White Wagtail and Pied Wagtail: a new look

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Probably every European birder is familiar with at least one of the two western European 'white wagtail' *Motacilla* taxa. White Wagtail *M alba* (hereafter *alba*) is a common breeding bird in nearly all European countries outside of Britain and Ireland, breeding as far north as Greenland, Jan Mayen (Norway) and Novaya Zemlya (Russia). Pied Wagtail *M yarrellii* (hereafter *yarrellii*) breeds commonly in Britain and Ireland, and scarcely from north-western France to southern Norway (Glutz von Blotzheim & Bauer 1985, Cramp 1988). Regular field guides aside, identification has been dealt with in depth by Glutz von Blotzheim & Bauer (1985), Cramp (1988), Harris et al (1989), Svensson (1992), Vinicombe (2000) and Alström et al (2003). In theory, separating the two taxa is rather straightforward: *yarrellii* typically has blackish upperparts and flanks, while these parts are grey in *alba*. Yet, why is it that birders seem to struggle time and time again with some contentious individuals?

In this paper, we propose a set of criteria that, in combination, will separate most birds. However, we also try to highlight the difficulties involved in this process and discuss a number of intermediate-looking birds – all of which we suggest to leave unidentified. Such intermediate birds have received little or no attention in the literature; yet, they appear to occur regularly throughout Europe.

We studied criteria for identification at the population level first, gathering data from museum skins and statistically analysing them. The relevant criteria could then be applied at the level of

315 Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, first summer, Maasvlakte, Zuid-Holland, Netherlands, 19 March 2008 *(Lesley van Loo)*. Aged by worn, brown outer greater coverts, lesser coverts, primary coverts and remiges. This bird had been caught and ringed as an *alba* in Scotland in September 2007 (Iain Livingstone in litt).

316 White Wagtail / Witte Kwikstaart *Motacilla alba*, Kalmthout, Antwerpen, Belgium, 29 June 2006 *(Glenn Vermeersch)*. Typical bird. Worn, brown primaries may suggest first-summer but cannot reliably be used for ageing after (early) spring. Possibly female, as nape does not appear deep black and does not run down onto upper mantle. Thin, dark pencil-like streaks on central mantle and scapulars are artefact of light often showing up in photographs of *alba*.

individual birds in the field, and are summarised in the second part of this paper.

To explain the intermediate appearance of some individual birds, we did extensive literature research on mixed breeding between *alba* and *yarrellii,* as well as on melanism in *alba*.

Mixed breeding

In Britain, *alba* occasionally breeds in Scotland, especially Shetland (Sharrock 1976), where birds have either paired with *yarrellii* or have bred in pure *alba* pairs. Forrester et al (2007) confirm that one or two pure or mixed pairs nest most years, usually in the Northern Isles (Orkney and Shetland). It occasionally breeds in the Outer Hebrides, Scotland, where a mixed pair (male *alba* and female *yarrellii*) was seen feeding young in 2003 (Andrew Stevenson in litt). In 1997, a pair of *alba* nested in Norfolk, England (Taylor et al 1999). *Alba* has colonised the Channel Islands, where *yarrellii* does not breed (Gibbons et al 1993). Many migrant *alba* pass through Britain and these are generally Icelandic birds (Cramp 1988).

Yarrellii, on the other hand, regularly breeds on the European continent, in Belgium, Denmark, France, Germany, the Netherlands, southern Norway and Sweden. The estimated population sizes for these countries are shown in table 1. Most birds nest in mixed pairs with *alba*, and many successfully produce young (cf plate 324), but there is not much information on the breeding success of hybrids in literature. Breeding is not confined to the coastal zones; there are records far inland from Doubs, France (near the Swiss border), in 1996 (Michelat & CHR 1999), from Bodensee, Baden-Württemberg, Germany, in 1998 (Hemprich & Frenz 2004), from the province of Liège, Belgium, in 1978 and Hainaut, Belgium, in at least 1985 and 2006 (Schmitz 1988; Dirk Verroken in litt), and from Limburg, the Netherlands, at least in 1949, once between 1973 and 1977, in 1991 and in 2003 (Swinkels 1992, Bakhuizen et al 2004). In France, a small, 'instable' hybrid population was present near Calais, Pas-de-Calais, in at least the late 1990s (Dubois et al 2008).

As most records of breeding *yarrellii* on the continent concern birds paired with *alba*, hybridization is relatively frequent. In the Netherlands, 74% of breeding *yarrellii* in 1990-2001 were paired with *alba* (SOVON Vogelonderzoek Nederland

TABLE 1 Annual number of breeding Pied Wagtails *Motacilla yarrellii* outside Britain and Ireland. Most birds pair up with *alba*.

Country	**Number of breeding birds (annually)**	**Source**
France	20-30 (but only 8 in 1985-89)	Yeatman-Berthelot & Jarry 1994, Dubois et al 2008
Belgium	2-6	Vermeersch 2004, Vermeersch et al 2006
Netherlands	4-30 (at least 20-30 during 1998-2000)	SOVON 1987, Bijlsma et al 2001, van Dijk et al 2002, SOVON Vogelonderzoek Nederland 2002
Germany	(irregular breeder)	Cramp 1988, Hemprich & Frenz 2004
Denmark	1-8	Grell 1998; Kent Olsen in litt
Norway	1-11	http://artsobservasjoner.no/fugler; Alexander Hellquist in litt
Sweden	1-5	SOVON Vogelonderzoek Nederland 2002; www.artportalen.se/birds; Alexander Hellquist in litt

2002). Because in most of the mixed pairs the *yarrellii* is a male, it is suspected that many breeding female *yarrellii* (and hybrids) are overlooked or misidentified. Therefore, the population estimates in table 1 should be considered minima.

Information on the appearance of hybrids, however, is very scant. The only references we found were Sueur (1982) and Triplet (1983). Sueur (1982), in a short note, presented two black-and-white drawings of presumed hybrids from Picardie, France. The first one (a) shows a bird with black mantle, grey scapulars and rather pale flanks, while the second (b) looks rather identical to a male *yarrellii*. The rump is not shown. The author also mentions a singing male bird from 1981, paired with a female *alba*, which had 'dark grey back and wings'. 'Wings', in this case, should presumably be interpreted as scapulars rather than the actual wing itself. Triplet (1983) presented a short (rather vague and slightly confusing) note without illustrations on the same singing male from 1981 as Sueur (1982), but described it as having 'blackish upperparts but dark grey uppertail-coverts, while the crown and bib were connected by a dark grey plumage'. He mentions another male, with a 'dark grey back contrasting with the crown, and connected to the bib by a dark grey zone, as in the previous bird; the wings were grey as in *M. a. alba*'. The author went on to say that, in the Bay de Somme area (north-western France), wagtails with the colour of the upperparts intermediate between *alba* and *yarrellii* are frequently seen. Even though Sueur (1982) stated that the birds observed were 'adult hybrids beyond doubt', it is not clear how this was established. In Triplet (1983), there was no mention of

317 White Wagtail / Witte Kwikstaart *Motacilla alba*, first-winter, Spain, 2 October *(Javier Blasco Zumeta)*. Note distinct moult contrast in greater coverts: outer four clearly browner than rest and showing thinner, abraded pale edges. **318** White Wagtail / Witte Kwikstaart *Motacilla alba*, first-summer female, Öland, Sweden, 4 May 2008 *(Anna Lindgren)*. Individual with rather dark grey rump but still within variation of *alba*. Female because of largely grey nape; aged by brown primaries (barely visible below longest tertial of right wing here, but clearly showing in other photographs of same bird) and obvious moult contrast in greater coverts (not visible here).

how the birds were sexed. It therefore appears that the only *known* hybrids documented so far have all been nestlings or recently fledged juveniles (cf plate 324), which cannot readily be identified.

