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Ageing and sexing the Yellowhammer *Emberiza citrinella caliginosa* during the non-breeding season

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Short title: Ageing and sexing the Yellowhammer

Abstract

Individual or population-level analyses using ringing data require accurate identification of the age and sex of birds in the hand. Many species are difficult to age and sex: work on known age and sex birds is essential if we are to increase the value of ringing data for these species. In this study we have used molecular sexing techniques and known-age birds to characterise plumage characteristics useful in distinguishing the age and sex of Yellowhammers *Emberiza citrinella caliginosa*. Tail feather shape was useful in ageing both adult and first year birds, supporting current ageing criteria; other features were associated with first year birds but not with adults. Most, but not all, birds could be sexed using the amount of yellow visible on the side of head and crown. The amount of black on the longest tail covert shaft and the amount of white colouration on the fifth and sixth tail feathers were useful for identifying both sexes. The rump-feather shaft colour and under-tail covert colouration may be useful for sexing ambiguous birds. Our results provide additional ageing and sexing criteria for *E. c. caliginosa* and can be used to improve the accuracy of ringing data for this declining subspecies.

Introduction

Knowledge of the age and sex of a bird is crucial when undertaking any analysis of condition, reproductive success (Kokko 1998) or survival (Tavecchia *et al* 2001). The sex of a bird intrinsically influences its reproductive success, especially in species with high levels of extra-pair copulation (Sundberg & Dixon 1996), and factors such as immunocompetence and susceptibility to disease are frequently sex-linked (e.g. Roulin *et al* 2007). The age, and thus breeding experience, of birds influences sexually-selected traits and reproductive success in many avian species (Sundberg & Dixon 1996, Komdeur *et al* 2005) and age may also influence the frequency or intensity of breeding strategies such as mate guarding (Johnsen *et al* 2003). Survival may be sex-linked (Tavecchia, et al. 2001, Eeva *et al* 2006) and frequently the probability of surviving until the next year is higher for older birds (Martin 1995, Tavecchia, et al. 2001).

Around 50% of avian species exhibit sexual dimorphism (Griffiths *et al* 1996), allowing easy identification of the sex of a bird in the field or in the hand. Age in small passerines is largely categorised as birds either hatched during the previous breeding season (first/second year birds, herein referred to as first years) or birds born before this (adults). In many species this is identified by observing a contrast in wing covert colour in first year birds that have undergone a partial post-juvenile moult (Svensson 1992). Other species, such as those in the bunting family, frequently moult all their greater coverts, and sometimes the carpal covert, tertials and alula (Jenni & Winkler 1994, Blasco-Zumeta 2008). As a result, no contrast within wing coverts is visible and assessing age in these species is largely dependent on an assessment of the wear and bleaching on primary feathers and tail feathers grown in the nest (first-year birds) in comparison with recently-moulted feathers on adult birds (Svensson 1992, Jenni & Winkler 1994). However, as winter progresses the wear on adult feathers increases and differences between the age classes are less obvious: late-hatched birds may have similar amounts of wear to adults that have undergone post-breeding moult, so this criterion can often be inaccurate, as has been found within known-age reed buntings (Baker 1986).

The Yellowhammer (*Emberiza citrinella*) is a temperate bunting species that exhibits marked plumage variation. The most marked differences are between adult males and first-year females, adult male birds having a high proportion of intense yellow colouration on their head and breast, and first-year female birds being markedly dull with very little yellow on their head and pale yellow on their breast.

Males of this species acquire the breeding plumage on their head by abrasion in spring, with black and brown feather tips during the non-breeding season obscuring the yellow head colour of a breeding bird. This makes the differences between first-year males and adult females at this time of year less clear-cut and consequently many birds cannot be aged reliably using known criteria in the non-breeding season (e.g. Thompson 1987), reducing the reliability of data collected by ringers.

