of haddock and whiting discarded, 1975-1998

For comparison, the figures also indicate the results of the baseline projections.
Note that the Y-axis scales for the haddock and combined species plots are truncated for legibility.





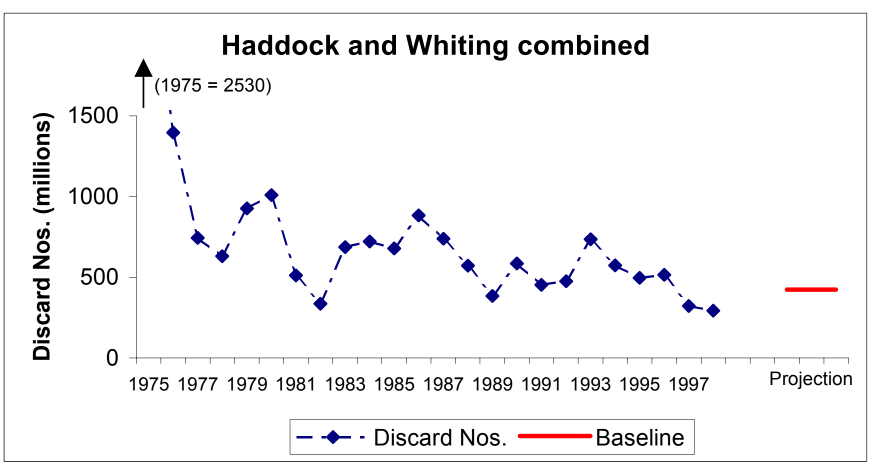
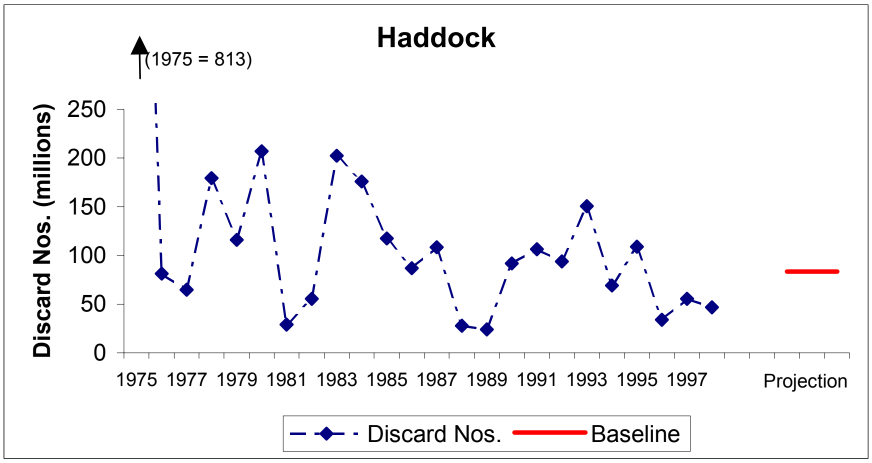
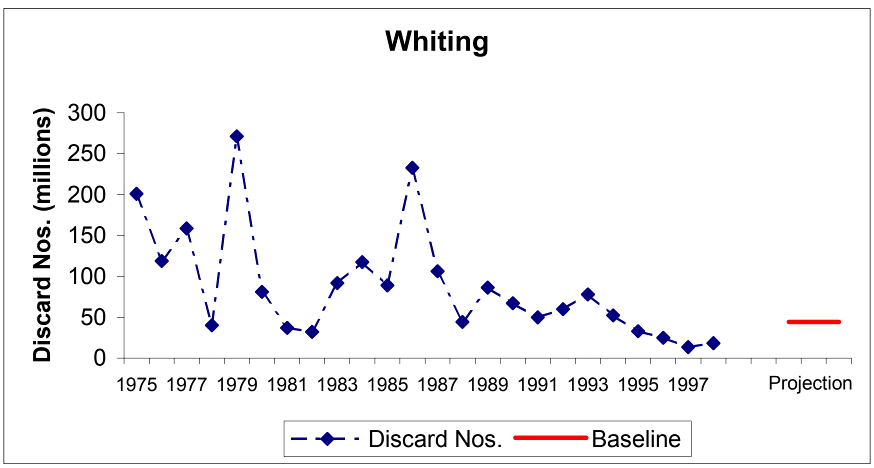


Figure 1.3 Numbers of haddock and whiting < 26cm in length discarded, 1975-1998

For comparison, the figures also indicate the results of the baseline projections.
Note that the Y-axis scales for the haddock and combined species plots are truncated for legibility.





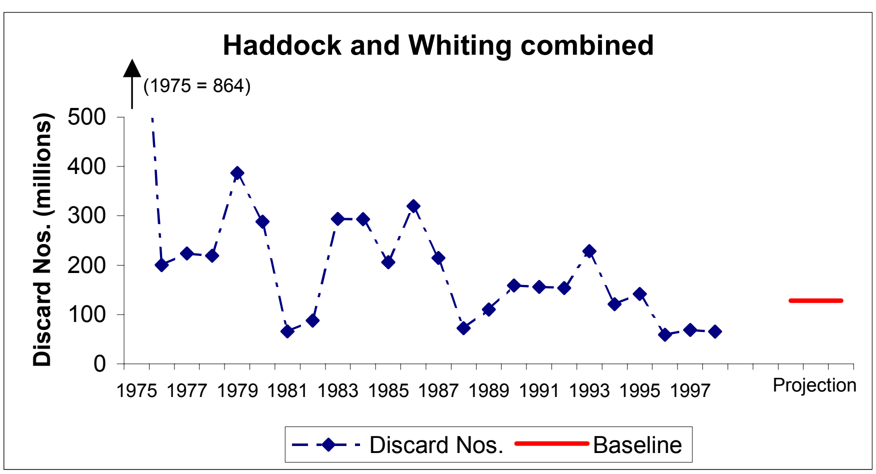
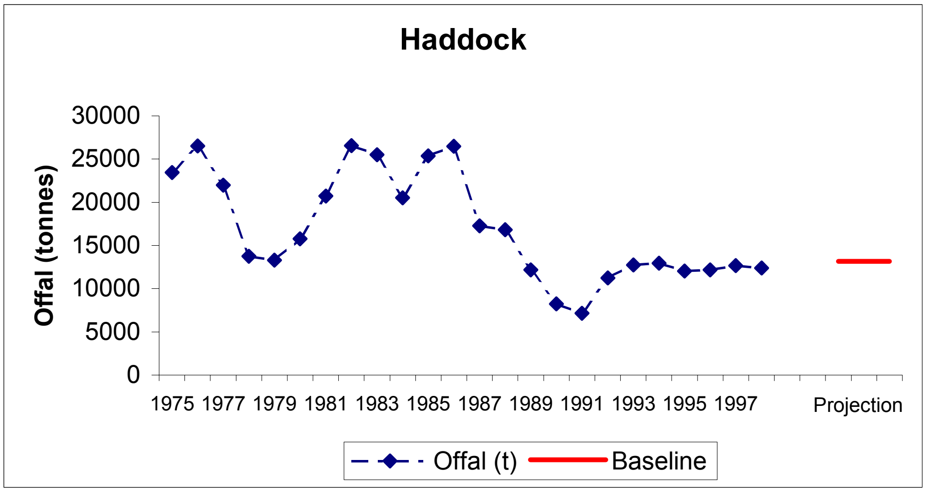
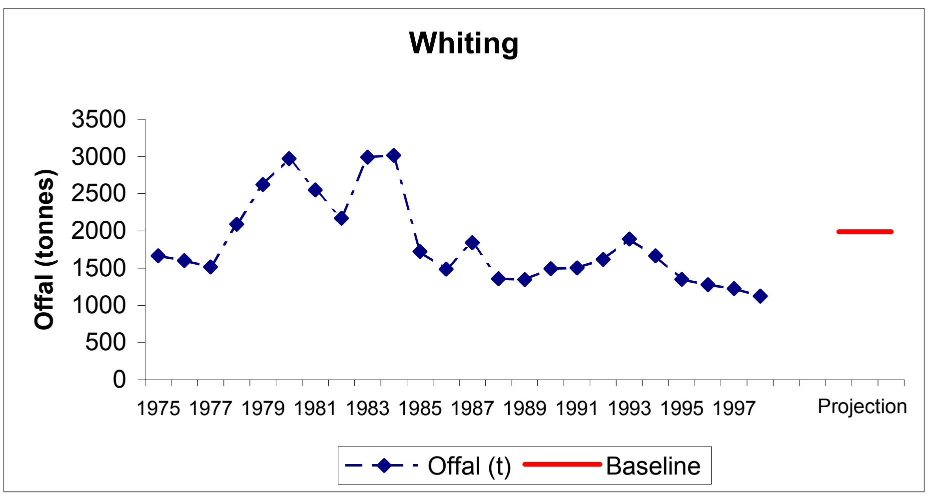
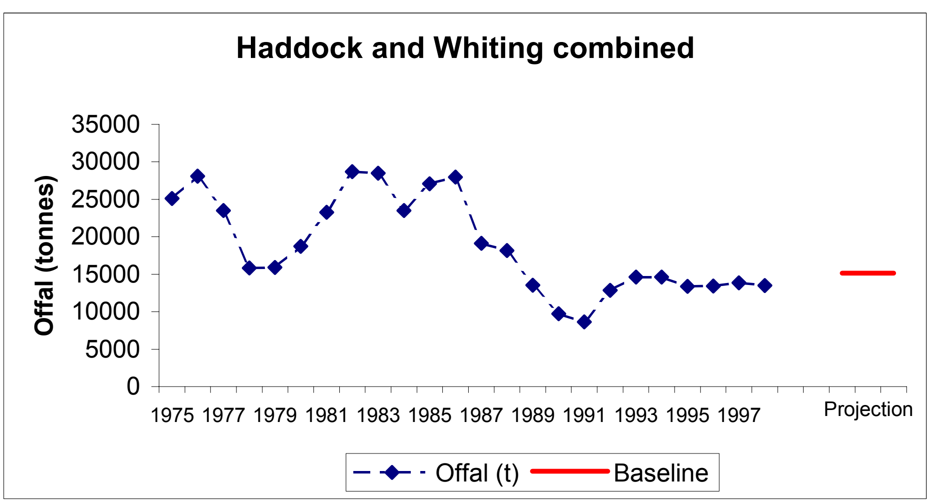


Figure 1.4 Estimated production of haddock and whiting offal, 1975-1998

For comparison, the figures also indicate the results of the baseline projections.







It is likely that future management will entail both an overall reduction in fishing effort and the mandatory adoption of the more selective gear (*ie* the square-mesh panel – see Section 1.2.3), with further such restrictions likely with the implementation of recovery measures for the North Sea cod stock. The size at which fish are discarded is not directly controlled by these management measures, but there has been a trend for haddock and possibly also whiting to be discarded at a larger size. Taking these together, the 'most likely' scenario is that all UK vessels will adopt the more selective gear, there will be an overall reduction in effort by, say, 20%, and that the length at which 50% of fish are discarded will increase by, say, 2cm for each species. Results from this scenario are summarised in Table 1.3, with more detailed results from the projections given in Section 2.

Table 1.3 Changes in the relative availability of discards and offal following introduction of the new technical conservation measure, reduced fishing effort and revised discarding practice

Table shows the results of projections assuming full implementation of the technical conservation measure (TCM, *ie* the square mesh panel), 20% reduction in fishing effort, and an increase in size at 50% discarding (DL50) by 2cm for both species. Results are given for haddock, whiting and the two species combined.

	Haddock	Whiting	Combined
Total number of discards	-25.8%	-36.0%	-41.2%
Number of discards <26cm in length	-60.4%	-47.5%	-55.9%
Offal production	+5.6%	+87.4%	+16.4%

Assuming effective implementation of both the technical conservation measure (*ie* the square-mesh panel in this case) and the effort reduction, this would result in a drop in the total numbers of discards by 45% for haddock and 52% for whiting. An increase in the discarding size would tend to counter these decreases; a 2cm increase in the length at 50% discarding (DL50) would change these discard reductions to 26% for haddock and 36% for whiting. The improved gear selectivity has more influence on these results than the effort reduction, but the results indicate that both of these would be negated by only a relatively small change in discarding practice. Taking the two species together, and assuming no change in discarding practice, the projections indicate an overall reduction of 47% in the total number of discards, 70% of which would be haddock, reflecting the relatively low abundance of whiting in recent years.

As an index of the availability of discards to smaller seabird species, it is useful to consider how the availability of discards of 25cm or less will be affected by the potential management changes. The results indicate that the implementation of the more selective gear would reduce haddock discards of this size range by 51%. Combining this measure with an effort reduction of 20% leads to an overall reduction of 60%. For whiting, the corresponding figures are 37% and 49% reductions. Combining the two species, the overall result is a 56% reduction in the number of discards in this size range, 59% of which is due to haddock. These results are not affected by any change in discarding practice, as all fish of this size are already discarded.

Assuming effective implementation of the technical measure and a 20% reduction in effort, along with a 2cm increase in DL50, the production of haddock offal would be increased by about 6%. Although the reduction in effort, and the improved gear selectivity, would increase the average size of fish in the catch, and thus the proportion of fish of legal landing (and hence, guttable) size in the short-term, it would only be in the long-term that actual numbers of larger fish and, consequently, offal quantity would increase. However, any long-term increase in offal production would be largely negated by a relatively small (2cm) increase in discarding length. Without the change in discarding practice, the production of haddock offal is forecast to increase by 25%. For whiting under this scenario, an increase of 90% in offal production is forecast assuming no change in discard practice, whereas if the change in discard practice is assumed, an increase of 88% is indicated. The high values forecast for whiting irrespective of any change in discarding practice contrast with the result for haddock and reflects the fact that only relatively large whiting are gutted. Taken overall, whiting contribute a relatively small proportion of the overall offal. If the forecast for both species are combined, then disregarding any possible change in discarding practice, the results indicate an increase of 34% in offal production, 81% of which comes from haddock.

To summarise, from the recent (1998) situation of relatively low discard quantities and offal production, the likely gear selectivity improvements and effort reduction are forecast to lead to a further reduction in the overall amount of discards of both species, although this result will tend to be negated by any increase in the discarding size. Gear selectivity is the most important factor in determining the number of discards of 25cm or less, and this is not influenced by any likely change in discarding practice. The combination of anticipated effort reduction and improvements in gear selectivity lead to increases in offal production for haddock and particularly whiting. Haddock are much more important than whiting as a source of offal due to the smaller length at which the former are gutted, hence a change in discarding practice for haddock will tend to counteract these changes.

