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Identification of Marsh Warblers *Acrocephalus palustris* and Reed Warblers *A. scirpaceus* on autumn migration through the eastern Mediterranean

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Published criteria for the separation of Reed Warbler Acrocephalus scirpaceus *and Marsh Warbler* A palustris *in the hand were found to be of limited value in identifying these species in samples captured during autumn migration through the island of Lesvos in the Aegean Sea. This is probably because Reed Warbler morphology varies clinally with birds in eastern Europe (likely to be migrating through Lesvos) being more similar to Marsh Warblers than are populations in western Europe from which existing identification criteria were calculated. However, a modified biometric index did separate a sample of 364 birds captured during August and September 1994-1996 and 1998 into two clear-cut groups along the morphological gradient which is known to distinguish the two species. We were therefore confident that these two groups comprised Marsh and Reed Warblers. Linear Discriminant Function Analysis confirmed that this index could be used to identify approximately 95% of the birds in our sample. The index also correlates well with independent assessments of bare part colouration (eg leg colour) which are known to be of use in distinguishing the two species. We suggest that this index will be useful for identifying Reed and Marsh Warblers wherever migrating populations of the two species drawn from a wide geographical area occur together.*

With the exception of singing males, separation of Marsh Warblers *Acrocephalus palustris* from Reed Warblers *A. scirpaceus* is difficult. Plumage and bare part colouration overlap considerably, especially amongst first-year birds, which means that safe identification of most individuals in the hand should be based on a combination of biometrics (Walinder *et al.* 1988, Cramp 1992, Svensson 1992). Svensson (1992) suggested that the two species can be distinguished according to the measurement criteria listed in Table 1. These criteria are based on samples of birds captured in northern and western Europe.

During 15-21 September 1994, 7-19 September 1995, 29 August - 10 September 1996, and 6-16 September 1998 we captured a total of 364 Marsh or Reed Warblers in mist-nets erected in scrub and dry reedbed habitats at Charamida Marsh on the island of Lesvos, Greece (39° 01'N 26° 33'E) during a programme of general ringing of autumn migrants. Reed Warblers migrating southwards across the Aegean Sea at this time originate from central and eastern Europe (nominate race), and may also include small numbers of the Asian race *A. s. fuscus* which breeds as close to Greece as eastern Turkey, Cyprus and the Middle East, and migrates in a southerly or south-westerly direction to reach its east African wintering grounds. Marsh Warblers may have originated almost anywhere within their European breeding range (Cramp

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Table 1. Measurements quoted by Svensson (1992) as being of value in distinguishing Marsh and Reed Warblers. Those variables marked with an asterisk show bimodality which reflects morphological differences between the two species, and are of greatest value in helping to identify birds. A = adult, FY = first year. + referred to hereafter as the 'Walinder' index (from Walinder *et al.* 1988).

Measurements (mm)	*Marsh Warbler*		*Reed Warbler*	
	A	FY	A	FY
Wing length	68-76	67-74	62-73	
Bill tip to skull	14.3-17.2		15.0-18.5	
Length of notch on second primary	8.5-12.0	7.5-11	11-15	9.5-13.5
Wing-point to tip of first secondary measured on closed wing	17.5-22.0		15.0-19.0	
Foot span	30.3-33.2	no data	32-37	no data
Indices				
	A	FY	A	FY
Notch length/Wing length*	0.125-0.160	0.107-0.157	0.167-0.231	0.144-0.200
Wing length/Bill tip to skull*	4.16-4.86		3.67-4.21	
Bill tip to skull - (Tarsus width x bill width at nostrils)*+	4.5-8.0		8.5-12.5	

1992). Timing of autumn migration of the two species does not differ markedly (Cramp 1992), and it was very likely that at the time of our visit we were capturing both species. However, measurements from the first individuals captured indicated that use of the criteria in Table 1 was unsatisfactory. Many birds fell into the overlap zones between the quoted measurement ranges for the two species making specific identification uncertain. This problem has also been encountered in studies in Hungary and Bulgaria where 20% of adult birds and 50% of juveniles fell into the overlap zone (Kormos & Csörgö 1991). We therefore recorded a wide range of biometrics in order to determine whether an alternative set of criteria could be found to separate the two species with greater confidence. This paper presents the results of these analyses.

