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Can changes in fishery landings explain long-term population trends in gulls?

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ABSTRACT

Capsule: Long-term population trends of gulls on the Isle of Canna, Scotland, showed a correlation to fish tonnage landed in a nearby port.

Aims: To assess whether gull numbers and breeding success at Canna have been influenced by the amount of fish discarded in the area.

Methods: We examined data on gull breeding numbers, breeding success and diet studied at Canna from 1969 to 2014, and data on fish landings at the nearby port of Mallaig for 1985 to 2014. We examined correlations between gull and fishery data, and performed a detrended analysis of Herring Gull *Larus argentatus* numbers in relation to demersal fish catch (the latter as a proxy for discard volumes).

Results: Gulls fed extensively on discards. Gull breeding numbers declined at Canna, especially between 2000 and 2006, the decline being more pronounced than seen in national totals. Gull breeding numbers correlated with demersal landings, even after detrending for long-term decreases in both.

Conclusions: Correlation between detrended Herring Gull breeding numbers and detrended demersal fish landings provided strong evidence for a causal link between fishery discarding and gull breeding numbers.

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A range of factors drive seabird population dynamics (Ratcliffe 2004), including food availability (Furness & Birkhead 1984, Cury *et al.* 2011), fisheries (Tasker *et al.* 2000, Bicknell *et al.* 2013), climate change (Sandvik *et al.* 2012, Frederiksen *et al.* 2013, Macdonald *et al.* 2015), presence of non-native predators (Ratcliffe *et al.* 2009) and competition from other seabirds (Oro & Furness 2002, Votier *et al.* 2004). Some species, such as the Northern Gannet *Morus bassanus*, have been able to exploit abundance in food that suits their breeding requirements enabling large population growth (Murray *et al.* 2015). In contrast, declines in Black-legged Kittiwake *Rissa tridactyla* breeding numbers, particularly in the Northern Isles of Scotland, have been linked to a dramatic reduction in sandeels *Ammodytes* sp., their primary food source (Oro & Furness 2002, Frederiksen *et al.* 2005, Macdonald *et al.* 2015). *Larus* gulls, which include Great Black-backed Gull *Larus marinus*, Lesser Black-backed Gull *Larus fuscus* and Herring Gull *Larus argentatus*, are opportunistic scavengers, able to exploit a wide range of food sources. Discards from fisheries represent an important part of the diet of these gulls (Furness *et al.* 1992, Garthe *et al.* 1996, Camphuysen 2013). Changes in discarding by the demersal trawl fishery in the western Mediterranean have been shown to have profound impacts on breeding success and population size of gulls in that region, where fishery closures show this effect clearly (Oro *et al.* 2004). However, the influence of discarding from fisheries on gull numbers in Scotland has been less clear, at least in part because discarding in Scottish waters has not been subject to such abrupt change as in the Mediterranean.

Canna, one of the Small Isles in the Inner Hebrides, is situated south of Skye at the southern end of the Minch off northwest Scotland. It is a Special Protection Area under the European Commission Birds Directive for its nationally important concentrations of breeding seabirds. Seabird monitoring began on Canna in 1969 as part of Operation Seafarer, the first complete census of all seabird colonies in Britain and Ireland. The island has been visited every year since 1969, rendering it one of the longest continuously running seabird monitoring sites in the British Isles (Swann 2000). In 1986 it was adopted as one of the key monitoring sites in the UK Government's Joint Nature Conservation Committee (JNCC) Seabird Monitoring Programme (SMP).

In this paper, we assess the long-term trends in breeding numbers of three species of gulls on the Isle

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of Canna: Great Black-backed Gull, Lesser Black-backed Gull and Herring Gull. We contrast the gull population trends on Canna with the Scotland population trends. To determine whether a potential causal link may exist between the trends observed for gulls and changes in fishery landings we looked at the trends in fish landings from 1985 to 2014 at Mallaig, which provide an index of the amount of discarded fish being made available to scavenging seabirds. Most fish landed at Mallaig are caught by small inshore fishing vessels working within sight of Canna, and so these fishing boats represent a potential feeding opportunity for gulls breeding on the island.

