Ringing & Migration (2009) **24**, 233–239

Sexing Black-legged Kittiwakes by measurement

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The effectiveness of using biometric data to sex Black-legged Kittiwakes *Rissa tridactyla* in northeast England has been examined. No single measurement or group of measurements was successful in sexing all individuals. The head and bill length was the best measure and correctly sexed 94% of individuals. Mass was an unsatisfactory value to identify sex, as it varied with the time since feeding, throughout the season and probably between years. There was also a significant trend for older individuals to be heavier. Wing length showed considerable overlap between the sexes and both wear of the tip of the longest primary and age adversely influenced the reliability of this measure. There was no obvious or appreciable advantage in using a combination of measurements, such as wing length and head and bill length to produce a combined discriminant value, and the improvement in sexing was marginal and of dubious significance. The Kittiwake shows geographical variation in size and it is suggested that, in other areas, plus and minus 2.6 mm of the average head and bill length of the sample taken from that area will adequately estimate the mean head and bill lengths of male and female Kittiwakes respectively, while the overall mean approximates to the best separation value.

Males of all gull species are, on average, larger than females, but there is always an overlap in the size of individuals between the sexes. As a result, sexing based on measurements is not totally reliable. In addition, repeatability, precision and which are the best measurements to use are often not fully known.

Information obtained from museum skins confirms that, on average, male Black-legged Kittiwakes *Rissa tridactyla* (subsequently referred to as Kittiwakes) are larger than females. For example, Cramp & Simmons (1983) reported that wing length of males ranged from 290 mm to 326 mm in a sample of 20 specimens, while wings of females measured 279–318 mm based on 21 birds. The overlap in wing length between the sexes in these samples was 28 mm, while the overall extreme, irrespective of sex, was only 47 mm. The same publication reported other biometrics, such as tail length, mass and bill length, tarsus and toe length, but these all showed even greater overlap between the sexes and are of little value for sexing. The key questions are, first, which are the best biometric measurements to sex gulls and, second, how effective they are in achieving this.

The overlapping measurements between the sexes have caused some researchers to use discriminant analysis, a method that combines several measured parameters into a formula that potentially allows a higher proportion of individuals to be sexed than if a single measurement is used. However, this method involves more time and effort because several different measurements are required on each individual, something which may be undesirable if a large catch is made at one time *eg* by cannon netting. Furthermore, Coulson *et al* (1983) showed that for gulls, only minimal advantage was obtained by using a combination of measures over a single measure, and even when using several measurements, individuals were still not all sexed with certainty.

Because biometrics failed to sex reliably every Kittiwake that was colour marked in studies made in northeast England, the birds were sexed by their sexual behaviour at the colony once each had been given a unique combination of colour rings. This method of sexing was almost totally successful (99%+) and, over several breeding seasons, most birds had their sex identified and confirmed on several occasions. But useful observations of behaviour are restricted to the immediate pre-laying period at the colony, when intensive food begging by the female and mating occur. It is also highly labour-intensive, requiring many hours of observations.

In addition to giving each Kittiwake captured a unique combination of colour rings, the wing length, mass and, in more recent years, a new measurement – the total head and bill length – were also recorded for most individuals captured. As a result, several hundreds of records were obtained of the biometrics of Kittiwakes which were correctly sexed by behaviour. These have allowed an efficient and independent evaluation of different body measurements as a means of sexing Kittiwakes and the results of this are presented here.

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METHODS

The data used in this study were obtained from adult Kittiwakes captured at colonies in the Tyne and Wear region of northeast England, mainly at North Shields (latitude 55°N), between 1954 and 2000.

DNA samples (Griffiths *et al* 1998) were not used to sex the individuals, mainly because the method was not available until the latter part of the study. This method was 97% correct when applied to Kittiwakes (Jodice *et al* 2000), but newer, refined procedures may now be even more successful. However it is relatively expensive to use and requires laboratory support.

Sexing marked Kittiwakes by observing copulations proved to be totally reliable. Reverse mounting was not recorded. Intensive food begging by the female, when she crouched, chick-like and made repeated upward jerks of the bill accompanied by a squeaking call, was also reliable, and often led to feeding by the male or to copulation. However, such behaviour was sometimes expressed at low intensity and this was less reliable, and so sexing was restricted to cases when one individual crouched and begged repeatedly, and was fed, or when copulation took place.