METHODS

The following data were recorded from each individual captured: age (first year or adult), wing length, length of notch on second primary ('notch'), bill length measured to the skull ('bill-to-skull'), distance between the wing-tip and the tip of the first (outermost) secondary measured on the closed wing ('wing-tip to first secondary'), bill width at the nostrils ('bill width'), tarsus length (using the 'bent toes' method), tarsus width, hind claw length, and foot span (including claws). All measurements were recorded using a steel wing rule or dial calipers, according to the procedures set out in Svensson (1992). Wing length was measured to an accuracy of ±1mm, foot span to an accuracy of ± 0.5mm, and the remaining measures to an accuracy of ±0.1mm. The abdominal fat score (Gosler 1994) and mass (to an accuracy of ±0.1g using a 50g Pesola balance) of each bird were also recorded but were not used in the following analyses since they vary considerably both within and between days, especially in the case of migrating birds. In 1996 and 1998, leg and claw colouration was recorded on an arbitrary scale of 1-3 in order to provide an additional measure, correlated with a known difference between the species in other populations, that was independent of body size measures. A score of '1' indicated a bird with dull bluish-grey legs typical of classical Reed Warblers, a score of '3' indicated a bird with pale straw-yellow legs typical of a classical Marsh Warbler (Harris *et al.* 1996), whilst all birds intermediate between these extremes were scored as '2'. Birds were measured either by one of the authors (JDW), or by other observers whose measurements were known to be consistent with those of JDW. Statistical analyses were carried out using version 11 of the MINITAB statistical software package.

RESULTS

In total, biometrics were recorded for 48 adult and 316 first year Reed/Marsh Warblers, although foot span was not recorded for 24 birds caught in 1994. Adults were much less frequently captured than first year birds, probably because most adults of both species had already left Europe by the time of our visits in September (Cramp 1992, Akriotis 1998). The raw data are summarised in Table 2. Visual inspection of the distribution of each of the variables listed in Table 2 revealed no evidence of marked bimodality that might indicate that the birds present in the sample were significantly dimorphic in any single measure, or in the indices recommended by Svensson (1992) (Fig 1). This means either (i) that the criteria proposed by Svensson to assist identification cannot be applied because populations of the two species migrating through Lesvos overlap too greatly along these morphological gradients, or (ii) that we were capturing only one of the two species. We considered the latter explanation unlikely because of the similar timing and route of migration of the two species through the eastern Mediterranean, and because the sample of birds spanned the range of plumage and bare part colouration described and illustrated by Cramp (1992) and Snow & Perrins (1998).

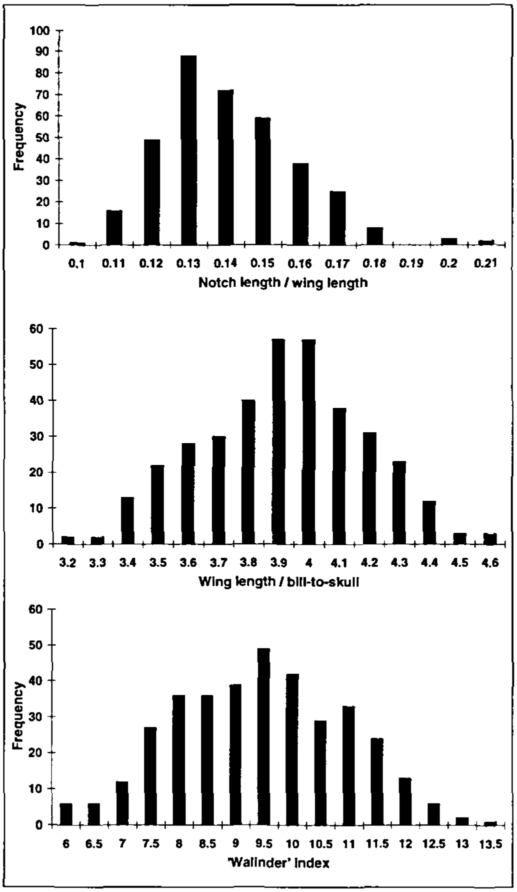

Figure 1. Frequency distribution of three biometric indices recommended by Svensson (1992) for the sample of Reed/ Marsh Warblers in our study. (a) notch length / wing length, (b) wing length / bill-to-skull, (c) bill-to-skull - (bill width x tarsus width).