Migration

Yarrellii either winters in its breeding range or migrates to western France, western Spain and Portugal (Cramp 1988). A few reach Morocco (Cramp 1988). *Alba* from western Europe (including Switzerland) migrates through the same areas and winters abundantly in Morocco (Thévenot et al 2003). There appears to be a migratory divide just east of Denmark at c 10-12 °E, with *alba* west of this line heading well south-west to western France, Iberia, and western Africa, and those east of this line heading south-east towards the eastern Mediterranean (Cramp 1988). There are, however, records of vagrant *yarrellii* quite far east, such as in Cyprus (1), the Czech Republic (2), Estonia (2), Finland (31 records, most of which will be reviewed though) and Hungary (1). Most of these are spring or summer records, with just three in September and one (the Hungarian record) in January. There are indications that *yarrellii* may follow a slightly easterly migration route in spring, and '100s' are reported to pass through the Netherlands in March-April (Cottaar 1995, Meininger & Wolf 1995), though some of these seem to be identified on flight views only, which we would not recommend. In autumn, on the other hand, British *yarrellii* seem to head directly south to north-western France, as shown by ringing in Scotland (Dougall 1991), and in the Low Countries they are much rarer in autumn than in spring.

Based on the distribution and migration routes, hybrids may be expected to predominantly migrate south-west.

Melanistic wagtails

Glutz von Blotzheim & Bauer (1985) briefly mention that 'melanistic *M. a. alba* are not rare', and they give three German references as examples (Thein 1953, Harry 1954, Kooiker 1977). As no other authors seem to mention anything about melanism in White Wagtails, we were intrigued and looked up these German references. All three are very short notes, not much more than five to 10 lines long. Thein (1953) described a bird with entirely deep black body but white outer tail-feathers. Harry (1954) noted a largely black bird, but 'with the natural pattern of *alba* still visible' and Kooiker (1977) saw an individual with a completely black body, including the underparts and tail. Nothing more is said about the appearance of these birds. In August 2007, a partially melanistic *alba* was photographed at Virelles, Belgium. This bird looked rather more like a normal (though scruffy) *alba*, but with dark grey flanks and largely grey belly and vent (PostFormPiafs 2008).

Ageing and sexing

When trying to identify some challenging birds, ageing and/or sexing them may help to narrow down the possibilities, particularly in autumn. However, this method is only helpful to a limited extent and its importance should not be overstated. Ageing wagtails is complicated, and should preferably be done in the hand. Sexing is far from always possible (see below). Ageing and sexing have been dealt with in detail by Glutz von Blotzheim & Bauer (1985), Svensson (1992) and Alström et al (2003). Here, we summarize some elements that are most helpful in the field.

Autumn ageing

Many first-winter birds differ from adults in showing a *moult contrast in the greater coverts*: the outer, juvenile ones are slightly duller, less contrasting in pattern than the rather black-and-white moulted coverts, and may show rather thin, brownish edges (plate 317). If no greater coverts have been moulted, ageing is (very) difficult and depends on correct judging of the age of the feathers: juvenile greater coverts show slightly greyer or browner centres and thinner, abraded pale edges. Generally, these edges show a dirty grey or brownish tinge sharply set off from the white covert tips. In adult greater coverts the colour of the edges and tips is more similar (greyish or white). However, there is some individual variation and overlap: some first-winter birds show rather contrasting juvenile greater coverts with prominent greyish or white edges, while in other birds the adult (or post-juvenile) greater coverts show grey edges and white tips. If all greater coverts have been replaced, ageing is best done in the hand. Note that the inner two or three greater coverts have greyer tips than the rest in all birds (including adults), which may simulate a moult contrast when there is none. A strong yellowish wash on the face is a good indication of first winter, but some adult females show a pale yellow wash there. Also, a bird with pinkish base to the lower mandible is more likely a first winter than an adult, but the colour may turn up in both age classes.




319 Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, female, Kluizen, Oost-Vlaanderen, Belgium, 11 April 2009 *(Peter Adriaens)*. Individual with adult-like plumage (no brown tinge on remiges and no greater coverts of juvenile type – as confirmed in further photographs of this individual), but with plain grey mantle and scapulars (except for few tiny black dots on upper mantle). Quite similar to *alba* but note extensive black rump (reaching between shortest pair of tertials) and extensively dark flanks. Few grey streaks on belly (not visible here). **320** Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, female, Oudenaarde, Oost-Vlaanderen, Belgium, 30 April 2007 *(Bart Heirweg)*. Plumage adult-like. Upperparts near paler end of variation in *yarrellii* but still much darker grey than in *alba*. Note also blackish lower rump and dark grey foreflank (score 1 – most of flank pattern hidden beneath wing here). **321** Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, first-winter, Cornwall, England, November 2008 *(Bart Heirweg)*. Aged by distinct moult contrast in greater coverts, outer ones being browner and shorter. Typical *yarrellii* of this age group; note blackish rump, lower back, crown and nape, white forehead and wide white tips to central greater coverts. **322** Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, first-winter, Cornwall, England, November 2008 *(Bart Heirweg)*. Aged by distinct moult contrast in greater coverts. An extreme bird of this age; note jet-black patch on rear ear-coverts (joining blackish nape and black gorget), pale forehead, black crown, blackish nape, extensively dark grey flanks, and few grey streaks on belly.

Autumn sexing

Sexing in autumn is only possible if the taxon is already known, rendering it useless for identification.

ALBA If age has been established, the extremes of *alba* can be sexed. Adult *alba* with extensive white forehead and solid black crown and nape are likely to be males, while those with grey forehead and nape should be females. Sexing of first-winter birds is usually not possible, but a first-winter *alba* showing quite adult-like head pattern with extensive white forehead and black nape should be a male.

323 Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, first-winter female, Oxfordshire, England, 31 January 2009 *(Jyrki Normaja)*. Aged by pattern of greater coverts: all still juvenile, being rather dull blackish-brown with thin, brownish-grey edges contrasting with white tips. Individual with unusually grey crown and upper forehead, perhaps not safely identifiable outside its usual range. Note, however, extensively grey flanks, dirty greyish belly, rather dark grey upperparts and partly white forehead. **324** Hybrid Pied x White Wagtail / hybride Rouwkwikstaart x Witte Kwikstaart *Motacilla yarrellii* x *alba*, juvenile, Jylland, Denmark, 18 June 2008 *(Kent Olsen)*. Offspring of male *yarrellii* and female *alba*. Quite impossible to identify in this plumage. **325** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, adult male, Falsterbo, Skåne, Sweden, 31 March 2002 *(Fredrik Hansson)*. Intermediate bird, first caught at Falsterbo in June 2000, when aged as first-summer and proved to be male by cloacal examination. It returned to area each spring up to 2006. In 2004, it bred successfully with female *alba*. Note obviously striped pattern on mantle, not fitting adult male *yarrellii*. **326** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, adult male, Falsterbo, Skåne, Sweden, 21 April 2004 *(Sophie Ehnbom)*. Same intermediate bird as in plate 325. In its sixth calendar-year, bird still shows pattern on upperparts not fitting adult male *yarrellii*. In the field, sexing birds like this would be quite impossible on plumage, and they might be easily passed off as female *yarrellii*. Note, however, in this case, striped pattern on mantle.

YARRELLII Unlike *alba*, the head pattern is similar in both sexes of *yarrellii*. In adults, the pattern of the upperparts may offer better clues: extensive black on upperparts should indicate a male and uniformly grey upperparts a female. Sexing of first-winter birds is usually not possible, but a *yarrellii* lacking black on crown and nape is likely a first-winter female.