Over a number of years, many of the marked Kittiwakes changed mates and so one observed mating often led to the sex being identified for a chain of other individuals. In one case, the sex of 96 other individuals was established from observing a single mating. As a result, the sex of most individuals was determined and then confirmed on several occasions, usually without contradiction. There was never more than one contradictory record for any individual. In the few cases without total agreement, the majority of records allocated the sex. The few exceptions in sexing probably arose from misreading or incorrectly recording the colour-ring combinations. Of over a thousand individuals studied, only two individuals were excluded because only two, but contradictory, records of the sex were made.

Wing chord length, using the standard method of straightening and flattening the closed wing, is relatively easily taken using a stopped rule (Svensson 1992). However Jodice *et al* (2000) (their Table 2) showed that the difference between the 'natural' wing length and that obtained by flattening and straightening the wing of Kittiwakes varied by 10 mm, and so it is essential to standardise the measurement. The length of the longest primary, which determines the wing length, is subject to variable wear at the tip and sometimes over 3 mm had been lost.

Initially, birds were weighed on spring balances that required regular adjusting to zero and had an accuracy of about 5 g. From 1957, mass was recorded more accurately, using direct-reading balances which displayed to 0.1 g, and mass was recorded to the nearest gram. A check weight was regularly used to confirm the reliability of the balances, but adjustment was never required. If an individual regurgitated food after capture but before weighing, the mass of this food was added to that of the individual.

In the early years of the study, most of the adult Kittiwakes captured had wing length and mass recorded, and since 1982 the combined length of the head and bill was also measured. This was measured using a scale with a 10x10-cm stop plate fixed to one end of a rule and a similar plate that slid over the rule (see illustration in Coulson *et al* 1983). The tip of the beak and the back of the head were placed against the plates and the length read from the rule.

Because a policy of minimum disturbance of birds in the colonies was used, most individuals were captured and measured only once. However in cases where re-ringing was necessary, some individuals were measured a second time. In addition, a sample of birds was remeasured within 30 minutes to give an indication of the repeatability of measurements.

The author made the great majority of measurements, but five other people also contributed measurements after they had been trained in the standard methodology. None of the data collected differed appreciably or significantly between measurers, and all measurements have been used.

Wing length was recorded for 564 known females and 643 known males, mass was recorded for 561 females and 525 males and head and bill was recorded for 296 females and 255 males.

RESULTS

Repeatability of measurements

Head and bill length ranged from 81 mm to 98 mm, and showed the highest degree of repeatability (Table 1). Only three of 33 repeated measurements differed from that originally taken, and in each case by only 1 mm.

Mass of Kittiwakes showed considerable variation, ranging from 268 g to 471 g. A sample of 14 individuals weighed within 30 minutes (by the same or a different person) differed by an average of less than a gram (Table 1). In contrast, a total of 62 individuals weighed and reweighed on different dates showed much larger differences (in the extreme case a change of 86 g), presumably mainly reflecting the time since feeding.

The change in mass of individuals shown in Table 2 revealed that of the 52 birds reweighed in a subsequent year, 35 showed a mass gain and only 17 showed a loss. Chance would predict equal numbers of individuals with gains and losses (*ie* 26 gains and 26 losses), and the deviation from equality is statistically significant ($\chi^2_1 = 6.2$, $P < 0.02$). Since the average mass of Kittiwakes captured

Table 1. The mean difference in mass, wing length and head and bill length of individual adult Kittiwakes measured twice, after the elapse of different time periods.

	Interval between repeated measures			
	Within 30 min	Same year	1–2 years later	3–9 years later
Mass				
N	14	10	19	33
Mean difference	0.2±0.1g	2.0±0.3g	9.5±2.8g	8.9±3.2g
Wing				
N	14	10	19	33
Mean difference	0.3±0.1mm	0.4±0.02mm	8.2±0.3mm	0.2±0.06mm
Head and bill				
N	7	6	6	14
Mean difference	0.1±0.02mm	0.0±0.0mm	0.2±0.01mm	0.1±0.01mm

for the first time did not show a trend over the study period, it is possible that birds tended to be heavier as they became older.

