Long-term changes in numbers and distribution of wintering ducks and swans in the Moray Firth, Scotland, 1985–2002

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Abstract

Counts of ducks and swans in the Moray Firth between 1985 and 2002 were analysed to assess changes in their numbers and distributions. The average count for all ducks combined exceeded 20,000 in all winters. Wigeon *Anas penelope* was the most abundant species, followed by Mallard *A. platyrhynchos* and Teal *A. crecca*. The majority of species peaked in December and January, except Wigeon, which peaked in October. The average winter numbers of Mallard, Wigeon, Tufted Duck *Aythya fuligula*, Shelduck *Tadorna tadorna* and Whooper Swan *Cygnus cygnus* decreased significantly over the 17-year period, whilst those of Teal increased. Decline in numbers was greatest for Whooper Swan and Tufted Duck. For some of the species, trends in abundance reflected the general pattern observed throughout Britain. Adjacent inland lochs supported up to 11% of the overall number of wildfowl in the Moray Firth basin, with Loch Eye having the largest number. The Moray Firth as a whole supported internationally important numbers of Wigeon, Teal, Pintail *A. acuta* and Whooper Swan. Numbers of Mallard and Mute Swan *C. olor* were of national importance.

Key words: survey, estuary, Mallard, Wigeon, Tufted Duck, Teal, Shelduck, Pintail, swans.

The Moray Firth, comprising several estuaries (Loch Fleet, Dornoch Firth, Cromarty Firth, Beauly Firth, Inverness Firth and Findhorn Bay) and associated coastline, is one of the most important sites in Britain for migrating and wintering wildfowl. The area holds internationally important numbers of wildfowl in winter, regularly supporting more than 20,000 waders and 10,000 wildfowl in midwinter and up to 45,000 ducks in autumn (Symonds & Langslow 1986; Kalejta-Summers 2006). The autumn concentration of dabbling ducks is one of the largest in Britain (Symonds & Langslow 1986; Pollitt *et al.* 2003).

Counts of waders and wildfowl have been conducted at high tide in the Moray Firth since the early 1960s. However, the counts were initially irregular and rarely covered all the main areas. Annual and complete surveys of the main estuaries in the Moray Firth started only in 1985. These counts were coordinated mainly by staff from the Royal Society for the Protection of Birds (RSPB) and have continued to the present date. The counts are part of the Wetland Bird Survey (WeBS), a scheme run by the British Trust for Ornithology, Wildfowl & Wetlands Trust, RSPB and Joint Nature Conservation Committee/Scottish Natural Heritage in Scotland, which coordinates waterbird counts across the UK.

Several papers have been published on the numbers and distribution of waders and seaducks in the Moray Firth (Mudge & Allen 1980; Symonds & Langslow 1986; Swann & Mudge 1989; Evans 1998; Kalejta-Summers 2006; Kalejta-Summers & Butterfield 2006). However, no attempt has been made to analyse the available data for other ducks. The aim of this paper is to describe the numbers and seasonal distribution of dabbling ducks, Tufted Duck *Aythya fuligula* and swans in the Moray Firth between October 1985 and February 2002. In addition, the national and international importance of the area is discussed in the light of conservation priorities.

Study Area and Methods

The study area covered the estuaries (firths) and adjoining beaches between Brora in the north (58°01'N, 3°50'W) and Burghead in the east (57°42'N, 3°30'W). The coastal study area was divided into six sections, mainly along natural boundaries: Loch Fleet and coast (coast between Brora and Dornoch), Dornoch Firth, Cromarty Firth, Beauly Firth, Inverness Firth and Moray East (Fig. 1). Six adjacent inland lochs were also included: Abban Water, Loch Dochfour, Loch Eye, Loch Flemington, Loch Ussie and Bayfield Loch. Counts have been carried out at all the lochs, with the exception of Bayfield Loch, since 1991. Counts at Bayfield Loch did not commence until 1994. Although inland lochs are not part of the Moray Firth, birds move regularly between them and the coastal areas and they were therefore included in the analysis to provide a more accurate estimate of the numbers of birds utilising the area.

About 45 counters made synchronised counts at high tide on selected dates in October, December, January and February each year between 1985 and 2002. The majority of the sections were divided into sub-sections, and each counter surveyed one or more sub-sections. The counts for sub-sections were summed to provide a total count for the section. When estimating average winter numbers, counts for December, January and February were used.

In order to test for trends in winter, Spearman correlation coefficients were derived for the average winter numbers in the whole of the Moray Firth. To identify the trends in specific areas, the correlation coefficients were derived from the average winter numbers for each section. Finally, averages for the first and the last five years of the study were calculated to compare the earlier counts with the more recent data.

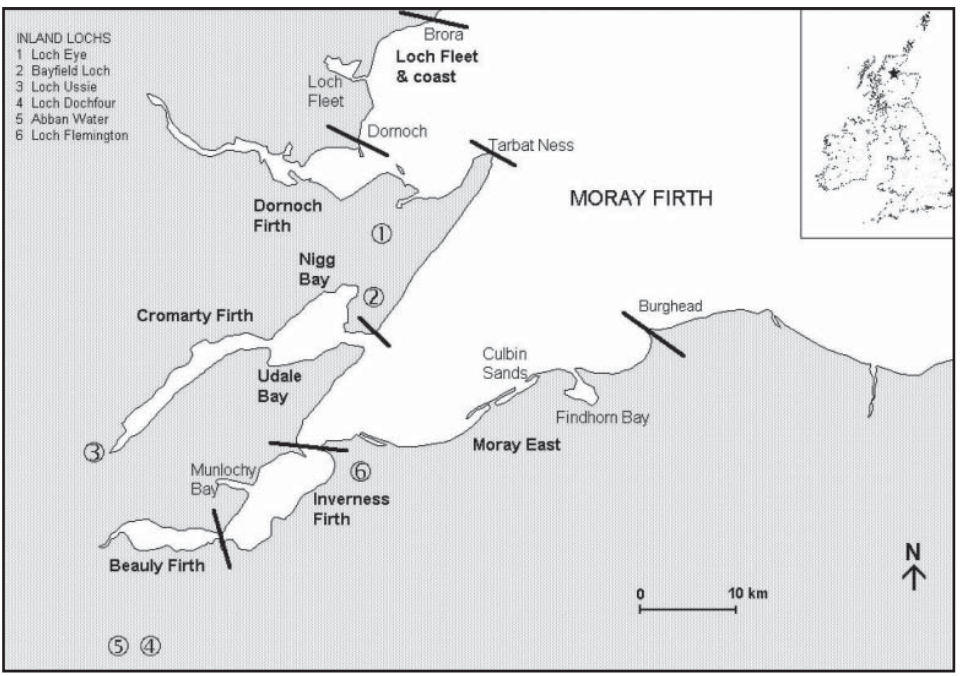

Figure 1. Map of the study site, showing the six different areas monitored within the Moray Firth. Divisions between the areas are marked with thick lines.