Methods

Study site

Canna, is one of the Small Isles, situated south of Skye at the southern end of the Minch off northwest Scotland (57.06142N 6.544736W). The island is around six miles long and two miles wide. It is bounded by large precipitous cliffs on its northern side which have extensive boulder fields and wave cut platforms that make for suitable nesting sites for a range of seabirds. Heathland and grassland are the predominate habitats away from the northern cliffs.

Seabird counts

Gulls have been counted annually on Canna since 1969 using the methods described in Walsh *et al.* (1995). Colonies were counted using two different methods: direct nest counts and counts of apparently occupied territories (AOTs). The application of these methods was consistent between years.

Gull breeding productivity

Between 1979 and 2006 nests in seven colonies of Herring Gull scattered throughout the island (Figure 1) were checked for signs of hatching (e.g. copious droppings, food remains or chicks). Nests with no such signs were classed as having failed.

Between 1989 and 2008 capture-mark-recapture studies were used in one Herring Gull colony (Tallabric; Figure 1) in order to estimate breeding success. Nests were first counted in late May. On the first sweep through the colony all nests were marked with a plastic coloured tag. On the second sweep each

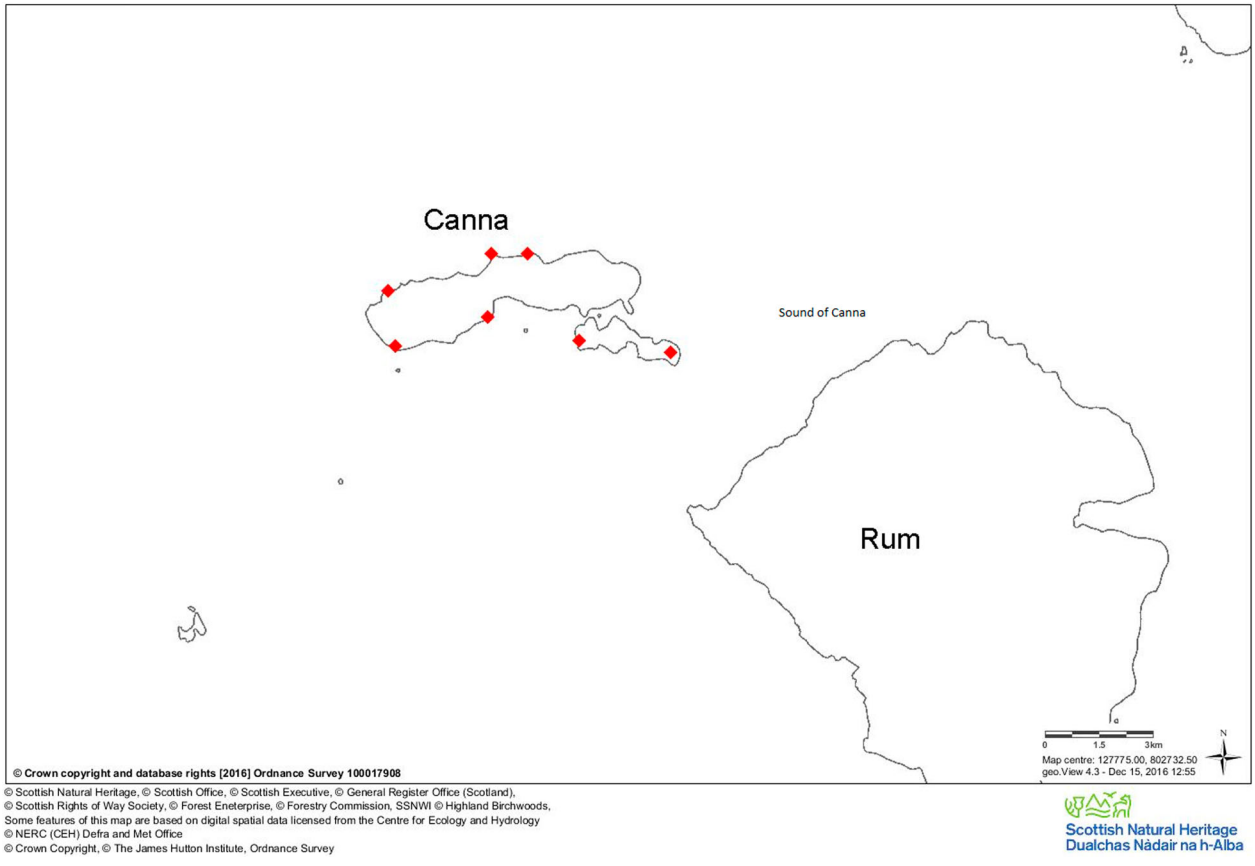

Figure 1. Location of gull colonies on Canna 1969–2006.

nest found with a tag was given a second tag and those without were given a different coloured tag. This enabled nest-finding efficiency to be calculated and the total number of nests in the colony to be estimated. In early July, the colony was revisited to ring chicks. The colony was visited again a few days later and the number of ringed chicks caught noted as were all newly ringed ones. This enabled a mark-recapture estimate to be made of the total number of chicks. Finally, the colony was revisited in early August to count dead young.

Since 2002 a sample of nesting pairs of Herring Gulls have been plotted on a map in late May. The sites were revisited in early and late July to count the number of large young present. This method has also been used to calculate Great Black-backed Gull productivity since 1997. We have not calculated breeding productivity for Lesser Black-backed Gull.

Gull diet

Samples of food regurgitated by chicks during ringing were collected between 1989 and 1994. These were sent to Glasgow University Zoology department for species identification and analysis of composition. Since then regurgitate samples have been collected on an ad hoc basis.