Wing length was measured independently twice within 30 minutes on 14 individuals and had an acceptable degree of consistency, with a maximum error of 2 mm (Table 1), with most giving identical readings. Pairs of measurement taken at intervals of more than a year for 47 individuals showed more variation, with an average difference of 5.7 mm, and seven individuals changing wing length by over 7 mm (Table 2). Table 2 reveals that nine of these individuals had shorter wings when the second measurement was taken a year or more later (by an average of 3.9 mm), but 28 birds showed a subsequent increase in wing length (by an average of 4.8 mm), while 10 showed no change. A greater number of individuals showed an increase in wing length in comparison with the number showing a reduction, and this difference is highly significant ($\chi^2_1 = 9.76$, P <0.002). Wing length of birds measured for the first time showed no trend over the period of study. These results suggested that the wing length of some individuals did not remain constant in subsequent years, but that there was a tendency for small increases in wing length in older birds.

Sexing

The means for wing-length, mass and head and bill measurements of adult male and female Kittiwakes are shown in Table 3, along with the extent to which males were larger than females. Table 3 also shows the standard deviation (SD) and the coefficient of variation (CV) for each mean value the differences, while in the upper or lower 95% values presented indicate the extent of overlap between the sexes. These values give an insight into the factors that might be most useful in sexing birds in the hand. While the proportionate differences in the means between the sexes were greatest for mass, this might be taken as indicating that it would be potentially the best measure to use for separating the sexes. However, the large standard deviation (spread) of mass and its large coefficient of variation (a measure of the proportionate variation) argue against this, as they both indicate there could be a considerable overlap in the weight recorded for individuals. Proportionately, wing length differed least between the sexes. The small CV for the head and bill length suggested that this might be the most appropriate value to use for sexing birds.

Mass

Mass was not a reliable measure of sex (Fig 1). A few females weighed over 400 g, and the heaviest was 445 g, while some males weighed as little as 300 g. Thus only Kittiwakes weighing below 300 g or above 445 g were sexed with total confidence, and these involved only 2.5% of the individuals considered. Taking the optimal mass for separation of the

Table 2. The distribution of the loss or gain in mass and wing length of individual adult Kittiwakes when weighed for a second time and in a different year.

			Loss						Gain			Total
Mass (g)	81–100	61–80	41–60	21–40	1–20	0	1–20	21–40	41–60			
Number	1	0	2	5	9	0	13	16	6			52
Wing length (mm)		7–8	5–6	3–4	1–2	0	1–2	3–4	5–6	7–8	9–10	
Number		1	1	5	2	10	9	4	8	3	4	47

Table 3. The mean mass, wing length and head and bill length of known adult male and female Kittiwakes. 1.96 times the standard deviation estimates added to and subtracted from the mean gives the range within which 95% of individuals will occur. Note that with all three parameters, the male lower 95% values and female upper 95% values overlap. SD is the standard deviation of the mean and CV is the coefficient of variation (SD^2/mean).

	Female					Male					% male larger than female	Overlap range at 95% limits
	N	Mean	SD	CV	95% upper limit	N	Mean	SD	CV	95% lower limit		
Mass (g)	752	347.9	28.8	2.380	404	759	386.0	27.8	2.00	332	11.0	72 g
Wing length (mm)	591	301.9	6.39	0.135	314	604	310.9	5.87	0.111	299	3.0	15 mm
Head and bill (mm)	302	87.9	1.87	0.040	91.5	314	93.2	1.75	0.033	89.8	6.0	1.7 mm

sexes as 356 g, 80% of individuals would be correctly sexed if those above this value were considered to be males and those below were classified as females.

Wing length

Kittiwakes with wing lengths below 294 mm and above 315 mm could be reliably sexed as female and male respectively, but this represented only 7% of the birds considered (Fig 2). Taking the optimal wing length for separating the sexes as 308.5 mm, 74% would be correctly sexed.

Head and bill length

This was the best means of sexing individuals. Measurements of 90 and 91 mm (12% of all individuals) could be equally of either sex, but those below or above these values (88% of individuals) could be sexed with 98% confidence (Fig 3). Those measuring below 89 mm or above 92 mm were totally separated. Taking the optimal measurement for separation to be 90.5 mm, 94% of individuals would be correctly sexed.