A further pitfall is formed by birds that retain their juvenile plumage longer than usual, which is characterized by a thinner, duller blackish gorget and slightly duller head pattern than in first-winter birds. Some wagtails retain all or most of their juvenile feathers well into October and even migrate in this plumage. This may indicate a northern origin, but may also be a strategy for avoiding

aggressiveness from adult birds, which are more tolerant towards juvenile individuals (López et al 2005). In such largely juvenile birds, both *alba* and *yarrellii*, forehead, crown, nape and upperparts may be all grey.

Spring ageing
Ageing in spring is more complicated than in autumn, and we feel that its importance for identification in spring has been overstated sometimes. As the pre-breeding moult is only partial in both adult and first-year birds, moult contrasts are seen in both age classes. In addition, wear and pattern of the feathers vary individually to some extent. It is therefore not enough to note a moult contrast in the greater coverts; some experience is required to correctly interpret it. In adult birds, the old greater coverts are only moderately worn and still show rather blackish centres and whitish edges, making the difference with the new feathers rather subtle. In first-summer birds, the old outer greater coverts are often very worn and brownish. These may be distinctly shorter than the new feathers (beware of adults still growing a few coverts though), and may lack the pale edges completely. Some first-summer birds show *two moult limits in the greater coverts* (old, juvenile outer feathers, slightly fresher central feathers that were replaced in the post-juvenile moult in autumn, and newly moulted inner coverts), which is never shown by adults. One or two inner *tertials* may be very worn and brown too. Note, however, that adult birds show some contrast here too, as the inner two tertials are greyer than the black-and-white longest one. The wear and colour of the *primaries* can be of use too: clearly worn and brown flight-feathers in early spring indicate a first-summer bird, while birds that show dark grey or blackish primaries with thin pale edges in late spring are more likely adults. Some first-summer *yarrellii* (and probably *alba* too) show rather fresh and dark primaries throughout spring though. First-summer birds that have undergone an extensive pre-breeding moult can be impossible to distinguish from adults.

Spring sexing
ALBA Sexing is not always possible either in *alba*. Males usually differ from females in their solid black lower nape, which reaches down to (or onto) the upper mantle. Most females have a rather grey lower nape. However, our sample of museum skins contained a few known females (sexed by cloacal examination) that looked identical to males in this respect. Glutz von Blotzheim & Bauer (1985), Cramp (1988) and Alström et al (2003) also pointed out that a few female *alba* are indistinguishable from males. Some female *alba* show whitish spots on chin and/or throat, while this area is normally solid black in males (beware of birds still moulting though). Birds with a lot of black spots on the white forehead are more likely females, but many male *alba* show some spots too. A few first-summer female *alba* show a grey forehead, crown and nape and are easily told from males.
YARRELLII The head pattern is not helpful in *yarrellii*, and first-summer birds are often impossible to sex. Females usually have a solid black lower nape just like males. Birds with uniformly grey upperparts should be females though, and birds with entirely black upperparts males. Adult male *yarrellii* normally has largely black upperparts (though a few greyish patches may be admixed). The amount of black can be smaller in first-summer males, but our sample of museum skins did not contain known males with less than 40% solid black on the upperparts.

Identification: population level

Material and methods
As a basis for statistical analysis, we examined skins of three different populations: *yarrellii* (n=69; all from Britain); western *alba* (n=71; from Germany, France and the Netherlands, and one from Denmark); and eastern *alba* (n=65; from Armenia, Austria, Bahrain, Cyprus, Egypt, Finland, Greece, Hungary, Iran, Israel, Italy, Malta, Poland, Russia, Saudi Arabia, Switzerland and Turkey). The distinction between 'western' and 'eastern' *alba*, made in the British Museum of Natural History (Tring, London) and adopted by us, is a rather arbitrary one. We pooled all *alba* collected in western Europe into one group, and all other *alba* in another. The idea was to investigate whether birds breeding close to the range of *yarrellii* differed from other *alba* in any way. We focused solely on spring birds in summer plumage, as the differences between the taxa in this plumage are more pronounced than in winter plumage. We also examined a small number labelled as so-called '*dukhunensis*' (n=17; from India and Siberia, Russia) but these were not included in the results as the status of this taxon is unclear; some authors consider it a distinct subspecies (eg, Cramp 1988, Svensson 1992), while others include it in *alba* (eg, Alström et al 2003).

We checked several key parts of each bird's plumage and compared them with a Kodak grey-scale (a standard scale of grey values ranging from

327 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, male (dissected), collected in Poland on 16 May 1936 *(© National Museum of Natural History, Tring)*. Intermediate bird, probably first-summer because of worn, brownish inner pair of tertials. Labelled '*alba*' but with greyish-black mantle (some feathers missing) and some dark spots on lower scapulars. Upperparts (including rump = Kodak 12) otherwise rather too pale for male *yarrellii*. Flanks medium grey (Kodak 10), with extent score of 1. Length of white wedge on t5 59mm. **328** Pied Wagtail / Rouwkwikstaart *Motacilla yarrellii*, female, collected in Britain on 19 March 1944 *(© National Museum of Natural History, Tring)*. Example of spring bird without black on mantle/scapulars. Plumage rather adult-like (no juvenile wing-coverts; remiges fresh). Flanks dark grey and score = 1. Pattern of t5 = B. **329** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, first-summer male, collected in Iran on 1 April 1919 *(© National Museum of Natural History, Tring)*. Intermediate bird, aged by worn, very brown primaries. Note unusually large amount of black on mantle. Pattern of t5 (not visible here) = B.

FIGURE 1 Kodak grey values of rump in 'white wagtails' *Motacilla alba/yarrellii*; 0 = white and 19 = jet-black; A = white, M = medium grey and B = blackish

0 – white – to 19 – jet-black; see figure 1 and plate 327 for an example). This is an objective way of measuring, which prevented any potentially mislabelled specimens to influence the results. In particular, we noted the following: ***1*** (character A) Kodak grey value of rump (ie, area between the tips of the middle pair of tertials; see figure 2); ***2*** (character B) Kodak grey value of scapulars (in palest area); ***3*** (character C) Kodak grey value of mantle (in palest area); ***4*** (character D) Estimated amount (%) of black on mantle and scapulars. The mantle was seen as 40% of this area, the scapulars 60%, which means that if, for instance, black spotting was restricted to the mantle the estimate could never be larger than 40%; ***5*** (character E) Kodak grey value of flanks; ***6*** (character F) Extent of dark wash on flanks (0 = dark wash limited to upper flank; 1 = dark wash reaches down to belly in some parts of the flank; 2 = entirely dark lower flank, along belly. See figure 3); and ***7*** (character G) Number of dark spots on belly. In addition, we also checked the tail-pattern, as this is known to be a useful character in some taxa of 'white wagtail' (cf Sibley & Howell 1998) and in other wagtail species, such as various subspecies of Grey Wagtail *M cinerea* (Vaurie 1957, Cramp 1988, Alström et al 2003). We measured the length (in mm) of the white wedge on the inner web of t5 (the one but outermost tail-feather); this was called 'character H'. We also looked at the shape of this wedge towards the base of the feather (A = sharply pointed; B = rounded or oblique ≥45°) (see figure 4), but did not include this character in our statistical analysis as it did not produce a quantitative variable, but only an A or B value. The pattern of the other tail-feathers appeared to be of no use.

A further 252 skins of wagtails were examined and photographed (160 *yarrellii*, 80 western *alba* and 12 eastern *alba*) but were not compared with a Kodak greyscale and therefore not included in the analysis. This sample contained many autumn birds and was merely used as additional reference material.