Fish landings

Data regarding fish landings were obtained from the Scottish Government Sea Fisheries Statistics (http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/PubFisheries). Fishery landings data were available for Mallaig for each year from 1985 to 2014, separately for demersal and for pelagic fish. Although gulls feed on the discard fraction of catches rather than on landed fish, the volume of the catch is the main factor determining the quantity of discards, although the latter is also influenced from year to year by the age structure of the fish stock and changes in technical measures and quotas. Because gulls obtain many discards from demersal fisheries but very few from pelagic fisheries and tend to avoid feeding on marine invertebrates when fish are available (Garthe *et al.* 1996), we have focused on the data for the demersal fishery.

Scottish gull populations

Details of trends from other Scottish colonies were obtained from JNCC as part of the SMP (http://jncc.defra.gov.uk/smp/). Since 1986, the SMP has coordinated annual seabird counts for a sample of coastal colonies. There are no recent Scottish data for Lesser Black-backed Gull breeding numbers.

Statistical analysis

Relationships between fishery landings and year, gull breeding numbers and year, gull breeding numbers and fishery landings were tested for the years 1985–2014 by correlation analysis. Where the trend in fishery landings and trend in gull numbers showed a statistically significant correlation with year, a detrended correlation was calculated between gull breeding numbers and fishery landings. Residuals between observed gull numbers and numbers predicted for each year based on the linear regression were correlated against residuals between fishery landings and predicted landings for each year based on the linear regression. Detrended correlation was only carried out for Herring Gull data, as the breeding numbers of Lesser Black-backed Gulls and Great Black-backed Gulls were too small for analysis.

Results

Seabird counts

Herring Gull. The number of Herring Gulls nesting on Canna fluctuated but showed an overall increase between 1971 and 1988 when they reached 1525 AOTs. There then followed a slow decline to 1282 AOTs in 2000. This was followed by a rapid decline to only 96 AOTs in 2006. Since then numbers have fluctuated between 63 and 95 AOTs (Figure 2). Over the period for which we have fishery landings data (1985–2014) breeding numbers declined following the equation: number of pairs = 11 6437 − 57.824 × year. This linear decline explains 77.5% of the variation in breeding numbers ($r = 0.881$, $N = 30$, $P < 0.01$).