The morphological data in Table 1, and other data presented in Cramp (1992) and Svensson (1992) suggest that Reed Warblers have generally shorter, more rounded (distance from wing tip to first secondary) wings than Marsh Warblers, but have a longer notch on the second primary feather, longer, narrower bills, and longer feet and claws. Superimposed on this, foot and claw size of Reed Warblers tends to be greater in southern and eastern Europe where reed stem diameter is larger (Cramp 1992), and there is a general tendency for nominate race Reed Warblers to increase in wing length from the south and west to the north and east of their breeding range. In contrast, Marsh Warblers are not known to show any geographical variation in morphology (Cramp 1992). The cline in wing length of Reed Warblers may explain the failure of two of the composite measures ('notch' / 'wing length' and 'wing length' / 'bill-to-skull') to distinguish the two species in our sample of birds, due to a greater degree of overlap between the two species. The failure of the third composite measure (the 'Walinder' index) to distinguish Reed and Marsh Warblers in our data has no obvious explanation in the literature. However, comparison of 'bill-to-skull' data in Tables 1 and 2 does show that our sample of birds tended to have longer bills than the samples reported in Svensson (1992), which may lead to a greater overlap between the two species in this index in our data set.

In order to identify any remaining interspecific dimorphism between the Reed and Marsh Warblers in our sample of birds, we calculated

Table 2. Mean, standard error and range of all measurements recorded from Reed/Marsh Warblers. FY = first year, A = adult. All linear measurements are in mm.

Measurement	*Age Class*	*Sample*	*Mean*	*SE*	*Range*
Wing length	FY	316	68	0.11	62-74
	A	48	67	0.31	63-72
Notch length	FY	316	9.7	0.06	7.0-13.6
	A	48	10.8	0.19	8.1-14.4
Bill-to-skull	FY	316	17.0	0.05	14.7-19.5
	A	48	17.6	0.13	15.9-19.7
Wing tip to first secondary	FY	315	19.6	0.08	16.0-23.2
	A	47	17.9	0.24	14.6-21.9
Tarsus length	FY	315	22.4	0.04	20.2-24.3
	A	48	22.4	0.12	20.5-24.5
Hind claw length	FY	316	6.5	0.03	5.0-8.7
	A	48	7.0	0.10	5.5-8.5
Bill width	FY	315	4.3	0.02	3.6-5.3
	A	48	4.1	0.03	3.6-5.0
Tarsus width	FY	315	1.8	0.01	1.4-2.1
	A	48	1.6	0.02	1.4-2.0
Foot span	FY	284	31.5	0.09	28.0-36.0
	A	48	32.6	0.28	28.0-36.0
Fat score	FY	315	3.7	0.09	0-6
	A	48	4.4	0.17	0-5
Weight (g)	FY	315	13.9	0.13	7.3-19.6
	A	48	14.3	0.28	10.9-20.0
Notch / Wing length	FY	316	0.143	0.001	0.108-0.206
	A	48	0.162	0.003	0.119-0.210
Wing length / Bill-to-skull	FY	316	3.98	0.015	3.28-4.70
	A	48	3.80	0.036	3.30-4.32
Bill-to-skull - (Bill width x Tarsus width)	FY	315	9.50	0.082	6.06-13.80
	A	48	10.85	0.176	8.48-13.14

an index of the general form (A x B x C) / (D x E x F) where A, B, and C are the three individual size measures considered by the literature to be greatest in Reed Warblers, and D, E and F are the three size measures considered to be greatest in Marsh Warblers. In this case, the biometric index is given by ('hind claw length' x 'notch length' x 'bill-to-skull') /('wing length' x 'wing-tip to first secondary' x 'bill width'), and thus includes all the main size traits in which Reed and Marsh Warblers are known to differ. Hind claw length was used in place of foot span since the former had been measured for the larger sample of birds. As illustrated in Fig 2, the frequency distribution of this measure in our sample is strongly bimodal, with one large group of birds with low index values considerably outnumbering a smaller sample of birds with a broad spread of higher index values. We concluded that the birds in the right-hand group (high index values) were Reed Warblers, and that those in the left-hand group (low index values) were Marsh Warblers, with a probable overlap zone (index values of roughly 0.21 to 0.25) where identification was uncertain. The suggestion of a further split into two groups within the 'Marsh Warbler' category probably reflects sexual dimorphism (approximately 1% in wing length - data in Cramp 1992). However, the clinal variation in morphology of Reed Warblers is likely to have masked the effect of sexual dimorphism in the frequency distribution of the index for the 'Reed Warbler' category.