To establish the national and international importance of a particular species, the highest single count for each winter in the most recent five years (1997/98–2001/02) was averaged to give the average maximum count. A site was considered to be of international importance for a particular species if it regularly supported at least 1% of the western European population (Wetlands International 2002) or if it regularly supported at least 20,000 waterbirds. Similarly, a site was considered to be of national importance if it regularly supported 1% of the British population (Kershaw & Cranswick 2003).

Results

Coastal area

Annual and seasonal variations in abundance

Ten species of dabbling ducks were recorded in the Moray Firth between October 1985 and February 2002. Black Duck *Anas rubripes*, American Wigeon *A. americana* and Green-winged Teal *A. crecca carolinensis* were vagrants and were excluded from the analysis. The numbers of Gadwall *A. strepera* and Shoveler *A. clypeata* contributed less than 1% to the total number of ducks and therefore were also excluded from this analysis.

The winter average for all dabbling ducks in the whole Moray Firth varied between 21,156 (in 2001/02) and 29,430 (in 1996/97) (Table 1). The highest count of all ducks, however, was recorded in October 1991 when their numbers reached almost 48,000. Wigeon *A. penelope* was the most abundant species, contributing over 60% to the total number of ducks; the highest average winter count was just over 19,000 in 1985/86 and 1996/97 (Table 1). Mallard *A. platyrhynchos* and Teal *A. crecca* were the next most numerous species, with the highest average winter counts of 5,532 (1987/88) and 5,028 (1996/97), respectively (Table 1). The least numerous were Pintail *A. acuta*, with the highest average winter count of 513 in 1990/91.

Statistical analysis of the average winter numbers between 1985/86 and 2001/02 revealed significant trends for several species. Mallard, Wigeon, Tufted Duck, Shelduck *Tadorna tadorna* and Whooper Swan *Cygnus cygnus* declined significantly in number (Table 1). The most pronounced declines were observed for Whooper Swan and Tufted Duck, whose numbers decreased by 68% and 50%, respectively, when their averages for the first and last 5-year periods of the study (1985/86–1989/90 and 1997/98–2001/02) were compared. Mallard declined in number by 22% and Shelduck and Wigeon both declined by 15%. Teal was the only species that increased significantly over the 17-year period, by 35%. Pintail and Mute Swan *C. olor* showed no trends.

The majority of species showed similar seasonal fluctuations in abundance, with peaks in December and January (Fig. 2). Wigeon was the only species that peaked in October in all years, with highest peaks of over 39,000 in October 1991 and 2000. Shelduck, by contrast, was the only species that arrived later in winter and reached its peak in abundance in February. Mute Swans maintained relatively stable numbers throughout the winter whereas Whooper Swans showed considerable change in seasonal abundance over the years. In the late 1980s, they arrived in large numbers (over 600) in October, and numbers remained at this level until December. Since the early 1990s, when their numbers dropped (Table 1), the seasonal pattern has been less pronounced.

Spatial distribution

The distribution of wildfowl varied amongst the species and showed marked annual and seasonal variations (Fig. 3). Generally, the Dornoch and/or Cromarty Firths supported the highest numbers of ducks, with the exception of Teal and Tufted Duck. Teal occurred in highest numbers in the Inverness Firth whereas Tufted Duck reached peak numbers in the Beauly Firth. This pattern, however, was not consistent and has changed recently (see below). The most pronounced changes were the declines in average winter numbers of Wigeon, Mallard, Tufted Duck, Pintail and Whooper Swan in the Cromarty Firth (Table 2). For all species except Tufted Duck, the decline in numbers in the Cromarty Firth since 1997/98 has coincided with an increase in the Dornoch Firth (Fig. 3).

In addition to the decline in the Cromarty Firth, there was a significant decrease in the average numbers of Mallard at Loch Fleet