Lesser Black-backed Gull. Following a peak of 69 AOTs in 1975, numbers remained fairly stable around 40 AOTS between 1979 and 2002. There then followed a rapid decline to only 4 AOTS in 2005, since when there has been a small increase to 13 AOTs.

Great Black-backed Gull. There was a slow increase in numbers from 58 AOTs in 1969 to 93 AOTs in 1997. Numbers declined rapidly from 89 AOTs in 2000 to only 17 AOTs in 2009. Numbers have since fluctuated between 15 and 18 AOTs.

Scottish gull population trends

Figure 3 shows that Scottish Herring Gull populations declined slowly by around 60% from 1986 to 2011

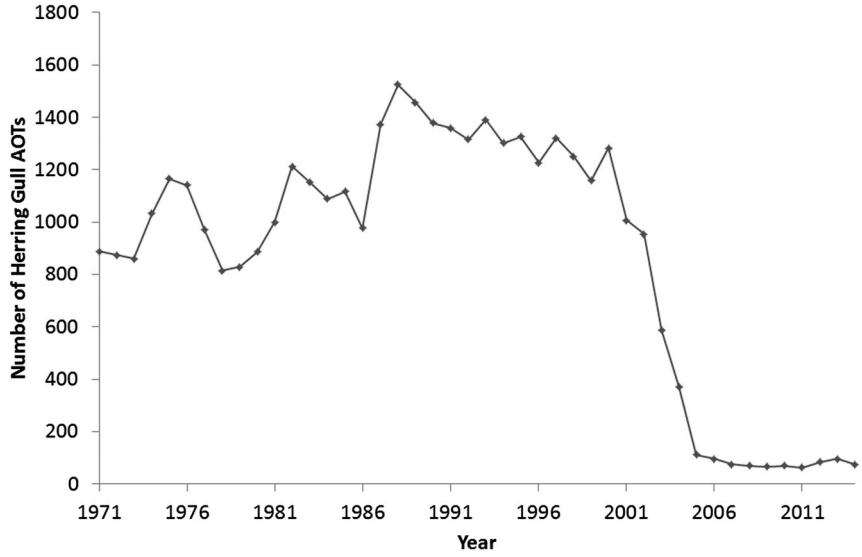

Figure 2. Number of Herring Gull AOTs on Canna 1971–2014.

since when there has been some evidence of an increase. Great Black-backed Gull populations fluctuated but were high between 1986 and 2003 and then declined rapidly to a low in 2012, since when there has been a slight increase.

Breeding success – Herring Gull

The percentage of nests deemed to have successfully hatched chicks was generally high between 1979 and 2000, averaging 64% with only two years (1979 and 1999) when the percentage was less than 20%. Between 2001 and 2006, the percentage of successful nests declined from 10% to 2% and thereafter samples were too small to use this method. In Tallabric, the number of chicks per nest estimated to have fledged averaged 1.04 between 1989 and 2000. Thereafter between 2001 and 2005 this dropped to 0.16 with four of these six years resulting in no chicks being produced in this colony. Between 2002 and 2006 only 0.13 young per pair were reared in territories plotted on maps in May and revisited close to fledging. From 2007 to 2015 this had risen to an average of 1.32 with much annual variation.

