Identification of Caspian Gull: Part 2: Phenotypic variability and the field characteristics of hybrids

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Identification of Caspian Gull

Part 2: phenotypic variability and the field characteristics of hybrids

Chris Gibbins, Grzegorz Neubauer and Brian J. Small

Chris Gibbins

Abstract Variability in large gulls creates problems for field observers, not least because of the possibility that hybridisation might be responsible for the appearance of what are perceived to be atypical individuals. However, without detailed information on the phenotypic variability in birds of known provenance, it is difficult to resolve debates about the identification of such atypical birds. This paper is the first attempt to develop a quantitative system to address this problem. We use numerical scores from a sample of 404 birds (including pure and hybrid individuals) to describe objectively patterns of variability in the structural and plumage traits traditionally used to identify Caspian Gulls *Larus cachinnans*. Our results lend statistical support to many of these traits but also indicate that some traits are less useful than previously thought. There was considerable overlap between Herring *L. argentatus* and Caspian Gulls in the scores for individual traits, but little or no overlap in summed values. While many hybrids had intermediate sum scores, others overlapped with one of their parents in certain characters, indicating that they cannot be identified with any degree of confidence. This emphasises the need for caution when dealing with Caspian Gull records. There are limitations to our approach and there remains a need for more data on hybrids. Nonetheless, the paper provides an objective framework for the treatment of less typical Caspian Gulls and suspected hybrids. We suggest specific threshold scores that can be used as an aid to records assessment, to separate acceptable birds from those which show a combination of traits that make their identification unsafe. Application of the scoring system requires careful observation and good-quality photographs, so it may not always be possible to score candidate birds. We discuss how incompletely documented birds can be treated.

Introduction and aims

Part 1 of this paper (Gibbins *et al.* 2010) dealt with the identification of typical Caspian Gulls *Larus cachinnans*. It summarised published literature and presented results from ongoing field studies in order to help observers and records committees identify and assess typical Caspian Gulls (plate 394). In part 2 we focus on the identification of less typical individuals and present information on the appearance of hybrids.

Most birders are aware that large gulls show a considerable degree of variability. In part 1, 'normal' variability among Caspian Gulls (that might be encountered on a regular basis) was described. For example, we discussed the variability in the eye colour of adult birds, emphasising that not all Caspian Gulls look dark-eyed in the field. Such variability is dealt with routinely by birders, and perhaps largely without explicitly quantifying or assessing it. However, at some point, a particular trait becomes unusual rather than part of the expected variability – for example, an adult Caspian Gull with a *thayeri* pattern on P10 (plate 395). In order to assess whether such a bird can still be identified safely, information is required on the frequency of this pattern in proven Caspian Gulls. More difficult problems come with those birds that show more than one unusual trait – for example, if a bird has pale eyes and/or a robust bill in addition to an unusual primary pattern, we might begin to question its identification. At this point we need a more formal way of dealing with the variability, to set limits to the 'acceptable variability' of individual traits and to isolate the point at which the identification of a particular individual becomes unsafe, owing to a combination of unusual features.

In terms of the Caspian Gull, the need to define limits within which birds are safely identifiable is brought into sharp focus because of hybridisation. As the species has expanded its range westwards, it has come into contact with other gulls. Ongoing work in the mixed Herring *L. argentatus* and Caspian Gull colonies in Poland (Neubauer *et al.* 2006, 2009) is shedding light on the frequency of hybrid pairing and, through ringing data, the appearance and dispersal of hybrid offspring (Beran *et al.* 2010; Neubauer *et al.* 2010). Numerous proven (ringed) and suspected (unringed) hybrids have reached western Europe and Britain, and thus raise concerns over the identification of putative Caspian Gulls that show one or more atypical features. Nonetheless, the hybrid issue needs to be set against the growing realisation that Caspian Gulls, like all other large gulls, show a considerable degree of variability.

Against this background, in part 2 of this paper we: (a) outline some of the extremes of variability shown by Caspian Gull; (b) determine whether there are features that, individually or in combination, can be used to identify Caspian Gulls with confidence (and in so doing highlight those traits which make the identification of certain individuals unsafe); and (c) highlight areas where further research is needed to resolve debates about the identification of less typical Caspian Gulls. Essentially, we take the key features that have traditionally been used to identify Caspian Gulls (see part 1) and make a quantitative assessment of the extent of their overlap with Herring Gulls and hybrids between the two species. The resulting statistics allow us to determine how useful these features are for identification.

The summary section of the paper (p. 740) distils our key findings; those readers less interested in the more technical aspects of the work, or the full details of the patterns of phenotypic variability, may wish to go directly to this section. In combination with the tables and plates, they will find sufficient information in the summary to gain an understanding of the most useful identification features for less typical birds, the extent of overlap between pure Herring and Caspian Gulls, and the characteristics that point to a bird being a likely hybrid.

Approach

Sample birds and scoring system

The paper is based on studies of Caspian Gulls in the Ukraine, Romania, Latvia, Lithuania and Poland, and Herring Gulls in Britain and Poland (fig. 1). Owing to the availability of data and the extreme variability of other age groups, we focus on adult birds and those in first-winter (1W) plumage (defined further below). However, some information on the variability of birds in

juvenile plumage is also presented.

We have been able to examine large numbers of breeding adults in the hand, through work in the Ukraine and on the mixed colonies in Poland; this has allowed us to develop criteria based on detailed in-hand examination of primary and bare-part patterns. Adult gulls trapped in mixed colonies have been assigned to species based on a combination of genetic markers (see Gay *et al.* 2007) and phenotypic traits. In the best-studied colony, in Poland, individuals intermediate between Herring and Caspian Gull accounted for 27–35% of all birds; mixed pairs involving pure individuals of the two species occurred fairly regularly (c. 15% of all pairs), while pairs involving at least one intermediate individual were even more frequent (40–50%; Neubauer *et al.* 2009).

The choice of study locations and data collected in each location was based on our desire to sample hybrids from mixed-species

Dušan Boucný

394. 2CY Caspian Gull (first-winter plumage), Vrbice, Czech Republic, March 2011. This is a textbook bird in every respect, and it has the ring to prove its credentials (PUNU was ringed as a chick in the Ukraine). However, not all Caspian Gulls are this distinctive, and not all carry a helpful ring. Unringed and less typical individuals can create identification headaches, especially given the problems posed by hybrid Caspian x Herring Gulls.

Chris Gibbins

395. Adult (or near-adult) Caspian Gull, Histria, Romania, September 2006. Data collected for this study show that the pattern on P10 is relatively stable in pure Caspian Gull and hence critical for identification. However, there is some variability in this feature. This bird, for example, shows a *thayeri* pattern on the outermost primary (P10) as well as P9.

Magdalena Zagalska-Neubauer

Magdalena Zagalska-Neubauer

396. 10CY male hybrid Caspian x Herring Gull, Włocławek, central Poland, 2nd May 2005. Ringed as a chick at middle Vistula, south of Warsaw, in May 1995. Like many hybrids, this bird is intermediate in appearance: note the slightly dark-spotted iris (scored as 2; see table 1) and slim bill (scored 1; actual bill ratio computed from depth/length measurements was 3.21, thus matching Caspian perfectly; see Neubauer *et al.* 2007). Both of these features exclude pure Herring. Conversely, in P10 there is more black than white and the short tongue is grey, features that exclude pure Caspian. This combination of characters means that the bird would be unacceptable as a pure Caspian and also out of the range of pure Herring; if unringed, such a bird should be left as unidentified and flagged as a likely hybrid.

colonies (e.g. Poland) and pure individuals from core areas, away from the hybrid zones (e.g. Caspian Gulls in Ukraine and Romania). However, practical constraints dictated that sampling from core areas was not possible for all age classes. For example, GN lives in Poland, where he has the necessary licences to handle birds and take blood samples. Thus, out of necessity, sample data on adult Herring Gulls are from his long-term, mixed-species study colonies in Poland. To increase our sample size, data from 1W birds photographed in core areas were supplemented with data from Poland and Latvia. Ringed Caspian Gulls in the sample came predominantly from the core range in the Ukraine, where the influence of other species should be minimal. Ringed birds of known provenance in the sample showed patterns similar to unringed ones, so we have no concerns that the inclusion of Herring and Caspian Gulls from the hybrid zone undermines our general conclusions.