1.5 Discussion – Possible implications of fishery management for seabird populations

The discard and offal estimates summarised above indicate that in recent years the availability of these resources has been relatively low compared to the years back to 1975 when discard sampling started in Scottish fisheries. This broadly reflects the general declines in the haddock and whiting stocks observed over this period. The projections indicate that any additional management measures are likely to lead to a further decline in the availability of discards to seabirds. However, any management scenario which leads to a reduction in discards also leads to an increase in offal production due to the increase in the numbers of fish surviving to the legal (and thus guttable) size. There may also be differences in the relative size composition of the discards, as any improvement in gear selectivity results in fewer small fish being caught and thus discarded. In addition to fishery management measures, the availability of discards is also influenced by the discarding behaviour of fishermen, and there are some indications that they may discard fish of a larger size if quotas are restrictive, but such indirect responses to management actions have not been well studied.

In the absence of comprehensive census data it is not straightforward to establish the current picture with regard to the North Sea's seabird populations. However, there is evidence that, after many decades of sustained population growth to unprecedented numbers, populations of black-legged kittiwakes and several other gull species are declining at present in the North Sea. In addition, although great skua numbers increased dramatically from very few pairs in Shetland in 1900, at a rate of about 7% per annum, this rate of increase has slowed greatly in the last few decades, and some of the largest colonies have decreased in breeding numbers since the late 1970s. There are also indications of reduced food supply leading to diet switching by great skuas, which are now tending to prey more on other seabird species.

Whether changes in discarding have contributed to these recent changes in seabird communities, or may exacerbate declines in the future, deserves attention. Given the trend for reduced discarding of haddock and whiting, the main discard species in the northern North Sea taken by scavenging seabirds, and predictions of further reductions as a consequence of technical measures and reduced fishing effort currently coming into effect, we can anticipate that the supply of discards to some scavenging seabirds may cause conservation problems over coming years. Changes in quantities of offal are not predicted to be severe, and offal production may even increase. The most pronounced change will be the reduction in the amount of small discards produced by the fishery. These small discards are particularly important for great skuas, herring gulls and lesser black-backed gulls, and it may be these species that will show the most pronounced changes. In contrast, the ability of northern gannet and great black-backed gull to handle larger discards means that their populations are less likely to be affected, if at all. Northern fulmars are more dependent on offal than on discards, so again are less likely to be affected, though recent declines in haddock and whiting catches will already have reduced offal availability. The highest catches of haddock, whiting, cod and saithe in the North Sea are from areas close to Orkney and Shetland. It is therefore likely that impacts of reduced discarding will be most evident in Orkney and Shetland's scavenging seabird populations.

At present, it appears that great skua breeding numbers are continuing to increase at small colonies, but are remaining fairly stable at larger ones, with decreases noted at the biggest. The current pattern of population change should become more evident when 'Seabird 2000' results become available. As a consequence of likely changes in discarding over the coming years and the likely impact of diet switching by great skuas to preying on other seabirds, there is a need to monitor great skua breeding and diet. If other feeding opportunities remained unchanged, reductions in discarding might result in reductions in numbers of great skuas, herring gulls and lesser black-backed gulls while having little direct negative effect on populations of northern fulmars, northern gannets or great black-backed gulls. However, increased predation by great skuas as a consequence of diet switching when discard supplies are low might impact a number of other seabird species on which great skuas may feed, including black-legged kittiwakes, Atlantic puffins, European storm petrels (*Hydrobates pelagicus*), Leach's petrels (*Oceanodroma leucorhoa*), red-throated divers (*Gavia stellata*), common eiders (*Somateria mollissima*), and even great black-backed gulls, although variation in sandeel abundance may have a greater influence than variation in discard availability on predation rates of great skuas on other seabirds. Bird killing by great skuas will probably be a function of both sandeel and discard abundance.

It seems almost inevitable that quantities of fish discarded will decline further in the North Sea in future. Reducing discarding is a major objective of the FAO Code of Conduct for Responsible Fisheries

(FAO, 1995), and it is also a basic tenet of the present Common Fisheries Policy (CFP) of the EC (1982-2002), as well as featuring strongly in proposed reform of the CFP. However, it is not easy to see how best to manage interactions that will arise as a consequence of reductions in discarding. It would be foolish to suggest that rates of discarding should be maintained at current levels 'for the sake of seabirds'. That would not be a practical proposition and even if it could be achieved, it would only serve to perpetuate the imbalance in seabird community composition that now exists in the North Sea as a consequence of many decades of intensive discarding.

The greater the populations of larger scavenging seabirds become as a result of continued feeding on discards, the greater the secondary impacts of prey switching by great skuas and the large gulls are likely to be on their prey seabirds as discard supplies decline. Purely from the seabird perspective, therefore, there may be a case for suggesting that a complete cessation of discarding would be the best strategy to minimize longer term impacts on seabird communities, as this would probably bring seabird populations to a new sustainable equilibrium very much faster than if discarding were slowly reduced over decades. However, from a fishery perspective, the effective implementation of such a ban would involve considerable practical difficulties. Even in Norwegian waters, where a discard ban has been attempted, it is not clear whether it has been effective even for commercially important fish species to which the ban exclusively applies (other fish species being exempt from the ban). There is clearly a need for further research into interactions between scavenging seabirds and other wildlife, in order that the impacts of a discard reduction (or complete discard ban) on the seabird community can be better understood and possibly also managed.

Discarding is extremely wasteful of the fishery resources. Over 1975 to 1999, vessels fishing for haddock for human consumption in the North Sea are estimated to have discarded on average 39% of their catch in weight of haddock, and 44% of their catch in weight of whiting (ICES, 2000a). Most of these discards do not survive so they are lost to the fishery. While a significant reduction in the availability of discards may have serious short-term consequences for North Sea seabird populations, this to some extent reflects the fact that populations of some seabird species are artificially high due to the ready availability of discards in the past. Clearly it is desirable on both fishery and ecosystem grounds that discarding is substantially reduced or even stopped. Improved technical measures such as the mesh size increases which may be introduced as part of the North Sea cod recovery plan may be one step towards this. However, the effectiveness of such measures depends on their acceptance by fishers, and this cannot be guaranteed in a mixed-species fishery context such as the North Sea, as measures which are effective for cod are likely to lead to substantial short-term losses of haddock and whiting. The mixed-species nature of the fishery also means that TACs (Total Allowable Catches) are unlikely to be effective in constraining fishing effort as vessels are able to continue fishing even after the quota for one of the target species has been exhausted. Ultimately, what is required are substantial reductions in fleet capacity in order to restore the age structure of the fish populations and ensure sustainable exploitation.

Effects of fishery closure on scavenging seabirds have been evident in the Mediterranean and northwest Atlantic. In the Mediterranean these effects became clearly evident because a total closure of the demersal fishery came into effect, causing an abrupt end to the supply of discards to scavenging seabirds, and consequently having obvious effects on seabird breeding success, activity budgets and interspecific interactions. In the northwest Atlantic some dramatic changes in herring gull breeding numbers correlate well with changes in stocks and catches of cod, although in that instance a direct causal relationship is not proven. In contrast, effects of reduced discarding in the North Sea are not immediately obvious at present. It is uncertain whether they will become evident when 'Seabird 2000' reports on breeding seabird numbers throughout Britain and Ireland. However, it may be some time after changes in discarding patterns have begun to influence seabird populations that they become evident in terms of recorded declines in breeding numbers of scavenging seabirds. This report is intended to set the scene, in particular to suggest what effects are likely, and on which seabird species. This may assist in early detection of effects in the future and so may facilitate a more sensitive approach to managing seabird populations affected by changes in discarding pattern.

2 Technical Report - Fisheries Models and Projections

This section is intended to give full technical details of the data and models used in this study. Section 2.1 describes the models used to represent the process involved, *ie* population dynamics, gear selectivity, discarding etc, and introduces the parameters which it is necessary to estimate. Section 2.2 describes the current situation in the North Sea fisheries and how this is reflected in the parameter estimates used for the baseline projections. Section 2.3 then discusses possible changes in fishery management and how these may change the parameter values used in the projections. The results of the projections are presented in Section 2.4 and discussed in Section 2.5.

2.1 Fisheries Models

To describe the relevant processes, we require models of both the exploited fish population and the processes such as gear selectivity and discarding which may be affected by fisheries management actions. These are considered below.

2.1.1 Basic population models

To model the underlying dynamics of the fish populations, we make the conventional assumptions that

$$N_{a+1,t+1} = N_{a,t} e^{-(F_{a,t}+M_a)} \tag{1}$$

and that

$$C_{a,t} = \frac{F_{a,t}}{F_{a,t}+M_a} N_{a,t} \left(1-e^{-(F_{a,t}+M_a)}\right) \tag{2}$$

Where $N_{a,t}$ is the number of fish of age *a* in the population at the start of time *t*; $F_{a,t}$ is the instantaneous coefficient of fishing mortality at age *a* during time *t*; M_a is the instantaneous coefficient of natural mortality at age *a* (which is assumed constant with respect to time), and $C_{a,t}$ is the catch of fish at age *a* during time *t*.

2.1.2 Gear selectivity and fishing effort

The key parameter we are concerned with here is the fishing mortality, $F_{a,t}$, which is a measure of the effect that fishing is having on the fish population. Changes in fishing effort and/or gear selectivity will have an influence on fishing mortality, but the effects due to the two factors will differ. Broadly speaking, fishing effort will affect fishing mortality at all ages to a similar extent, but a change in gear selectivity will only change fishing mortality on fish within a relatively narrow size/age range. To model this it is convenient to assume that :

$$F_{a,t} = q_a . f_t \tag{3}$$

where q_a, the catchability at age *a*, is a measure of the relative vulnerability to capture of fish of age *a*, and f_t is a measure of the overall amount of fishing activity during time *t*. From this it is apparent that changes in gear selectivity will change the values of q_a whereas changes in fishing effort will change the values of f_t.

Considering first gear selectivity, we are concerned here with the selectivity of towed gears such as trawls and seines where the selectivity characteristics are often described by a sigmoid curve of the form :

$$p_l = \frac{1}{3^{((l_{50}-l)/(l_{50}-l_{25}))}+1} \tag{4}$$

where p_l is the proportion of fish of length *l* which are retained by the gear, and l_{50} and l_{25} are the lengths at which respectively 50% and 25% of fish are retained. The steepness of this selectivity curve is known as the selection range (SR) which is defined as $2(l_{50}-l_{25})$.

To assess the effects of a new technical measure, it is appropriate to subdivide the fishing vessels exploiting the fishery into a number of fleets (or more strictly speaking 'metiers'; see Mesnil & Shepherd, 1990) consisting of groups of vessels which are similar in terms of size, gear used, species targeted etc., and thus have similar gear selectivity. If we have *j* fleets, and $p'_{l,j}$ is the proportion of fish at length *l* which are retained by fleet *j* after the introduction of the revised technical measure, and the proportion of fleet *j* affected by the revised technical measure is given by A_j, then the resultant change in selectivity at length *l* for fleet *j*, $S_{l,j}$, will be given by :

$$S_{l,j} = A_j \frac{p'_{l,j}}{p_{l,j}} \tag{5}$$

This gives the relative change in selectivity at length, but we need to estimate how this will affect the estimate of catchability at age. This conversion between length and age requires information on the relationship between length and age in the relevant fish population. The age composition of catches from a fish population is normally obtained by measuring the length composition of a sample from the catch, and then determining the age of a sub-sample from these fish to obtain an age-length key (ALK) which provides estimates of the proportion of fish of each age at each length. By combining the sample length composition with the ALK, an estimate of the sample age composition is obtained. ALKs are usually expressed as proportions such that each element, $ALK_{a,l}$ is given by $B_{a,l}/B_{.,l}$, where $B_{a,l}$ is the number of fish of length *l* found to be of age *a*, and $B_{.,l}$ is the total number of fish of length *l* which were aged. An ALK expressed in proportions in this way contains no information on the relative abundance by length which is of interest here as we are concerned with how a change in the length selectivity of the gear will affect catches and we require to allocate numbers at age to length. By raising the ALK by the total numbers at length in the sample length composition it is possible to obtain first the sample length-age composition and then a length-age key (LAK). This is analogous to an ALK but here each element of the LAK, $LAK_{a,l}$, is given by $B'_{a,l}/B'_{a,.}$, where $B'_{a,l}$ is the raised total of fish of length *l* attributed to age *a*, and $B'_{a,.}$ is the raised total of fish of age *a*. This approach is equivalent to the ALD (age-length distribution) matrix of Mesnil & Shepherd (1990).

Given this information, $q'_{a,j}$, the catchability at age *a* for fleet *j* following a change in gear selectivity, is given by :

$$q'_{a,j} = q_{a,j} \sum_{l_0}^{L} S_{l,j} . LAK_{a,l} \qquad (6)$$

where l_0 to L is the length range of fish encountered in the population

Modelling the effects of a change in effort in fleet *j* is straightforward. By using a multiplier, α_j, the change in effort in fleet *j* becomes :

$$f'_{t,j} = \alpha_j . f_{t,j} \qquad (7)$$

To achieve a change in effort by fleet *j* to *X*% of the current level by that fleet, α_j is thus set to *X*/100.

2.1.3 Discarding practices

The discarding process on board deck is comparable to the gear selection process, in that fish are either discarded or retained, and the probability of retention increases with the size of the fish. Hence, by analogy, discarding can be modelled by a similar sigmoid curve to that used for the gear selectivity, *ie* :

$$r_l = \frac{1}{3^{((DL50-l)/(DL50-DL25))} + 1} \qquad (8)$$

Here, r_l is the proportion of fish caught of length l which are retained, and DL50 and DL25 are the lengths at which 50% and 25% of fish caught are retained, and by analogy, the discarding selection range, DSR = 2(DL50 – DL25).