Winter	Wigeon	Mallard	Teal	Tufted Duck	Shelduck	Pintail	All Ducks	Mute Swan	Whooper Swan
1985/86	19,095 (4,087)	4,642 (446)	2,190 (898)	798 (468)	1,084 (143)	353 (19)	28,162 (4,331)	309 (26)	225 (173)
1986/87	16,534 (6,084)	4,512 (248)	2,892 (511)	763 (474)	1,038 (338)	325 (49)	26,064 (5,677)	239 (34)	274 (358)
1987/88	15,661 (5,190)	5,532 (475)	2,524 (223)	757 (302)	999 (197)	156 (43)	25,630 (4,973)	267 (58)	207 (81)
1988/89	12,815 (4,754)	4,179 (1,185)	2,875 (957)	313 (26)	931 (299)	216 (51)	21,329 (6,117)	239 (27)	215 (187)
1989/90	18,405 (10,080)	4,412 (806)	3,336 (1,174)	555 (336)	1,181 (297)	202 (36)	28,091 (11,963)	236 (56)	66 (55)
1990/91	15,537 (5,355)	4,988 (429)	4,582 (1,429)	838 (192)	1,086 (261)	513 (187)	27,546 (6,619)	235 (64)	80 (29)
1991/92	15,327 (7,441)	4,419 (998)	3,564 (910)	456 (197)	1,028 (267)	194 (82)	25,000 (9,327)	237 (54)	101 (36)
1992/93	17,808 (9,851)	3,564 (946)	3,100 (1,251)	525 (364)	937 (320)	193 (110)	26,133 (11,624)	285 (26)	33 (35)
1993/94	14,803 (7,373)	4,138 (1,051)	3,087 (1,494)	671 (402)	950 (137)	362 (92)	24,016 (9,951)	287 (17)	50 (62)
1994/95	15,711 (9,134)	3,546 (1,314)	3,641 (1,679)	451 (243)	984 (145)	352 (263)	24,784 (11,940)	255 (18)	93 (92)
1995/96	15,910 (9,041)	3,289 (896)	3,808 (1,107)	605 (31)	951 (155)	494 (278)	25,061 (10,049)	253 (41)	32 (26)
1996/97	19,010 (6,484)	3,553 (446)	5,028 (288)	698 (182)	817 (169)	314 (164)	29,430 (6,477)	289 (41)	69 (56)
1997/98	15,462 (7,822)	3,395 (767)	4,665 (1,603)	387 (43)	997 (189)	396 (120)	25,312 (10,070)	252 (43)	17 (11)
1998/99	15,176 (9,072)	3,822 (1,755)	4,081 (1,941)	249 (206)	868 (37)	388 (124)	24,591 (12,762)	318 (15)	67 (41)
1999/00	11,998 (5,260)	3,625 (1,153)	4,379 (2,078)	366 (153)	789 (226)	302 (164)	21,462 (8,296)	322 (21)	55 (39)
2000/01	14,613 (5,566)	3,994 (811)	4,737 (1,175)	349 (99)	822 (200)	360 (118)	24,887 (4,007)	300 (44)	32 (4)
2001/02	12,671 (4,216)	3,273 (1,197)	3,536 (1,981)	260 (75)	964 (78)	435 (91)	21,156 (7,095)	198 (52)	150 (112)
Spearman correlation coefficient	-0.544	-0.772	0.735	-0.667	-0.657	0.427		0.235	-0.600
P	<0.05	<0.001	<0.002	<0.005	<0.01	n.s.		n.s.	<0.02

Table 1. Averages of the monthly counts recorded for different species of wildfowl on the Moray Firth in winter (December–February) from 1985/86 to 2001/02. Standard deviations are given in brackets.

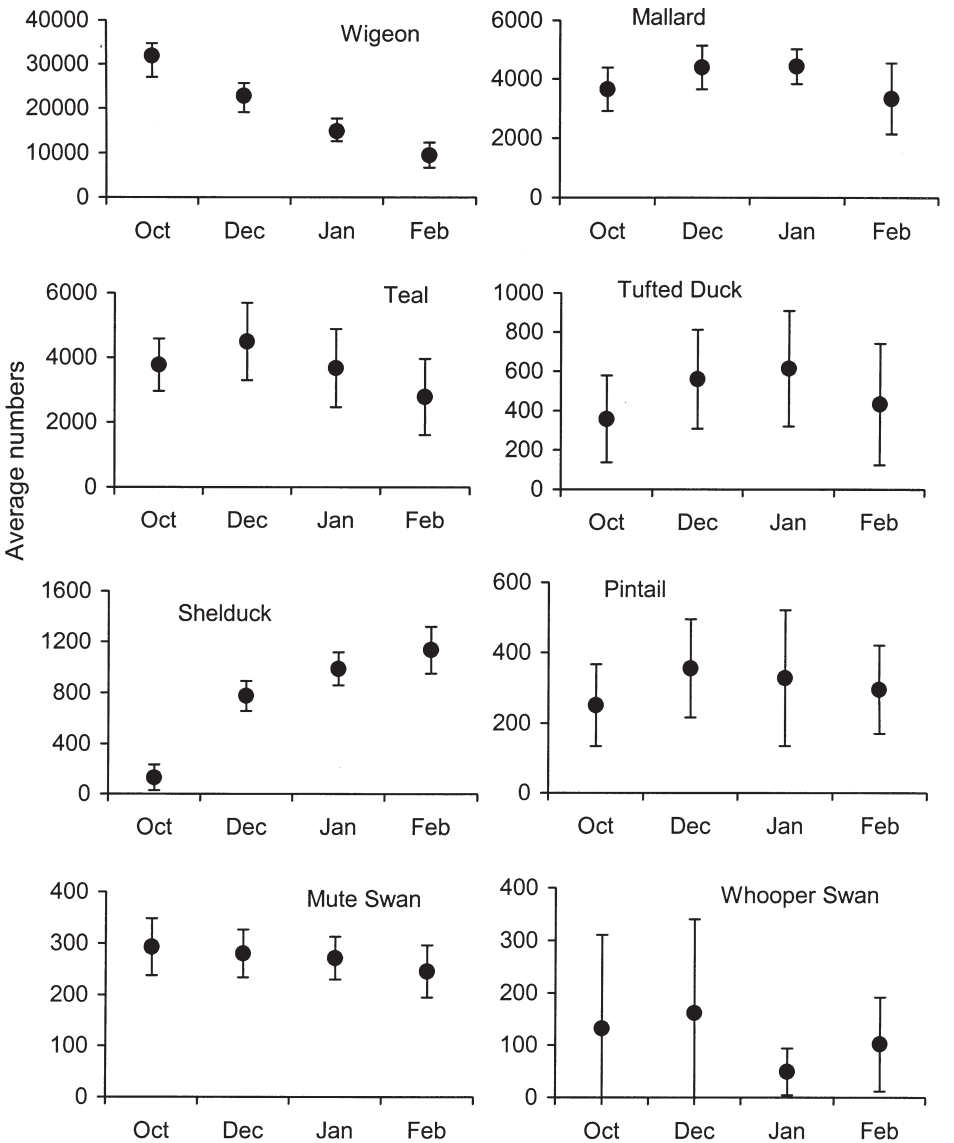

Figure 2. Average number (± s.d.) of selected species of wildfowl in October, December, January and February in the Moray Firth between 1985/86 and 2001/02.