Birds ringed in the hybrid zone were considered hybrids based on certain knowledge of both parents (through observations of nest attendance). Parentage was not confirmed genetically, other than for one individual (depicted in plate 407). However, preliminary results of an ongoing study in the colony where these hybrids come from indicate that cases of extra-pair young (offspring that are fathered outside the pair bond) are not common (c. 15% among over 200 chicks from 62 families; M. Zagalska-Neubauer and G. Neubauer, unpubl.). Thus, we assume that the likelihood of an extra, unknown adult attending the nest is low.

In order to assess phenotypic variability

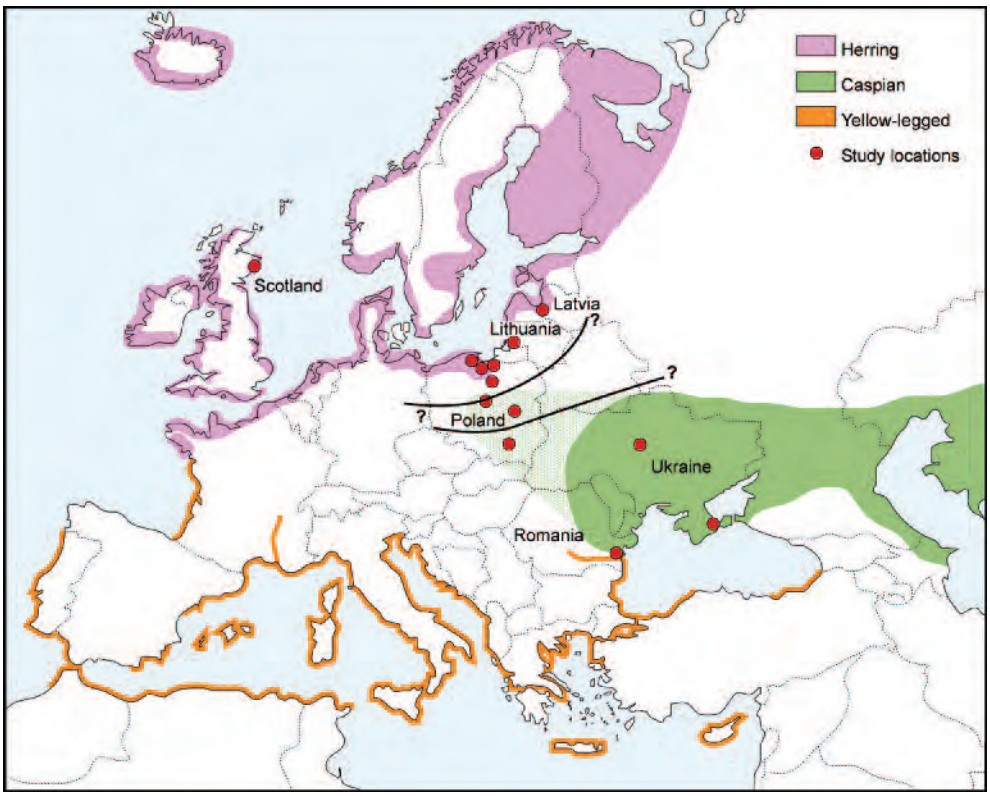


Fig. 1. Location of sampling areas relative to the distribution of Herring *Larus argentatus* and Caspian Gulls *L. cachinnans*. For completeness, the breeding range of Yellow-legged Gull *L. michahellis* is also shown. The distributions are taken from Malling Olsen & Larsson (2003). However, for Caspian Gull we have added shading (light green) to include recently colonised areas in Poland. This species has also colonised inland Russia, Belarus and Lithuania, and is known to breed in eastern Germany, but the paucity of data from these areas means that the distribution shown in this figure is best treated as approximate. The two black lines delimit the approximate hybrid zone, based on the best available current knowledge.

Grzegorz Neubauer

397. Male hybrid Caspian x Herring Gull in a breeding territory, Włocławek, central Poland, April 2008. The same bird as in plates 396 & 398 (the red colour ring was replaced in 2005). Note the typical Caspian Gull structure in this pose; in many larger-billed Caspians, as well as some slimmer-billed birds such as this hybrid, the bill, despite being deep at the base, lacks a gonys bulge and so the bill tapers continuously and markedly towards the tip.

Visa Rauste

398. Male hybrid Caspian x Herring Gull, Konin, central Poland, October 2003. The same bird as in plates 396 & 397, photographed c. 70 km south of the breeding colony. Note the dense and rather diffuse Herring Gull-like head-streaking on this date, when the bird is in nearly complete winter plumage (the two outer primaries are not fully grown yet, so it has still to complete the moult). In practice, such a heavily streaked individual would arouse suspicion even without the ring (and the bird's known history).

Armin Deutsch

399. 6CY hybrid Caspian x Herring Gull, Pohlsche Heide, Germany, 21st January 2010. Mother known as Herring and father as Caspian; ringed as a chick in central Poland on 14th May 2005. This hybrid is strikingly Caspian-like, particularly the elegant structure and slim bill, pure white head, and P10 with less black than white and a virtually pure white tip. However, the P10 tongue was grey and the eyes pale and unspotted. Its overall score was 9, and most UK birders would probably identify this bird as a Caspian Gull.

quantitatively, and hence the frequency of extremes, we developed a scoring system that allows patterns of variability in adult and 1W birds to be described in a multivariate way. Similar approaches have been used previously to produce so-called 'hybrid indices', where there is a need for formal and objective assessment of the position of a particular individual between parental (pure) species in 'phenotypic space' (see Bell 1997 and Good *et al.* 2000 for examples of a similar system of scoring for Western *L. occidentalis* and Glaucous-winged Gulls *L. glaucescens* in the Pacific hybrid zone). Application of the system involves scoring individual birds based on a number of traits. The traits we chose to include (tables 1 & 2) are only those that are generally regarded as being useful in the identification of Caspian Gull. This allowed us to maximise between-species differences, since using traits known not to differ (or to differ only slightly) would obscure patterns. It is therefore important to recognise that the traits do not represent a full phenotypic characterisation of the species and that the approach focuses on only the most divergent traits.

For each trait, we developed scores that reflect observed patterns of variability. The system was intended to allow the separation of Herring and Caspian Gulls and their hybrids. Scores were intentionally polarised, with high scores corresponding to Herring Gull and low scores to Caspian. The system is categorical and so cannot fully capture the true nature of the continuous variability observed for each trait. It would be possible to develop a more complex system (e.g. with more categories within each trait in order to better capture subtle variability) but, because we wanted to produce something that was relatively simple and useful for birders in the field, we kept the number of categories to a minimum. For the same reason, we avoided the use of absolute measurements and detailed biometrics; traits that involve assessment of length or other dimensions are all expressed in relative terms (i.e. as ratios).

Adult birds

Adults were scored using measurements, and the appearance of features observed in photographs of the head and wing-tip of birds captured in Ukrainian and Polish colonies during the breeding season (Caspian n=100, Herring n=132, known hybrids n=12). All the adult Herring Gulls sampled were from Poland, and so were of the nominate race *argentatus*. Birds of this race can be extremely similar to Caspian Gull in plumage (e.g. primary pattern) and bare-part colours, and thus are a potential pitfall. It was not felt necessary to include *L. a. argenteus* in the sample because this race differs considerably from Caspian in adult plumage and so should not present any identification problems.

Eye pigmentation and orbital-ring colour were assessed in the field, with each assigned a score as per table 1. Wings were held open, photographed and a number of aspects of the primary pattern were assessed from these images. Advances in digital photography mean that it is possible to capture high-quality images of birds in the field, either in flight or while wing-stretching, and these can be used by birders to assess details of the wing-tip pattern. Thus, while the scoring system is relatively detailed, it should be possible to capture all the necessary features in photographs of birds in the field and hence score an adult gull's wing-tip pattern in the same way as we have done using photographs of birds in the hand.

Bill shape was expressed as the ratio of bill length (measured in the standard way, along the culmen) to depth at the gonys, with the ratio being scored as per table 1. Leg length was measured in millimetres and then converted to a trait score, to reflect how long-legged each bird might appear in the field. The trait score for each bird was based on its length relative to the mean length of all individuals of that sex in the sample; since we were interested in the relative leg length of an individual irrespective of species, the means were calculated from data pooled across both species (but separately for each sex). Thus, each bird was scored as having relatively short, relatively long or average-length legs, given its sex. We did not include leg colour in the adult criteria as this is well known to overlap completely between Herring and Caspian Gull – both species can have either pink or bright yellow legs and so this feature is of little value in identification (details in part 1).