2.1.4 Gutting and offal production

The length-weight relationship for commercial fish species is often given in the form :

$$W_l = RF.al^b \quad (9)$$

where W_l is the total weight of a fish of length l, RF is a raising factor to convert from gutted weight to total weight, and a and b are the parameters of the length-weight relationship. From this it follows that the weight of offal produced by gutting a fish of length l, O_l, is given by :

$$O_l = (RF-1)al^b \quad (10)$$

Further, if it assumed that of the fish which are retained, all fish at or above a certain length, l_g, are gutted, then the total weight of offal produced from a given catch is given by :

$$O. = \sum_{l_g}^{L} r_l C_l O_l \quad (11)$$

where C_l is the catch in numbers at length l.

2.1.5 Projections

To investigate the effects of management measures and changes in onboard processing on the availability of discards to seabirds, we are concerned with variation in the fleet catchability at age, as determined by changes in the l_{50} of the gear in use by the fleet; in the relative effort by each fleet, determined by the effort multiplier α_j, and in the discarding practice, which is dependent on the fleet's Dl_{50}. Hence we need to run a baseline projection holding these parameters at their current values and a range of other projections where these parameters are varied within appropriate ranges of values. We then require a number of performance measures by which to gauge the effects of varying these parameters. In this context we are most interested in the numbers of discarded fish and in the quantity of offal available to seabirds. As the size of discarded fish can also influence its availability to some species of seabird, we are interested in the number of discards below a critical size, l_s, as well as the total number of discards.

The projections are done on a 'per-recruit' basis as we are concerned with the long-term effects of management measures on the availability of discards, and not in the short-term variation due to variation in year class strength. Hence we require estimates of the current fishing and natural mortality at age in the stock, but not stock numbers at age. These are available from a recent ICES assessment of the relevant stock (see below). In addition, we need to disaggregate the total fishing mortalities at age into the partial fishing mortalities for each fleet, *ie* :

$$F_{a,t,j} = F_{a,t,\cdot} \frac{C_{a,t,j}}{C_{a,t,\cdot}} \tag{12}$$

where $C_{a,t,,j}$ is the catch at age *a* during time *t* by fleet *j*. For the projection the estimates of partial F are modified using appropriate estimates of $q'_{a,j}$ (eqn. 6) and $f'_{t,j}$ (eqn. 7) in equation 3, then aggregated to give an estimate of the resultant total F at age. The projections are then run using these inputs in equations 1 and 2. This gives estimates of the equilibrium catches at age. These are then partitioned between fleets and allocated to length classes using :

$$C_{l,j} = \sum_{a_0}^{A} \frac{C_{a,j}.LAK_{a,l}S_{l,j}}{\sum_{l_0}^{L} LAK_{a,l}S_{l,j}} \tag{13}$$

Note that the relative selectivities, $S_{l,j}$, are here used to modify the length-age key to reflect the change in length-composition of the catches. The catches at length by fleet are then aggregated across fleets to give the total catch at length. The number of discards at length *l*, D_l, is then obtained from :

$$D_l = (1 - r_l)C_l \tag{14}$$

and the total number of discards smaller than length l_s is given by summing this expression over the range l_0 to l_s-1. Estimated offal production is obtained from equation 11.

2.2 Baseline Parameter Estimates

The starting point for the projections is the current situation, i.e. the fishery before any changes in management come in to force. This forms the baseline for the subsequent projections. This section discusses the relevant aspects of the fishery, and how these are reflected in the initial parameter estimates used.

2.2.1 Population parameters

The initial estimates of fishing and natural mortality at age used in the projections are those used in the most recent catch forecasts available for these stocks at the time of this analysis. These are taken from the Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and

Skagerrak. (ICES, 2000a) and are given here in Table 2.1. The fishing mortality estimates given represent average values over the period 1996 to 1998.

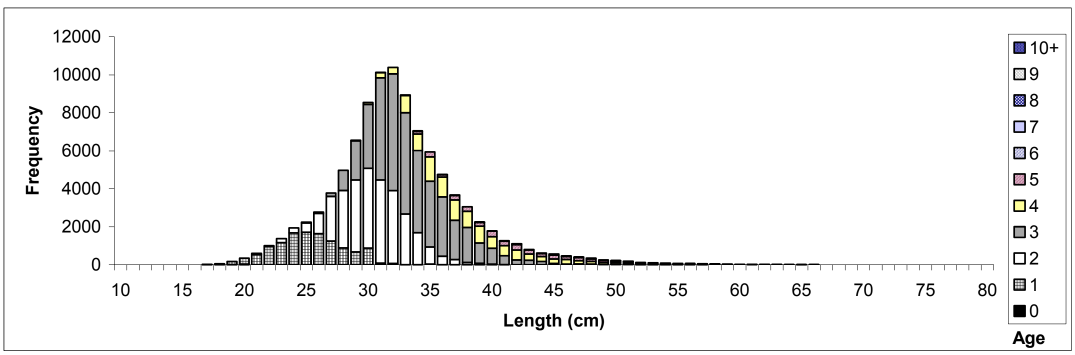
The LAKs used are based on data from Scottish market and discard sampling over 1995-1997. For practical reasons, the data used cover only light trawlers operating in the Shetland area. However, this sampling stratum is likely to be representative of the overall North Sea as it covers the most important gear and an area with both inshore and offshore components. The LAKs for each species are shown in Figures 2.1 and 2.2. Note that the LAKs from commercial catches are here used to represent the length-age composition of the population. This approach is only appropriate if the selectivity changes to be evaluated are relatively small and positive, as larger changes in selectivity would also lead to significant changes in the length-age composition of the population, necessitating a more complex approach to modelling the population size composition.

Table 2.1 Coefficients of fishing mortality (F) and natural mortality (M) at age used in projections

Haddock			Whiting		
Age	F	M	Age	F	M
0	0.022	2.05			
1	0.105	1.65	1	0.129	0.95
2	0.499	0.40	2	0.305	0.45
3	0.752	0.25	3	0.503	0.35
4	0.858	0.25	4	0.615	0.30
5	0.915	0.20	5	0.793	0.25
6	0.948	0.20	6	0.857	0.25
7	1.309	0.20	7	0.887	0.20
8	0.891	0.20	8+	0.887	0.20
9	0.827	0.20			
10+	0.827	0.20			

Figure 2.1 Length-age composition of haddock population used in the projections

A; Length composition



B; Length-Age Key (LAK)

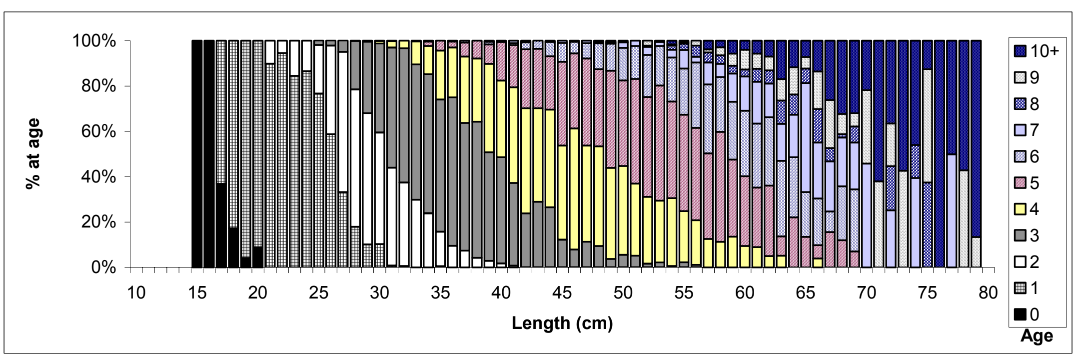
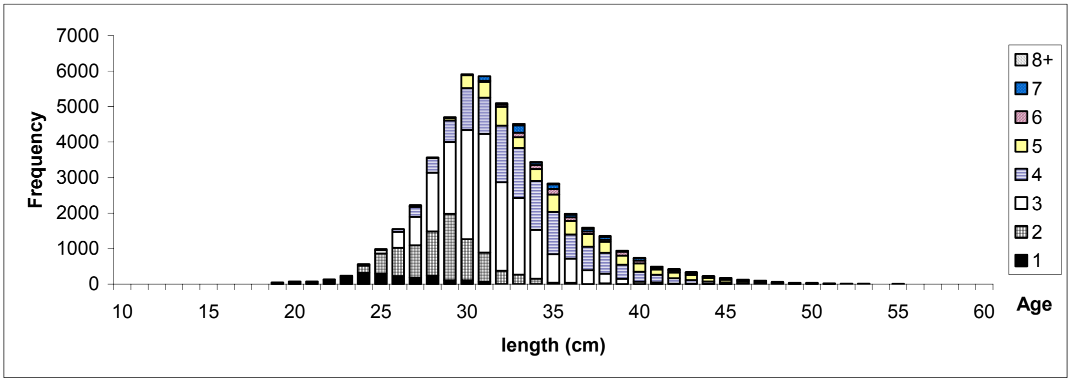
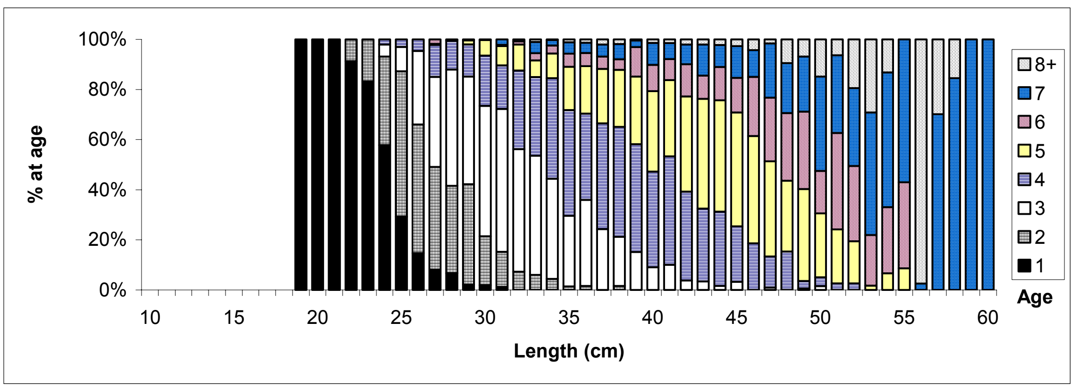


Figure 2.2 Length-age composition of whiting population used in the projections

A; Length composition



B; Length-Age Key (LAK)

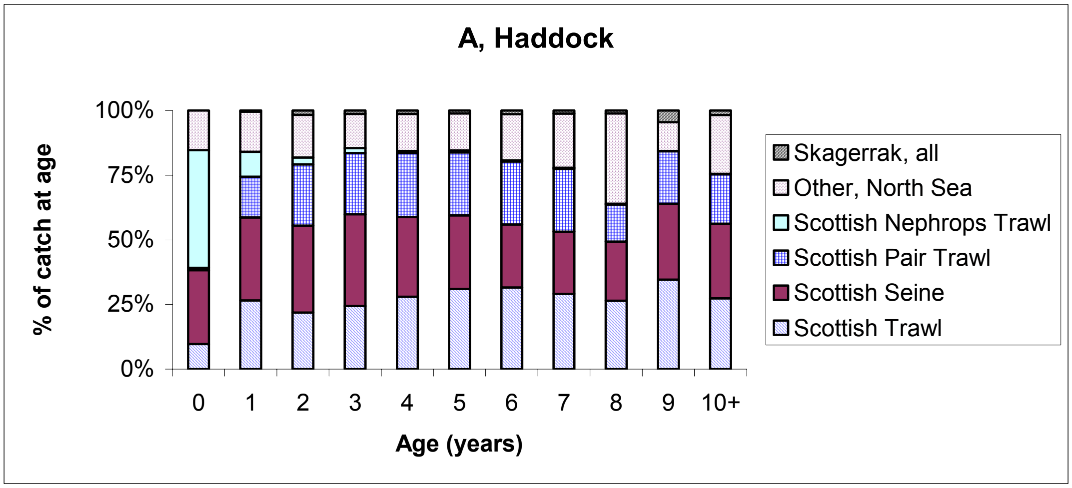


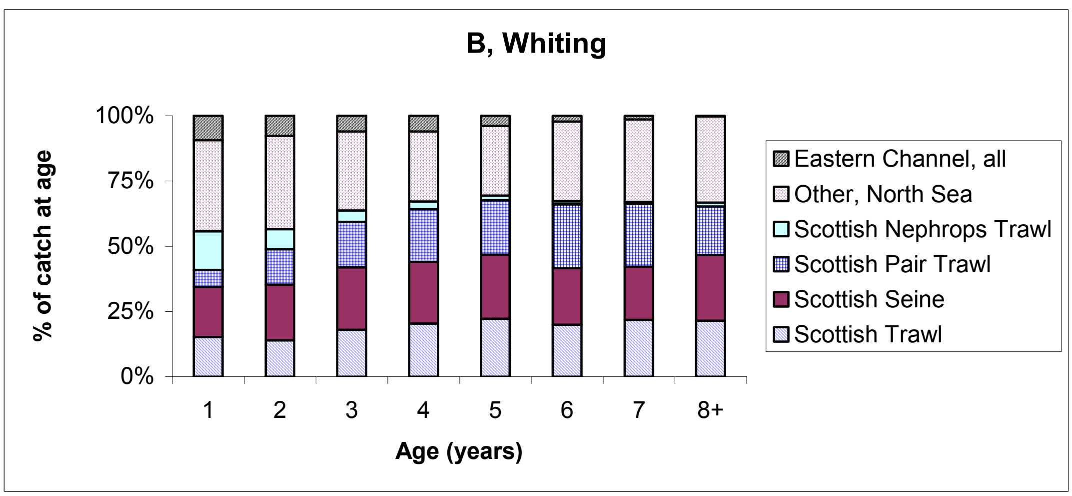
2.2.2 Fleet data

Ideally, the division of the North Sea demersal fishing fleet into smaller more homogeneous fleets would be based on information on vessel size, areas fished, characteristics of the gear used, discarding practices, etc. In practice, the information available is rather more limited, and the classification is largely determined by the categories used to distinguish between vessel types for the purposes of monitoring and sampling. The North Sea fisheries for haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) are predominantly Scottish, with landings into Scotland over 1996-1998 accounting for on average 84% of the total haddock landings and 69% of the total whiting landings over this period. Hence the main categorisation used here is the sub-division of the Scottish fleet into the principal gears, with other fleets grouped together. The assessment for haddock includes catches taken in the Skagerrak, and the whiting assessment includes catches taken in the Eastern Channel. In both cases the catches from these adjacent areas are small compared to the North Sea, and are treated as a separate fleet which is unaffected by changes in management measures. Similarly, relatively small amounts of both species are taken as a by-catch in small mesh industrial fisheries, and these are also treated as a separate fleet which is not affected by changes in management. The partial fishing mortalities at age for each fleet were estimated using the mean proportion of the catch at age taken by that fleet over 1996-1998. These catch proportions are illustrated in Figure 2.3.