Breeding success – Great Black-backed Gull

From 1997 to 2000 monitored Great Black-backed Gulls produced 1.1–1.5 young per pair. Between 2001 and

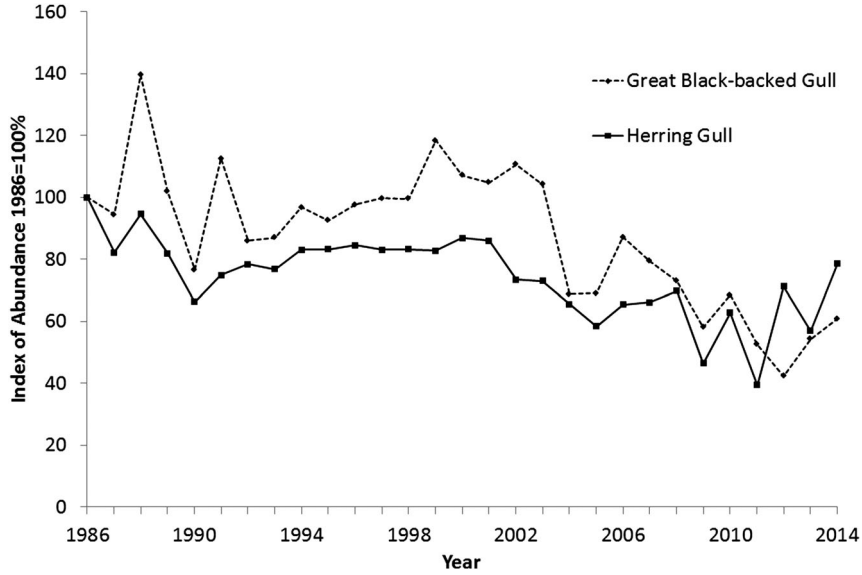

Figure 3. Index of abundance of Herring Gull and Great Black-backed Gull in Scotland 1986–2014.

Table 1. Details of Canna Herring Gull regurgitations analysed between 1989 and 1994.

	1989	1990	1991	1992	1993	1994	Total
No. of regurgitations	56	49	42	36	46	46	275
No. containing fish	52	47	42	36	45	46	268
No. containing cephlapods	7	3	0	0	1	0	11
No. containing molluscs	3	0	1	0	0	9	4
No. containing crustacea	4	6	0	7	5	2	24
Of fish							
No. identified as sandeels	18	9	24	1	2	16	70
No. identified as clupeids	9	9	8	7	8	1	42
No. identified as gadoids	12	17	10	16	19	11	85

2006 only 0.1–0.3 young were produced per pair. From 2007 to 2015 the number of young reared has varied between 0.5 and an exceptional 2.2 and averaged 1.1 young per pair.

Gull diet

Details of the regurgitations analysed between 1989 and 1994 are given in Table 1. Of the 275 regurgitations collected, 268 (97%) contained fish remains, 24 (9%) contained crustacea, mainly remains of Norway Lobster *Nephrops norvegicus*, 11 (4%) cephalopods and 4 molluscs. Of the fish that could be identified, 85 regurgitations contained gadoids, 70 sandeels and 42 clupeids. Of the identifiable gadoids, 34 were Whiting *Merlangius merlangus*, 9 Haddock *Melanogrammus aeglefinus*, 9 Poor Cod *Trisopterus minutus* and 6 Cod *Gadus morhua*. Of the identifiable pelagic fish, 32 were Herring *Clupea harengus* and 4 Mackerel *Scomber scombrus*.

Based on the size of the remains in the regurgitations it was surmised that, with the exceptions of the sandeels and molluscs, most other prey items (74% of all items) would likely have been derived from scavenging discards at fishing boats (Bernie Zonfrillo, pers comm.). The fish were of the specific size range known to be discarded by fishermen (sizes which are retained by the net but are below the legal limit for landing for sale; see Hudson & Furness 1988, Votier *et al.* 2004).

Between 2001 and 2006, 21 regurgitations were examined, 12 (57%) contained unidentified whitefish likely to have been scavenged from fishing boats and 9 contained sandeels. Between 2007 and 2015 only six regurgitations were recorded, four contained whitefish, one *Nephrops* remains and one a starfish, all probably scavenged from fishing boats.