Previous studies have attempted to find reliable methods of accurately determining age and sex in Yellowhammers: most have relied upon shape and wear of tail feathers (e.g. Svensson 1992) which can be unreliable as some first year birds will moult some, if not all of their tail feathers (Blasco-Zumeta 2008). Skull ossification is also a recommended technique for ageing this species (Svensson 1992); however this technique takes more time than is often available (e.g. Cobb 1997). Whilst some studies have examined additional plumage-colouration criteria, including crown feathers (Svensson 1992), tail feather colour (Norman 1992) and head and breast colouration (Blasco-Zumeta 2008), considerable confusion remains and results are not always consistent (Svensson 1996), which may be due to regional geographic variation or variation between subspecies.

The subspecies of Yellowhammer found in north and west Britain, *E. c. caliginosa* (Clancey), is slightly darker and more streaked than the more widespread *E. c. citrinella* subspecies found in southern England and into continental northern and central Europe (Svensson 1992). Crown feather markings are used to determine sex in *E. c. citrinella* (Svensson 1992); however, these are inaccurate when applied to *E. c caliginosa*. For example, males of the latter subspecies frequently possess a prominent black shaft streak restricted to females of the former subspecies (e.g. Fig 1).

Yellowhammers in Britain have undergone significant population declines since the beginning of the 1980s with an estimated population decrease of 25% between 1980 and 1994 (Siriwardena *et al* 1998), and a further significant decline of 19% between 1994 and 2007 (Risely *et al* 2008). Whilst still relatively widespread, it is important that population analyses of this species utilise accurate age and sex data to identify any sex or age-related variation in survival.

In this paper we describe a study of a population of *Emberiza citrinella caliginosa* from North Yorkshire during the non-breeding season. We have categorised plumage characteristics showing marked variation; using molecular techniques to establish sex, and a subset of birds of known age, we have assessed

whether variation in these plumage characteristics, along with morphometric variables, is related to age or sex and can thus be used as a reliable technique to identify the age or sex of an unknown bird of this subspecies in the hand.

METHODS

Study sites

Yellowhammers were caught and ringed at Leeds University Farms near Tadcaster, West Yorkshire, UK (lat. 53˚ 53'N, long. 1˚ 15'W). Birds were caught between December 2007 and April 2008 in static mist nets at established supplementary feeding sites, baited with wheat and weed seed, situated within an experimental agroforestry habitat surrounded by arable farmland.

Biometric data collection

Full morphometrics of a subset of birds (n = 111) were taken as shown in Fig. 2. If an individual was captured more than once, only the first set of measurements was included in the analysis to avoid pseudoreplication; to ensure consistency, all measurements were taken by the same person (JCD). The following measurements were recorded for each individual (see also Fig. 2): wing length, measured as the maximum wing chord; head and beak length (HB), measured from the tip of the bill to the centre of the back of the skull (Redfern & Clark 2001); tail length (TL), measured from the tail base to the tip of the longest outer retrix; beak length (BL), measured from the feathering to the tip of the beak; beak depth (BD), measured at the point of feathering (Svensson 1992); and tarsus length (TSL), measured as the minimum tarsus length from the foot to the inside of the knee. Measurements of wing length were taken using a standard metal wing rule and rounded up to the nearest mm; other measurements were taken using digital callipers (± 0.1 mm).

Age

The age of birds was assessed in the hand by considering the shape and colour of the central tail feathers, along with an examination of the amount of wear and bleaching on the tail, tertials, and primaries, and classified as either adult or first-year birds (Svensson 1992). Birds that were definitely adult (ringed before the previous breeding season) were noted, along with birds that were almost certainly first years: if a bird had a fault bar present in its tail along with three of either pointed, narrow, bleached or worn rectrices, it was considered to be almost certainly a first-year bird. A fault bar alone was not considered sufficient to indicate a first-year bird, as adults that lose their tail may re-grow rectrices simultaneously, potentially producing a fault bar. These birds were then used to confirm the accuracy of criteria identified as potentially useful through analysis of the entire dataset and are herein referred to as

"known adults" and "known first-years" although it should be noted that birds in the latter category could not be aged with the same absolute certainty as the ringed adults.

Sex

Sex of birds was assessed in the hand using the amount of colour on the head, along with wing length and age (as above) to differentiate between adult female and first-year male birds (Svensson 1992).