We next used Linear Discriminant Function Analysis (LDFA) to determine formally the probability that each individual could be identified as either a Marsh Warbler or a Reed Warbler based on this biometric index. LDFA is described accessibly by Tabachnick & Fidell (1996). Briefly, the analysis predicts the probability that a given case (in this case a bird) is a member of a particular group (in this case one of two groups; Marsh Warbler and Reed Warbler) given its combined score (the 'discriminant function') on a number of predictor variables (in this case the six measures comprising the biometric index). Our approach was to construct several candidate classifications of the birds as either Marsh or Reed Warblers, using a threshold value of the biometric index chosen, by eye, from the bimodal distribution in Fig. 2. These classifications were:

1 <0.28 = Marsh, >0.28 = Reed
2 <0.27 = Marsh, >0.27 = Reed
3 <0.26 = Marsh, >0.26 = Reed
4 <0.25 = Marsh, >0.25 = Reed
5 <0.24 = Marsh, >0.24 = Reed
6 <0.23 = Marsh, >0.23 = Reed
7 <0.22 = Marsh, >0.22 = Reed.

For each candidate classification, LDFA was performed using the six variables comprising the biometric index as predictors of membership of the two groups ('Marsh' & 'Reed'). Of the original 364 cases, three were dropped due to missing data. For the remaining 361 cases, data checks revealed no threats to the reliability of the analysis through departures from the assumptions of LDFA; namely, absence of multivariate outliers, linear relationships between predictor variables; absence of multicollinearity (ie high correlation coefficients between predictor variables), normal distribution of predictor variables, and homogeneity of variance of the discriminant function scores for the two groups (see Tabachnick & Fidell (1996) for details).

Of the seven candidate classifications, the sixth was most successful, with only five birds 'mis-classified' by the LDFA in comparison with our own classification based on the biometric index. In all five cases, these were birds classified by us as 'Marsh' and by the LDFA as 'Reed'. All of these birds had biometric index scores of between 0.21 and 0.23 so we chose to regard all birds with biometric index scores between these two extremes as unidentifiable. Within this range, statistical analysis by LDFA did not reliably confirm the tentative identification based on the biometric index.

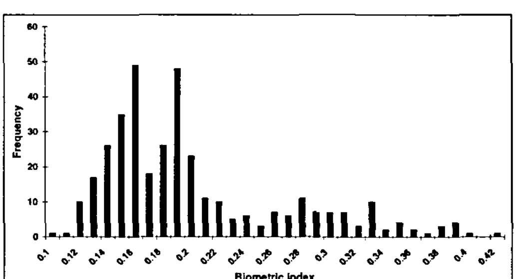

Figure 2. Frequency distribution of the biometric index ([hind claw length x notch length x bill-to-skull] /[wing length x wing-tip to first secondary x bill width]) for the sample of Reed/Marsh Warblers in our study.

The result of this procedure was that we finally identified 250 birds with a biometric index of 0.21 or below as Marsh Warblers (69.3%), and 90 birds with a biometric index of 0.23 or greater as Reed Warblers (24.9%), with 21 birds having an intermediate index remaining unidentified (5.8%). These results are shown in more detail in Fig 3 which plots the probability (derived from the LDFA) that a bird was identified correctly by our initial use of the biometric index (ie <0.23 = 'Marsh', 0.23 = 'Reed') against its biometric index score. The 21 unidentified birds with an intermediate index value are also shown. Clearly, we could instead have used the probability scores generated by the LDFA to identify birds (eg several of those left unidentified were classified as Marsh Warblers with a probability of >0.9 by the LDFA). However, the output from a complex multivariate statistical analysis is of little practical value to ringers operating in the field, whereas the biometric index is straightforward to calculate. In essence, therefore we were using the LDFA simply to corroborate our initial separation of the two species into 'Marsh' and 'Reed' Warbler categories on the basis of the biometric index alone.

Our final identifications are broadly corroborated by the leg colour categorisation of the 221 birds captured in 1996 and 1998. Of the 66 birds identified as Reed Warblers by the biometric index, 43 scored '1' for leg colour (ie bluish-grey typical of the species), 22 were intermediate '2' and only one scored '3' (ie the straw yellow typical of Marsh Warblers). In contrast, of 145 birds identified as Marsh Warblers by the biometric index, 12 scored '1' for leg colour, 80 were intermediate '2' and 53 scored '3'. As with the measurements, leg-colour alone is clearly insufficient to allow safe identification. However, the fact most (96 of 109) of the individuals with extreme leg colouration ('1' or '3') were assigned by the biometric index to the same species that their leg colour would predict suggest that bare part colouration could be used in conjunction with the biometric index to assist accurate identification.