First-winter birds

For 1W birds, traits included aspects of structure, plumage and moult (table 2). Scoring of sample birds (Herring n=85, Caspian n=63, hybrids n=12) was undertaken using digital photographs taken in the field between October and March. The 1W Herring Gulls were all from Scotland, while the Caspian Gulls were from the Ukraine, Romania, Poland and Latvia. Only perfectly side-on images were used, because of the need to measure relative lengths and depths (and calculate ratios) for bill and wing-tip features.

The moult traits represented an assessment of the extent of post-juvenile moult. This moult takes place soon after first-calendar-year (1CY) individuals gain independence and continues through the autumn, before being suspended for the winter. To score birds it was first necessary to set a cut-off point that represents the end of the moult. We did this based on moult scores for a sample of Caspian Gulls (fig. 2). The maximum scores were reached by October, with no statistically significant increase beyond this point. This indicates that most birds complete the post-juvenile moult by October, with no (or only exceptional) further replacement of feathers beyond this

Table 1. Traits and scores used to characterise adult gulls in this study. These are the traits that have long been used in Caspian Gull *Larus cachinnans* identification, so in essence all we have done is to allocate scores to each one. The scores allow patterns of variability in each trait to be assessed quantitatively.

Trait	Score	Description
P10 overall pattern: white to black ratio	0	less black than white
	1	approximately equal black and white
	2	more black than white
P10: white tip	0	clear white, no signs of black
	1	small dark spots on one or both webs
	2	incomplete subterminal bar (two large black spots, one on each web or an unconnected bar, broken in the middle)
	3	complete subterminal bar
P10: tongue	0	white or whitish
	1	greyish, paler than mantle
	2	same shade as mantle
P5: extent of black	0	black on both webs connected, forming band, black of equal depth on each web
	1	black on both webs connected, forming band, black on outer web deeper than inner
	2	black on both webs, but isolated spots (= incomplete bar)
	3	black on outer web only
	4	no black
P4: extent of black	0	black on both webs
	1	black on one web only
	2	no black
Iris peppering	0	dark-looking, >50% covered by dark spotting/peppering
	1	moderately dark, with 10–50% of the area spotted
	2	single or very few dark spots (area <10%)
	3	no dark spotting on iris
Eye-ring colour	0	dark/deep orange to red
	1	pale to moderately orange
	2	yellow
Bill shape	0	very long and slim, with little/no visible gonydeal angle (L:D ratio >2.8)
	1	slim, slight gonydeal angle (ratio 2.4–2.79)
	2	intermediate (ratio 2.0–2.39)
	3	short and deep, well-marked gonydeal angle (ratio <2.0)
Leg length	0	long
	1	moderately long
	2	short

Table 2. Traits and scores used to characterise birds in first-winter plumage (October–March inclusive).

Trait	Score	Description
Extent of scapular moult	0	no first-generation feathers remaining
	1	a small number (<⅓) of first-generation feathers remaining
	2	a significant number (>⅓) of first-generation feathers remaining
Greater-covert pattern	0	simple pattern with brown centres and sharp white edges, with no white vermiculation or notching
	1	white edges with delicate notches or vermiculation; or dark brown centre with white tip to ⅓ of length (i.e. white restricted to tip or distal third)
	2	clear white notches/barring creating a delicate 'piano key' pattern along the whole edge/feather; but much of feather dark
	3	lots of white (more than ½ of coverts looking white) distributed along the whole feather, or a bold notching ('piano key' pattern)
Ventral bulge	0	present
	1	absent
Primary projection	0	very long (ratio >0.6)
	1	moderately long (ratio 0.5–0.59)
	2	medium (ratio 0.4–0.49)
	3	short (ratio <0.4)
Moult: greater coverts	0	all or almost all new (>75%)
	1	51–75% new
	2	34–50% new
	3	10–33% new
	4	one or two feathers moulted
	5	no moult
Moult: median coverts	0	all or almost all new (>75%)
	1	51–75% new
	2	34–50% new
	3	10–33% new
	4	one or two feathers moulted
	5	no moult
Moult: tertials	0	3 or more new
	1	2 new
	2	1 new
	3	all old
Darkness of head and body	0	totally white
	1	reduced grey wash or streaking (confined to flanks and/or single streaks around nape)
	2	light streaking/wash to head (incl. some dark around eye); isolated streaks/blotches on body. Overall, body looks more white than brown
	3	well streaked: dark mask around eye and/or streaking covering the whole head/face; body with extensive but moderately dense streaks/mottles
	4	strong and dense streaking/mottling on body and head making it appear almost wholly dark
First-generation tertial pattern	0	diffuse white tip (like Common Gull *Larus canus*)
	1	fine pale fringe around distal portion (like classic *michahellis*), possibly also with some vermiculations
	2	edges moderately notched
	3	edges strongly notched and/or some dark barring or pale patches across the feather on some or all tertials
Second-generation scapular pattern	0	uniformly silvery-grey, darker patterning absent or very faint
	1	silvery-grey background, pattern stronger than on 0, but lacks strong barring or central dark diamonds (only dark shafts and subtle anchors), with only a minority (one or two) of such feathers admixed
	2	strong, contrasting shaft-streaks, anchors and/or dark central diamonds, but these more patterned feathers are less than ½ of all; ground colour creamy or silvery-grey, possibly with some grey feathers mixed in
	3	strong pattern described in 2 on most (more than ½) of feathers, but possibly also one or two plain grey feathers or feathers with grey ground tone
	4	all feathers contrastingly patterned (with dark cross bars or diamonds), lacking plain grey feathers; feather centres buffy-brown

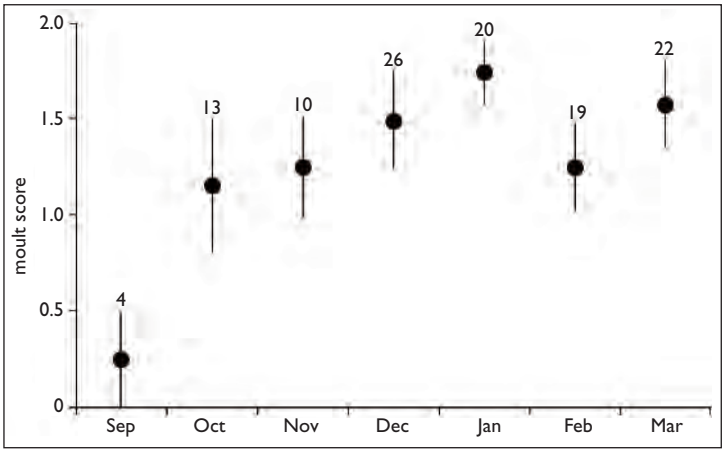


Fig. 2. Moult scores (mean and SE) from a sample of first-winter Caspian Gulls *Larus cachinnans* in southern Poland (n=114). The score for each bird is the sum of values for moult in its lesser, median and greater coverts and tertials. For coverts, scores are categorical: 0=no moult, 1=1–3 new feathers, 2=more than 3 feathers but less than a third of total, 3=between a third and a half of all feathers, and 4=more than half of all feathers in the group. Tertial scores are simply the number of new feathers present. Values shown in the plot are the number of individuals scored in each month.

point. Thus, to assess the final extent of the post-juvenile moult, sample birds had to be from October or later. Moult commences again in the spring, with feathers being dropped and replaced from April onwards. We therefore set the window within which to sample 1W birds as being from October to March inclusive.

Primary projection (fig. 3) and the presence of a ventral bulge are potentially useful in identification, and so were assessed for 1W birds. However, differences in posture mean that it is not possible to measure and assess these traits in the hand in a way that is useful for field identification. Thus, primary projection and presence of a ventral bulge were not assessed for adult birds, and we assume that results for 1W birds are valid for adults.