330 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, male (dissected), collected in Gelderland, Netherlands, on 8 June 1959 *(© National Museum of Natural History, Tring)*. Intermediate bird, aged as first-summer because of two moult limits in greater coverts, with outer ones very worn and brown. Scattered dark spots on mantle and scapulars unusual for *alba* but upperparts too pale for male *yarrellii*. Kodak grey value of rump (not visible here) = 11. Extent score of flanks = 0. Length of white wedge on t5 = 50mm; shape = A.

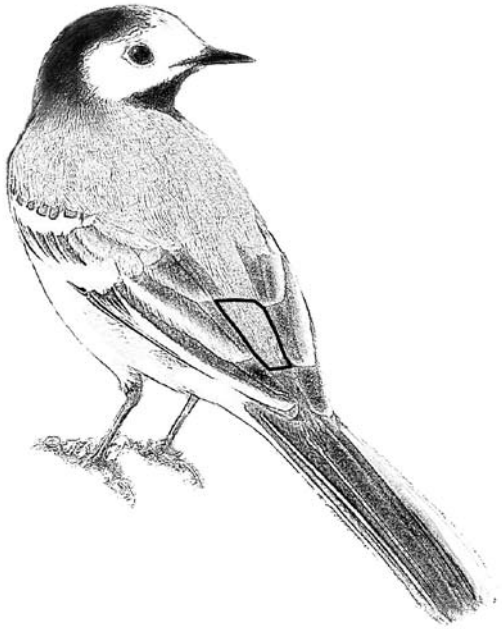

FIGURE 2 Exact indication of relevant rump area for identification of 'white wagtails' *Motacilla alba/yarrellii*

FIGURE 4 Shape of white wedge on inner web of t5 in 'white wagtails' *Motacilla alba/yarrellii*; pattern A = sharply pointed; B = rounded or oblique ≥45°

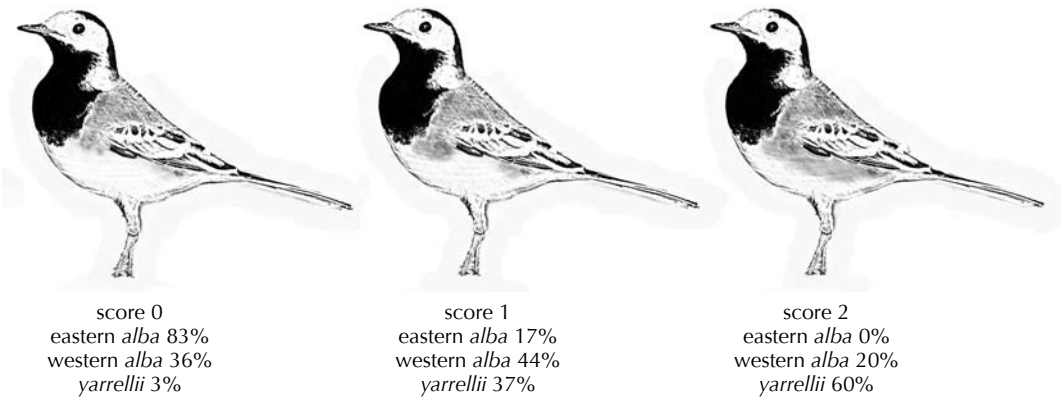

FIGURE 3 Extent of dark wash on flanks in 'white wagtails' *Motacilla alba/yarrellii*

Results and discussion

The statistical analyses (see appendix 1) divided our total sample in two distinct groups which corresponded very well with the classification into *alba* and *yarrellii* by museum staff. This shows that most summer-plumaged *alba* and *yarrellii* can be separated using a combination of characters. In our sample, the linear combination of characters A-E and G-H distinguished almost completely between these two taxa except for one *yarrellii* that

overlapped with (western) *alba*. The latter concerned a (probable) first-summer female collected in Wales on 20 March 1899 (figure 6 in appendix). If character H, the length of the white wedge on t5, is left out – as will usually be the case in field conditions – the number of birds in the overlap zone increases slightly (three birds labelled '*yarrellii*' in our sample; see figure 7 in appendix). The structure matrix of the most useful characters for separating *yarrellii* from *alba* is shown in table 5 (in appendix); the characters are discussed in detail below.

It is interesting to see that the statistical analyses of the museum data show a slight (but incomplete) discrimination between western and eastern *alba* (figure 6 and 7 in appendix). Both groups overlap broadly, but eastern *alba* averages slightly paler than western. The difference is most visible on the flanks: most show rather restricted grey wash on the flanks (score 0), and the colour is also quite pale (Kodak 1-8 in 96% of the eastern *alba* in our sample). No birds in our sample showed extensively dark flanks (score 2; see figure 3), but a few photographs from Israel in winter do show birds with such dark flanks. The preliminary conclusion could be that, at the population level, eastern *alba* is slightly more 'distant' in characters from *yarrellii* than western *alba*, but this should not be exaggerated; the discrimination between eastern and western *alba* is rather arbitrary and subtle, with a lot of overlap. Asian *alba* on average also tend to show more white in the wing-coverts compared to western birds, sometimes creating large white wing patches, but there is complete overlap in this respect, and western *alba* with a large amount of white in the wing-coverts are not rare.

Kodak grey value of rump (character A; measured in palest parts only)
In *yarrellii*, the colour ranges from dark grey to black, while it is medium to blackish-grey in *alba*. The grey values are shown in figure 1. As can be seen, there appears to be some overlap around value 13 (dark grey) and 14 (blackish-grey); 11% of *yarrellii* and 25% of western *alba* fell in this overlap zone. However, most of these pale-rumped *yarrellii* still showed blackish patches admixed. Note that it is important to look at the specific area between the tips of the middle pair of tertials (figure 2). The uppertail-coverts (area between the tips of the longest pair of tertials) are normally blackish in both *alba* and *yarrellii*. Of the *yarrellii* with palest rump in our sample (three birds with grey value of 13), two were females (one possibly an adult) but one was a male (with much black on the upperparts). Only the male had an entirely grey rump, contrasting with the black upperparts. Note also that the rump can be quite dark grey in *alba*, especially in western birds. Some even have a few blackish patches admixed, creating a rump area that is distinctly darker than the rest of the upperparts – although the rump is apparently never jet-black in its entirety. Some *yarrellii* have a blackish lower back (area between shortest pair of tertials) in addition to the rump, which again is not shown by *alba*.

Kodak grey value of scapulars (character B)
The colour ranges from fairly dark grey to black in *yarrellii* (Kodak 10-18), and medium grey to dark grey in *alba* (Kodak 7-11). Because the colour was measured in the palest parts only, the results may suggest a broad area of overlap around Kodak 10-11 between *yarrellii* (53%) and western *alba* (70%). However, the amount of black spotting on mantle/scapulars (character D) should also be considered and will separate many more birds.

Kodak grey value of mantle (character C)
In *yarrellii*, the colour of the mantle varies from fairly dark grey (Kodak 10) to black (Kodak 18). As the grey value was measured in the palest parts of the mantle only (see material and methods), there were two males among the palest birds but they had extensive black spotting on mantle and scapulars (50-70%). The other birds with a grey value of 10 on the mantle (four more birds) were all females; one was labelled as a first-summer, one as adult but looked more like a first-summer to us, and two were not aged. In *alba*, the colour of the mantle ranged from medium (Kodak 7) to very dark grey (Kodak 12), overlapping with *yarrellii*. One surprise, however, was an eastern *alba* with an exceptional value of 15 (greyish black) and 40% black spotting on mantle/scapulars (plate 327). It was a known male (sexed by dissection) collected in Poland on 16 May 1936. The full suite of characters put it within the range of *alba* but it could perhaps be considered as an intermediate bird.