Fish landings

Between 1985 and 2000 total landings of demersal fish, pelagic fish and shellfish at Mallaig ranged from 9195 to 19 952 (tonnes) per annum (Figure 4) and averaged over this period 13 726. Between 2001 and 2006 the total amount landed fell from 8252 in 2001 to 4006 in 2006. Between 2007 and 2014 the total amount landed varied between 3689 and 5666 and averaged 4456. Landings of pelagic fish at Mallaig showed a statistically significant positive correlation ($r = 0.585$, $N = 30$, $P < 0.01$) with landings of demersal fish, as did landings of shellfish ($r = 0.834$, $N = 30$, $P < 0.01$); all three groups declined over the study period. Demersal fish landings declined from 1985 to 2014 following the equation: Landings = 493 003− 244.59 × year. This linear decline explains 62.2% of the variation in amount landed ($r = 0.789$, $N = 30$, $P < 0.01$).

Relationships between breeding gull numbers and fish landings

Figures 5–7 show a close correlation between annual breeding gull numbers on Canna and annual landings of demersal fish at Mallaig. After detrending, Herring Gull breeding numbers showed a statistically significant positive correlation with detrended demersal fish landings between 1985 and 2014 ($r = 0.556$, $N = 30$, $P < 0.01$).

Discussion

Gull populations on Canna increased throughout the 20th century. Herring Gulls increased from 100 pairs in 1936, to over 300 pairs in 1963 to reach a peak of 1525 pairs in 1988. Great Black-backed Gulls increased from 10 pairs in the 1930s to about 80–90 pairs in the 1990s, whilst Lesser Black-backed Gulls increased from a few pairs in 1933, to 12 pairs in 1963 to a peak of over 60 pairs in the mid-1970s (Evans & Flower 1967, Swann 2000).

An examination of Herring Gull diet on Canna in the late 1980s and early 1990s showed the importance of discards from the local fishing fleet to breeding gulls. During this time, when demersal fish appeared to be the main item in the diet of breeding gulls at Canna, both breeding numbers and breeding success were high.

The sudden decline in landings in Mallaig, and therefore fishing activity in the Sea of the Hebrides, evident since 2000, coincided with a major decline in gull numbers breeding on Canna. It also coincided with a period of reduced breeding success on the island. Since 2006, fish landings at Mallaig have remained at low but relatively stable levels. Likewise on

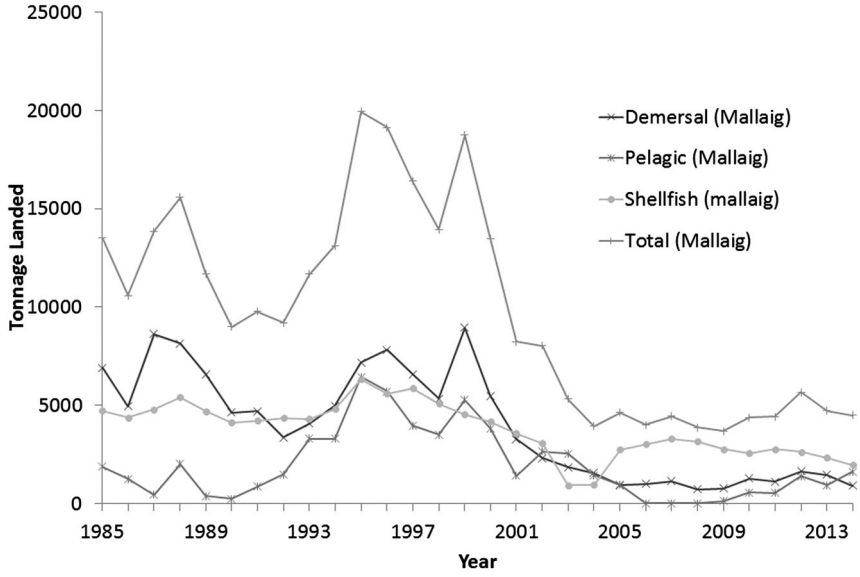

Figure 4. Landings of fish (demersal, pelagic and shellfish) at Mallaig 1985–2014. Source: Scottish Government Statistics.