Figure 2.3 Proportions of total catches at age taken by major fleets

Figures are mean proportions, 1996-1998, of the combined human consumption landings and discards.





2.2.3 Gear selectivity

We require estimates of the current selectivity characteristics for the gears used by each of the fleets detailed above. The selectivity of these gears is determined primarily by aspects of the construction of their codends. These include the mesh size as well as the number of meshes around the codend and the thickness of the twine used in the mesh. A panel constructed of square mesh inserted in an appropriate position in the top of the codend can also improve its selectivity characteristics. By using information on the twine thickness, mesh size etc. in use by a specific fleet in a model of the form developed by Fryer *et al* (1998) it is then possible to obtain an estimate of the overall selectivity characteristics of that fleet.

Fryer *et al* (1998) combined data from a number of different selectivity trials for haddock and concluded that there is no evidence of any significant gear effects, *ie* the selectivity characteristics of a given codend are similar whether attached to *eg* a seine or a pair trawl. On this basis, we only need to distinguish between boats fishing for roundfish, which are required to use codends of at least 100mm mesh size, and boats fishing for *Nephrops norvegicus* (Norway Lobster, sold as 'scampi'), which, subject to certain restrictions, can use mesh size down to 70mm.

For roundfish vessels, the codends in use are thought to be reasonably homogeneous, with a mesh size of 100mm and 100 meshes around. There is some variation in the twine thickness in use, but an overall value of 5.5mm double twine is considered representative. The *Nephrops* trawlers represent a much more heterogeneous group of vessels, comprising both single and twin trawlers, and vessels using 70, 80 or 100mm mesh with various combinations of twine thickness. Under UK regulations, vessels using the smaller mesh sizes are required to fit a square mesh panel in the top of the net. No information is available on the relative proportions of vessels using all the various combinations of single/twin trawls and mesh size/twine thickness. To represent an 'average' *Nephrops* trawler, we have assumed a mesh size of 80mm constructed from 3.5mm double twine with a 90mm square mesh panel in the top.

The selectivity data analysed by Fryer *et al* (1998) do not include data on the effects of square mesh panels on selectivity, hence their models are not directly applicable here. A preliminary model, based on unpublished data from the Marine Laboratory Aberdeen (MLA), is available to account for this effect, and this has been used in the study. Given the assumed codend characteristics, this model can be used to estimate the selectivity of current roundfish and *Nephrops* gears for haddock. Recent selectivity data for whiting have not been of sufficient quality to allow direct estimation of the selectivity of these gears to whiting. However, by using data from earlier selectivity trials when adequate numbers of whiting were caught, it is possible to derive a relationship between the selectivity of a given gear for haddock and that of the same gear for whiting. This relationship can then be used to obtain indirect estimates of the selectivity of current gears for whiting. The estimates derived using these approaches are given in Table 2.2.

Table 2.2 Estimates of the selectivity of current gears for haddock and whiting in the North Sea. The table gives estimated values for the length at 50% retention (l_{50}) and the selection range (SR).

Gear	Species	l_{50} (cm)	SR (cm)
Roundfish, all	Haddock	26.4	4
Nephrops trawl	Haddock	26.3	4
Roundfish, all	Whiting	30.7	4
Nephrops trawl	Whiting	32.8	4

2.2.4 Discarding practices

Data on the length composition of discards and landings by Scottish vessels are available from Scottish discard sampling programmes, hence it is possible to estimate the parameters of retention curve directly from this information. Using data for each fleet from 1998, the proportions retained at length were first logit transformed, then the curves were fitted using least squares. The between-fleet differences in DL50 for each species were small, so the same value was used for all fleets for each species. The values used are given in Table 2.3. For both species, the values used for DL50 are slightly higher than the current minimum landing sizes (MLS), which are 30cm for haddock and 27cm for whiting. Note that here discarding is described by a retention curve, which is the inverse of the discard curve used by Stratoudakis *et al* (1998) in their study of discarding practices by Scottish vessels. However both approaches use a curve which is centred on DL50, hence the values used for DL50 are directly comparable between the two studies.

With regard to the availability of discards to seabirds, the smaller scavenging species have difficulty handling fish of 26cm or greater in length (Camphuysen *et al*, 1995) hence the size limit of discards available to the smaller scavenging species, l_s, has been set at 26cm for both fish species.

Table 2.3 Estimated parameters of discard curves for haddock and whiting in the North Sea

Discarding is described by a sigmoid curve centred on the length at 50% discarding (DL50), with the steepness of the curve defined by the discard selection range (DSR).

Species	DL50 (cm)	DSR (cm)
Haddock	31.76	2.65
Whiting	29.13	4.18

Table 2.4 Length-weight relationships for haddock and whiting

The relationship is of the form : Weight = RF [A x (Length)^B]; Weight in g, Length in cm.

Parameters taken from Coull *et al* (1989).

Species	RF	A	B
Haddock	1.16	0.0157	2.8268
Whiting	1.13	0.0093	2.9456

2.2.5 Gutting practices and offal production

Information on the length-weight relationships for many commercial fish species is given in Coull *et al* (1989). The values used for haddock and whiting are given in Table 2.4. Gutting practices are rather variable, but to summarise current practices, (P Clark, FRS Marine Laboratory, Aberdeen, pers. comm.) for haddock, all fish over 40cm are gutted at sea, but it is often the case that all haddock are landed gutted because of the price advantage. For whiting typically all fish of 36 cm and over would be landed gutted, but it is often the case that the whole whiting catch would be landed ungutted reflecting the lower value of the species. To try to capture these effects, the minimum length at gutting, l_g, for haddock has been set at 10cm (*ie* essentially assuming that all haddock are landed gutted), whereas for whiting l_g has been set at 36cm.

To estimate long-term trends in total offal production in the North Sea roundfish fishery, estimates of offal production have also been derived for cod (*Gadus morhua*) and saithe (*Pollachius virens*). These estimates again used raising factors from Coull *et al* (1989) , the values being 1.17 for cod and 1.19 for saithe.

2.3 Management Scenarios and Projections

To estimate the extent to which a change in fishery management is likely to influence the availability of discards, it is first necessary to consider how fishery management is likely to change, then identify the likely direction and magnitude of this change for each of the key parameter values in the models.

2.3.1 Fleet effort

The relative effort of a fishing fleet is influenced by a number of factors, but broadly speaking it results from the trade-off between the size and efficiency of the vessels in the fleet and the catching opportunities available to the fleet. With continuing technological improvements, the efficiency, and thus effective capacity and effort, of a fleet will tend to increase with time. Within the European context, the Multi-Annual Guidance Programmes (MAGPs) of the Common Fisheries Policy (CFP) have been intended to constrain the capacity of national fleets, but as yet this does not appear to have been effective (Anon,1999). As a result, in the short-term relative effort is likely to be constrained more by the catching opportunities available to the fleets. These are determined to a large extent by the annual Total Allowable Catches (TACs) set for the stocks.

The initial stage in the setting of a TAC is the scientific advice provided by the ICES Advisory Committee for Fishery Management (ACFM). Typically, ACFM advice will be framed in terms of the change in fishing mortality (F) required to bring or maintain fishing mortality below the precautionary value set for that stock, and bring or maintain the spawning stock biomass (SSB) above the relevant precautionary value. In principle, the TAC for the following year is then set at a value reflecting the current abundance of the stock and the advised level of fishing mortality. In practice however, political and administrative considerations also influence the resultant TAC, which as a result may be less restrictive than the original intention.

In October 1998, ACFM advised a reduction of fishing mortality by 10% for haddock and at least 20% for whiting. The 1999 advice was again for a 10% reduction for haddock, but for whiting the advice was for the lowest possible catch coupled with the implementation of a recovery plan for the stock. The advice for whiting was not reflected in the 2000 TAC and it is unclear at present whether such catch restrictions will be implemented in the future. However, given *t*hat both haddock and whiting are taken as part of a single mixed fishery, and that haddock is a higher value species, it is here assumed that the overall level of effort will be dictated more by the advice for haddock than for whiting. In the longer term, if reductions in fleet capacity are achieved, then greater reductions in overall fishing mortality may be attained, but for the purposes of the current study, reductions of no more than 20% in effort have been assumed.

TACs are allocated to national fleets using pre-determined allocation keys, hence a TAC set to reduce effort affects all fleets to a similar extent. For this reason the same value of relative effort, α, has been used for all fleets.

2.3.2 Gear selectivity

Changes in the selectivity of current gears can be anticipated on the basis of new and forthcoming legislation. European Council Regulation 850/98, implementing a number of technical conservation measures intended to improve the protection of juvenile marine organisms, came into force on 1 January 2000. In addition, further measures were introduced in unilateral UK legislation during the summer of 2000.

The large majority of catches of roundfish from the North Sea are taken using towed gears, *eg* trawls and seines. For vessels targeting roundfish, existing legislation dictates a minimum mesh size of 100mm. EC Regulation 850/98 has added restrictions on the permissible number of meshes around the codend and on the twine thickness within the codend. These imply no more than 100 meshes around the codend which can be constructed from twine no more than 8mm (for single twine) or 6mm (for double twine) thick. However, as codends currently in use typically fall within this specification, these restrictions are unlikely to have any practical effect on the selectivity of the gears in use. The Regulation also allows for the incorporation of a square mesh panel or a "Baltic Panel" (Madsen *et al*, 1999) into a codend or extension. These measures could improve the selectivity of the gear, but their incorporation is not mandatory.

Subsequent to the introduction of the EC regulation, talks took place between the UK administration and fishermen's organisations aimed at introducing further measures to improve the selectivity of current gears (Ferro & Graham, 2000). As a result, these were implemented in UK legislation during summer 2000. The measures introduced are as follows. For all whitefish and *Nephrops* nets with a mesh size in the range from 70 to 119mm, the use of a 90mm square mesh panel in a specific position in the net is mandatory. The whole of the panel must be no more than 12m from the codline except in the case of nets targeting *Nephrops* where the panel must be no more than 18m from the codline. For *Nephrops* trawlers two options are available; for twin trawlers towing two nets, a minimum mesh size of 80 mm is required and can be used only in a defined area known as the Fladen Area whereas for single trawlers the minimum mesh size is 70mm. From 1 March 2001, twine thickness is restricted to no more than 5mm double or 8mm single twine, , except for nets targeting *Nephrops* in which 4mm single twine should be used. Similar legislation was introduced in the rest of the UK in April 2001.

For roundfish, the effect these measures will have on the gear selectivity is straightforward to estimate using the same models as used for the baseline selectivity parameters (Section 2.2.3). In this case, we assume a codend mesh size of 100mm, with 100 meshes around, constructed from 5mm double twine with a 90mm square mesh panel in the top. To reflect the fact that initially only UK vessels will be affected, it is assumed that uptake by Scottish vessels will be 100%, with 50% uptake by other vessels. The *Nephrops* option is rather less straightforward, as the option for single trawls may actually be less selective than current gears. Hence, for *Nephrops* trawls it has been assumed that these measures will not affect the overall selectivity of the fleet. The changes in selectivity anticipated in relation to the forthcoming legislation are given in the Table 2.5.

Table 2.5 Estimated changes in selectivity parameters resulting from changes in technical conservation measures

The table gives the estimated changes in the length at 50% retention (l_{50}) and selection range (SR) which will result from the introduction of the square-mesh panel etc.

Gear	Species	Change in l_{50} (cm)	Change in SR (cm)
Roundfish, all	Haddock	+ 2.83	0
Nephrops trawl	Haddock	0	0
Roundfish, all	Whiting	+ 3.96	0
Nephrops trawl	Whiting	0	0

2.3.3 Discarding practices

A study by Stratoudakis *et al* (1998) looked at discarding practices by Scottish vessels for gadoids in the North Sea. The study considered the influence of regulatory measures, such as MLS, as well as other factors such as area fished and catch rate. For haddock, the DL50 was most influenced by area, being smaller in inshore areas. The reason for this was not clear, but it probably reflected the smaller size of haddock found in inshore areas. Within the offshore areas, DL50 was then most influenced by the median size of haddock in the catch; a larger median size leading to a higher DL50. Within the inshore areas, there was evidence of an increase in DL50 from 1989 onwards, possibly corresponding to an increase in MLS from 27cm to 30cm at that time. For whiting, the picture is rather more complex.

In offshore areas, whiting tend to be discarded at a larger size when catch rates of haddock and cod are high relative to those of whiting, but the DL50 decreases if whiting are abundant, reflecting a shift in the target species. In inshore areas, the DL50 for whiting is more closely linked to the MLS. For both species, the changes in DL50 with time are area and gear specific, but the analysis indicates that DL50 changes systematically with time rather than in response to noisy, short-term effects, such as recruitment variation. Only occasionally were the observed temporal patterns adequately explained by biological or regulatory variables such as MLS. In relation to this, Stratoudakis *et al* note that this does not necessarily mean that biological and regulatory variables do not affect DL50, merely that the changes in DL50 are more complicated than can be explained by these variables alone.

In the current context, we are concerned with possible changes in DL50 with time within fleets across the entire North Sea. For haddock, the time trends in DL50 presented by Stratoudakis *et al* generally indicate either no change or an increase for the most recent years of the analysis (1988-1993). One of the most marked increases is shown by pair trawlers at Shetland, where a steady increase in DL50 by around 2cm over 1988 to1993 is indicated. This is generally the most important gear/area for haddock landings. Further, the combined landings and discard data for the North Sea show general increases in the proportion discarded at each age in recent years. Taken together, this indicates an overall tendency for the DL50 of haddock to increase in recent years. No such clear picture emerges for whiting, which is perhaps to be expected given that discarding of whiting appears to be as dependent upon availability of other species as it is on whiting abundance and MLS.

In their analysis Stratoudakis *et al* (1998) did not find any link between discarding practice and minimum mesh size, and at present no changes are anticipated in the MLS for haddock or whiting, so in the short-term it appears unlikely that any changes in management will influence the discarding practices of Scottish vessels. However, the available information indicates that for haddock there has been a tendency for the DL50 to increase in recent years. On this basis, the effects of an increase in DL50 for both species by up to 2cm have been investigated.