Molecular determination of sex

DNA was extracted from 30 μl of whole blood using a standard phenol-chloroform extraction technique and diluted to a working concentration of 25 – 100 ng μl^{-1}. Sex was determined using the polymerase chain reaction (PCR) technique with the P2 and P8 primers described by Griffiths *et al* (1998) to amplify sections of the CHD-Z and CHD-W genes. Sexes are differentiated on the basis that both sexes possess the CHD-Z gene, whereas the CHD-W gene is unique to females (Fig 3). The PCR was carried out in a total reaction volume of 10 μl, containing 0.8 mM deoxynucleotide triphosphates, 1 μM of each primer, 2 μl of 5X GoTaq Flexi buffer (Promega, Southampton, UK), 2 mM $MgCl_2$, 0.25 U GoTaq Flexi DNA polymerase (Promega) and 25 – 100 ng template DNA. No positive control was used as all samples were expected to produce bands; a negative control containing deionised water in place of template DNA was included with each PCR reaction to ensure lack of contamination. The PCR amplification protocol consisted of a denaturation step at 94˚C for 2 min, 40 cycles of 94˚C for 45 s, 48˚C for 45 s and 72˚C for 45 s, with a terminal extension step of 72˚C for 5 min. PCR protocols were carried out on a GeneAmp PCR System 9700 (Applied Biosystems, Warrington, UK). PCR products were separated by electrophoresis through a 3% agarose gel in standard Tris/borate/EDTA buffer, stained with ethidium bromide and visualised under UV light.

Photographic analysis of plumage characteristics

A series of digital photographs were taken of the crown, side of head, wing, breast, rump and tertials, wing coverts and tail of each bird in order to minimise the processing time for each bird in the hand. Photographs were taken using a Nikon CoolPix p5000 digital camera and analysed 'blind' with respect to molecularly-determined sex and assessment of age and sex using plumage criteria. Features that

were analysed to determine whether they showed any correlation with the age or sex of a bird, along with category classifications, are described in Table 1. Not all photographs were of sufficient quality to distinguish the necessary features and the number of birds for which each feature was analysed is given in the results in Tables 2 and 3.

The intensity of colour of a bird can frequently be used to determine sex in sexually dimorphic species (e.g. Molina-Borja & Avila 2006). However, the use of colour-intensity criteria to assess a bird whilst in the hand is dependent upon ambient light conditions and is often highly subjective. In this study, male birds with pale colouration and female birds with intense colouration were observed (Authors, pers. obs.), implying that other environmental determinants of colour intensity, for example haemoparasites (Sundberg 1995), may be important in this species. Thus, colour intensity is not considered further here.

Statistical analyses

Statistical analyses were conducted in R version 4.2.1 (www.R-project.org). For analyses of sex, molecular sex was used as the response variable. For significant terms, the association and percentage accuracy were calculated for each category classification. In addition, the data for birds misidentified in the hand (n=10: 5 males, 5 females) were examined to determine whether characteristics that were significant from the statistical analysis could have been used to sex these individuals correctly. Whilst the sample size of misidentified birds was small, examination of these data may point towards criteria that might be useful in sexing ambiguous birds. For age analyses, age as established in the hand according to Svensson (1992) was used as the response variable for initial analysis. For significant terms, the association and % accuracy were calculated for each category classification. Consistency was then checked using a subset of data from birds of known age (adults ringed during previous years, n = 31; first years as previously defined in the "Age" section, n = 10) as consistent misidentification of age in the hand would otherwise lead to inevitable biases in data.

Analysis of plumage data

Plumage analysis was conducted separately for age and sex. Generalised linear models with binomial error structure were constructed for each feature separately with either age or sex as the binary response variable, to determine whether significant

differences in frequency distribution were present between age classes, or between sexes, and thus whether this feature could be used reliably to determine age or sex.