The full length of the culmen is not visible from the side because of feathering. Thus, for 1W birds we had to use a different bill-length dimension from that for adults. We assessed bill length in 1W birds from the distal point of the feathering to the bill tip and used this to calculate length:depth ratios and scores (see fig. 3). We do not use these data to generate overall bill length:depth frequency statistics for Caspian versus Herring Gull (we use the adult data for this), but instead use them to calculate overall trait scores for individual 1W birds (see 'Data analysis', below). The different measuring techniques result in different ratio values (greater for in-hand measurements), but the relative differences between species remain constant (see Neubauer *et al.* 2006 for discussion). Appendix 1 shows the raw ratios calculated for all 1W birds from photographs; these should be useful for birders assessing ratios in the field.

Relative leg length for 1W birds was assessed from photographs, with each bird scored according to whether its legs looked short, moderately long or long. As with the bill-length dimensions, these data were used only to calculate sum trait scores for each bird; assessment of the frequency of different leg lengths in the two species is based only on data for adults.

In very few cases were high-quality photographs available both in flight and on the ground for the same individual gull. While traits visible only in flight are important for field identification of 1W birds (specifically the underwing pattern), the lack of matching image sets meant that it was not possible to incorporate in-flight criteria into the scoring system for this age group. We therefore treat variability in the underwing pattern separately.

Data analysis

The variability of individual traits, and hence the extremes recorded in each species, was assessed simply by looking at the frequency statistics for individual trait scores. Each bird was also given an overall score, calculated by summing the scores across all traits. Species were then compared by looking at patterns in sum scores. These simple analyses permitted an assessment of the magnitude and nature of variability in the traits typically used to

identify Caspian Gulls, and consequently overlap between species in either individual traits or sum scores.

Principal Component Analysis (PCA) was used to visualise patterns of variability between individual birds in a truly multivariate way and to help identify (statistically) those traits which are most useful for distinguishing the two species. Appendix 2 gives further details of this technique. PCA produces an easy-to-interpret, two-dimensional diagram (an ordination biplot) in which the distances between samples (birds) reflect the overall similarity of each individual to all other individuals. This overall similarity is calculated by integrating all the measured characteristics, in our case the quantitative values (scores) of each trait. On the diagram, traits are represented as arrows, with the length of the arrow for a given trait being proportional to its importance in driving patterns of similarity between sample birds.

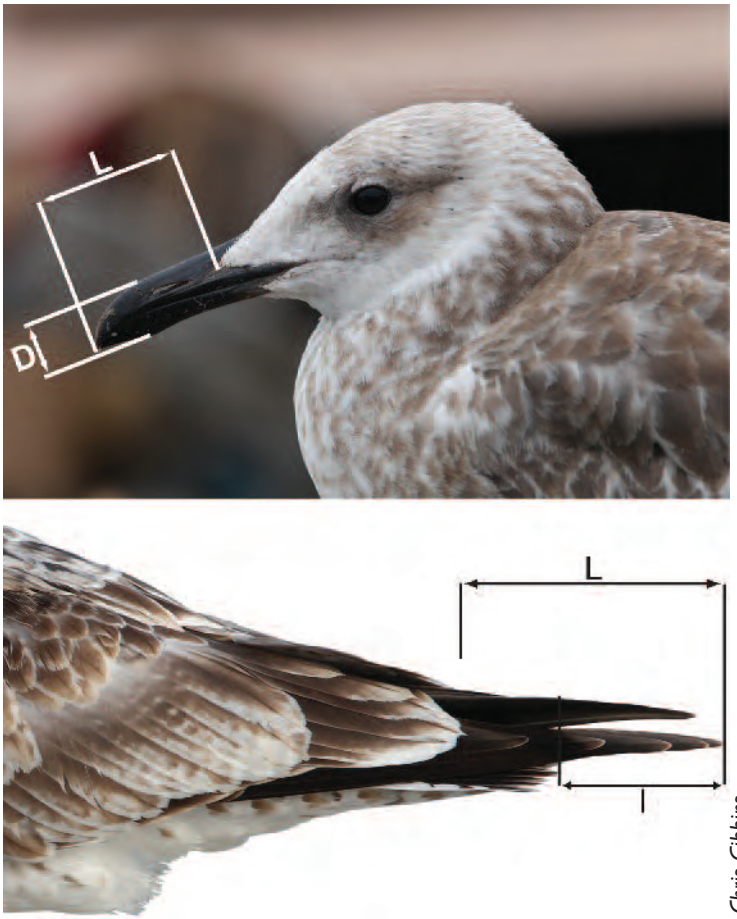
Fundamentally, we were interested in assessing: (1) the extent to which Caspian and Herring Gulls separated out on the PCA biplots; and (2) the relative positions of hybrids. Interpreting this PCA together with the individual trait scores gives us a quantitative basis for deciding whether a particular extreme individual can be identified safely or not. We do not expect that birders will analyse candidate birds using PCA, and so we also present a means of placing a given bird in PCA-defined multivariate space using its trait score (Appendix 3). In this way, the position of a given bird relative to pure and hybrid individuals can be determined quickly and easily.

Identification of adult birds

Table 3 summarises statistical data on the frequency of different trait scores for adult gulls. The following text uses those data to assess the reliability of features used to identify Caspian Gulls. The focus is on the extreme values and the extent of overlap between the species at these extremes.

Variability in structure

The basic differences in structure between Caspian and Herring Gull were outlined in part 1 (Gibbins *et al.* 2010). The quantitative



Chris Gibbins

Fig. 3. Measurements used to derive bill-length to depth and primary-projection ratios for the sample of first-winter birds. Bill ratio is calculated as L/D, primary projection as l/L (projection beyond tail/length beyond tertials). Both images show Caspian Gulls *Larus cachinnans*: the upper bird is from Riga, Latvia, and the lower is from Preila, Lithuania (both September 2010).

data from our sample birds indicate that bill shape and leg length contribute to species separation (table 3) and so are good clues to identification. Caspian Gulls had higher bill length:depth ratios than Herring Gulls, indicative of proportionally longer and slimmer bills with a less marked gonys (fig. 4). While 87% of Caspian Gulls had slim bills (trait score 1), 92% of Herring Gulls had bills that were either short and deep with a well marked gonydeal angle (score 3) or slightly longer but still relatively stout (score 2). None of the sample Caspian Gulls had short and deep bills (score 3) but 8% of Herring had slim bills (score 1). Thus, while there were overall differences in trait-score frequencies between the species, there was also a degree of overlap.

Leg length was clearly different between Caspian and Herring Gulls overall, with typical trait scores apparent for each species. In the sample, 52% of Caspian Gulls had long legs (score 0) versus 5% of Herring

Table 3. Percentages of sample adult birds with scores for selected plumage, structural and bare-part traits.

Trait	Score	Description	Herring (n=132)	Hybrid (n=12)	Caspian (n=100)
P10 overall pattern: white to black ratio	0	less black than white	39	25	100
	1	approximately equal black and white	31	25	0
	2	more black than white	30	50	0
P10: white tip	0	clear white, no signs of black	36	25	54
	1	small dark spots on one or both webs	44	42	31
	2	incomplete subterminal bar	14	8	3
	3	complete subterminal bar	7	25	12
P10: tongue	0	white or whitish	2	17	76
	1	greyish, paler than mantle	37	25	24
	2	same shade as mantle	61	58	0
P5: extent of black	0	black on both webs connected, forming band, black of equal depth on each web	2	25	1
	1	black on both webs connected, forming band, black on outer web deeper than inner	7	42	7
	2	black on both webs, but isolated spots (= incomplete bar)	20	8	14
	3	black on outer web only	27	25	77
	4	no black	44	0	1
P4: extent of black	0	black on both webs	0	0	1
	1	black on one web only	1	17	27
	2	no black	99	83	72
Iris peppering	0	dark-looking, >50% covered by dark spotting	0	0	47
	1	moderately dark, with 10–50% of the area spotted	2	9	27
	2	single or very few dark spots (area <10%)	17	33	26
	3	no dark spotting on iris	81	58	0
Eye-ring colour	0	dark/deep orange to red	6	57	21
	1	pale to moderately orange	27	36	79
	2	yellow	67	7	0
Bill shape	0	very long and slim little/no visible gonydeal angle (L:D ratio >2.8)	0	8	0
	1	slim, slight gonydeal angle (ratio 2.4–2.79)	8	42	87
	2	intermediate (ratio 2.0–2.39)	59	25	13
	3	short and deep, well-marked gonydeal angle (ratio <2)	33	25	0
Leg length	0	long	5	42	52
	1	moderately long	50	42	46
	2	short	45	17	2

Gulls; conversely, while only 2% of Caspian Gulls had short legs (score 2), 45% of Herring Gulls did so. However, about half of all individuals fell in the intermediate category (score 1), indicating considerable overlap in relative leg length.