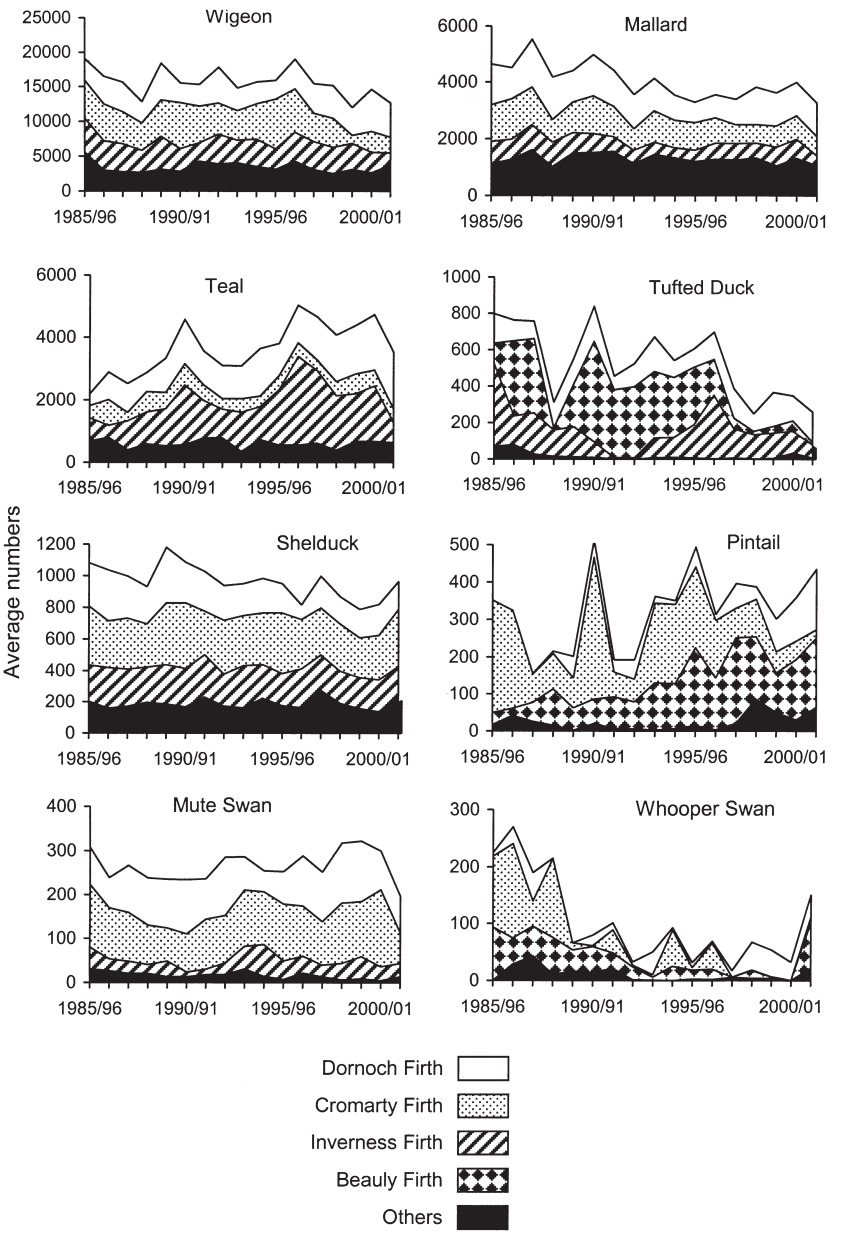

Figure 3. Average winter counts (December–February) for selected species of wildfowl in different sections of the Moray Firth between 1985/86 and 2001/02. Only the four most important sites are given for each species. The remaining sites are grouped as 'Others'.

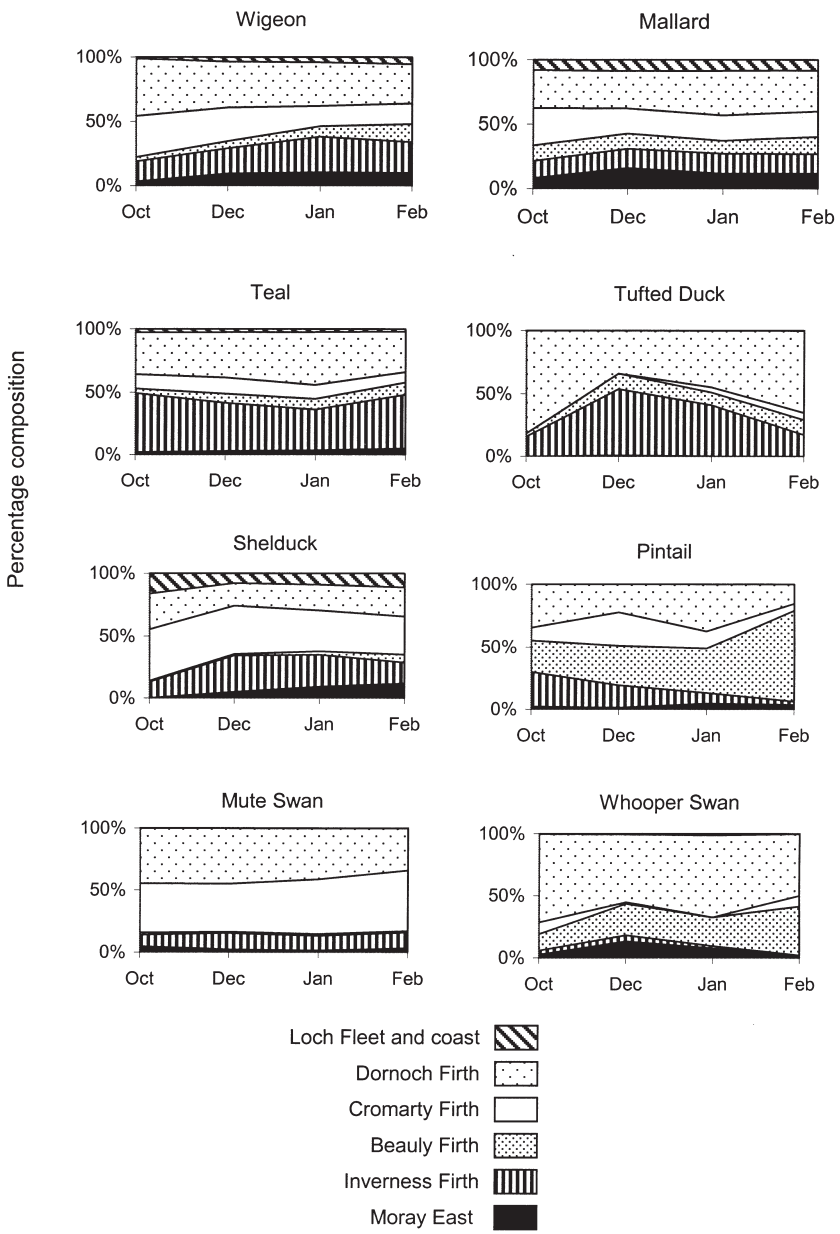

Figure 4. Distribution of different species of ducks and swans across the Moray Firth in October, December, January and February between 1991/92 and 2001/02.

and the adjacent coast, and also at Inverness Firth, whereas in Moray East Mallard numbers showed a gradual increase (Table 2). Numbers of Whooper Swan and Tufted Duck declined not only in the Cromarty Firth but also in the Beauly Firth. The numbers of the latter species varied considerably in the Beauly Firth in the late 1980s, but declined following a peak of 550 in 1990/91 (Table 2, Fig. 3).