Analysis of morphometric data

For morphometric data, generalised linear models were constructed for each morphometric variable separately, with the morphometric variable in question as the response variable and age, sex and age*sex interaction as fixed factors, to determine whether each morphometric variable was influenced by age and/or sex. Where necessary, models were fitted with quasi-gaussian error distributions to control for overdispersion of data. Non-significant terms were removed from the model in a stepwise fashion until only terms significant at $p<0.05$ remained.

Results

Plumage data

Plumage data were collected from 151 Yellowhammers between December 2007 and April 2008. Whilst there were many significant associations between age/sex and plumage characteristics (Table 2: age; Table 3: sex), only those which had an accuracy of greater than 80% are described and discussed as only these will be sufficiently reliable for determining the age and sex of unknown Yellowhammers. Characteristics that were examined but were not associated with age or sex are summarised in Appendices 2 (age) and 3 (sex).

Age

Head: No significant associations with age were found for any plumage features of the head (Appendix 2).

Wing: Tertial markings showed a significant relationship with age: 89% of birds with distinct demarcation on the tertial feathers (Fig1ai) were identified as first year, supported by 90% of known-age first years (Table 2). The amount of wear and bleaching on the tertials also differed with age, although reliability across the entire dataset was below 80%. First-year birds tended to have worn and bleached tertials, supported by 80% of known-age first years (Table 2). Secondary feather shape also differed with age, although the accuracy within the entire dataset was below 80% (Table 2): first-year birds tended to have a notched end to their secondaries (Figure 4di) and this feature was present in 88% of known first years. In contrast, adult birds tended to have a flat tip to their secondaries (Table 2; Figure 4dii), but this was not supported by the sample of known adults. Whilst primary-tip shape and primary-covert wear and shape differed significantly between adult and first-year birds, associations were neither clear, nor supported within the subset of known-age birds (Table 2).

Tail: Tail feather shape, width, colour and wear differed according to age. It was not possible to categorise the tail morphology of 11% of birds due to tails either being missing or dampened prior to processing (n=16). Rounded central feather tips were associated with adult birds, whereas worn and bleached central feathers were associated with first year birds, as were sharply angled or pointed outer tail feathers (Table 2). All birds with white colouration reaching the shaft on both sides of the outermost tail feathers were first years, although this was relatively rare (Table 2).

Coverts and body feathers: The extent of black on the upper tail coverts, along with the colour of the under-tail covert shafts had significant associations with first years, but not adult birds. 87% of birds with no black on the longest upper tail covert were first years, as were 82% of birds with chestnut colouration on the shaft of the under-tail coverts.

Sex

141 birds were successfully sexed using molecular techniques. 10 birds (5 males, 5 females) had been incorrectly sexed in the hand: these were used to determine which features that show significant differences between the sexes may be most useful in identifying ambiguous birds. The results of statistical analyses showing the features which may be useful in determining sex are shown in Table 3; plumage features that had no association with sex are summarised in Appendix 3.

Head: All plumage features of the head that were examined showed significant and accurate associations with sex (Table 3). 84% of birds with >20% of the crown showing visible yellow colouration were identified as male on the basis of molecular evidence, and 89% of birds with <10% visible yellow colour on the crown were confirmed as female on the basis of molecular evidence. However, this criterion only accurately sexed the misidentified male birds, not the females (Table 3). Birds with yellow or chestnut malar stripes tended to be male, as did birds with a distinct bright yellow region above and behind the eye (Fig 2b). Birds without this region tended to be female, and this trend was consistent within ambiguous birds (Table 3).

Wing: Tertial feather markings showed significant differences between the sexes; however, the association was neither clear nor reliable. Thus, no plumage characteristics of the wing proved to be significantly and accurately associated with sex (Table 3; Appendix 3).

Tail: The amount of white on the tail showed significant and reliable associations with sex for a small number of birds: all birds with white colouration reaching the shaft on both sides of the outer tail feather were male, as were all birds with white colouration reaching the shaft on one side of the fifth tail feathers (Table 3). 80% of birds with a very small patch of white on the fifth tail feather when compared to the amount on the sixth tail feather (Fig 4bi) were female and all birds with similarly sized white patches on the fifth and sixth tail feathers (Fig 4biv) were male (Table 3).