Variability in plumage

All the sample Caspian Gulls had less black than white on the outermost primary (P10), confirming that this is a relatively invariant feature in this species (table 3). Herring Gulls showed more variation, with a similar proportion of individuals falling into each score category. The pattern on the tip of P10 was variable in both species, but most Caspian Gulls showed either a pure white tip or a tip with just small black spots (scores 1 and 2). The colour of the tongue on P10 proved to be useful in separating the two species, as Caspian and Herring showed opposite patterns (fig. 5). All Caspian Gulls in the sample had white to pale grey tongues (scores 0 and 1), always paler than the mantle, while most Herring Gulls (61%) had grey tongues, roughly the same shade as the mantle. A substantial proportion of Herring Gulls (37%) had a P10 tongue paler than the mantle, but still grey; birds showing white tongues were exceptional (just two individuals). An important point here is that a *thayeri* pattern (i.e. when the pale colour of the tongue breaks through the black to meet the white feather tip) can occur in both species. However, our sample indicates that when it occurs in Herring the tongue remains distinctly darker than the white tip, while in Caspian, because the tongue and tip are equally pale, the wingtip has a very striking pied appearance.

The patterns on P4 and P5 involve the inward extension of black in the primaries. On average, Herring Gulls have fewer primaries with black pigmentation than Caspian, and black portions on the equivalent inner primaries are thinner. Only one Herring Gull in the sample (i.e. <1%) had black on P4 (a single black spot on the outer web of the feather). In Caspian, 28% of birds had black markings on P4, mainly in the form of a single spot but one bird showed a complete band. Our data indicate that Caspian also has more black on P5: nearly all birds (77%) had at least a single spot, while the remaining birds showed a band on P5, either complete or broken; just one Caspian lacked any black on P5. In Herring Gull, 44% of birds had no black on P5 and many had either a single black spot (outer web, 27%) or an incomplete bar (20%) on P5. Individuals in the sample with complete bars on P5 were in general rare (9% in Herring, 8% in Caspian).

Bare-part coloration

Iris peppering differed strongly between species (table 3): no Herring Gulls had a

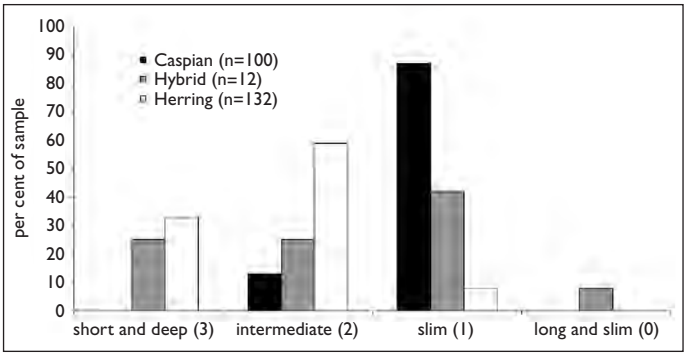


Fig. 4. Length to depth bill ratios for sample adult birds. The ratio values (0–3) relate to the trait categories described in table 1.

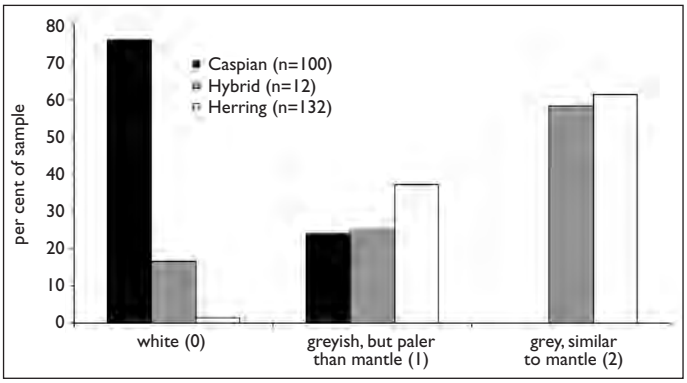


Fig. 5. Trait scores for P10 tongue colour tone for sample adult birds.

strongly peppered iris (score 0), while nearly half the Caspians (47%) did so. None of the Caspian Gulls lacked dark spots on the iris completely, although 26% had relatively little peppering (score 2) and some of these birds would probably look pale-eyed in the field.

In terms of eye-ring coloration, perhaps the most striking statistic was the complete lack of Caspian Gulls in the sample showing a yellow eye-ring. Species shared the other two trait scores (dark/deep orange to red and pale to moderately orange), although it is also evident that, overall, Herring Gulls have a paler eye-ring and individuals that show a deep orange or red eye-ring are infrequent (6%).

Multivariate analyses and the character of hybrids

Overall patterns in the sum of all trait scores for adult gulls are shown in fig. 6. Caspian Gulls had consistently lower scores than Herring (mean values of 8.1 and 15.9 respectively) and the overall distribution of scores differed markedly between the two. Nonetheless, there was not complete separation – the highest-scoring Caspian and the two lowest-scoring Herring Gulls (1.2% of all birds) shared a score of 12. Hybrids had a range of intermediate scores that overlapped with both Herring and Caspian Gulls at the upper and lower parts of the distribution respectively.

An important point to bear in mind when interpreting the scores for individual birds is that a given sum score can result from different combinations of individual trait scores. Consequently, in themselves, the sum scores do not provide any insight into combinations of traits that might give rise to a bird being extreme or unusual in its overall character. This can be assessed using the PCA, however. Adult Herring and Caspian Gulls showed complete separation across the PCA biplot (fig. 7), with no overlap in the polygons which delimit the two species. This separation was across component (axis) 1, with Herring Gulls located to the left and Caspian Gulls to the right.

Arrows for several of the measured traits (notably P10 tongue colour, iris peppering and bill shape) sit more or less parallel to axis 1, indicating that they are primarily responsible for the separation of the species in this horizontal (left-to-right) dimension. The arrow for P5 is long, indicating that this feature differs markedly among sample birds. The P5 arrow sits very close to component (axis) 2. This indicates that the separation of sample birds in the vertical dimension is related primarily to variability in their P5 pattern. However, the fact that the two species do not separate in this dimension (i.e. there is no overall difference in the positions that the species occupy across axis 2) indicates that the extent of black on P5 does not differ systematically between them; consequently, this feature is not important for field identification. The arrow for the pattern on the P10 tip is also long and lies close to component 2, so again we conclude that while it differs between sample birds, it is not important in the separation of the two species.

All ten known F1 hybrids included in the analysis showed a generally similar phenotype; across axis 1 of the PCA they were located in the area between the distributions of pure species, while several were separated from pure individuals in having high axis-2 scores. Detailed aspects of the phenotype of

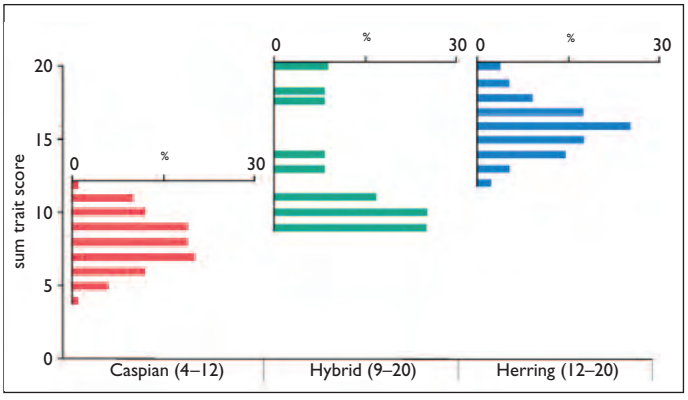


Fig. 6. Sum trait scores for adult Caspian *Larus cachinnans* and Herring Gulls *L. argentatus*, and hybrids. Scores are calculated by summing individual trait score values. The figure shows the percentage of individuals in the sample with a given sum value. Numbers in parentheses are the minimum and maximum values recorded.

examples of some of these birds are discussed in respective plate captions (plates 396–413). An additional F1 hybrid, which could not be scored because details of its wing-tip were not visible, is shown in plate 406. While some hybrids were rather obvious as birds with intermediate phenotypes (e.g. plates 396–398), others (e.g. plate 399) were very Caspian-like. Unless extreme caution is applied and all important features are examined critically, birds such as that in plate 399 are easily misidentified as Caspian in the field.