Canna, gull numbers have stabilized at what appears to be a new low level, which is closer to what was recorded in the 1930s. Diet studies suggest birds are still exploiting food associated with fishing activity, but this is now present at a much reduced level and its availability is likely to impact on breeding success.

The statistically significant correlation between detrended herring gull breeding numbers and detrended demersal fish landings shows that these variables are still closely linked after taking account of their long-term declines between 1985 and 2014. This provides strong evidence for a causal link between fishery catch and gull breeding numbers, an inference that is supported by the observed importance of discarded demersal fish in gull diet at Canna during the breeding season and by research elsewhere showing the importance of discards from fishing vessels for large gulls (Tasker *et al.* 2000, Oro *et al.* 2004, Camphuysen 2013). Extending the evidence base for seabirds and the possible effects of changing fishery discard levels is vital for understanding and aiding their conservation. Changes to discard quantities have been shown to affect seabird populations (Garthe *et al.* 1996, Votier *et al.* 2004, Patrick *et al.* 2015). Francesc *et al.* (2015) state that the new obligation to land discards in European Seas may have unpredictable and

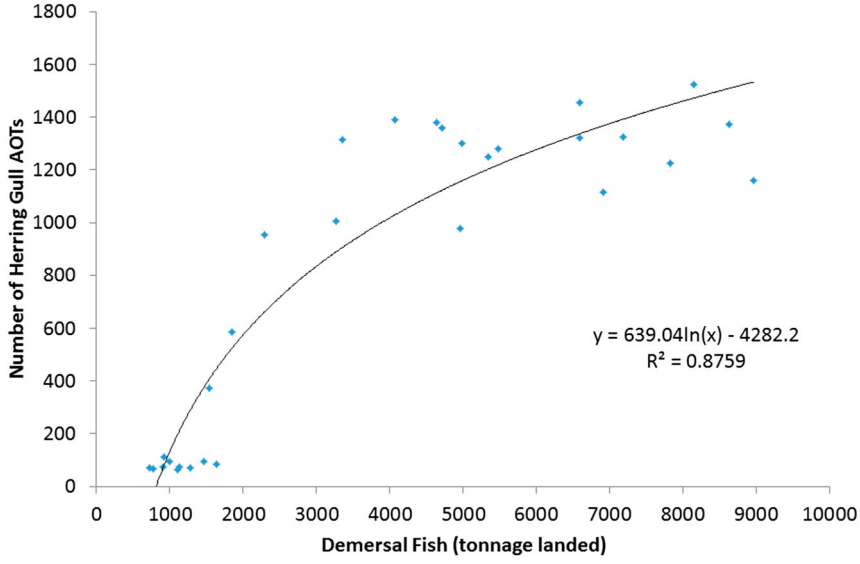

Figure 5. Herring Gull breeding numbers (AOTs) in relation to demersal fish landings (tonnes) at Mallaig in the same year; data for 1985–2014.