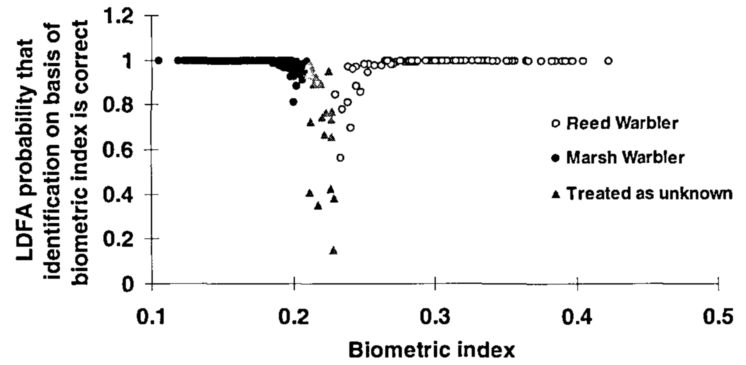

Figure 3. Results of the Linear Discriminant Function Analysis (ie probability that a bird initially assigned to one of the two species on the basis of the biometric index is 'correctly' classified) plotted against biometric index for the sample of birds in our study. Birds with a biometric index of <0.23 were initially classified as Reed Warblers (open circles), and those <0.23 as Marsh Warblers (filled circles). There were five cases where birds classified as Marsh Warblers by us were classified as Reed Warblers by LDFA (ie points below 0.5 on the y-axis). These and other individuals in the same range of the biometric index (0.21-0.23) were considered 'unidentifiable' (shaded triangles) although most were probably Marsh Warblers.

DISCUSSION AND CONCLUSIONS

Reed and Marsh Warblers passing through the eastern Mediterranean in autumn were difficult to identify in the hand. The biometric indices and critical values provided by Svensson (1992) (Table 1), based on birds captured in western Europe did not distinguish the two species, because our sample of birds showed a greater degree of morphological overlap (see also Kormos & Csörgö 1991). This may be due to the wide geographical spread of origin of birds of both species passing through the eastern Mediterranean at this time. Our results suggest that a biometric index of the form ('hind claw length' x 'notch length' x 'bill to skull') / ('wing length' x wing-tip to first secondary' x bill width') using the measurement techniques described in Svensson (1992) should identify approximately 95% of individuals of the two species where samples of both species are caught and a frequency distribution of the index can be plotted (see Fig 2).

We do not recommend uncritical use by other workers of the critical values that separated the two species in our data sets, since it is clear that significant geographical difference in the species' biometrics do occur and, in addition, observer-related differences in measurements are inevitable. For example in the UK, where separation of Reed and Marsh Warblers is usually more straightforward on the basis of colouration and because the species show less morphological overlap, the use of this biometric index may

Table 3. Mean, standard error and range of all measurements recorded from birds identified as Reed or Marsh Warbler, using the biometric index. FY = first-year, A = adult. All measurements are in mm.

Measurement	*Species/Age*	*Sample size*	*Mean*	*SE*	*Range*
Wing length	Marsh/FY	238	68.1	0.11	63-74
	Reed/FY	59	65.9	0.27	62-71
	Marsh/A	12	69.3	0.48	66-72
	Reed/A	31	66.0	0.29	63-69
Notch length	Marsh/FY	238	9.3	0.05	7.0-13.0
	Reed/FY	59	10.9	0.10	9.8-13.6
	Marsh/A	12	9.6	0.22	8.1-10.7
	Reed/A	31	11.4	0.20	10.1-14.4
Bill-to-skull	Marsh/FY	238	16.8	0.05	14.7-19.5
	Reed/FY	59	18.1	0.10	15.6-19.5
	Marsh/A	12	17.0	0.15	16.2-17.8
	Reed/A	31	17.9	0.17	15.9-19.7
Wing tip to outermost secondary	Marsh/FY	238	20.0	0.08	16.6-23.2
	Reed/FY	59	18.4	0.16	16.0-21.1
	Marsh/A	12	19.5	0.34	17.5-21.9
	Reed/A	31	17.2	0.25	14.6-20.0
Tarsus length	Marsh/FY	237	22.2	0.05	20.2-24.3
	Reed/FY	59	22.8	0.08	21.0-23.9
	Marsh/A	12	21.9	0.25	20.5-23.3
	Reed/A	31	22.6	0.14	21.2-24.5

Table 3. (continued) Mean, standard error and range of all measurements recorded from birds identified as Reed or Marsh Warbler, using the biometric index. FY = first-year, A = adult. All measurements are in mm.