A significant long-term increase in numbers at certain sites was evident only for Pintail and Teal. Average numbers of Pintail increased significantly in the Dornoch Firth, Beauly Firth and Moray East whereas those of Teal increased in the Dornoch Firth, Inverness Firth and Moray East (Table 2, Fig. 3).

There were also marked monthly variations in the abundance of birds amongst the sites (based on the 5-year averages) (Fig. 4). The Dornoch Firth was the most important site for most ducks at the beginning of the season. However, the use of this site changed for some species as the winter progressed. For instance, the site became less important for Tufted Duck in December when higher proportions of birds were found in the Inverness Firth. By the end of the winter, however, the Dornoch Firth again held more birds. Pintail occupied the Dornoch, Cromarty, Beauly and Inverness Firths in similar proportions in October. However, after some fluctuations in abundance at those sites in December and January, proportionally more birds occurred in the Beauly Firth in February. For Wigeon and Shelduck, on the other hand, the relative importance of certain sites decreased as winter progressed, with birds showing a much wider distribution throughout the Moray Firth at the end of the winter than at the beginning. Mallard, Teal and Mute Swan showed the least variation in distribution between months and remained faithful to their sites throughout the winter (Fig. 4).

	Loch Fleet and coast	Dornoch Firth	Cromarty Firth	Beauly Firth	Inverness Firth	Moray East
Wigeon	-0.485*		-0.537*	0.534*	-0.507*	
Mallard	-0.784***		-0.762***		-0.598*	0.694**
Teal	-0.646**	0.841***			0.485*	0.733**
Tufted Duck			-0.569*	-0.542*		
Pintail		0.755***	-0.538*	0.855***		0.801***
Shelduck		-0.887***			-0.645**	
Mute Swan	-0.806***					-0.596*
Whooper Swan			-0.683**	-0.652**		

Table 2. Spearman correlation coefficients (r_s) and level of significance (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$) for changes in wildfowl numbers between 1985/86 and 2001/02 at different areas within the Moray Firth. Level of significance is given only for those species that showed significant trends in average winter numbers over the 17-year period (see Fig. 3).

Winter	Wigeon	Mallard	Teal	Tufted Duck	Pintail	All ducks	Mute Swan	Whooper Swan
1991/92	1,786 (1,005)	434 (253)	34 (36)	361 (177)	14 (24)	2,629 (1,126)	101 (34)	7 (5)
1992/93	1,352 (1,053)	294 (135)	183 (305)	209 (134)	13 (22)	2,050 (1,512)	11 (6)	1 (1)
1993/94	344 (568)	241 (203)	131 (193)	110 (131)	0	826 (1,037)	9 (8)	0
1994/95	1,447 (532)	356 (81)	170 (54)	118 (6)	32 (53)	2,124 (611)	26 (18)	33 (58)
1995/96	1,068 (406)	454 (83)	44 (13)	194 (80)	10 (14)	1,770 (336)	45 (14)	65 (22)
1996/97	322 (336)	369 (32)	325 (67)	132 (141)	147 (254)	1,295 (655)	25 (19)	<1 (1)
1997/98	497 (412)	278 (33)	791 (671)	203 (58)	99 (167)	1,868 (974)	29 (5)	16 (8)
1998/99	359 (263)	211 (76)	403 (338)	189 (115)	134 (125)	1,296 (649)	16 (6)	1 (1)
1999/00	980 (750)	250 (27)	447 (329)	203 (87)	139 (70)	2,019 (1,152)	22 (7)	1 (1)
2000/01	278 (146)	278 (199)	492 (437)	80 (105)	18 (29)	1,145 (877)	14 (10)	3 (2)
2001/02	1,384 (451)	322 (45)	446 (254)	105 (47)	154 (113)	2,412 (383)	88 (45)	26 (40)

Table 3. Average numbers of different species of wildfowl in winter (December–February) between 1991/92–2001/02 at six inland lochs in the Moray Firth basin. Counts for Bayfield Loch cover the period between 1994/95 and 2001/02 (see Methods for explanation). Standard deviations are given in brackets.

Lochs

The lochs supported up to 11% of the whole average winter population of ducks in the Moray Firth Basin. The winter average for all ducks combined varied between 826 (in 1993/94) and 2,412 (in 2001/02) (Table 3). The pattern in the abundance of wildfowl in the lochs reflected that observed in the coastal habitats, with Wigeon being the most abundant species. The number of Wigeon in all the lochs combined varied between 278 in 2000/01 and 1,786 in 1991/92 (Table 3). Shelduck, on the other hand, were absent from the lochs.

Analysis of the average numbers for all of the lochs combined (Bayfield Loch having been excluded from the analysis, because counts did not commence there until 1994/95) did not reveal significant trends for any of the species except Teal. The number of Teal increased significantly over the 11-year period from 1991/92 to 2001/02 ($r_s = 0.82$, d.f. = 9, $P < 0.005$; Table 3)

Loch Eye supported the largest number of birds, with an average peak winter count of over 1,300 in 2001/02 and the peak count exceeded 2,400 in October 1991 (Table 4). Wigeon, Mallard and Teal were the most abundant species at Loch Eye (Fig. 5). Teal was the only species that showed a significantly increase over the 11-year period from 1991/92 to 2001/02 ($r_s = 0.84$, d.f. = 9, $P < 0.005$) at Loch Eye. Average winter numbers of Mallard decreased significantly at Loch Dochfour ($r_s = -0.83$, d.f. = 9, $P < 0.005$) during the 11-year period. However, at the same time, their numbers increased at Loch Flemington ($r_s = 0.86$, d.f. = 9, $P < 0.002$). A significant decline in numbers of Tufted Duck was recorded at Loch Dochfour ($r_s = -0.71$, d.f. = 9, $P < 0.02$).