Estimated amount (%) of black on mantle and scapulars (character D)
In *yarrellii*, the amount of black on the mantle/scapulars is really variable, ranging widely from 1-100%. Birds with less than 40% black were all females according to the museum labels, but many had not been sexed by dissection, so we do not know if these sex labels are correct. One of these birds (with only 3% black) was labelled




331-332 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, adult male, Nieuwpoort, Oost-Vlaanderen, Belgium, 15 March 2008 *(Peter Adriaens)*. Similar to male *alba* but note extensive black rump (reaching between shortest pair of tertials). Upperparts and flanks paler than in female *yarrellii*. **333** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, Wijster, Drenthe, Netherlands, April 2002 *(Rik Winters)*. Intermediate bird, similar to male *alba*, and perhaps that is what this is but note solid blackish rump. **334** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, adult, Nijkerk, Gelderland, Netherlands, 15 April 2006 *(Peter van der Wijst)*. Same bird as in plate 335. Note grey rump. Pattern of t5 = A.

adult but looked more like a first-summer to us, like most of the females with little black. Quite a few of these birds (13%) had rather plain grey mantle/scapulars (amount of black <5%; see plate 328 for an example). The darkest females had 60-80% black on the upperparts. Again, we do not know if their sex labels are correct. The palest males were two dissected, first-summer birds with 40% black. While it is quite normal to see (especially) male *alba* in which the black lower nape reaches onto the upper mantle (covering up to 10%), a few birds with black spots scattered across the mantle and scapulars were still a surprise to us. An example is shown in plate 330. In addition, three birds showed more than 10% of black on the upperparts: one male western *alba* with 15%, another male western *alba* with 30%, and the eastern *alba* shown in plate 327 with 40%.

Surprisingly, a few '*dukhunensis*' skins from Iran (not included in our sample for statistical analysis) also showed a large amount (c 40%) of black on mantle (see plate 329 for an example). We do not really know what such birds are; they were collected far outside the normal range of *yarrellii*. They might be the result of interbreeding between *alba* and another taxon; in Asia, interbreeding has been recorded with *personata, ocularis* and *baicalensis* (Alström et al 2003). However,

these three taxa show grey upperparts and rump (without black) in all plumages. In addition, these skins showed white neck sides like *alba*, while the combination *alba* x *personata* (the most likely type to occur in Iran, and sometimes referred to as '*persica*') could perhaps be expected to show traces of the dark neck-sides of the latter taxon. Cramp (1988) also reports occasional black suffusion on mantle, scapulars and sides of breast in male '*alba*-like birds', not only from western but also central Europe far from the breeding range of *yarrellii*.

Kodak grey value of and extent of dark wash on flanks (characters E-F)
In both taxa the colour is similar to or paler than that of the upperparts (mantle and scapulars). In *yarrellii*, it ranges from medium grey to jet-black (9-16), while it is greyish white to fairly dark grey in *alba* (1-10). Note the overlap zone around Kodak grey values 9 and 10; it includes 27% of *yarrellii* and no less than 44% of western *alba*. Character E may be further supported by the precise extent of the dark wash on the flanks (character F). Extensively dark flanks (score 2) are slightly more typical of *yarrellii*, but certainly occur in western *alba* too (20%). Further details are shown in figure 3. Two *yarrellii* (3%) in our sample had rather restricted dark colour on flanks (score 0). Rather surprisingly, they were both males, and in one of them the flank colour was a bit paler grey than usual (Kodak 10). In all other respects, however, they showed the characters of typical *yarrellii*.

Number of dark spots on belly (character G)
The presence of several (>1) distinct, isolated dark spots on the belly seems to be a fairly good indication of *yarrellii*, and it is therefore surprising that this character is apparently not described anywhere in literature. 38% of the *yarrellii* in our sample showed 2-12 spots, which were found both in males and females. The vast majority of *alba* (96%) did not show any spots; a few birds showed one dark spot only, and only one bird (male western *alba* from the Netherlands) had five, all close to the black breast area (but not connected to it).

335 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, adult, Nijkerk, Gelderland, Netherlands, 15 April 2006 *(Peter van der Wijst)*. Same bird as in plate 334. Intermediate bird, aged (at this time of year) by blackish primaries with white edges and lack of juvenile wing-coverts. Very like female *yarrellii* but note pale flank (score = 0) and medium grey ground colour to upperparts. Longest uppertail-coverts (just visible below primary tips) seem strangely pale for *yarrellii*. Unfortunately, ring number could not be read.




336 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, Nieuwpoort, Oost-Vlaanderen, Belgium, 15 March 2008 *(Peter Adriaens)*. Intermediate bird, rather like *alba* but with scattered blackish patches on mantle and scapulars. Rump was grey (not visible here). Bird was present in same spot at same time as individual in plate 331-332. **337** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, Chiemsee, Bayern, Germany, 9 April 2008 *(Jörg Langenberg)*. Intermediate bird, rather similar to female *yarrellii* but note grey rump (just visible above middle tertial). **338** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, Maashorst, Noord-Brabant, Netherlands, 8 March 2008 *(Carel van der Sanden)*. Intermediate bird; dark grey with blackish upper mantle. Note grey rump. **339** 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, IJburg, Amsterdam, Noord-Holland, Netherlands, 19 April 2008 *(Jacob Garvelink)*. Intermediate bird; another example of a dark grey bird with blackish spots on upper mantle (suggesting *yarrellii*) but with grey rump (like *alba*).

Length of white wedge on inner web of t5 (character H)

The length of the white wedge on the inner web of the second outermost rectrix is variable (ranging from 35 to 76 mm in our sample) but tends to be shorter on average in *yarrellii* (maximum 67 mm). In *alba*, it is quite often longer than 60 mm, which was the case in only a few *yarrellii*. There is a lot of overlap though; see table 2 for more details. The shape of the white wedge should also be considered. It is usually either very pointed towards the base of the feather (cf figure 4: pattern A), or rather rounded or oblique (>45°; cf figure 4: pattern B). Pattern A is slightly more typical of *alba*, and pattern B slightly more typical of *yarrellii* but, again, there is much overlap. The tail-pattern is therefore of little use, and is very difficult to establish in the field. It could perhaps be used as a supporting feature by ringers though, in combination with characters A-G.

TABLE 2 Length of white wedge on inner web of t5

Length (mm)	**% *yarrellii***	**% western *alba***	**% eastern *alba***
< 50	37	8	17
50-60	57	66	53
> 60	6	26	30

Identification: individual level

Introduction

Our museum research provided us with a good reference base for the identification of *alba* and *yarrellii*. In addition, we also had access to numerous photographs of *alba* in the hand, and lots of photographs of *alba* and *yarrellii* in the field. From these data, and from our own field experiences, it is clear that separating *alba* and *yarrellii* should be done using a full combination of characters. This is important, as identification appears to be hampered by the regular occurrence of puzzling 'intermediate birds'. As Glutz von Blotzheim & Bauer (1985) state, when discussing the identification of the two taxa: 'Not every wagtail with a black(ish) back is a *yarrellii*'. This statement seems to have been overlooked by many authors. We will explain and illustrate it in the following sections. It should be noted that identification is more difficult in autumn than in spring, as many *yarrellii* show medium grey upperparts then, like *alba*. Some birds can be very tricky, and mistakes are sometimes made even with the bird in the hand (cf plate 315). A summary of the necessary field identification criteria can be found in table 3.