Discriminant functions

Including wing length, mass or both in addition to head and bill in a discriminant function increased the accuracy of sexing by less than 1% (to 95%) over the results obtained by using head and bill measurement alone. The reason for this small improvement was that wing length and mass were not independent indicators of sex, but were correlated with head and bill length (*eg* correlation between head and bill and wing length of females was $r_{165} = 0.442$, $P < 0.001$). In other words, a female with a large head and bill length tended to be large in all respects, and to have both a greater mass and a longer wing than a female with a shorter head and bill length, and so these additional measures, at best, only marginally assisted with sexing.

DISCUSSION

While information on mass can be biologically informative, it is best excluded as a method of sexing birds because it varies in an individual within a day, over the breeding season and possibly between years. Wing length is more satisfactory, but it varies seasonally due to normal wear of the tip of the longest primary, and this can reduce the recorded length for an individual by several millimetres. It is noticeable in Fig 2a that males and females both showed a longer tail (skew) at the lower end of the wing length distribution, and this can probably be attributed to greater wingtip wear in some individuals, and this would lead to some males being misclassified as females. Wing length is not reliable when the longest primary is moulted or still growing. Fortunately, the outer primary is not moulted and replaced until late autumn, by which time most Kittiwakes have reverted to an offshore, pelagic life, so error in wing length measurements as a result of incomplete growth of the longest primary was not a problem in this study. It might be, however, if dead birds washed ashore in the late autumn and winter were being studied, and wing length were used to sex or indicate the origin of the dead Kittiwakes.

It is generally assumed that wing length is a constant characteristic of the individual, but does the annual replacement of the longest primary result in a feather exactly the same length as that which had been produced in the previous year? In the data presented in Table 2, there is an indication that this may not be so. Perhaps wing length changes marginally with age in the Kittiwake. More information is needed on the change in wing length after primary moult in individuals of this and other species.

Head and bill proved to be the best measurement to sex Kittiwakes. It is a reliable value and can be consistently taken by other researchers. The use of head and bill length has not been widely used in the past in ornithology, probably because of the practice of opening the back of the skull to remove the brain during preparation of museum specimens, thus making it impossible to measure the head and bill length correctly. However it was used successfully by Coulson & Strowger (1999) to determine the sex ratio of Kittiwakes that died during a period of high mortality, showing that about 71% of these were female.

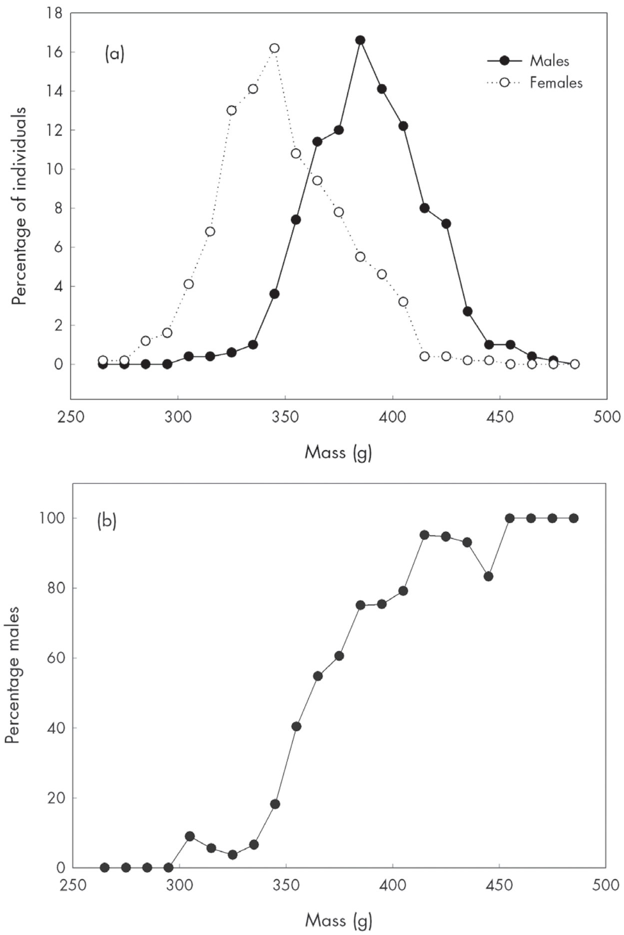

Figure 1. a) The percentage frequency distribution of mass of adult male and female Kittiwakes based on 525 males and 561 females. Masses have been grouped into 5-g categories and the midpoint for each has been used in the graphs. b) The percentage of males at each mass group derived from (a).