There was no consistent pattern in seasonal abundance of birds at the lochs (Table 4). Numbers generally peaked in February at Loch Ussie and Eye, in December and January at Loch Dochfour and remained rather stable throughout the winter at Bayfield Loch and Abban Water.

National and international importance of wildfowl

The highest average peak numbers of six species exceeded 1% of their national totals during in the most recent 5-year period (1977–2002) in the Moray Firth as a whole (Table 5). In addition, the Moray Firth supported internationally important numbers of four species: Wigeon, Teal, Pintail and Whooper Swan. Furthermore, the Moray Firth as a whole regularly supported over 20,000 dabbling ducks every year, with over 30,000 birds recorded on 59% of surveys. When individual sites were considered, the Dornoch Firth supported nationally important numbers of Wigeon, Teal and Whooper Swan and internationally important numbers of Wigeon. The Cromarty Firth supported almost 3% of the national total of Wigeon whereas the Inverness Firth was nationally important for Wigeon and Teal.

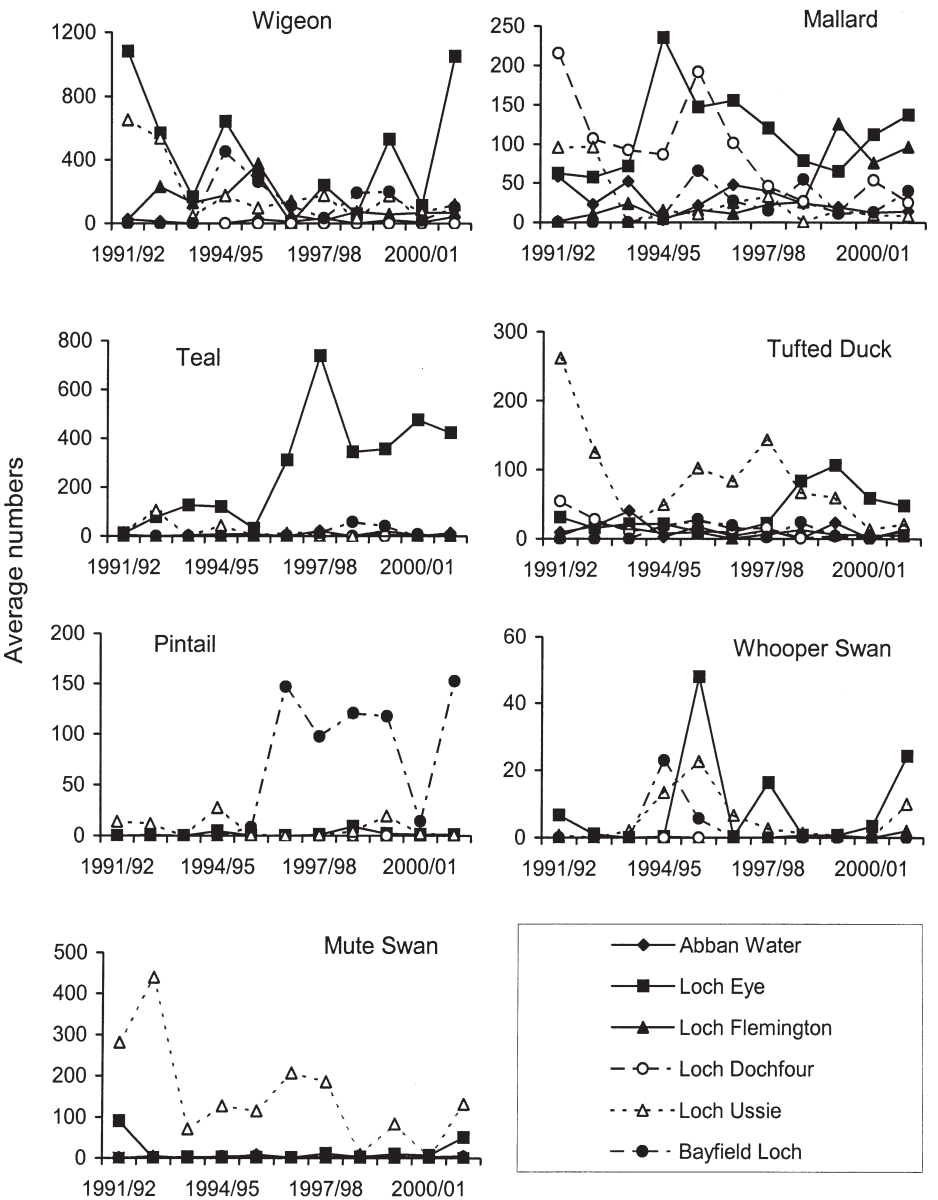

Figure 5. Average winter numbers (December–February) of ducks and swans counted on different inland lochs in the Moray Firth basin between 1991/92 and 2001/02.

Table 4. Averages, minimum and maximum numbers of all ducks in October, December, January and February between 1991/92 and 2001/02 for the inland lochs. Data for Bayfield Loch cover the period between 1994/95 and 2001/02. Standard deviations are given in brackets.

	October	December	January	February
Abban Water	75 (62) 0–188	57 (38) 0–110	50 (56) 0–158	87 (74) 0–281
Loch Dochfour	96 (86) 0–261	138 (144) 0–430	116 (115) 0–308	62 (59) 2-164
Loch Eye	872 (821) 140–2,406	484 (479) 0–1,427	722 (644) 0–1,859	1,378 (614) 356–2,238
Loch Flemington	46 (67) 6–222	115 (117) 10–383	168 (148) 0–454	214 (172) 2–554
Loch Ussie	258 (337) 12–1,249	224 (191) 0–513	378 (547) 0–1,830	430 (379) 0–1,313
Bayfield Loch	232 (288) 20–806	245 (206) 0–568	298 (263) 0–645	314 (351) 0–788

Table 5. Average maximum numbers of wildfowl in different sections of the Moray Firth between 1997/98 and 2001/02. ****** indicates sections of international importance, and ***** indicates sections of national importance for each species.