Identification characters

Spring

In spring and summer, the differences between *alba* and *yarrellii* are most pronounced but identification is hampered by the occurrence of intermediate birds (see next sections). It is therefore important to check as many characters as possible (see discussion of characters A-G above). Museum skins could be conveniently compared with a Kodak greyscale. In the field, however, assessing the grey tones of the upperparts may not be straightforward, especially on a lone bird. Light conditions play an important role, so patience and careful comparison with other wagtails nearby may be necessary for less than typical birds. Often the rump is hidden beneath the tertials, so patience may again be required. Individual variation should also be taken into account; a bird with slightly darker grey upperparts in a flock of typical *alba* is not necessarily a *yarrellii*, and vice versa.

Three additional points should be mentioned here: ***1*** In spring *yarrellii*, the mantle and scapulars are either solidly blackish, spotted with blackish or uniformly dark grey. They do not normally appear striped. ***2*** In a few spring female *yarrellii*, the uniformly grey upperparts contrast with a rather well-demarcated black nape, inviting confusion with *alba*. Check rump, flanks and belly, and note that the upperparts are slightly darker grey than in the latter taxon. However, it is possible that some birds are better left unidentified. ***3*** A grey lower nape is more typical of (female) *alba*, while in spring female *yarrellii* this area is typically blackish. There is overlap though, and some female *yarrellii* do have a grey lower nape.

Autumn

Character A-G are still important (and should be used in combination) but identification is complicated because many autumn *yarrellii* show uniformly medium grey mantle and scapulars without any black, like *alba*. A few birds also appear to lack black on the rump. The following additional features can be helpful though: ***1*** If it is possible to correctly age the bird, head pattern can be of some use. A first-winter wagtail with whitish forehead, black crown and blackish nape is more likely a *yarrellii*, as only a few first-winter male *alba* show this much black and white here. Some first-winter female *alba* show entirely grey forehead, crown and nape without black, which is uncommon in *yarrellii* (only a few first-winter females – but beware of late-moulting juveniles). Adult birds with no or little black on crown and nape should also be *alba*, as adult *yarrellii* show at least a blackish crown. Another feature may occasionally be seen on the ear-coverts: a few autumn *yarrellii* show a solid, extensively blackish patch here, joining the blackish nape with the black gorget (plate 322). Such a dark and extensive pattern, which may even recall Moroccan Wagtail *M subpersonata*, is only rarely matched by *alba*. Very occasionally, *yarrellii* may show blackish lores in autumn, which is not normally shown by *alba*. ***2*** Wing-coverts of the same age may differ slightly between both taxa: *yarrellii* on average shows slightly blacker centres and wider white tips to the greater coverts. ***3*** In some autumn *yarrellii*, the belly may show a

TABLE 3 Summary of field criteria of White Wagtail *Motacilla alba* and Pied Wagtail *M yarrellii*. For grey scale values, see section 'Identification: population level'.

	spring		**autumn (post-juvenile)**	
	alba	*yarrellii*	*alba*	*yarrellii*
rump (character A; cf figure 2)	medium grey to blackish grey	blackish to black	medium grey to blackish grey	blackish to black (very few exceptions)
colour of mantle/ scapulars (characters B-C)	medium grey to dark grey	dark grey to black; no distinct stripes on mantle	medium grey to dark grey	medium grey to black; no distinct stripes on mantle
% of blackish colour on mantle/scapulars (character D)	0-10%	1-100%	0(-10?)%	0-100%
colour of flanks (character E)	greyish-white to dark grey	medium grey to black	greyish-white to dark grey	medium grey to black
extent score of flank pattern (character F; cf figure 3)	mostly 0-1 but sometimes 2	mostly 1-2	mostly 0-1 but sometimes 2	mostly 1-2
pattern of belly (character G)	rather clean white	sometimes with distinct dark spots	rather clean white	sometimes with distinct dark spots or dark greyish streaks
head pattern			some have entirely grey forehead, crown and nape (without black), unlike most *yarrellii* (only few first-winter)	many first-winter show white forehead, black crown and blackish nape, unlike most first-winter *alba*; few birds show extensively blackish ear-coverts

few prominent dark spots (as in spring; character G) or may have dirty, greyish streaks. In *alba*, the belly is usually rather clean white.

Juveniles of both taxa cannot usually be told from one another, but a few juvenile *yarrellii* already develop a blackish rump and/or blackish crown and nape early on. Also, their greater and median coverts may give a more black-and-white impression due to deeper black centres and wider white tips, and their flanks may be more extensively grey.

The apparent lack of intermediate birds in autumn is striking, but is perhaps not so surprising when considering the great similarity between *alba* and *yarrellii* at this time of the year.

Intermediate birds

Particularly in spring, birds that appear to show mixed characters of both *alba* and *yarrellii* occur rather frequently, on the continent and in Britain. Examples are shown in plate 325-326 and 331-342; see also plate 327, 329 and 330. We prefer to leave such birds unidentified and call them 'intermediates' rather than hybrids, for various reasons: ***1*** We do not actually know what hybrids really look like; ***2*** Intermediate birds are sometimes found far from the usual range of *yarrellii*, eg, in Israel and on Crete, Greece (where even three such birds were seen within the same week; Newell 2008); they are also far from the usual range of other 'white wagtail' taxa that have been recorded to interbreed (ie, *personata*, *ocularis* and *baicalensis*) and do not show the characters of those taxa. See also the discussion under 'Population level'; and ***3*** Other factors could play a role, such as partial melanism (see above) or just unu-

sual variation in *alba* and/or *yarrellii*. While the appearance of intermediate birds is variable, two types in spring (ie, in summer plumage) seem slightly more frequent than others: ***1*** birds that look rather like a male *alba*, but with black rump. Such birds frequently have broad white edges to the wing-coverts and medium bluish-grey upperparts (contrasting with the rump), sometimes with a few black spots on the mantle (see plate 331-333); and ***2*** birds with medium grey upperparts (paler than most *yarrellii*) and little or no black on rump but with variable amount of black on mantle and/or scapulars. Flanks can be rather pale too. Some birds show a distinct pattern of strong, black stripes on the mantle (cf plate 325-326). This is not normally seen in *yarrellii* (Killian Mullarney, Aidan Kelly & Harry Hussey in litt). We have also seen photographs of birds (from the Netherlands) that look very similar to female *yarrellii*, but were paired with female *alba* and showed male-like behaviour, such as singing, which leaves little doubt of them actually being male *alba*, or hybrids.

Vocalizations

There seem to be very few vocal differences between the two taxa. However, while the song and calls of *alba* may all be matched by *yarrellii*, there appears to be one type of flight call in the latter that does not have an equivalent in *alba*. This subject is dealt with thoroughly in a separate paper (Robb et al 2010).

Conclusions

Identification of *alba* and *yarrellii* is hampered by the regular occurrence of birds with intermediate characters throughout Europe. While many of these birds are likely hybrids, as hybridization is regularly reported from western Europe and southern Scandinavia, it is suspected that some may concern birds with partial melanism or just unusual plumage variation. It is therefore strongly recommended to base the identification on as many characters as possible. We would advise against identifying wagtails solely in flight, as is often done on some migration watch points. The important field criteria are summarized in table 3.

340 'White wagtail' / 'witte kwikstaart' *Motacilla alba/yarrellii*, Toscana, Italy, 8 March 2008 *(Daniele Occhiato)*. Intermediate bird. Brownish tinge on the secondaries (contrasting with black centre of longest tertial) this early in the season, as well as slight brownish tinge and worn state of inner two tertials suggest this is a first-summer bird. Scattered black patches on mantle and scapulars may suggest *yarrellii* but rump and back too pale. Also, foreflank looks only medium grey.