2.3.4 Gutting and offal

From the limited information available, it seems likely that gutting practices are determined more by economic factors than by management regulations. As economic considerations are not within the scope of the current analysis, no attempt has been made to consider possible changes in gutting practice.

2.3.5 Management scenarios

For the purposes of the projections made here, a management scenario is considered to consist of a combination of relative effort, proportionate uptake of the technical measure and the change in DL50 which was used for the projection. Two values were used for each factor, leading to eight scenarios for each species. These scenarios are summarised in Table 2.6.

Table 2.6 Management scenarios assumed for projections

A management scenario consists of a combination of relative fishing effort, proportionate uptake of the technical conservation measure (TCM) and the change in discarding practice (DL50). The first row represents the baseline run, *ie* no parameters are changed.

Relative uptake of TCM	Relative fishing effort	Change in Discarding practice (DL50)
0	1.0	0
0	1.0	+ 2cm
0	0.8	0
0	0.8	+ 2cm
1	1.0	0
1	1.0	+ 2cm
1	0.8	0
1	0.8	+ 2cm

2.4 Results

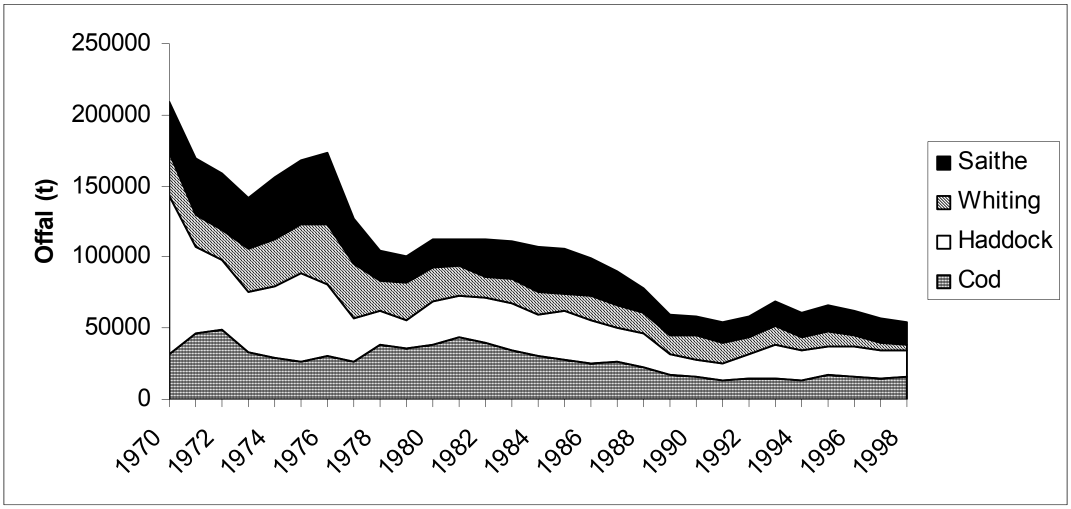
The results from the projections run here represent long-term equilibrium values. As such, they do not consider factors such as annual variation in recruitment and fishing mortality which in practice will have a marked effect on the availability of discards. For this reason it is most instructive to summarise the results by comparing them with the baseline run (*ie* assuming no change in management measure or discarding practice). Expressing the results as percentage changes relative to the baseline in this way gives a rather more robust estimate of the likely effects of any given scenario. For this reason most results from these projections will be summarised in this form.

2.4.1 Baseline projections and historical context

To make comparisons with the baseline more useful, the baseline estimates can be put into context by scaling them to make them comparable with the observed past trends in discards. As all the estimates are on a 'per recruit' basis, they can be scaled-up to absolute values by multiplying by appropriate estimates of mean recruitment for each stock. For haddock the long term (1963-1997) geometric mean at age 0 (26.3 billion) was used, whereas for whiting the recent (1990-1997) geometric mean at age 1 (1.51 billion). The use of these values reflects their usage in the most recent (up to the time of this analysis) short-term forecasts for these stocks (ICES, 2000a). The use of the geometric means reflects the fact that recruitment generally shows a log-normal distribution. The short-term mean was used for whiting as there are indications of an overall decrease in recruitment in recent years. Figure 1.2 (p. **XX**) gives the resulting estimates of total numbers of discards from the baseline runs, along with the estimated numbers of discards over 1975-1998. Figure 1.3 (p. **XX**) gives the corresponding figures for discards less than 26cm in length. The estimates for 1975 –1998 presented here were derived assuming the same length-age composition for the population as assumed in the projections. A similar assumption was also made for the estimates of offal production over 1975-1998 presented in Figure 1.4 (p. **XX**). These also assume similar gutting practices to those used in the projections. These assumptions may not be appropriate for whiting in earlier years hence the estimates of whiting offal for that period may well be under-estimates. To allow for this, Figure 2.4 gives estimates of offal based on the assumption that all fish were landed gutted. Figure 2.4 also includes estimates of offal production from cod and saithe. Although these species are otherwise not considered here, these species have contributed to the availability of offal so it is instructive to include them to give the historical perspective of offal production.

Figure 2.4 Estimated offal production from North Sea roundfish fisheries, 1970-1998

Estimates assume that all fish were landed gutted



The values for haddock given in Figure 1.2 show very high numbers of fish discarded in 1975 and 1976. This is a result of the exceptionally strong 1974 year class. The baseline projection indicates a level of discarding which is slightly below the average since 1977. For whiting, the numbers of fish discarded has declined since 1986 to a very low level in recent years. The baseline projection indicates a continuation of this low level of discarding. When the two species are combined, the plot shows less year to year variation, but there are still indications of a decrease in recent years, and the baseline projection estimate again indicates a continuation of this relatively low level of discards.

In contrast to the figures for total discards, the estimates of numbers of discards <26cm in length (Figure 1.3), show greater inter-annual variation and less evidence of an overall decline. This is because the numbers of smaller fish in the population, and thus the catches, reflect recruitment to the stock rather than absolute stock size. Neither haddock nor whiting in the North Sea show a strong relationship between spawning stock size and recruitment, so although spawning stock size for both species has been reduced substantially by fishing pressure, for haddock at least there is no clear indication that this has resulted in reduced recruitment. The North Sea whiting stock has shown a recent period of reduced recruitment, and this is reflected in the low numbers of small discards in recent years. However, it is not clear whether this reduced recruitment is due to depletion of the spawning stock. The baseline projections indicate a level of production of small discards slightly below the combined average for the two species. This reflects the recent reduced whiting recruitment and the recent relatively low level of fishing mortality on haddock.

It is apparent from the temporal trends for offal production given in Figure 1.4 that recent production of offal from both haddock and whiting has been at a relatively low level. This reflects the fact that both stocks are in a relatively depleted state. The baseline projections indicate a continuation of this low level. The decrease in whiting offal since about 1984 may actually be greater than shown in Figure 1.4, as the estimates for the earlier years also assume the recent practice of only gutting fish greater than 35cm in length. Figure 2.4 shows corresponding estimate for all four of the major roundfish species, based on the assumption that all fish were landed gutted. These estimates indicate a total reduction in offal production in the North Sea by roughly 75% between 1970 and 1998.

2.4.2 Changes relative to baselines

The results from the projections, in terms of changes relative to the baseline, are given for haddock in Table 2.7 and Figure 2.5. The corresponding figures for whiting are given in Table 2.7 and Figure 2.6, while Figure 2.7 summarises estimates for the two species combined. The figures illustrate how the percentage changes in numbers of discards (both overall and < 26cm in length) and in offal production are influenced by each of the separate factors, *ie* the introduction of the technical conservation measure (TCM), the reduction in fishing effort and the change in discarding practice.

For haddock, the introduction of the proposed technical measure is indicated to lead to a reduction in the number of discards by around 34%. Combining this with a 20% reduction in effort leads to an overall reduction in discards of 45%. An increase in DL50 by 2cm will offset these reductions to a certain extent, but the net result will still be an overall reduction in the number of discards. If only discards of less than 26cm are considered, the effects are more pronounced, with the introduction in the TCM leading to a reduction of 51%, with the effort reduction increasing this to 60%. These estimates are not affected by an increase in DL50 as all fish of less than 26cm in length are already discarded. With regard to the production of offal, the introduction of the TCM leads to an increase of 18%, which when combined with the 20% reduction in effort leads to an overall increase of around 25%. However, the results indicate that an increase in DL50 by 2cm would largely negate these increases.

For whiting, the effects on the quantity of discards are of a similar magnitude to haddock. The introduction of the TCM leads to a 42% reduction in discards, and when combined with the 20% effort reduction, the net effect is a 52% reduction in discards. For discards of less than 26cm in length, the effects are slightly less marked, with the corresponding reductions being 37% and 49%. A 2cm increase in DL50 would have a small influence on the availability of the smaller discards, as some fish of around this size are retained at present. The introduction of the TCM leads to large increase in the production of whiting offal, with a figure of 84% indicated. The effort reduction makes relatively little contribution to this, leading to an overall increase in offal production of 90%. The change in DL50 has effectively no influence on these estimates, as the minimum gutting size assumed for whiting (36cm) is well above the DL50.

Table 2.7 Effects of changes in management measures and discarding practices on the relative availability of discards and offal of haddock, whiting, and the two species combined

Tables show the results of projections for a number of implementation combinations of the technical conservation measure (TCM), relative fishing effort and discarding practice (DL50).

A: Total number of discards

TCM ?	Relative Effort	Change in DL50	Change in total No. discards		
			Haddock	Whiting	Combined
No	1.0	0 cm	+0.0%	0.0%	0.0%
No	0.8	0 cm	-15.6%	-15.2%	-18.3%
Yes	1.0	0 cm	-34.3%	-41.8%	-58.2%
Yes	0.8	0 cm	-44.8%	-51.6%	-88.9%
No	1.0	+2cm	+21.7%	+31.2%	+19.9%
No	0.8	+2cm	+4.0%	+12.5%	+6.4%
Yes	1.0	+2cm	-13.0%	-23.8%	-19.8%
Yes	0.8	+2cm	-25.8%	-36.0%	-41.2%

B: Number of small (<26cm in length) discards

TCM ?	Relative Effort	Change in DL50	Change in No. discards <26cm		
			Haddock	Whiting	Combined
No	1.0	0 cm	0.0%	0.0%	0.0%
No	0.8	0 cm	-19.3%	-18.9%	-19.1%
Yes	1.0	0 cm	-50.8%	-36.7%	-45.9%
Yes	0.8	0 cm	-60.4%	-49.0%	-56.5%
No	1.0	+2cm	+0.1%	3.8%	+1.4%
No	0.8	+2cm	-19.2%	-15.8%	-18.0%
Yes	1.0	+2cm	-50.7%	-34.8%	-45.2%
Yes	0.8	+2cm	-60.4%	-47.5%	-55.9%

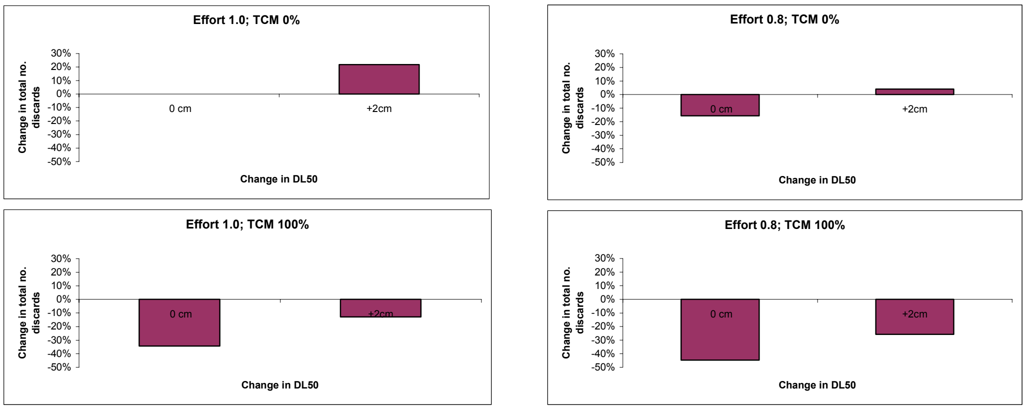
C: Offal production

TCM ?	Relative Effort	Change in DL50	Change in offal production		
			Haddock	Whiting	Combined
No	1.0	0 cm	0.0%	0.0%	0.0%
No	0.8	0 cm	+9.0%	+12.5%	+9.4%
Yes	1.0	0 cm	+17.6%	+84.1%	+26.3%
Yes	0.8	0 cm	+25.2%	+89.9%	+33.7%
No	1.0	+2cm	-21.7%	-1.7%	-19.1%
No	0.8	+2cm	-10.9%	+10.7%	-8.0%
Yes	1.0	+2cm	-4.3%	+81.6%	+7.0%
Yes	0.8	+2cm	+5.6%	+87.4%	+16.4%

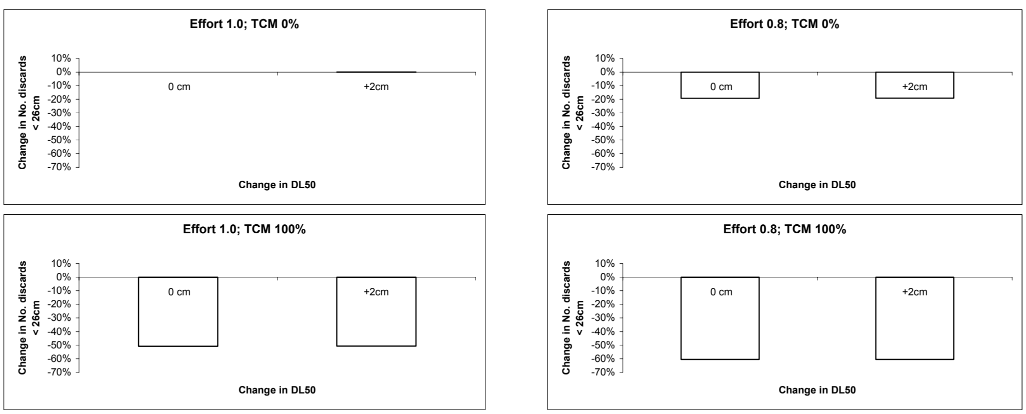
Figure 2.5 Effects of changes in management measures and discarding practices on relative availability of discards and offal of haddock

Each plot shows the effects of a 2cm increase in the length at which 50% of fish are discarded (DL50) for one management scenario. A management scenario is a combination of relative fishing effort (1.0 = no change) and percentage uptake of the technical conservation measure (TCM).