The proportion of black and white in P10 was variable in the hybrids: some showed more black than white (plates 396 & 400) and others the opposite pattern (plate 404). Most hybrids had only small black dots at the tip of P10 and roughly one-third showed a complete or incomplete subterminal bar. The P10 tongue was most frequently as grey as the mantle (plates 396, 399 & 400), but paler, approaching whitish, in other birds (plate 407). One of the F1 hybrids (plate 405) had a wing-tip very like Caspian, with a deep P10 tongue, pure white tip and correct white to black proportions. The one feature that did not fit Caspian was its P10 tongue colour, which was similar in tone to the mantle (although it looks paler in the plate reproduced here). The inward extension of black in the wing-tip was quite variable in the adult hybrids, but all the sample birds had some black on P5 (single spots or, in most cases, an incomplete or complete bar). With respect to P4, the proportion of hybrids lacking black was similar to that of pure species (table 3), indicating that most often hybrids also had six black-tipped primaries.

Iris peppering was rather limited in most of the hybrids (91% had scores of 2 or 3), although it was moderate (score 1) in one backcross. Consequently, hybrids generally looked pale-eyed in the field. Notably, eye-ring colour was darker and more intense than in pure individuals of either species, including Caspian Gull. The coloration was

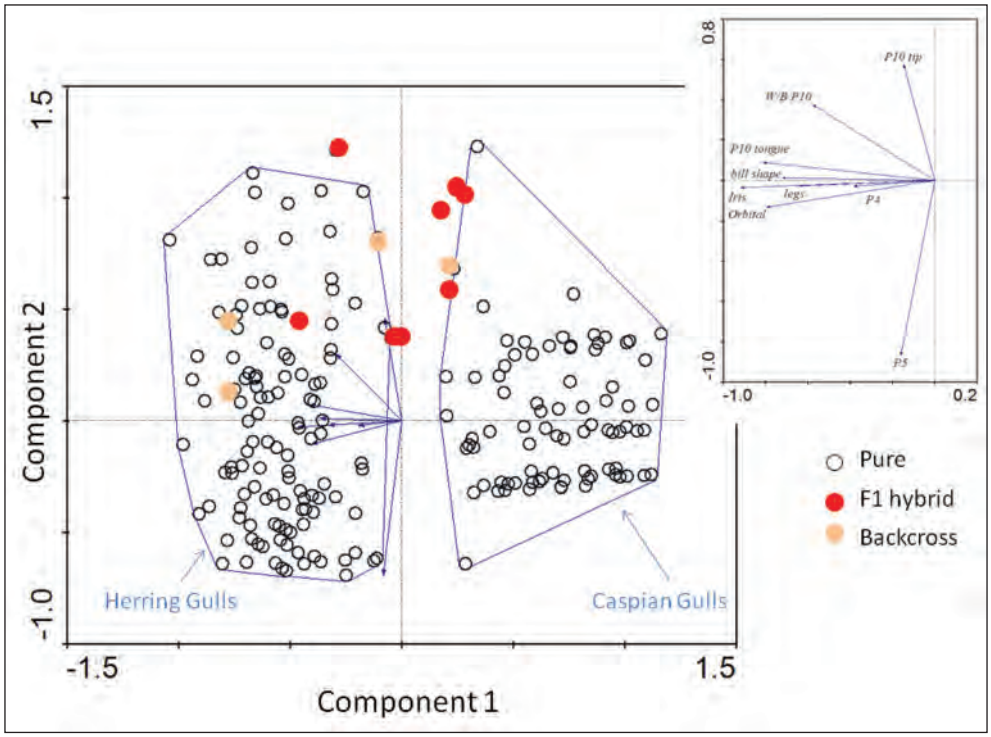


Fig. 7. PCA biplot showing sample adult Herring *Larus argentatus* and Caspian Gulls *L. cachinnans* and a number of proven hybrids. Each circle represents a sample bird. Together, axes 1 and 2 explain 62.3% of the overall variance in the measured traits of the sample birds. Polygons group pure individuals of the two species, while hybrids are shown as coloured symbols. Trait arrows are shown on the main part of the figure (radiating from the origin); to avoid clutter, the inset shows the labels for these.

Grzegorz Neubauer

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400. Male 5CY hybrid Caspian x Herring Gull, Włocławek, central Poland, April 2009. Mother known as (yellow-legged) Herring, father as Caspian. Ringed as chick in Włocławek, May 2005. Not all hybrids appear intermediate between their parent species: notice this bird's striking resemblance to a Yellow-legged Gull. Its P10 pattern excludes Caspian (more black than white; see table 3), while its structure has intermediate scores between Herring and Caspian. Its overall score is 14, higher than that of any pure Caspian (which has a maximum of 12). This individual was discussed in Neubauer *et al.* (2010).

deep orange to red in 57% of hybrids, while most of the remaining individuals had pale to moderate orange eye-rings and only one bird had yellow (plate 410).

Bill shape showed large variation in the hybrids, but in most it was intermediate between the parent species; just one bird had a clearly slim-looking bill (plate 399). In line with their generally rather slim, Caspian-like or intermediate overall jizz, the leg length of hybrids was long to moderately long, and only two birds looked quite short-legged (plates 406 & 412).

In a few cases, hybrids were photographed in late autumn or early winter, and were thus in winter plumage. Some of these had heavy head-streaking, thus clearly excluding Caspian Gull (e.g. plates 398 & 406). Others, however, had almost wholly white heads (plate 407) or showed reduced streaking compared with a typical Herring, although still too heavy for a textbook Caspian (plate 413 left).

Identification of first-winter birds

Table 4 presents the frequency of different trait scores for birds in first-winter plumage (in October to March inclusive; see above).

Marcin Sidelnik/Michal Rycak

Marcin Sidelnik/Michal Rycak

401. 6CY hybrid Caspian x Herring Gull, Vistula, near Warsaw, Poland, May 2011. Ringed as chick on 20th May 2006 in Włocławek, central Poland. Mother known as Herring, father as Caspian. The P10 pattern of this bird was close to Caspian, with less black than white and a completely white tip to the feather. However, its bill was rather deep with a well-marked gonydeal angle, while its iris was non-spotted and its P10 tongue grey. These traits combined rule out a pure Caspian Gull.

These frequency statistics form the basis of the following text.

Variability in structure

Primary projection proved to be a very useful means of distinguishing between the species. Caspian Gulls typically had a long projection of the primaries beyond the tail, with the majority of birds (72%) having a ratio >0.6 (trait score 0). The majority of Herring Gulls had either a medium (score 2) or a moderately long (score 1) projection (45% and 38% of birds respectively). However, some extremely long-winged Herring Gulls occurred in the sample, with 6% of birds having a projection of >0.6, while some Caspian Gulls (3%) had only a medium primary projection, so there is a degree of overlap. Nonetheless, it is clear that a bird with a short primary projection (ratio <0.4) is extremely unlikely to be Caspian.

Contrary to much of the published literature, the presence of a ventral bulge did not prove (quantitatively) useful for distinguishing between the species. It was not uncommon for Caspian Gulls to lack a ventral bulge (38%), while some Herring Gulls (at least in some stances) appeared to show one (14%). The statistics indicate that it would be misleading to refer to a Herring Gull with a ventral bulge or to a Caspian Gull without one as extreme or unusual.

Variability in plumage

While the Herring Gulls in the sample had a rather consistent pattern on the greater coverts (all birds were either trait score 2 or trait score 3), Caspian Gulls varied considerably. The most frequent plumage (63%) was the textbook pattern of trait score 1: a pale bar formed by the contrast between the generally dark basal and pale distal portions of each feather (plate 414). Another frequent pattern in the greater coverts of Caspian Gulls (30% of sample birds) was a delicate 'piano key' pattern or vermiculation along the whole feather edge, with the remainder of the feather being dark (trait score 2). However, 4% of the sample birds had a pattern which was much more typical of Herring and Yellow-legged Gulls *L. michahellis* (trait score 3), with bold notching along the feather (see plate 417). At the other extreme, some Caspian Gulls (3%) had simple pale fringes around each feather, lacking any notching (trait score 0). None of the sample Herring Gulls showed this pattern, although we have seen it on Herring Gulls in the field on rare occasions.