341 'White wagtail' / 'witte kwikstaart' *Motacilla alba/ yarrellii*, singing male, Veghel, Noord-Brabant, Netherlands, 26 March 2008 *(Carel van der Sanden)*. Intermediate bird; plumage adult-like. Medium grey bird with blackish pattern on mantle. Rump was grey (not visible here). Plumage much too pale for male *yarrellii*.

342 'White wagtail' / 'witte kwikstaart' *Motacilla alba/ yarrellii*, Nieuwpoort, Oost-Vlaanderen, Belgium, 13 April 2008 *(Diederik D'Hert)*. Intermediate bird; extensive white forehead, reaching slightly beyond eye, suggests male. Scattered black patches on mantle and scapulars may suggest female *yarrellii* but upperparts medium grey like *alba*. If this is a male indeed, it is much too pale for *yarrellii*.

Note that identification often comes down to correct assessment of the colour of upperparts and flanks. In the hand, a Kodak grey scale is a useful aid for this, but in the field extensive experience with both taxa may be required. The pattern of the belly can be a helpful feature in some birds, and has received little or no attention up to now.

Ageing and sexing may be of some further help at times (particularly in autumn), but can be extremely difficult in the field. It should be emphasized that, in spring, some (first-summer?) female *yarrellii* (with uniformly grey upperparts) may show very adult-like greater coverts, tertials and primaries, as well as a sharply demarcated black lower nape, making them sometimes difficult to age, sex and identify. Birds that do not match the criteria in table 3 should probably be seen as intermediate and left unidentified. Again, we want to point out that individuals with a prominently striped pattern on the mantle (as sometimes seen on the continent) do not match the usual appearance of British and Irish *yarrellii*.

This paper is far from the last word on the subject, and we realize that it leaves certain questions unanswered. In particular, colour-ringing of hybrid offspring would be interesting, so we could learn more about their appearance and movements. Also, genetic studies on western *alba* (including intermediate birds) might be helpful.

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Samenvatting

WITTE KWIKSTAART EN ROUWKWIKSTAART OPNIEUW BEKEKEN

Dit artikel behandelt de herkenning van Witte Kwikstaart *Motacilla alba* en Rouwkwikstaart *M yarrellii*. Onderzoek toont aan dat de determinatie lang niet altijd eenvoudig is en dat 'intermediaire vogels' regelmatig voorkomen. Aan de hand van statistische analyse van onderzoek aan balgen is een set criteria bepaald die het mogelijk maakt om de meeste Rouwkwikstaarten van Witte Kwikstaarten te onderscheiden (in ieder geval in zomerkleed). De grenzen van de variatie in beide taxa worden aangegeven. De set criteria is samengevat in tabel 3 en de relevante Kodak-grijswaarden worden aangegeven in de tekst.

In het artikel worden tevens de meest bruikbare leeftijds- en geslachtskenmerken besproken. Die kunnen in sommige gevallen helpen om een vogel correct op soort te brengen. Vooral in het voorjaar kan het erg moeilijk tot zelfs onmogelijk zijn een exemplaar correct op leeftijd en geslacht te brengen. Zo hebben sommige eerstezomer Rouwkwikstaarten het hele voorjaar een erg adult-achtige vleugel en zien sommige vrouwtjes Witte Kwikstaart er net als mannetjes uit. Vogels die kenmerken van zowel Witte Kwikstaart als Rouwkwikstaart combineren, zijn tenminste in het voorjaar niet zeldzaam en kregen tot nu toe nauwelijks aandacht in de literatuur. Het verenkleed van dergelijke vogels is variabel maar twee typen lijken iets frequenter voor te komen dan andere: ***1*** exemplaren die er uitzien als mannetje Witte Kwikstaart maar met een zwarte stuit en soms ook enkele zwarte vlekjes op de mantel, die vaak nogal blauwachtig grijs is; ***2*** exemplaren met neutraal grijze bovendelen en stuit (als Witte Kwikstaart of iets donkerder) maar met variabele hoeveelheid zwart op mantel en/of schouderveren (als Rouwkwikstaart). Sommige vogels tonen een opvallend patroon van zwarte lengtestrepen op de mantel, wat Rouwkwikstaart normaal niet heeft. De meest voor de hand liggende verklaring is dat ten minste een deel van deze vogels hybriden betreft maar daarover bestaat geen zekerheid. Gemengde broedparen van Witte Kwikstaart en Rouwkwikstaart zijn niet zeldzaam en worden (vrijwel) jaarlijks vastgesteld in België, Denemarken, Frankrijk, Nederland, Noorwegen en Zweden (zie tabel 1). Andere mogelijkheden zijn dat het in sommige gevallen gaat om partieel melanisme (bij Witte Kwikstaart) of om kleedvariatie (bijvoorbeeld Witte Kwikstaart met ongewoon donkere mantel, Rouwkwikstaart met ongewoon bleke stuit etc). Het is zeker op plaatsen waar Rouwkwikstaart een dwaalgast is aan te raden een exemplaar alleen te determineren als de combinatie van kenmerken zoals vermeld in tabel 3 sluitend is.

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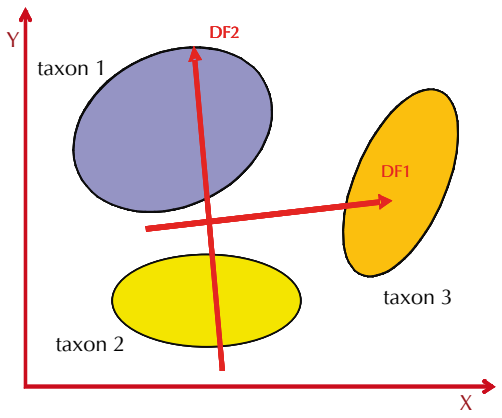
APPENDIX 1

Results of discriminant function analyses (DFA)

All of the values of the eight characters (or variables) were entered into an Access database, and several discriminant function analyses (DFA) were performed on this dataset using SPSS 16 and SAS 9_2 statistical packages. For three groups (in this case: *yarrellii*, western *alba* and eastern *alba*), a DFA will produce two discriminant axes/functions (figure 5). This can only be achieved through two linear transformations of the original variables, $Z_1 = a_1X_1+b_1X_2+c_1X_3+d_1X_4+e_1X_5+f_1X_6+g_1X_7+h_1X_8$ and $Z_2 = a_2X_1+b_2X_2+c_2X_3+d_2X_4+e_2X_5+f_2X_6+g_2X_7+h_2X_8$ with $a_{1,2}$-$h_{1,2}$ the relative importance of the eight original variables X_{1-8} to the new variables $Z_{1,2}$ along the two discriminant axes respectively. So, the two discriminant functions independently hold information about all the original variables and their relative importance, and in addition can be represented in a two-dimensional X-Y scatter plot. This makes visualization and interpretation of the data much more feasible. A first note of caution is that DFA is used for continuous variables. For the wagtail database, the only true continuous variable is 't5' (character H). Character A-C and E are categorical data measured on a Kodak greyscale from 0 to 19. We argue that they are continuous enough to be treated as such. Character F, with its three classes only (0, 1 and 2), is troublesome in this respect and is therefore excluded from the analysis. This variable is dealt with in figure 3. Character D and G represent proportional and count data respectively. Violation of the normality assumption is, however, not fatal. Second, there is a high degree of multicollinearity. Not surprisingly, character B, C and D show high within-group correlations (table 4). In plain English this means that a wagtail with a darker mantle will also tend to have darker scapulars and more extensive dark spotting or covering on mantle and scapulars.