A: Total number of discards



B: Number of small discards (<26cm in length)



C: Offal production

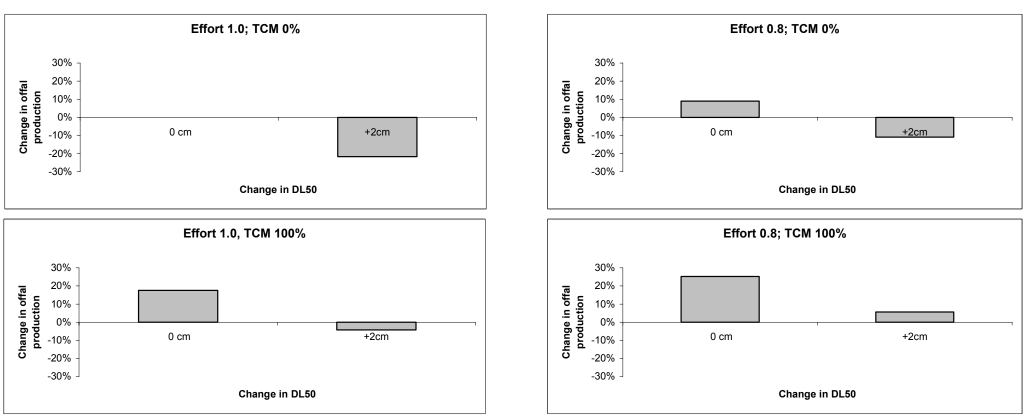
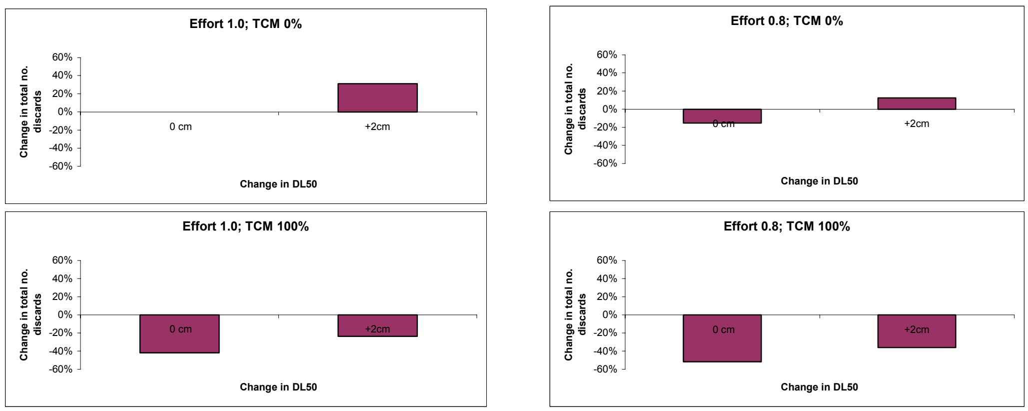


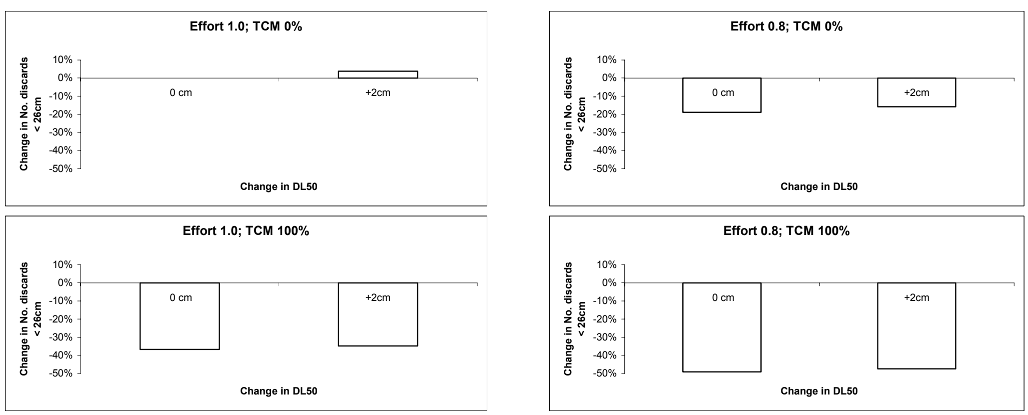
Figure 2.6 Effects of changes in management measures and discarding practices on relative availability of discards and offal of whiting

Each plot shows the effects of a 2cm increase in the length at which 50% of fish are discarded (DL50) for one management scenario. A management scenario is a combination of relative fishing effort (1.0 = no change) and percentage uptake of the technical conservation measure (TCM).

A: Total number of discards



B: Number of small discards (<26cm in length)



C: Offal production

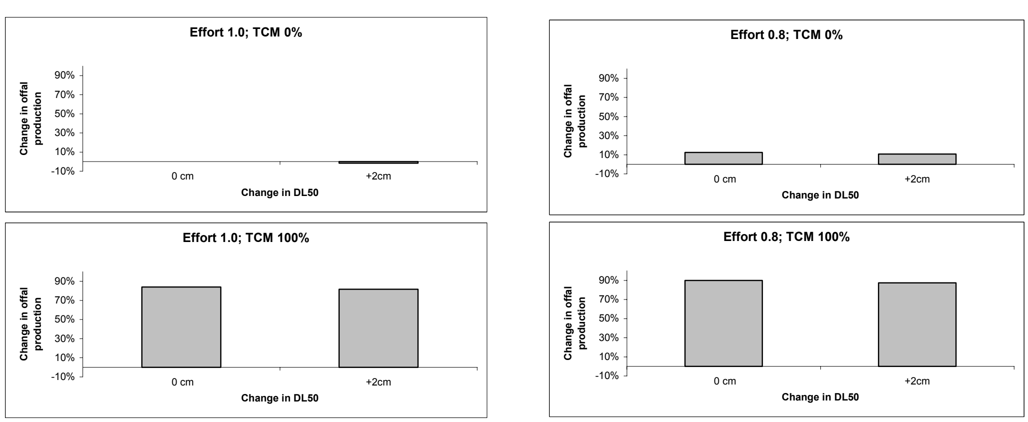
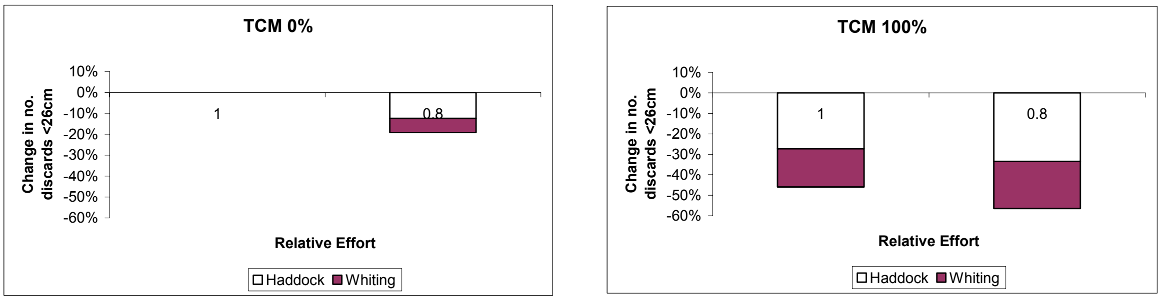


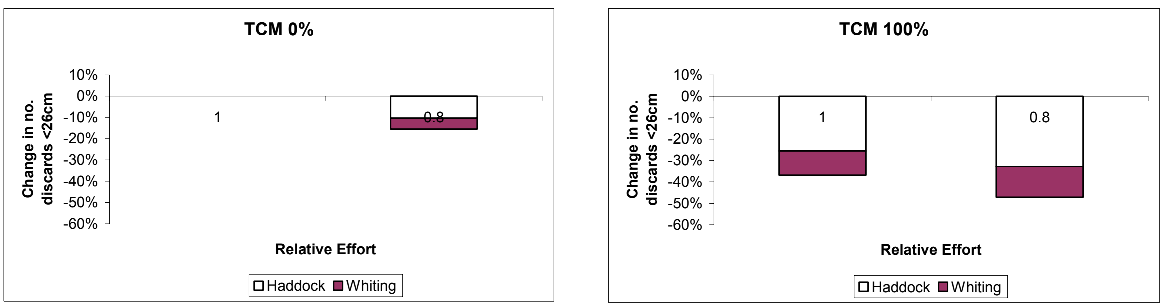
Figure 2.7 Effects of changes in management measures on relative availability of discards and offal from haddock and whiting combined

Each plot shows the changes due to a reduction in effort to 80% of the current level for a given percentage uptake of the technical conservation measure (TCM).

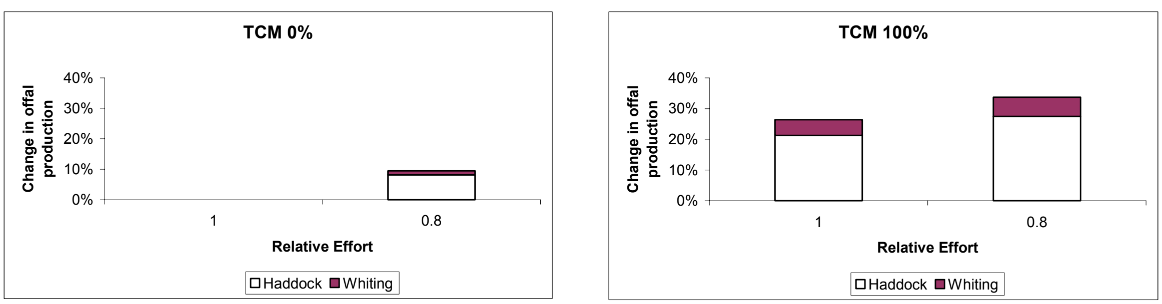
A; Total number of discards



B; Number of small discards



C; Offal production



In terms of their importance to seabirds, it is probably more relevant to consider the overall availability of the two species combined. As discarding practices may not change in the same manner for both species, Figure 2.7 summarises the effects of improved gear selectivity (the TCM) and the effort reduction on the estimates. The estimate of the total number (combined haddock and whiting) of discards is most influenced by the introduction of the TCM which on its own leads to a 37%

reduction in discard numbers. Combining this with the 20% effort reduction leads to an overall reduction of 47%. These figures mainly reflect the availability of haddock discards as haddock constitute between 67% and 70% of these estimates. The results are similar for discards under 26cm in length, with the TCM leading to a reduction in availability of 46%, and the effort causing a further 10% decrease. Haddock are less dominant in this case, making-up 60-65% of the total. The TCM is also the most influential factor in determining the offal production, with a 26% increase indicated if the TCM is introduced. Combining this with the effort reduction leads to an overall 34% increase in offal production. These increases are largely due to greater production of haddock offal; this species accounting for 81-87% of the total offal production, reflecting the assumption that all haddock are landed gutted.

2.5 Discussion

At the time of this analysis, the most recent assessments of the North Sea haddock stock (ICES, 2000a) indicate that the 1999 year class is very strong. In the short-term, this will lead to an increase in discards of haddock as catches will contain large quantities of young, undersized haddock until fish of this year class reach a large enough size to be landed legally. It is not possible to anticipate when this will occur as the growth rate is variable, particularly at younger ages. In the longer term, even in the absence of any changes in management, the projections made here indicate a relatively low level of haddock discards compared with past trends (Figure 1.2).

For whiting in the North Sea, as noted in Section 2.1.3, the 1999 ACFM advice was for the lowest possible catches in 2000. This was because the SSB has declined over the last 20 years to its lowest observed level. Recruitment has declined considerably since 1980 and has been unable to sustain the SSB despite a recent decrease in fishing mortality. The projections made here assume that the recent low level of recruitment will be maintained, and this, together with the relatively low recent F, is why projected discards of whiting are indicate very low levels compared to the historical series (Figure 1.2).

From this low baseline, any management action is likely to lead to a further reduction in the overall number of discards. For the range of parameter values investigated here, the TCM will have a more pronounced effect on the availability of discards than a 20% reduction in fishing effort. The projections indicate an overall reduction of 37% in the availability of discards of haddock and whiting combined would result from the gear change. While it is difficult to anticipate how discarding practices might change, any increase in DL50 would ameliorate this reduction in discards, but it would not increase the availability of the smaller (<26cm) discards which are of greater importance to some smaller seabird species. Assuming the continuation of current gutting practices, any measure which reduces discards will also tend to result in an increase in offal production, as a greater proportion of fish would survive to be caught at a size at which they would be gutted. Disregarding any possible change in discard practice, the results from the current projections indicate that this relationship between changes in discards and changes in offal is roughly linear, *eg* a scenario generating a 20% reduction in the total number of discards also implies a 15% increase in the weight of offal produced.

As noted above, the projections indicate that the revised technical conservation measures will have a greater effect on the availability of discards than the possible effort reductions. This is notable as, by their nature, the effects of TCMs are more immediate than an effort reduction. The current technical measures were prompted largely by the recruitment of the strong 1999 haddock year class against the background of the current poor state of the main North Sea roundfish stocks. It has been widely recognised that for the next few years fishermen will be largely dependent upon this one year class for their catches, hence any measure which reduces the discarding of this year class is seen to be beneficial. For this reason, there seems to be general acceptance of the current technical measures by the UK fishing industry and as a result, they are likely to be implemented effectively. In contrast, effort reduction can typically only be achieved much more slowly, and even when fleet capacity is reduced, the effects tend to be countered by continuing improvements in the technical efficiency of individual vessels. Hence in the current context, the new technical conservation measures are likely to have a much greater effect than any reductions in fishing effort on the availability of discards to seabirds in the North Sea.

3 Acknowledgements

The authors are grateful to Peter Clark and Ken Coull of FRS Marine Laboratory, Aberdeen, for their assistance with information and data on discarding and gutting aboard Scottish fishing vessels; to Dick Ferro of FRS Marine Laboratory, Aberdeen, for information on recent legislation on fishing gears, and to Euan Dunn and Sharon Thompson of the RSPB for their extensive and helpful comments on earlier drafts of the Report. RWF gratefully acknowledges funding from IFOMA.