The tertial patterns on the sample Herring and Caspian Gulls differed markedly. Trait score 3 was typical of Herring (63%), and score 0 typical of Caspian (65%); thus, typically, the species were very different. Nonetheless, variability meant that a significant proportion of the sample Caspian Gulls (32%) had a pattern more like that of Yellow-legged Gull (trait score 1) and some had tertials which were moderately (2%) or strongly (1%) notched (scores 2 and 3 respectively), patterns typical of Herring Gull. Conversely, some Herring Gulls (c. 1%) had the diffuse pale tip that is typical of Caspian.

The pattern on the second-generation scapulars differed overall between the species. A significant proportion of the Caspian Gulls had trait score 0, 1 or 2 for their scapulars (68% of the sample), patterns characterised by simply marked feathers lacking strong diamonds or anchors, with numerous wholly grey feathers present. The textbook Caspian Gull pattern (e.g. plates 418 & 419) was different from that seen in the majority of Herring Gulls, in which trait score 4 was predominant (95% of birds). However, an important point is that a significant proportion of 1W Caspian Gulls had strongly patterned second-generation scapulars (32% of the sample had a pattern scored as 3 or 4).

Grzegorz Neubauer

402. Adult Caspian Gull, Azov Sea, Ukraine, May 2001. This bird has only five black-tipped primaries. While this is very rare in Caspian (just a single bird amongst the 100 adults examined in the hand), such birds do occur in the core range of Caspian, as illustrated by this individual.

Contrary to common perception, it is therefore not at all unusual for Caspian Gulls to have second-generation scapulars patterned with strong basal diamonds and/or subterminal anchors. In contrast to that of Herring Gull, the pattern frequently differs across these second-generation feathers, with a mixture of well-marked and plainer scapulars being a common feature of Caspian. The uniform silvery or grey scapular pattern seen in many Caspian Gulls (trait score 0 and 1) was not recorded in any of the sample Herring Gulls.

Our sample showed that it is not uncommon for Caspian Gulls to appear rather heavily streaked on the head and body in 1W plumage. While most birds were much whiter overall than Herring Gulls (84% of Caspian Gulls scored 1 or 2), 16% were as well streaked as a typical Herring Gull (i.e. trait score 3). Some (e.g. PUSZ in plate 422) were extremely heavily streaked and so quite unlike the search image that most birders have of Caspian Gull.

Variability in extent of the post-juvenile moult

Moult data indicate that it would be extremely unusual to find a Caspian Gull after October of its first calendar-year with anything more than one or two first-generation scapulars remaining. The extent of the

Table 4. Percentages of sample first-winter birds with trait scores for selected plumage, structural and moult characteristics.

Trait	Score	Description	Herring (n=85)	Caspian (n=63)	Hybrid (n=12)
Extent of scapular moult	0	no first-generation feathers remaining	13	92	78
	1	a small number (<⅓) of first-generation feathers remaining	43	8	22
	2	a significant number (>⅓) of first-generation feathers remaining	44	0	0
Greater-covert pattern	0	no white vermiculation – simple pattern with brown centres and sharp white edges	0	3	0
	1	white edges with delicate notches or vermiculation; or dark brown centre with white tip to ⅓ of length (i.e. white restricted to tip or distal third)	0	63	12
	2	clear white notches/barring creating a delicate 'piano key' pattern along the whole edge/feather; but much of feather dark	6	30	38
	3	lots of white (more than ½ of GC looking white) distributed along the whole feather, or a bold notching ('piano key' pattern)	94	4	50
Ventral bulge	0	present	14	62	34
	1	absent	86	38	66
Primary projection	0	very long (ratio >0.6)	6	72	56
	1	moderately long (ratio 0.5–0.59)	38	25	33
	2	medium (ratio 0.4–0.49)	45	3	11
	3	short (ratio <0.4)	11	0	0
Greater-covert moult	0	all or almost all new (>75%)	0	0	11
	1	51–75% new	0	3	0
	2	34–50% new	0	2	0
	3	10–33% new	0	24	0
	4	one or two feathers moulted	0	36	11
	5	no moult	100	35	78
Median-covert moult	0	all or almost all new (>75%)	0	0	0
	1	51–75% new	0	13	0
	2	34–50% new	0	20	11
	3	10–33% new	0	35	0
	4	one or two feathers moulted	1	13	22
	5	no moult	99	19	67

post-juvenile scapular moult varied considerably in the sample of Herring Gulls, however, which probably reflects the mixture of both *argenteus* (more extensive moult) and *argentatus* (little or no moult) in the sample. The extent of moult in the coverts and tertials differed considerably among Caspian Gulls (ranging from none to extensive), but was extremely consistent in the Herring Gull sample: just one bird showed any sign of covert or tertial moult, having two new inner median coverts. Thus, while a 1W with new wing-coverts or tertials is most likely to be a Caspian (or Yellow-legged) Gull, a bird with a completely first-generation wing could be any one of these species.

Multivariate analyses and the character of hybrid birds

Fig. 8 shows summary information on the total scores for sample 1W birds. Despite the variability of individual trait scores, as discussed above, the sum values for Caspian were consistently lower than those for Herring Gull, with no overlap in the distribution of scores. The mean value for Caspian Gull was 18, with 95% of birds having scores between 12 and 24. The highest score recorded by any single Caspian was 25. Thus, if sample data are representative, they indicate that any bird with a score greater than 25 should not be a Caspian Gull. The lowest score of any Herring Gull in the sample was

Table 4. *continued*

Trait	Score	Description	Herring (n=85)	Caspian (n=63)	Hybrid (n=12)
Tertial moult	0	3 or more new	0	10	11
	1	2 new	0	8	0
	2	1 new	0	16	0
	3	all old	100	66	89
Darkness of head and body	0	totally white	0	0	0
	1	reduced grey wash or streaking (confined to flanks and/or single streaks around nape)	0	41	0
	2	light streaking/wash to head (incl. some dark around eye); isolated streaks/blotches on body. Overall, body looks more white than brown	17	43	22
	3	well streaked: dark mask around eye and/or streaking covering the whole head/face; body with extensive but moderately dense streaks/mottles	68	16	78
	4	strong and dense streaking/mottling on body and head making it appear almost wholly dark	15	0	0
First-generation tertial pattern	0	diffuse white tip (like Common Gull *Larus canus*)	1	65	33
	1	fine pale fringe around distal portion (like classic *michahellis*), possibly also with some vermiculations	3	32	12
	2	edges moderately notched	33	2	22
	3	edges strongly notched and/or some dark barring or pale patches across the feather on some or all tertials	63	1	33
Scapular pattern (second generation)	0	uniformly silvery-grey, darker patterning absent or very faint	0	8	0
	1	silvery-grey background, pattern stronger than 0, but lacks strong barring or central dark diamonds (only dark shafts and anchors), with only a minority (single) of such feathers admixed	0	30	0
	2	strong, contrasting shaft-streaks, anchors and/or dark central diamonds, but these more patterned feathers are less than ½ of all; ground colour creamy or silvery-grey, possibly with some grey feathers mixed in	0	30	0
	3	strong pattern described in 2 on most (more than half) of feathers, but possibly also one or two plain grey feathers or feathers with grey ground tone	4	17	12
	4	all feathers contrastingly patterned (with dark cross bars or diamonds), lacking plain grey feathers; feather centres buffy-brown	96	15	88

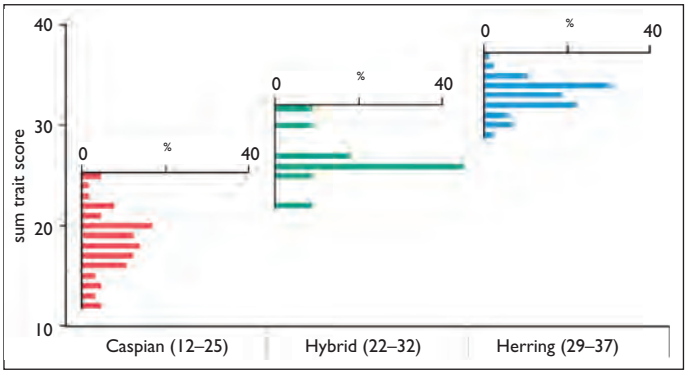

Fig. 8. Sum trait scores for first-winter Caspian *Larus cachinnans* and Herring Gulls *L. argentatus*, and hybrids. Scores are calculated by summing individual trait score values. The figure shows the percentage of individuals in the sample with a given sum value. Numbers in parentheses are the minimum and maximum values recorded.