Measurement	*Species/Age*	*Sample size*	*Mean*	*SE*	*Range*
Hind claw length	Marsh/FY	238	6.4	0.03	5.0-7.8
	Reed/FY	59	7.2	0.07	6.2-8.7
	Marsh/A	12	6.3	0.13	5.5-7.0
	Reed/A	31	7.3	0.10	6.4-8.5
Bill width	Marsh/FY	238	4.3	0.02	3.6-5.0
	Reed/FY	59	4.0	0.03	3.6-4.6
	Marsh/A	12	4.3	0.08	3.9-5.0
	Reed/A	31	4.0	0.03	3.6-4.4
Tarsus width	Marsh/FY	238	1.8	0.01	1.4-2.1
	Reed/FY	59	1.7	0.02	1.4-1.9
	Marsh/A	12	1.7	0.03	1.5-1.8
	Reed/A	31	1.6	0.02	1.4-1.8
Foot span	Marsh/FY	213	31.0	0.08	28.0-35.0
	Reed/FY	58	33.4	0.19	29.0-36.0
	Marsh/A	12	30.8	0.28	29.5-32.0
	Reed/A	31	33.3	0.33	28.0-36.0
Notch/wing length	Marsh/FY	238	0.14	0.001	0.108-0.181
	Reed/FY	59	0.17	0.002	0.147-0.206
	Marsh/A	12	0.14	0.003	0.119-0.153
	Reed/A	31	0.17	0.003	0.151-0.210
Wing length/ bill-to-skull	Marsh/FY	238	4.07	0.01	3.49-4.70
	Reed/FY	59	3.65	0.02	3.28-4.17
	Marsh/A	12	4.08	0.04	3.82-4.32
	Reed/A	31	3.69	0.04	3.30-4.13
Bill-to-skull - (bill width x tarsus width)	Marsh/FY	238	9.07	0.08	6.06-12.68
	Reed/FY	59	11.20	0.13	8.04-13.8
	Marsh/A	12	9.62	0.24	8.48-11.25
	Reed/A	31	11.46	0.17	9.60-13.14

rarely be necessary. Ideally, observers working where Reed and Marsh Warblers drawn from a wide geographical area occur together, should plot their own frequency distribution of this index based on a sample of birds, before assigning identity to individuals based on its bimodality. Even then, a small proportion of intermediate birds may best be left unidentified, although the location of any subsequent recovery could help both to identify the individual concerned, and to identify the breeding range of these 'difficult' birds. Where single individuals or small samples of birds are involved, use of the index values described above, in conjunction with careful assessment of plumage and bare part colouration (Svensson 1992, Harris *et al.* 1996) should allow most individuals to be identified correctly, despite observer differences in measurement. In addition, a second biometric measure may assist. Dr Jósef Gyurácz has reported to us that some Hungarian ringers use the relative length of the inner and mid toes as a guide to identification; birds in which the inner claw over-reaches the 'bed' (fleshy part) of the mid-claw are considered to be Reed Warblers, and others as Marsh Warblers. However, we are not aware of any published papers which have compared this technique with others. It would be interesting to make such comparisons.

When the indices suggested by Svensson (1992) are applied to our sample of birds identified using the biometric index (Table 3), at least one still has utility in separating the two species, although the critical values are very different. Thus, inspection of Table 3 shows that first-year birds with a 'notch length / wing length' ratio of <0.147 in our sample were all Marsh Warblers. This accounted for 187/238 (78.5%) of all first-year Marsh Warblers in our sample. Amongst adults, all birds with a ratio of >0.153 in our sample were Reed Warblers. This accounted for 29/31 (93.5%) of the adult Reed Warblers in our sample. The other two indices were of less value, although adult birds with a 'wing length / bill-to-skull' ratio of <3.82 were all Reed Warblers, and accounted for 22/31 (71.0%) of the adult Reed Warblers in our sample. Similarly, adult birds with a 'Walinder' index of >11.25 were also all Reed Warblers, and accounted for 21/31 (67.7%) of the adult Reed Warblers in our sample. Overall, it seems that of the indices proposed by Svensson (1992), the 'notch length /wing length' ratio can identify the majority of first-year Marsh Warblers, and all three indices can identify the majority of adult Reed Warblers. However, none of these measures will provide the same degree of confidence as the biometric index described above.

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