	Wigeon	Mallard	Teal	Tufted Duck	Pintail	Shelduck	Mute Swan	Whooper Swan
Loch Fleet and coast	747	398	182	<1	<1	112	<1	<1
Dornoch Firth	**15,048	1,454	*2,272	259	146	238	145	*121
Cromarty Firth	*11,086	1,088	817	19	143	355	149	14
Beauly Firth	1,374	519	590	75	256	63	6	42
Inverness Firth	*5,448	692	*2,361	210	95	243	45	8
Moray East	2,088	770	285	4	23	119	17	15
The whole Moray Firth	**35,791	*4,921	**6,506	567	**663	*1,131	*362	**200

Discussion

Numbers and distribution

Ducks found in the Moray Firth originate mainly from Iceland, Fenno-Scandia and Russia (Prater 1981; Lack 1986). After arrival in the Moray Firth, some ducks stay throughout winter, whereas others move south to other wintering localities in Britain. Therefore a peak in abundance, at least for some species, occurs earlier in the Moray Firth than in other parts of Britain (Pollitt *et al.* 2003). The October peak in the overall numbers of ducks reflects the early influx of Wigeon, the most abundant species. After October, many Wigeon disperse, mostly south and southwest to England and Ireland, where many overwinter. Here, they reach peak numbers in December and January (Owen & Williams 1976; Lack 1986). Ringing recoveries also indicate that some Wigeon migrate from the Moray Firth to the west coast of France (Wernham *et al.* 2002). Similarly, the number of Teal in the Moray Firth peaks in December (Fig. 2), which is earlier than in other parts of Britain. Nationally, peak counts for Teal occur in January (Pollitt *et al.* 2003).

Across the Moray Firth five species of wildfowl (Mallard, Wigeon, Tufted Duck, Shelduck and Whooper Swan) have shown a significant decline in numbers since 1985 (Table 1). The site most affected was the Cromarty Firth, where four species declined..

In the past, the variations in numbers of several wildfowl species in the Moray Firth were closely linked to changes in food supply associated with human activity. In the 1960s, for instance, the newly opened Dalmore Distillery in the Cromarty Firth discharged large quantities of waste barley seeds into the firth, and this attracted large flocks of Wigeon, Whooper Swan and Mute Swan (Owen *et al.* 1986). When improvements were made to the disposal system, the amount of potential food decreased and duck numbers declined. Although, at present, there are five distilleries on the coast of the Moray Firth (Balblair and Glenmorangie Distilleries in the Dornoch Firth, and Dalmore, Invergordon and Teaninich Distilleries in the Cromarty Firth) the discharges are entirely liquidised with almost no suspended matter, a procedure that has not changed since the 1980s (Scottish Environment Protection Agency (SEPA), pers. comm.). The most recent change was made by Glenmorangie and Dalmore Distilleries in 1990, when they increased their capacities and relocated their discharges to deeper waters away from the shore (SEPA, pers. comm.).

Similarly, sewage discharges once attracted large flocks of ducks. Flocks of up to 350 Tufted Duck used to feed regularly at the Carn Arc outfall in Inverness (Barrett & Barrett 1985). When it closed in 1982, the birds disappeared from the area. The Longman outfall in the Beauly Firth also supported small flocks of Tufted Duck in the early 1990s. The sharp drop in their abundance in the Beauly Firth in 1996 cannot be explained by changes in the sewage outfall, however, because no such alterations took place at the time (SEPA, pers. comm.).

It is unlikely that the current discharges from sewage outfalls and distilleries attract

ducks to the Moray Firth, except where this occurs indirectly by enhancing intertidal and sublittoral plants and invertebrates. The bulk of the suspended solids and nitrate loading in the firths now emanates from rivers where, despite considerable fluctuations in individual rivers, the overall totals for suspended solids and nitrate loading have changed little since the mid 1980s (SEPA, pers. comm.). Preliminary results from monitoring the phosphate loads show an increase since the 1980s in almost all the rivers assessed. This is probably due to changes in land and water management, including forestry, agriculture and freshwater fish farming (SEPA, pers. comm.). If such an increase is confirmed, this could account for an increase in the biomass of algae and other vegetation, which provide food for several species of wildfowl. In order to improve understanding of the fluctuations in numbers of wildfowl in the Moray Firth, a better understanding of the food resources is necessary.

National trends and numbers

For some species, the trends in numbers observed in the Moray Firth reflect a general pattern in their abundance in the whole of Britain. Numbers of Mallard, for instance, have been falling in Britain in the last 13 years (Pollitt *et al.* 2003). The reason for this national trend is largely unknown. It is possible, however, that the decline in Mallard numbers observed since 1985 in the Moray Firth is not as severe as it appears, because the Mallard is a widespread species and occurs on many small inland wetlands that are not included in the WeBS surveys.

Similarly, the decrease in numbers of Shelduck in the Moray Firth reflects the decline at several other important localities in Britain. Shelduck numbers have declined at the Wash, eastern England, where the peak count in winter 2000/01 was amongst the lowest at this site in the last 30 years. At Poole Harbour, southern England, a site of national importance, there has been a decline of over 60% in the last five years (Pollitt *et al.* 2003).

By contrast, the long-term decline in Whooper Swans in the Moray Firth differs from the national trend. The annual index for Whooper Swans in Britain has increased in the last 35 years (Pollitt *et al.* 2003). The results presented in this paper, however, must be treated with caution, because it is uncertain whether the Whooper Swan is actually declining in the Moray Firth, or whether it is making more use of areas that are not included in the surveys, such as nearby fields and freshwater pools (see below).

The decrease in the numbers of Tufted Duck in the Moray Firth is of particular concern, because the long-term trend in numbers in Britain is stable (Pollitt *et al.* 2003). It has been noted recently that Tufted Ducks congregate at high tide on the Inverness canal and other inland waters that are not included in the WeBS surveys (D. Butterfield, pers. comm.). If there are similar sites elsewhere not being monitored by WeBS, the Tufted Duck decline in the Moray Firth might not be as severe as it appears.