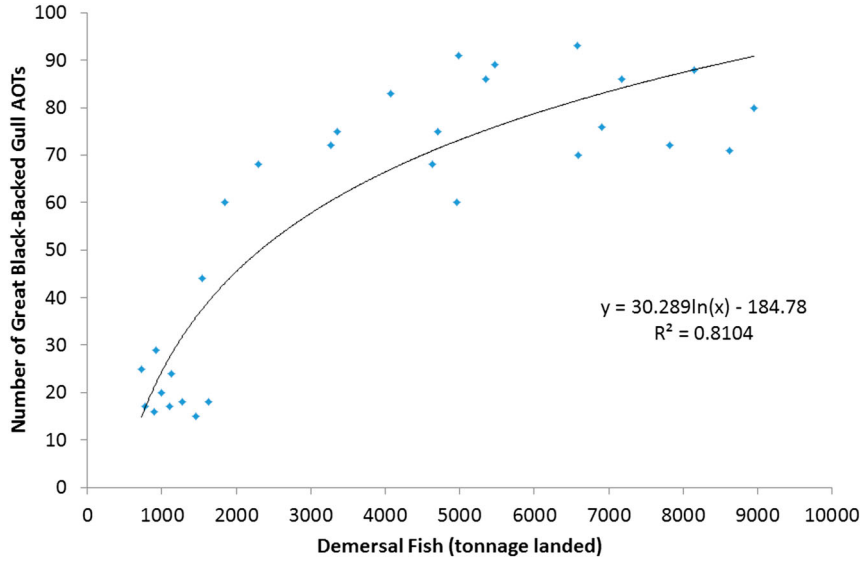

Figure 6. Great Black-backed Gull breeding numbers (AOTs) in relation to demersal fish landings (tonnes) at Mallaig in the same year; data for 1985–2014.

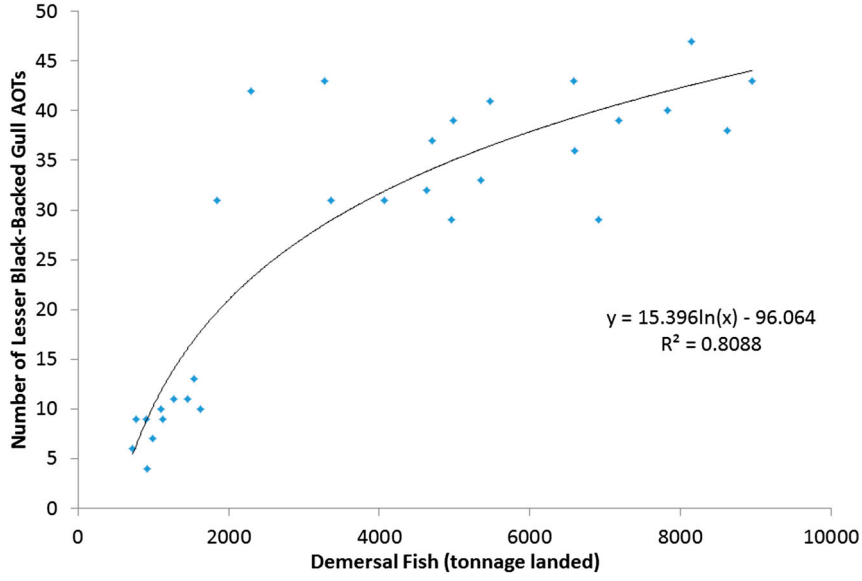

Figure 7. Lesser Black-backed Gull breeding numbers (AOTs) in relation to demersal fish landings (tonnes) at Mallaig in the same year; data for 1985–2014.

unwanted ecological, socioeconomic and operational impacts, and may contribute to the impoverishment of marine ecosystems.

The decline in Herring Gull populations witnessed on Canna between 2000 and 2006 is far more dramatic than that noted in Scotland as a whole during the same time period. The number of breeding Herring Gulls at coastal colonies in Scotland declined by 55% from 1969–1970 to 1998–2002 (Mitchell *et al.* 2004), though this was mainly driven by major declines in North Sea colonies. Suggested reasons behind this decline have included culling, botulism, improved management of waste tips and changes in fisheries (Forrester *et al.* 2007). Great Black-backed Gull numbers remained fairly stable in Scotland from 1969–1970 to 1998–2002 (Mitchell *et al.* 2004), though have since shown major declines, as witnessed on Canna. Lesser Black-backed Gulls showed a 79% increase in Scotland from 1969–1970 to 1998–2002, though this was mainly due to large increases in colonies in southern Scotland, with colonies in north Scotland either declining or showing no change (Mitchell *et al.* 2004).

It is likely that the high level of fishing activity in the Sea of the Hebrides up to 2000 resulted in an abundant

food supply for gulls via the high levels of discards from the demersal and shellfish fisheries. This allowed gull numbers to remain locally high, whilst they were declining in other areas of Scotland. The sudden contraction of these local fisheries apparently resulted in a dramatic decline in gull numbers at Canna.

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