4 References

Abrams, RW (1983) Pelagic seabirds and trawl-fisheries in the southern Benguela Current region. *Marine Ecology Progress Series*, **11**: 151-156.

Alverson, DL, Freeberg, MH, Murawski, SA & Pope, JG (1994) A global assessment of fisheries bycatch and discards. *FAO Fisheries Technical Paper **339***.

Anon. (1999) *Report of the Scientific, Technical and Economic Committee for Fisheries, Brussels 26-30 April, 1999*. European Commission Staff Working Paper.

Arcos, JM & Oro, D (1996) Changes in foraging range of Audouin's gulls *Larus audouinii* in relation to a trawler moratorium in the western Mediterranean. *Colonial Waterbirds* **19**: 128-131.

Becker, PH (1995) Effects of coloniality on gull predation on common tern (*Sterna hirundo*) chicks. *Colonial Waterbirds* **18**: 11-22.

Berghahn, R & Rösner, HU (1992) A method to quantify feeding of seabirds on discard from the shrimp fishery in the North Sea. *Netherlands Journal of Sea Research*, **28**: 347-350.

Blaber, SJM. & Wassenberg, TJ (1989) Feeding ecology of the piscivorous birds *Phalacrocorax varius*, *P. melanoleucos* and *Sterna bergii* in Moreton Bay, Australia: diets and dependence on trawler discards. *Marine Biology*, **101**: 1-10.

Blaber, SJM, Milton, DA, Smith, GC & Farmer, MJ (1995) Trawl discards in the diets of tropical seabirds of the northern Great Barrier Reef, Australia. *Marine Ecology Progress Series,* **127**: 1-13.

Bosch, M, Oro D, Cantos FJ, & Zabala M (2000) Short term effects of culling on the ecology and population dynamics of a yellow-legged gull colony. *Journal of Applied Ecology*, **37**: 369-385.

Cairns, DK (1987) Seabirds as indicators of marine food supplies. *Biological Oceanography*, **5**:261-271.

Camphuysen, CJ (1994) Flatfish selection by herring gulls *Larus argentatus* and lesser black-backed gulls *Larus fuscus* scavenging at commercial beamtrawlers in the southern North Sea. *Netherlands Journal of Sea Research*, **32**: 91-98.

Camphuysen, CJ & Garthe, S (1997). An evaluation of the distribution and scavenging habits of northern fulmars (*Fulmarus glacialis*) in the North Sea. *ICES Journal of Marine Science,* **54**: 654-683.

Camphuysen, CJ, Calvo, B, Durinck, J, Ensor, K, Follestad, A, Furness, RW, Garthe, S, Leaper, G, Skov, H, Tasker, ML & Winter, CJN (1995) Consumption of discards by seabirds in the North Sea. *NIOZ Rapport* **1995-5**. Netherlands Institute for Sea Research, Texel, the Netherlands.

Castilla, AM & Perez, JJ (1995) Relationships between fishery activities and presence of the Audouin's gull *Larus audouinii* in the Columbretes Islands. *Colonial Waterbirds,* **18**: 108-112.

Catry, P, Phillips RA, Hamer KC, Ratcliffe N, & Furness RW (1998) The incidence of nonbreeding by adult great skuas and parasitic jaegers from Foula, Shetland. *Condor*, **100**:448-455.

Chapdelaine, G & Rail, JF (1997) Relationship between cod fishery activities and the population of herring gulls on the north shore of the Gulf of St. Lawrence, Québec, Canada. *ICES Journal of Marine Science*, **54**: 708-713.

Coull, KA, Jermyn, AS, Newton, AW, Henderson, GI & Hall, WB (1989) Length/Weight Relationships for 88 Species of Fish Encountered in the North East Atlantic. *Scottish Fisheries Research Report* **43**. FRS Marine Laboratory, Aberdeen, UK.

Coulson, JC, Monaghan, P, Butterfield, J, Duncan, N, Thomas, C & Shedden, C. (1983) Seasonal changes in the herring gull in Britain: weight, moult and mortality. *Ardea* **71**, 235-244.

Dändliker, G & Mülhauser, G (1988) L'exploitation des déchets de chalutage par les oiseaux de mer au large des Orcades et des Shetland (Nord-Est Atlantique). *Nos Oiseaux*, **39**: 257-288.

Dunn, E (1994) *Interactions between fisheries and marine birds: Research Recommendations.* The Royal Society for the Protection of Birds, Sandy, UK

Dunn, E (1995) *Global Impacts of Fisheries on Seabirds.* BirdLife International, Cambridge, UK.

Durinck, J, Skov, H, Jensen, FP & Pihl, S (1994) Important marine areas for wintering birds in the Baltic Sea. *Ornis Consult report 1994*, 110pp. Ornis Consult, Copenhagen, Denmark.

Evans, SM, Hunter, JE, Elizal, & Wahju, RI (1994) Composition and fate of the catch and bycatch in the Farne Deep (North Sea) *Nephrops* fishery. *ICES Journal of Marine Science*, **51**: 155-168.

FAO (1995) Code of conduct for responsible fisheries. United Nations Food & Agriculture Organisation (FAO), Rome.

Ferro, RST & Graham, GN (2000) A recent UK joint initiative to revise technical conservation measures regulating the design of mobile gears. *ICES* **CM 2000/W:05**, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Freeman, AND (1997) The influence of hoki fishing vessels on Westland petrel (*Procellaria westlandica*) distribution at sea. *Notornis*, **44**: 159-164.

Freeman, AND & Smith, PJ (1998) Iso-electric focusing and the identification of fisheries' waste in the diet of Westland petrels (*Procellaria westlandica*). *New Zealand Journal of Marine & Freshwater Research*, **32:** 177-180.

Fryer, RJ, Ferro, RST & Graham, N (1998) Combining selectivity data from different trials. In Report of the Study Group on the use of Selectivity and Effort Measurement in Stock Assessment, *ICES* CM 1998/B:6, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Furness, RW (1992) Implications of changes in net mesh size, fishing effort and minimum landing size regulations in the North Sea for seabird populations. *JNCC Report* ***No. 133***, Joint Nature Conservation Committee, Peterborough, UK

Furness, RW (1997) The impact of predation by great skuas on other seabird species, with particular reference to special protection areas in Shetland. *Report to Scottish Natural Heritage*. Applied Ornithology Unit, University of Glasgow, Glasgow, UK.

Furness, RW (1999) Will reduced discarding help or harm seabird populations? pp. 481-488 In *Ecosystem Approaches for Fisheries Management, Alaska Sea Grant College Program AK-SG-99-01*.

Furness, RW & Camphuysen, CJ (1997) Seabirds as monitors of the marine environment. *ICES Journal of Marine Science* **54**: 726-737.

Furness, RW, Ensor, K & Hudson, AV (1992) The use of fishery waste by gull populations around the British Isles. *Ardea*, **80**: 105-113.

Garthe, S & Hüppop, O (1993) Gulls and fulmars following ships and feeding on discards at night. *Ornis Svecica*, **3**: 159-161.

Garthe, S & Hüppop, O (1994) Distribution of ship-following seabirds and their utilization of discards in the North Sea in summer. *Marine Ecology Progress Series*, **106**: 1-9.

Garthe, S, Camphuysen, CJ & Furness, RW (1996) Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. *Marine Ecology Progress Series*, **136**: 1-11.

Garthe, S, Grémillet, D & Furness, RW (1999) At-sea activity and foraging efficiency in chick-rearing northern gannets (*Sula bassana*): a case study in Shetland. *Marine Ecology Progress Series*, **185**: 93-99.

Garthe, S, Walter, U, Tasker, ML, Becker, PH, Chapdelaine, G & Furness, RW (1999) Evaluation of the role of discards in supporting bird populations and their effects on the species composition of seabirds in the North Sea. pp. 29-41 In: Diets of Seabirds and Consequences of Changes in

Food Supply. *ICES Cooperative Research Report* **No. 232**, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Hamer, KC, Furness, RW & Caldow, RWG (1991) The effects of changes in food availability on the breeding ecology of great skuas *Catharacta skua* in Shetland. *Journal of Zoology, London*. **223**: 175-188.

Hamer, KC, Thompson, DR & Gray, CM (1997) Spatial variation in the feeding ecology, foraging ranges, and breeding energetics of northern fulmars in the north-east Atlantic Ocean. *ICES Journal of Marine Science*, **54**: 645-653.

Heubeck, M, Mellor, RM & Harvey, PV (1997) Changes in the breeding distribution and numbers of kittiwakes *Rissa tridactyla* around Unst, Shetland, and the presumed role of predation by great skuas *Stercorarius skua*. *Seabird,* **19**: 12-21.

Heubeck, M, Mellor, RM, Harvey, PV, Mainwood, AR, & Riddington, R (1999) Estimating the population size and rate of decline of kittiwakes *Rissa tridactyla* breeding in Shetland, 1981-97. *Bird Study* **46**:48-61.

Howes, LA & Montevecchi, WA (1992) Population trends of gulls and terns in Gros Morne National Park, Newfoundland. *Canadian Journal of Zoology*, **71**:1516-1520.

Hudson, AV (1989) Interspecific and age-related differences in the handling time of discarded fish by scavenging seabirds. *Seabird*, **12**: 40-44.

Hudson, AV & Furness, RW (1988) Utilization of discarded fish by scavenging seabirds behind whitefish trawlers in Shetland. *Journal of Zoology, London*, **215**: 151-166.

Hudson, AV & Furness, RW (1989) The behaviour of seabirds foraging at fishing boats around Shetland. *Ibis*, **131**: 225-237.

Hunt, GL, Jr & Furness, RW (eds) (1996) Seabird/Fish Interactions, with Particular Reference to Seabirds in the North Sea. *ICES Cooperative Research Report,* **No. 216**. Pp 87.

Hunt, GL, Montevecchi, WA & Leopold, MF (1999) A review of issues related to seabird consumption of fish and shellfish stocks, discards and mariculture as well as the trophic role and ecology of seabirds and waders. pp. 2-5 In: Diets of Seabirds and Consequences of Changes in Food Supply. *ICES Cooperative Research Report* **No. 232**. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Hüppop, O & Wurm, S (2000) Effects of winter fishery activities on resting numbers, food and body condition of large gulls *Larus argentatus* and *L. marinus* in the south-eastern North Sea. *Marine Ecology Progress Series*, **194**: 241-247.

ICES (1997a) Report of the ICES Advisory Committee on the Marine Environment 1997. *ICES Co-operative Research Report*, **No. 222**, International Council for the Exploration of the Sea, Copenhagen, Denmark.

ICES (1997b) Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skaggerak. *ICES **CM 1997/Assess:6***, International Council for the Exploration of the Sea, Copenhagen, Denmark.

ICES (1998) Report of the Working Group on Ecosystem Effects of Fishing Activities. *ICES **CM 1998/ACFM/ACME:1 Ref.:E***, International Council for the Exploration of the Sea, Copenhagen, Denmark.

ICES (2000a) Report of the Working Group on Demersal Stocks in the North Sea and Skagarrak. ICES **CM 2000/ACFM:7**, International Council for the Exploration of the Sea, Copenhagen, Denmark.

ICES (2000b) Report of the Study Group on Estimation of the Annual Amount of Discards and Fish Offal in the Baltic Sea (SGDIB). *ICES **CM 2000/ACME:6***, International Council for the Exploration of the Sea, Copenhagen, Denmark.

ICES (2000c) Report of the Working Group on Seabird Ecology. *ICES **CM 2000/C:04***, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Lloyd, C, Tasker, ML & Partridge, K (1991) The Status of Seabirds in Britain and Ireland. T & AD Poyser, London, UK.

Madsen, N, Holst R & Foldager L (1999) The escape window as a management option to improve the size selectivity of the Baltic Sea cod fishery. *ICES **CM 1999/R:01***, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Mavor, RA, Pickerell, G, Heubeck, M & Thompson, KR (2001) *Seabird numbers and breeding success in Britain and Ireland, 2000*. Joint Nature Conservation Committee, Peterborough, UK.

Mesnil, B & Shepherd, JG (1990) A hybrid age- and length-structured model for assessing regulatory measures in multiple-species, multiple-fleet fisheries. *Journal du Conseil International pour l'Exploration de la Mer*, **47** :115-132.

Moore, G & Jennings, S (2000) Commercial fishing: The Wider Ecological Implications. Blackwell Scientific, London, UK.

Noordhuis, R & Spaans, AL (1992) Interspecific competition for food between herring *Larus argentatus* and lesser black-backed gulls *L. fuscus* in the Dutch Wadden Sea area. *Ardea*, **80**: 115-132.

Oro, D (1995) The influence of commercial fisheries in daily activity of Audouin's gull *Larus audouinii* in the Ebro Delta, NE Spain. *Ornis Fennica*, **72**: 154-158.

Oro, D (1996a) *The effects of commercial fisheries on the biology of Audouin's gull Larus audouinii at the Ebro Delta, northwestern Mediterranean*. PhD thesis, University of Barcelona, Spain.

Oro, D (1996b) The effects of trawler discard availability on the egg-laying and the breeding success of the lesser black-backed gull *Larus fuscus* in western Mediterranean. *Marine Ecology Progress Series*, **132**: 43-46.

Oro, D & Martinez-Vilalta, A (1994) Factors affecting kleptoparasitism and predation rates upon a colony of Audouin's gull (*Larus audouinii*) by yellow-legged gulls (*Larus cachinnans*) in Spain. *Colonial Waterbirds*, **17**: 35-41.

Oro, D & Ruiz, X (1997) Exploitation of trawler discards by breeding seabirds in the north-western Mediterranean: Differences between the Ebro Delta and the Balearic Islands areas. *ICES Journal of Marine Science*, **54**: 695-707.

Oro, D, Bosch, M & Ruiz, X (1995) Effects of a trawling moratorium on the breeding success of the yellow-legged gull *Larus cachinnans*. *Ibis*, **137**: 347-349.

Oro, D, Jover, L & Ruiz, X (1996a) Influence of trawling activity on the breeding ecology of a threatened seabird, Audouin's gull *Larus audouinii*. *Marine Ecology Progress Series*, **139:** 19-29.

Oro, D, Genovart, X, Ruiz, X, Jiménez, J, & Garcia-Gans, J (1996b) Differences in diet, population increase and breeding performance between two colonies of Audouin's Gulls *Larus audouinii* during breeding seasons affected by a trawling moratorium. *Journal of Avian Biology*, **27**:245-251.