FIGURE 5 Theoretical structure of discriminant function analysis



Multicollinearity does not reduce the reliability of our DFA as a whole, because an analysis with correlated variables can still indicate how well the entire bundle of predictor variables (X_{1-8}) predicts the outcome variable (= taxonomic group), but it may not give valid results

TABLE 4 Within-group correlation of some identification characters in 'white wagtails' *Motacilla alba/yarrellii*

	C (mantle)	**B (scapulars)**	**D (% black on upperparts)**
C (mantle)	1		
B (scapulars)	0.78	1	
D (% black on upperparts)	0.76	0.71	1

TABLE 5 Structure matrix of character A-E and G-H

Character	**DF1**	**DF2**
A	0.893*	0.170
E	0.555*	0.445
C	0.531*	0.010
B	0.483*	0.154
D	0.478*	-0.443
G	0.209*	0.153
H	-0.189*	0.147

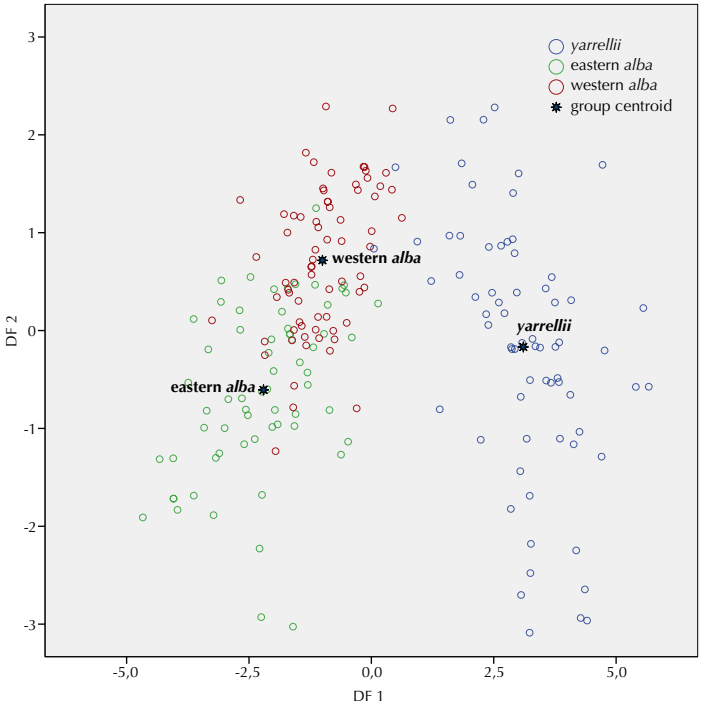
*. largest absolute correlation between each variable and any discriminant function

TABLE 6 Discriminant functions at Group Centroids of character A-E and G-H

taxon	**DF1**	**DF2**
yarrellii	3.104	-0.168
eastern *alba*	-2.203	-0.606
western *alba*	-0.999	0.718

about the relative importance of any individual variable, or about which variables are redundant to other ones. Last but not least, there is troublesome heterogeneity of variances. If the only goal is to find linear transformations to distinguish groups and not classification, this assumption can be slightly relaxed, but DFA remains very sensitive to any violation of this assumption. Transformation of the data did not reduce heterogeneity. We therefore want to stress that DFA is only used here in addition to a thorough graphical and manual exploration of the dataset. Nevertheless, we got interpretable results in accordance to our graphical analysis. A total of four DFAs were performed: ***1*** DFA-1 of all characters, except F; ***2*** DFA-2 of six out of eight characters (ie, excluding F and H, as the latter was considered not very useful in field conditions); ***3*** DFA-3 of all characters, except F, in males only (n=124); and ***4*** DFA-4 of all characters, except F, in females only (n=64).

FIGURE 6 Discriminant function analysis 1 of character A-E and G-H



DFA-1

The first discriminant function (DF1) was statistically significant, $\Lambda = 0.123$, χ^2 (14, n=205) = 416.8, p<0.001. It primarily separates *yarrellii* from western and eastern *alba* (figure 6] and table 6) and explains 94.4% of the between-group variability. The loadings in the structure matrix (table 5) show that wagtails (*yarrellii*) that scored high on DF1 have darker rumps in the first place (character A), but also tend to have darker mantle (C), scapulars (B) and flanks (E) and more black(ish) spotting or covering on mantle and scapulars (D). To a much lesser degree, they show a tendency for a higher number of dark spots on the belly (G) and a slightly shorter white wedge on T5 (H). Both

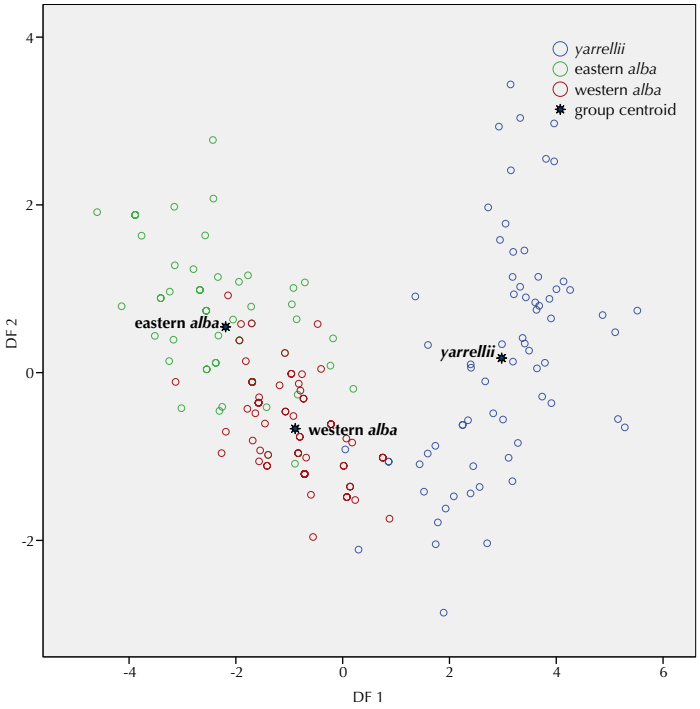


FIGURE 7 Discriminant function analysis 2 of character A-E and G

eastern and western *alba* fall below centre line for DF1 but with less negative and thus slightly higher scores for western *alba*, albeit with large overlap between the two (figure 6 and table 6). Hence, most eastern *alba* will be among the palest on upperparts and flanks. The second discriminant function (DF2) was again statistically significant, Λ=0.764, χ^2 (6, n=205) = 53.6, p<0.001. This one seems to discriminate (incompletely) between eastern and western *alba* and explains the remaining 5.6% of the between-group variability (figure 6 and table 6). Again we take a look at the structure matrix (table 5) and find that there is not a single variable that can be reliably interpreted, although the high loading for character E indicates that the darker flanks of western *alba* are important for the separation of western *alba* along DF2, in accordance with our graphical analysis.

DFA-2

The resulting output is quite the same as with character H included, though with more overlap between *yarrellii* and darker *alba* sensu lato and with our data points mirrored around the centre line of DF2, because by coincidence and omission of H the signs of the scores of eastern and western *alba* were switched (figure 7).

DFA-3 and DFA-4

These two DFAs, performed to investigate the influence of sex, gave similar results as the first analysis for both sexes concerning the discrimination between *yarrellii* and *alba* sensu lato (graphs not shown). Between eastern (n=17) and western (n=15) *alba,* however, females showed a larger discrimination along DF1 than males but due to the low sample sizes (n<20) – partly the result of incomplete labelling in the museum – we do not place much importance on this. Furthermore, this paper is primarily concerned with the separation of *alba* and *yarrellii*. We therefore conclude that the field marks are valid for both males and females.