Coverts and body feathers: The colour of the shaft of the under- and upper-tail coverts proved useful in identifying male and female birds (Table 3). 95% of birds with no black on the longest upper-tail covert shaft were male and 86% and 95% of birds with half and all the shaft black, respectively, were identified as female on the basis of molecular evidence. 95% of birds with chestnut under tail covert shafts were male. Although not highly accurate for the entire dataset, the colour of the rump feather shaft could correctly identify 100% of misidentified birds (although the sample size was small), with females having a black shaft and male shafts blending with the rest of the feather (Table 2).

Morphometric data

Significant differences were found between males and females in terms of wing length, tail length, beak length and beak depth, but not for head-beak length or tarsus length, with males having on average longer wings and tails than females, but females having longer and deeper beaks (Table 4). Age differences were found for wing length, tail length and beak depth, with adult birds having longer wings and tails, and deeper beaks than first year birds (Table 4). Mean values, along with standard deviations and range are displayed in Table 5.

Frequency distributions for wing length are shown for first years and adults in Figure 5. Male and female wing lengths overlap in both first years (Figure 5a) and adults (Figure 5b). However, on removal of the top 20% of female wing lengths and the bottom 20% of male wing lengths, the remaining adults could be sexed reliably using this measurement, with wing lengths below 87mm being from female birds and wing lengths above 87mm being from male birds. First-year birds could not be sexed reliably using wing length: with removal of 20% of overlapping wing lengths as before, 11% of male and 13% of female wing lengths still overlapped. However, birds with wing lengths of less than 80mm could be aged and sexed unambiguously as first year females (n=6; 4% of total birds); birds with wing lengths greater than 92mm were adult males (n=12; 8%), and birds with wing lengths greater than 90mm were male (n=22; 15%).

Birds with short tail lengths could not be aged or sexed reliably; however all birds with tail lengths greater than 75mm were male (n=12; 11%)

Discussion

Ageing

Current criteria used to age Yellowhammers involve the examination of abrasion and shape of the tail feathers along with an assessment of wear on primary tips (Svensson 1992). Here we assess the reliability of these criteria, as well as examining alternatives that may prove useful in increasing the accuracy of ageing this species, particularly the subspecies present in northern Britain, *Emberiza citrinella caliginosa*.

The shape of outer and central tail feathers had a high accuracy for ageing first-year and adult birds respectively, in agreement with existing ageing criteria (Svensson 1992). Whilst it must be taken into consideration that these criteria were initially used to age unknown birds in the hand, this relationship was consistent with birds of a known age so it is concluded that these criteria are reliable for ageing circa 80% of birds. The amount of wear and bleaching on central tail feathers proved reliable as the majority of birds with feathers classified as worn and bleached were first years (although it must be noted that this characteristic was used to identify first year birds in the first instance and that many known adults also had worn and bleached central tail feathers). However, many first years also had fresh feathers, probably due to a later hatching date, or a partial or full moult of tail feathers as seen in some first-year Reed Buntings (Baker 1986); therefore, ageing birds with fresh central tail feathers was less reliable. Central tail-feather width showed significant differences between adults and first years and this was also consistent with known-age birds; however the accuracy of this criterion was low, so it is not considered to be reliable in identifying unknown Yellowhammers. In view of this, and the fact it was not possible to categorise the tail morphology of 11% of birds due to tails either being missing or dampened prior to processing, it is desirable to have other features that are known to change reliably with the age of a bird.

Three novel criteria showed significant differences between adult and first-year birds, with a high degree of accuracy for at least one category within each. The majority of birds with no black on the shaft of the longest upper-tail covert were first years, although no relationship was found with other amounts of black. Interestingly, this relationship was also associated with male birds, suggesting that the vast majority of birds with this feature can be identified as first-year males. All birds with white on both sides of the shaft of the outermost tail feather were first years, although the sample size here was relatively small which may explain the inconsistency of this result with known-age birds. The majority of birds with a chestnut shaft on the under-

tail coverts were first years, although less than half of the known-age first years exhibited this characteristic. However, no novel criteria had reliable associations with adult birds.