The decline in numbers of Wigeon in the Moray Firth contrasts with the pattern observed for the whole of Britain. Despite

their decline in the Moray Firth in the last 17 years, their numbers exceeded those recorded prior to 1985/86. For instance, the size of the autumn peak in the Cromarty Firth varied between 3,000 and 12,000 during the period 1966–1970 (Owen *et al.* 1986), compared with 6,000 to 15,000 during the current study.

Numbers of Teal in the Moray Firth, as in the whole of Britain, have increased since 1985 (Pollitt *et al.* 2003). By contrast, numbers of Pintail showed no trends in the Moray Firth, but their annual index for Britain has fallen since the early 1970s (Pollitt *et al.* 2003).

The use of inland lochs

The majority of wildfowl in the Moray Firth basin occur mainly on the coast. However, it is unknown whether this is due to a shortage of suitable areas inland or their preference for estuarine habitats or food.

In the 1970s, some redistribution in Wigeon was observed in Britain, including colonisation of new inland sites. Inland pastures became the most important habitat and, although 80% of Wigeon roosted on the coast, only 54% of their feeding was done there_(Owen & Williams 1976). A similar shift in habitat use by wintering Wigeon was observed in the Netherlands, where Wigeon were found close to the sea at the beginning of winter but moved inland as winter progressed (van Eerden 1984). This change in habitat use was related mainly to a shift in the type of food consumed: saltmarsh plants and algae being preferred in autumn and grass in winter. Although seasonal movement between sites was evident for Wigeon in the Moray Firth (Fig. 4), it is not known whether this was due to changes in food selection or availability.

In Sweden, Tufted Duck are known to use estuaries exclusively (Pehrsson 1984), whereas in Britain they generally prefer inland waters to coastal areas (Prater 1981; Owen *et al.* 1986). This is not the case in the Moray Firth, where Tufted Duck are more abundant on the coast than on the inland lochs (Figs. 2 & 3).

Unusually high numbers of Pintail were also recorded on several inland floodplains in Britain in 2000/01, indicating that these sites can be quickly exploited by the birds when conditions become suitable (Pollitt *et al.* 2003). In the Moray Firth, Pintail are likely to feed on arable land around the firth and often use Bayfield Loch for roosting (Fig. 5). However, when Bayfield Loch is frozen, as happened in December 1990, February 1991 and January 1995, Pintail remained on the coast (Figs. 2 & 5). On occasions, they abandoned their intertidal feeding sites on the firth and moved onto Loch Eye during periods of strong winds (B. Swann, pers. comm.).

A comparison of the number of wildfowl in the Moray Firth recorded during the last 10 years of the study with earlier periods indicates much greater use of the inland lochs in the past. Loch Eye, in particular, became a stronghold for several species between the 1960s and early 1980s (Owen *et al.* 1986). For instance, the loch held internationally important numbers of Whooper Swan, with average counts of over 600 birds in 1978–1980 and a peak of over 1,200 in 1979 (Owen *et al.* 1986). Although these numbers are roost counts and are not

directly comparable with the WeBs counts, the average number of Whooper Swans on Loch Eye in the last 10 years (WeBs data) only once exceeded 40 birds (Fig. 5). The number of Whooper Swans using the loch as a roosting site still exceeds 600 birds (B. Swann, pers. comm.). Similarly, Loch Dochfour and Abban Water supported a peak of 350–550 Tufted Ducks in the 1980s (Owen *et al.* 1986). These figures far exceed the numbers recorded in the last 10 years.

Conservation

Despite a decrease in numbers of five species in the Moray Firth in the last 17 years, the area still holds internationally and nationally important numbers of six species of wildfowl (seaducks are discussed in Kalejta-Summers & Butterfield 2006). The Dornoch, Cromarty and Inverness Firths are the most important sections, with nationally and internationally important numbers of Wigeon, Teal and Whooper Swan.

The importance of the Moray Firth on international, national and local scales has long been recognised (Prater 1981; Owen *et al.* 1986) and the area has already received some protection**.** The Dornoch, Cromarty and Inner Moray Firth are designated as Special Protection Areas (SPAs), Ramsar Sites and Sites of Special Scientific Interest (SSSIs). Parts of Nigg and Udale Bays in the Cromarty Firth are National Nature Reserves (NNRs) managed by the RSPB. Loch Fleet and Culbin Sands (Moray East section) are reserves of the Scottish Wildlife Trust and the RSPB, respectively.

Increases in human disturbance, recreational activities, drainage of feeding areas and industrial development on estuaries have been listed as major threats for wintering wildfowl (Buchanan 1986). In the Moray Firth, discharges of sewage and trade effluents, and oil discharges from onshore and offshore installations and vessels were listed in the 1980s as major industrial threats to birds (Buchanan 1986). Pollution from sewage and distillery discharges is very low at present and probably is no longer a major issue (SEPA, pers. comm.); oil pollution, on the other hand, has been a source of concern since the late 1960s (MacLennan 1986). Birds have been shown in individual incidents to be extremely vulnerable to relatively small quantities of oil (MacLennan 1986). Between 1969 and 1976, 26 minor spillages within the Moray Firth affected over 5,000 birds, including many hundreds of ducks and swans (Owen *et al.* 1986). The main sources of oil pollution affecting birds in the Cromarty Firth in the 1970s–1980s were the Royal Naval fuel depot at Invergordon and other shore-based installations and vessels (MacLennan 1986). Although the incidents of oil pollution have decreased markedly since the 1980s, it still remains a potential threat to waterbirds in the area.

Wildfowling is a traditional sporting activity in the Moray Firth, and is at its most intense in October, when Wigeon numbers are at their highest (Hancock 1993). No assessment of the level of shooting on the bird populations in the Moray Firth has been conducted in recent years. There is also increasing pressure on coastal areas from recreation, including dog walking, jogging, jet skiing and use of boats. The impact of these activities on wildfowl in the Firth is currently unknown.

Continued management of human activities in the Moray Firth is crucial in order to ensure a large population of wintering wildfowl. A better understanding of the way in which food resources affect numbers and distribution of the wildfowl would help in the management of the area. At the moment, this knowledge is greatly limited. Counts of wildfowl in the Moray Firth should be continued to assess changes in the number and distribution of birds in the area.

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