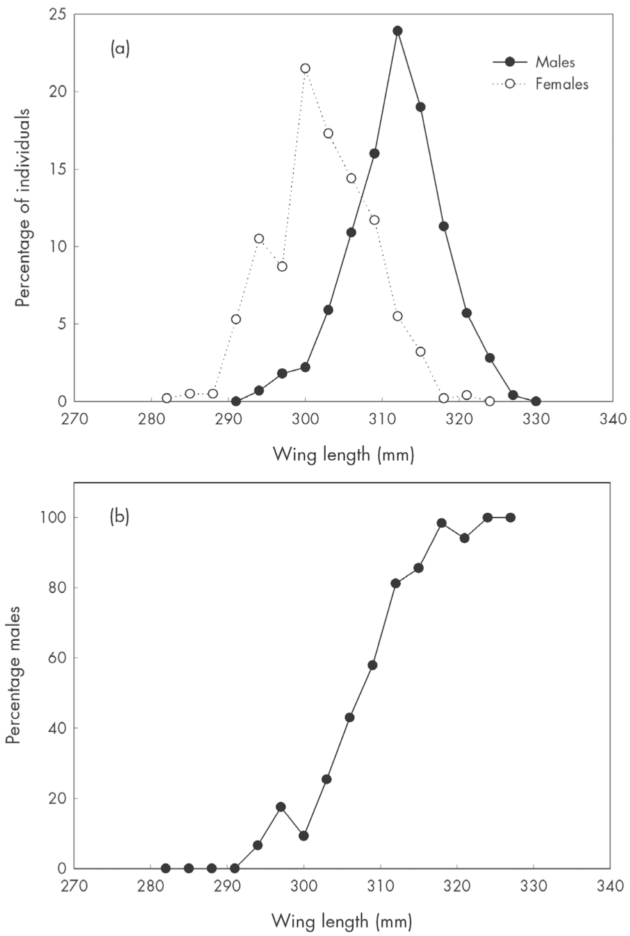

Figure 2. a) The percentage frequency distribution of wing lengths of adult male and female Kittiwakes based on 543 males and 564 females. The wing lengths have been grouped into 3-mm categories and the midpoint for each have been used in the graphs. b) The percentage of males at each wing length derived from (a).

The Kittiwake, like several other bird species and the Atlantic Puffin *Fratercula arctica* in particular, follows Bergmann's rule, in that the average size of individuals becomes larger towards the North Pole. Belopolskii (1957) recorded the average mass of female Kittiwakes in eastern Murmansk Region (in Arctic Russia) as 393 g, while females from northeast England averaged only 348 g, a 13% difference, and these more-northerly birds were larger in all respects. As a result, the biometrics recorded here are probably typical for the UK, but do not apply to areas further north. In northern England, female Kittiwakes had an average head and bill length of 87.9 mm and males 93.2 mm (slightly higher than values based on small samples in Coulson *et al* 1983), but these values do not apply throughout the geographical range of the species. Thus, the head and bill measurements would need to be adjusted for different geographical areas. This could be achieved by assuming that any sample of Kittiwakes measured elsewhere contained approximately equal numbers of the sexes, and that the mean of these will be the best value for separating the sexes. The difference between the mean head and bill for the sexes remained about 5 mm over a large part of the range, and so by determining plus and minus half of this value (say 2.6 mm) from the mean, an approximate average for the measurement of males and females can be obtained and the distributions shown in Figs 3a & 3b can then be rescaled. For example, other researchers found that Kittiwakes breeding in northern Norway had average head and bill measurements of 89.0 mm for females and 94.5 mm for males (Barrett *et al* 1985), while in Arctic Russia the comparable values were 90 and 95 mm (Tatarincova & Shklyarevich 1978). In the arctic area of the North Pacific, where Kittiwakes (subspecies *pollicaris*) are large, the head and bill of females averaged 94 mm and males 99.5 mm (Jodice *et al* 2000).