Whilst the shape of the primary tips differed significantly between adults and first years, there were no clear associations. Primary-covert shape and width both differed between age classes; however the associations here were not clear and this was not supported within the sub-sample of known-age birds. The shape of secondary feathers also differed between adults and first years, with adult secondaries tending to have a flat edge, and first year birds tending to have strongly notched edges to their secondaries. This association was upheld within the sub-sample of known-age birds; however, the associations were not strong enough to be reliable as a single criterion for ageing this species, but may be useful when considered in conjunction with other plumage characteristics and morphological measurements.

Sexing

Current criteria used to sex the Yellowhammer involve the examination of the colour of the crown feathers, with males having more than half of their crown feathers yellow with no prominent black distal streak, and females with virtually no yellow on their crown feathers. However, this is inaccurate with the subspecies in question (e.g. Fig 1) and so new criteria are needed in order to allow accurate sexing of this subspecies in the hand.

Three criteria involving examination of the head of birds had a high accuracy for identifying both male and female birds. The majority of birds with more than 20% yellow visible on their crown were male and the majority of birds with less than 10% visible were female. This could be used to identify accurately the majority of males misidentified as females in the hand, but less than half of females misidentified as males, indicating that old female Yellowhammers may be misidentified frequently as males due to increased yellow colouration (Blackburn 2006). Malar stripe colour seems to be a useful criterion in identifying male birds, with the majority of birds with chestnut flecks, or a solid chestnut malar stripe, and most birds with a pure yellow malar stripe identified as male on the basis of molecular evidence. However, less than half of the misidentified males could be successfully sexed using this method, suggesting that male birds with increased yellow or chestnut colouration are older and more easy to sex (Sundberg & Dixon 1996). Although only 77% of birds with brown flecks or a solid brown malar stripe were identified as female on the basis of

molecular evidence, all misidentified female birds could have been accurately sexed this way and thus this may be useful in identifying ambiguous female birds in conjunction with other criteria. The presence of a distinct yellow region above and behind the eye of a bird (Fig. 2b) could be used with high accuracy with both sexes, as male birds tended to possess this region and females tended not to. This could be used to identify 80% of both males and females previously misidentified in the hand.

Five novel criteria were found to differ significantly in their association with sex, with a high level of accuracy for at least one category within each. Most birds with only very small white patches on their fifth tail feathers were identified as female on the basis of molecular evidence, and all birds with white patches on their fifth tail feathers equivalent in size to the patches on the sixth were identified as male, although sample sizes within these two categories were relatively small and all misidentified birds possessed either small or medium white patches which show no significant association with either sex. The extent of the white colouration on the sixth and fifth tail feathers may be useful in sexing small numbers of birds: all birds with white colour reaching the shaft of the sixth tail feather on both sides were male, as were all birds with white colouration reaching the shaft of the fifth tail feather. The extent of black on the shaft of the longest upper-tail coverts may be useful in identifying both sexes: most birds with no black were male, nearly all birds with a completely black feather shaft were female, and the majority of birds with more than a third of the feather shaft black were also female. Whilst only 77% of birds with less than a third of the feather shaft black were male, there is a clear trend for females possessing more black on this feather shaft than males. However, less than half of misidentified birds could be sexed successfully using this criterion alone. Nearly all birds with a chestnut shaft on the short under-tail coverts were identified as male; however a large number of males, together with females, possessed a black shaft on these feathers.

The colour of the shaft of the rump feathers may be useful in sexing Yellowhammers, although accuracy was below 80%: female birds tended to have a black feather shaft, and male birds tended to have the shaft the same colour as the rest of the feather. All misidentified birds fitted this trend, so this criterion may be useful for sexing ambiguous birds.

Whilst tertial markings showed a significant differential association between sexes, the association was not clear, or accurate enough to be useful in determining sex. The longest under-tail covert colour showed a significant association although

accuracy was below 80%, with 68% of birds with black only identified as female and most birds with black and chestnut colouration identified as male. However, all male birds misidentified as female possessed black and chestnut colouration, so this may be a useful aid in identifying ambiguous males, but not females.