Oro, D, Ruiz, X., Jover, L, Pedrocchi, V & Gonzalez-Solis, J (1997) Diet and adult time budgets of Audouin's gull *Larus audouinii* in response to changes in commercial fisheries. *Ibis*, **139**: 631-637

Oro, D, Pradel, R & Lebreton, J-D (1999) The effects of nest predation and food availability on life history traits in Audouin's gull. *Oecologia* **118**:438-445.

Oro, D, & Pradel, R (1999) Recruitment of Audouin's gull to the Ebro Delta colony at metapopulation level in the western Mediterranean. *Marine Ecology Progress Series*, **180**: 267-273.

Oro, D, & R Pradel (2000) Determinants of local recruitment in a growing colony of Audouin's gull. *Journal of Animal Ecology*, **69**: 1-14.

Oro, D & Furness, RW (in press) Influences of food and predation on survival and population dynamics of kittiwakes. *Ecology*

Paterson, AM, Martinez-Vilalta, A & Dies, JI (1992) Partial breeding failure of Audouin's gull in two Spanish colonies in 1991. *British Birds*, **85**: 97-100.

Phillips, RA, Caldow, RWG, & Furness, RW (1996) The influence of food availability on the breeding effort and reproductive success of Arctic Skuas *Stercorarius parasiticus*. *Ibis*, **138**: 10-419.

Phillips, RA, Thompson, DR & Hamer, KC (1997). *The population and feeding ecology of great skuas Catharacta skua on Hirta, St Kilda.* Report to Scottish Natural Heritage.

Phillips, RA, DR Thompson, & Hamer, KC (1999a) The impact of great skua predation on seabird populations at St Kilda: a bioenergetics model. *Journal of Applied Ecology*, **36**: 218-232.

Phillips, RA, Petersen, MK, Lilliendahl, K, Solmundsson, J, Hamer, KC, Camphuysen, CJ & Zonfrillo, B (1999b) Diet of the northern fulmar *Fulmarus glacialis*: reliance on commercial fisheries? *Marine Biology*, **135**: 159-170.

Pons, JM (1992) Effects of changes in the availability of human refuse on breeding parameters in a herring gull *Larus argentatus* population in Brittany, France. *Ardea*, **80**: 143-150.

Pons, J-M, & Migot, P (1995) Life-history strategy of the herring gull: changes in survival and fecundity in a population subjected to various feeding conditions. *Journal of Animal Ecology*, **64**:592-599.

Ratcliffe, N, Furness, RW, & Hamer, KC (1998) The interactive effects of age and food supply on the breeding ecology of great skuas. *Journal of Animal Ecology*, **67**: 853-862.

Reeves, SA, Armstrong, DW, Fryer, RJ & Coull, KA (1992) The effect of mesh size, cod-end extension length and cod-end diameter on the selectivity of Scottish trawls and seines. *ICES Journal of Marine Science*, **49**, 279-288.

Regehr, HM. & Montevecchi, WA (1996) Interactive effects of food shortage and predation on breeding failure of black-legged kittiwakes: effects of fisheries activities and implications for indicator species. *Marine Ecology Progress Series*, **155**: 249-260.

Ruiz, X, Oro, D, Martinez-Vilalta, A & Jover, L (1996) Feeding ecology of Audouin's gulls *Larus audouinii* in the Ebro Delta. *Colonial Waterbirds*, **19**: 68-74.

Russell, JO & Montevecchi, WA (1996) Predation on adult puffins *Fratercula arctica* by great black-backed gulls *Larus marinus* at a Newfoundland colony. *Ibis*, **138**: 791-794.

Ryan, PG & Moloney, CL (1988) Effect of trawling on bird and seal distributions in the southern Benguela region. *Marine Ecology Progress Series*, **45**, 1-11.

Scherp, B (1999) *Nutzung von Fischereiabfällen durch Seevögel in der westlichen Ostsee*. Diploma thesis, University of Kiel, Kiel, Germany.

Stratoudakis, Y (1999) Recommendations for improving the estimation of the number of seabirds potentially sustained by fisheries discards. *Marine Ecology Progress Series*, **176**, 307-309.

Stratoudakis, Y, Fryer, RJ & Cook, RM (1998) Discarding practices for commercial gadoids in the North Sea. *Canadian Journal of Fisheries & Aquatic Science*, **55**: 1632-1644.

Stratoudakis, Y, Fryer, RJ, Cook, RM & Pierce, GJ (1999) Fish discarded from Scottish demersal vessels: Estimators of total discards and annual estimates for targeted gadoids. *ICES Journal of Marine Science*, **56**: 592-605.

Tasker, ML, Webb, A, Hall, AJ, Pienkowski, MW & Langslow, DR (1987) Seabirds in the North Sea. Nature Conservancy Council, Peterborough, UK. Pp. 336.

Tasker, ML & Furness, RW (1996) Estimation of food consumption by seabirds in the North Sea. pp. 6-42 In: Seabird/Fish Interactions, with Particular Reference to Seabirds in the North Sea. *ICES Cooperative Research Report,* **No. 216**.

Tasker, ML, Becker, PH & Chapdelaine, G (1999) Exploration of the short- and medium-term consequences of a reduction in the amounts of fish discarded. pp. 42-46 In: Diets of Seabirds and Consequences of Changes in Food Supply. *ICES Cooperative Research Report*, **No. 232**, International Council for the Exploration of the Sea, Copenhagen, Denmark.

Tasker, ML, Camphuysen, CJ, Cooper, J, Garthe, S, Montevecchi, WA & Blaber, SJM (2000) The impacts of fishing on marine birds. *ICES Journal of Marine Science*, **57**: 531-547.

Thiel, M & Sommer, T (1994) Wind-dependent impact of gulls (*Larus* spec.) on the breeding success of common terns (*Sterna hirundo*). *Ophelia*, **Suppl. 6**: 239-251.

Thompson, DR, Furness, RW & Lewis, SA (1995) Diets and long-term changes in $\delta^{15}N$ and $\delta^{13}C$ values in northern fulmars *Fulmarus glacialis* from two northeast Atlantic colonies. *Marine Ecology Progress Series*, **125**: 3-11.

Thompson, KR (1992) Quantitative analysis of the use of discards from squid trawlers by black-browed albatrosses in the vicinity of the Falkland Islands. *Ibis*, **134**: 11-21.

Thompson, KR & Riddy, MD (1995) Utilization of offal and discards from 'fin-fish' trawlers around the Falkland Islands by the black-browed albatross *Diomedea melanophris*. *Ibis*, **137**: 198-206.

Thompson, KR, Brindley, E, & Heubeck, M (1996) *Seabird numbers and breeding success in Britain and Ireland, 1995*. Joint Nature Conservation Committee, Peterborough, UK.

Thompson, KR, Brindley, E, & Heubeck, M (1997) *Seabird numbers and breeding success in Britain and Ireland, 1996*. Joint Nature Conservation Committee, Peterborough, UK.

Thompson, KR, Brindley, E, & Heubeck, M (1998) *Seabird numbers and breeding success in Britain and Ireland, 1997*. Joint Nature Conservation Committee, Peterborough, UK.

Thompson, KR, Pickerell, G, & Heubeck, M (1999) *Seabird numbers and breeding success in Britain and Ireland, 1998*. Joint Nature Conservation Committee, Peterborough, UK.

Upton, AJ, Pickerell, G, & Heubeck, M (2000) *Seabird numbers and breeding success in Britain and Ireland, 1999*. Joint Nature Conservation Committee, Peterborough, UK.

Walsh, PM, Sears, J, & Heubeck, M (1991) *Seabird numbers and breeding success in 1990*. Nature Conservancy Council, Peterborough, UK.

Walsh, PM, Sim, I, & Heubeck, M (1992) *Seabird numbers and breeding success in Britain and Ireland, 1991*. Joint Nature Conservation Committee, Peterborough, UK.

Walsh, PM, Sim, I, & Heubeck, M (1993) *Seabird numbers and breeding success in Britain and Ireland, 1992*. Joint Nature Conservation Committee, Peterborough, UK.

Walsh, PM, Brindley, E, & Heubeck, M (1994) *Seabird numbers and breeding success in Britain and Ireland, 1993*. Joint Nature Conservation Committee, Peterborough, UK.

Walsh, PM, Brindley, E, & Heubeck, M (1995a) *Seabird numbers and breeding success in Britain and Ireland, 1994*. Joint Nature Conservation Committee, Peterborough, UK.

Walsh, PM, Halley, DJ, Harris, MP, del Nevo, A, Sim, IMW, & Tasker, ML (1995b) *Seabird monitoring handbook for Britain and Ireland*. JNCC, RSPB, ITE, Seabird Group, Peterborough. Joint Nature Conservation Committee, Peterborough, UK.

Walter, U (1997) Quantitative analysis of discards from brown shrimp trawlers in the coastal area of the East Frisian islands. *Archives of Fisheries & Marine Research*, **45**: 61-76.

Walter, U & Becker, PH (1994) The significance of discards from the brown shrimp fisheries for seabirds in the Wadden Sea - preliminary results. *Ophelia*, **Suppl. 6**: 253-262.

Walter, U & Becker, PH (1997) Occurrence and consumption of seabirds scavenging on shrimp trawler discards in the Wadden Sea. *ICES Journal of Marine Science*, **54**: 684-694.

Annex 1: Glossary

ACFM	The Advisory Committee for Fishery Management. The Committee is responsible, on behalf of ICES, for scientific information and advice on living resources and their harvesting.
B_{PA}	A precautionary biomass reference point used to define whether or not a fish stock is in a depleted state. If the current SSB is below B_{PA}, then the stock is considered to be in a depleted state.
CFP	The Common Fisheries Policy (CFP), is the European Union's instrument for the management of fisheries and aquaculture.
Codend	The mesh bag at the rear of a towed fishing gear (*eg* a trawl or a seine) where the catch is retained. Regulations intended to influence the selectivity of such gears usually apply to the mesh size and construction of the codend.
DL50	The length at which 50% of fish are discarded.
DSR	Discard selection range. By analogy with a selectivity curve, this represents the length range over which partial discarding occurs,
F	Coefficient of Fishing Mortality. Estimated as part of a stock assessment, F is a measure of the proportion of the fish at each age which are removed by fishing each year. F is thus an index of the level of exploitation of the stock.
F_{PA}	A precautionary fishing mortality reference point used to define whether or not a fish stock is being overfished. If current F is above F_{PA} then the stock is considered to be overfished.
ICES	The International Council for the Exploration of the Sea. ICES is the oldest intergovernmental marine science organization in the world. It is a leading forum for the promotion, coordination, and dissemination of research on the physical, chemical, and biological systems in the North Atlantic and advice on human impact on its environment, in particular fisheries effects in the Northeast Atlantic.
l_{50}	The length at which 50% of the fish entering a fishing gear are retained. Similarly, l_{25} is the corresponding length for 25% retention.
M	Coefficient of natural mortality. An estimate of the proportion of fish lost through natural mortality at each age in each year.
MAGP	MAGPs, or Multi-Annual Guidance Programmes, are programmes which set conditions on the development of EU national fishing fleets with the aim of matching the fleet capacity to the available resources.

Recruitment	The number of young fish entering a stock in a given year. The recruits resulting from spawning in a given year, eg 1999, are referred to as the 1999 year-class.
Selectivity curve	A selectivity curve or ogive is a curve used to describe the proportion of fish at each length which are retained by a fishing gear. For a towed gear such as a trawl, this is usually a sigmoid curve with its position defined by l50 and its steepness defined by SR.
SR	The selection range of a selectivity curve. It measures the steepness of a selectivity curve and is defined as $2(l_{50} - l_{25})$
SSB	Spawning Stock Biomass. SSB is estimated as part of a stock assessment and is used as an index of the stock's reproductive capacity.
Safe Biological Limits	In its advice, ACFM (see this Glossary) describes the current state of a fish stock with reference to the precautionary reference points F_{PA} and B_{PA} (qv). If the current spawning stock is below B_{PA} and the fishing mortality is above F_{PA} then the stock is described as being 'outside safe biological limits'. Management should then aim to return the stock to within safe biological limits.
TAC	Total Allowable Catch. The maximum weight of fish of a given species/area which is permitted to be caught in a given year.
TCM	Technical Conservation Measure. A measure such as a legal limit on the minimum mesh size which may be used in a fishery, and which is intended to assist the conservation of the target fish stocks by reducing fishing pressure.

The Royal Society for the Protection of Birds is the UK charity that takes action for wild birds and the environment. With over one million members, it is the largest wildlife charity in Europe. It leads the way in the effective conservation of birds and makes a positive contribution to a better environment. We aim to be the UK's foremost authority on the conservation of birds and their environment and, while working principally in the UK, are becoming increasingly active elsewhere in the world.

BirdLife International is a global network of more than 100 non-governmental organisations working for the conservation of birds and their habitats. It has partner organisations in all the EU member states, as well as information and co-ordination offices in Brussels, Belgium and Wageningen, The Netherlands. www.birdlife.net

This report was written for the RSPB and BirdLife International by Stuart A Reeves, Danish Institute for Fisheries Research, Charlottenlund Slot, DK-2920 Charlottenlund, Denmark (formerly at FRS Marine Laboratory, PO Box 101, Victoria Road, Aberdeen AB11 9DB, UK when work commenced), and Robert W Furness, Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, UK.

The report should be cited as: Reeves SA and Furness RW (2002) *Net loss – seabirds gain? Implications of fisheries management for seabirds scavenging discards in the northern North Sea*. The RSPB, Sandy, UK.

For further information, please contact:

Euan Dunn
RSPB UK Headquarters
The Lodge
Sandy
Bedfordshire SG19 2DL
United Kingdom
Tel: +44 1767 680551
Fax +44 1767 692365
e-mail: euan.dunn@rspb.org.uk

Clairie Papazoglou
BirdLife International
European Community Office
Rue de la Loi 81a
B-1040 Brussels
Belgium
Tel: +32 2280 0830
Fax: +32 2230 3802
e-mail: clairie.papazoglou@birdlifeeco.net

Visit the RSPB website to find out how you can help birds and wildlife.
www.rspb.org.uk

Front cover image W Wisniewski (FLPA)   RSPB Regd charity number 207076   27-0666-02-03