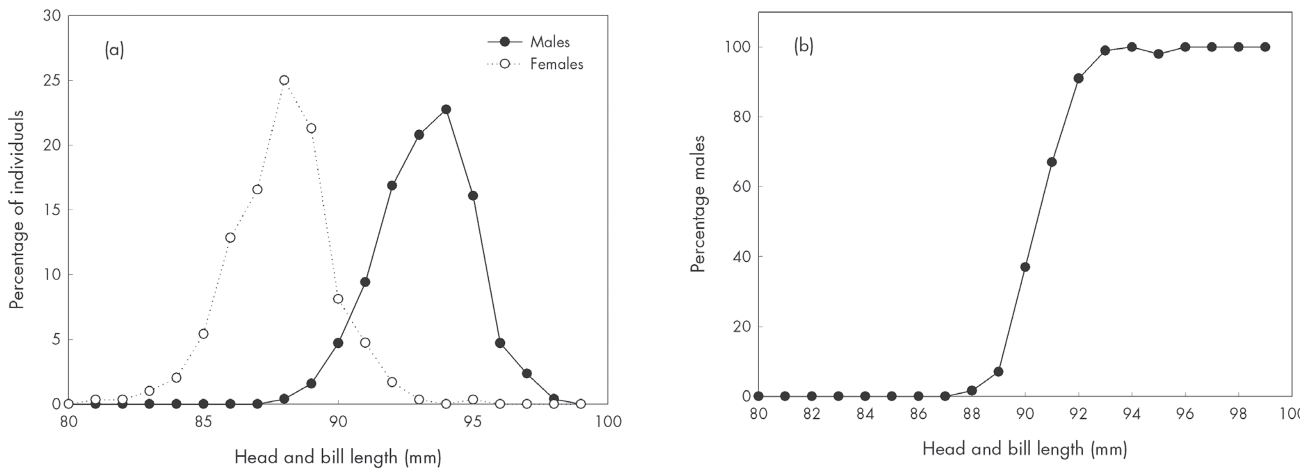

Figure 3. a) The percentage frequency distribution of head and bill length of adult male and female Kittiwakes based on 253 males and 296 females. b) The percentage of males at each head and bill length based on (a).

A further problem might occur if samples of dead Kittiwakes found in winter were being investigated, since the birds found could originate from very different latitudes, and sexing these could therefore be difficult. Such mixing would produce a greater spread of values (measured by the standard deviation) of the head and bill lengths than that obtained in birds breeding in northern England, and therefore the areas of origin could be investigated by considering the mean and standard deviation and also whether the spread of head and bill lengths were normally distributed or skewed.

Recommendations for sexing Kittiwakes breeding within the UK

There is little advantage in taking measurements in addition to the head and bill length to sex Kittiwakes (and probably most gulls). In many studies of birds where multiple measurements have been used to produce a discriminant function, virtually no advantage is gained by including a third value and often the second added little to the accuracy of sexing from one biometric measurement. Unfortunately, many studies have uncritically applied discriminant functions to sex birds and, for example, have not reported the gain in accuracy obtained by adding each additional parameter, *eg* Green (1982), Green & Theobald (1989), Brown *et al* (2003) and Alarcos *et al* (2007), amongst many. Including an additional factor always increases (by chance or otherwise) the proportion correctly sexed in the study sample. The crucial test is to measure the efficiency against a different data set, and this has rarely been done in ornithology.

In the Kittiwake, neither mass nor wing length reliably improved the identification of sex over that obtained by using head and bill length alone. It remains at about 94% correctly sexed. Kittiwakes with head and bill measurements of 90 mm and 91 mm (about 13% of individuals) cannot be sexed from measurement. Kittiwakes with head and bill of 89 mm or 92 mm are sexed with about 92% accuracy, while those with measurements below 89 mm or above 92 mm are sexed with a minimum of 99% accuracy. If sexing is imperative, then the cost of using DNA to sex individuals could be greatly reduced by using this method only on individuals with head and bill lengths between 89 mm and 92 mm (about 30% of individuals), while the overall accuracy then achieved is likely to exceed 99%. Alternatively, sexing individually identifiable birds by behaviour, if observations are possible, is strongly recommended.

ACKNOWLEDGEMENTS

I thank Julie Porter, John Chardine, Ron Wooller, Nicholas Aebischer and Callum Thomas for their contributions to the biometric database of Kittiwakes breeding at North Shields.

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(MS received 14 September 2008; accepted 22 October 2008)