Morphometrics

Wing length and tail length both differed significantly between sexes and between age classes. Although there was a significant degree of overlap, over 80% of adults could be sexed accurately using wing length, provided they had been aged by other means; 80% of female wing lengths were below 87mm and 80% of male wing lengths were above this value. However, first years could, in general, not be sexed reliably using wing length alone except at the extremes, although this measurement could still be useful when considered in conjunction with other criteria.

Whilst tail length, beak length and depth differed between ages and sexes, these differences were small and thus could not be reliably used to differentiate between sexes or age classes.

Conclusion

The shape of outer and central tail feathers proved useful in ageing adult and first year birds respectively. Birds with worn and bleached central tail feathers tended to be first years; however first years often had fresh feathers so ageing birds with fresh central tail feathers was inaccurate. Birds possessing no black on the longest upper-tail covert tended to be first years, as did birds with white on both sides of their outermost tail feather shaft and birds with a chestnut shaft on the under-tail coverts.

The majority of birds could be sexed accurately using the amount of yellow visible on the crown and side of head. Chestnut and yellow malar stripe colour also proved useful in sexing some males. The amount of white on the outermost two tail feathers may be useful in identifying both sexes, with females tending to have less white on the fifth tail feather than males, and birds with white on both sides of the shaft of the outermost tail feather being male. The extent of black on the shaft of the longest upper-tail covert showed a clear relationship with sex, with females having a much larger amount of black than males, which tended to have very little or none. A chestnut shaft on the shorter under-tail coverts proved useful for identifying some

males. The shaft colour of the rump feathers and presence of black and chestnut colouration on the under-tail coverts may be useful in identifying ambiguous birds.

Birds with extremes of wing length could be identified as first year females and adult males and birds with long tails could be identified as males; the majority of adults, but not first years, could be sexed using wing length providing they had first been aged. No other morphometric variable considered here is likely to prove useful in ageing or sexing this species.

Criteria found to be useful for ageing and sexing this species are summarised in Appendix 1.

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Table 1. Features considered as likely predictors of age or sex, along with criteria used for each feature.

Feature	Criteria
Head	
% of visible yellow on crown	Less than 10% More than 20%
Malar stripe colour	Completely yellow (Yellow) Chestnut or chestnut flecks (Chestnut) Black or black flecks (Black) Brown or brown flecks (Brown)
Distinct bright yellow above and behind eye (region c in Figure 2b)	Yes No
Wing	
Shape of primary tips	Square Pointed Rounded Intermediate
Shape of primary coverts	Rounded Pointed
Width of primary coverts	Narrow Wide
Shape of secondary tips (Figure 4	Flat Notched
Wear and bleaching on tertial feathers	Fresh Worn and bleached
Markings on tertial feathers (Figure 4a)	Distinct demarcation between light and dark colouration (Distinct) Blurred boundary between light and dark colouration (Diffuse)
Shape of 2nd alula	Rounded Pointed
Shape of 3rd alula	Rounded Pointed
Yellow/white edging on median coverts	Yes No
Tail	
Shape of central tail feather tip	Pointed Rounded
Width of central tail feather	Narrow Wide
Central feather wear and bleaching	Worn and bleached Fresh
Angle/shape of outer tail feather (Svensson 1992)	Sharp Shallow
Extent of white on sixth (outer) tail feather	Reaches shaft Does not reach shaft
Extent of white on fifth tail feather	Reaches shaft Does not reach shaft
Size of white patch on fifth tail feather (Figure 4b)	Very small Small Medium Same as white patch on sixth tail feather
White on fourth tail feather	Present Absent
Coverts and body feathers	
Colour of shaft of rump feathers level with middle tertial	Black Chestnut (Blended)
Extent of black on shaft of longest tail covert (Figure 4c)	No black Short (less than 1/3 of shaft) black

	Half (1/3 – 2/3) of shaft black Entire feather shaft black
Colour of longest under-tail covert (in addition to yellow)	Black Black and chestnut
Colour of shaft of shorter under-tail coverts	Black Chestnut

1