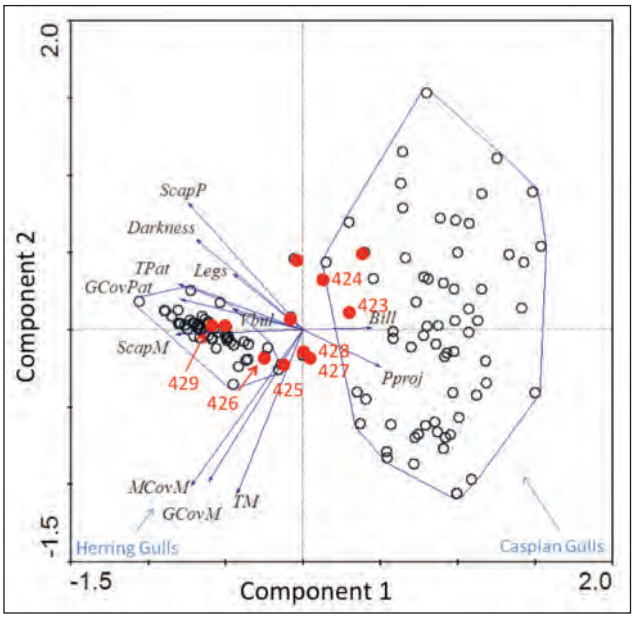

Fig. 9. PCA biplot showing sample first-winter Herring *Larus argentatus* and Caspian Gulls *L. cachinnans* and a number of proven and suspected hybrids. Each circle represents a sample bird. Together, axes 1 and 2 capture 73.4% of the variance in the sample data. The polygon to the right groups sample Caspian Gulls, while that to the left groups Herring Gulls. Hybrid birds are highlighted in red; numbers relate to plates that show examples of some of these hybrids. Codes for traits are: Bill=bill length:depth ratio, Pproj=length of primary projection, TM=extent of tertial moult, GCovM=extent of greater-covert moult, MCovM=extent of median-covert moult, ScapM=extent of scapular moult, GCovPat=greater-covert pattern, Tpat=tertial pattern, Legs=leg length, Vbul=presence of ventral bulge, Darkness=extent of streaking on head and body, and ScapP is the pattern on second-generation scapulars.

29, with 95% of the Herring Gulls having scores between 30 and 36. Scores for hybrids were intermediate between the parental species, with overlap at the upper (i.e. with Herring) and lower (with Caspian) ends.

Fig. 9 shows the biplot resulting from the PCA analysis of 1W birds. There is clear separation between Herring and Caspian Gulls, with this separation occurring across component 1. Importantly, there is no overlap between the two species in terms of their positions on axis 1. There is considerable individual variation, this being more pronounced in Caspian Gull than Herring. This intraspecific variability is evident most obviously by the much larger space occupied by the polygon which groups the sample *cachinnans*.

Some of the traits we analysed were useful for separating the two species, while others were more responsible for the intraspecific variability. Those traits whose arrows lie on or close to (i.e. more parallel with) axis 1 are responsible for the separation of birds in this horizontal dimension, and consequently for separating Herring from Caspian Gull. These traits are, in order of proximity to axis 1 (and hence importance in separating birds in this dimension): (i) bill length:depth ratio; (ii) extent of scapular moult; (iii) greater-covert pattern; and (iv) primary projection. Conversely, arrows for some traits (e.g. extent of covert and tertial moult and the pattern of second-generation scapulars) point away from axis 1. The position of these arrows relative to axis 1 indicates that

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403. 9CY female hybrid Caspian x Herring Gull, Przykona Reservoir, central Poland, May 2011 (trapped also in 2009). Parents known as Herring (mother) and Caspian (father). This hybrid was ringed as a chick in May 2003 in Włocławek, c. 80 km northeast of the colony where it bred in 2007–11. Its wing-tip generally resembles that of Caspian, but there is a little more black than white on P10, the tongue is grey (not white), and the white mirror on P9 is relatively small. Note the intense coloration of the bare parts, but that the iris is nearly non-spotted. Bill ratio computed from depth/length measurements was 3.02, thus falling between Herring and Caspian (see Neubauer *et al.* 2007). Its overall score was 9, just on the safe limit for identification of Caspian.

they are not important for separating the two species but the fact that they are long, relative to those of the other traits, indicates that they contribute importantly to the variability observed in the sample. Most of the spread in the Caspian Gull polygon occurs in approximately the vertical and/or northeast–southwest dimension. This dimension corresponds most closely to the covert and tertial moult traits. There is also some spread in the Caspian Gulls in a northwest–southeast dimension, a dimension represented by long arrows for scapular pattern and plumage darkness.

Overall, the PCA indicates that much of the variability in Caspian Gulls relates to differences in the extent of post-juvenile moult, scapular patterns and overall darkness. It is notable that the arrows for leg length and the presence of a ventral bulge do not lie close to axis 1 and are rather short. This indicates that these features are of little use in differentiating between Caspian and Herring Gulls; this is borne out by the overlap apparent in tables 3 and 4.

The positions of known and suspected hybrids included in the analysis are highlighted in red in fig. 9; examples of these are shown in plates 423–429, and their phenotypic characteristics are discussed in the respective captions. In general, most of

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404. 5CY hybrid Caspian x Herring Gull, Dumpiai, Lithuania, 10th September 2008. Mother known as Caspian, father as Herring Gull. Ringed as a chick in the Włocławek colony, Poland, 9th May 2004. In many ways this bird shows classic intermediacy. Its bill is easily within the range of Caspian, but it has a Herring Gull-like pale eye and P10 pattern (more black than white). Its legs are yellow-toned, but this is of no real consequence.

Magdalena Zagalska-Neubauer

Magdalena Zagalska-Neubauer

405. 7CY hybrid male Caspian x Herring Gull, Włocławek, central Poland, 29th April 2009. Mother known as Herring and father as Caspian. Ringed as a chick in Włocławek on 22nd May 2003. Note that the wing-tip is very Caspian-like (e.g. fully white tip to P10, more white than black in P10 and a full band across P5). However, it has a non-spotted iris, pale orange eye-ring and intermediate bill proportions; these features count against Caspian. Although hard to judge from this photograph, when computed from in-hand measurements the bill ratio was 2.96, too low for classic Caspian. Its overall score was 11, roughly halfway between the Herring and Caspian distributions, illustrating its intermediate phenotype.

these show an odd combination of traits that make them look like neither parent (plates 423–425). Most of the F1 hybrid birds occupied intermediate space on PCs 1 and 2. Two backcrosses are extremely troublesome as they sit within the core of the space occupied by pure Herring Gulls. They look very similar to a Herring Gull (e.g. plate 429) and without the evidence provided by the ring would most likely be overlooked as that species. Overall, the PCA results support the evidence from the trait sum scores (fig. 8), which indicate that some individuals of mixed parentage are not separable with confidence.

Underwing pattern

Plate 432 (p. 734) shows the underwing of a selection of Caspian Gulls. The birds were all photographed in either September or October of their first calendar-year and were selected to illustrate the continuum of underwing markings.

The most typical impression of Caspian is an underwing which is paler overall than that of Herring (or Yellow-legged) Gull. The ground colour is silvery-white, and this is overlain with a degree of brown barring and mottling. In many birds, the median underwing-coverts are paler (less well marked) than the rest, and this gives rise to a pale band

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406. 5CY hybrid Caspian x Herring Gull, Pohlsche Heide, Germany, 12th October 2007. Mother known as Caspian, father as Herring Gull. Its similarity to Caspian is evident in the structure (longish bill) and pale bill colour; on the other hand, its pale iris, P10 pattern and moderate head-streaking are all pro-Herring Gull traits. Overall, this bird is not eye-catching. It may go unnoticed, but if detected this combination of traits should preclude identification as a pure Caspian.

Armin Deutsch

Armin Deutsch

407. 5CY Female F2 hybrid Caspian x Herring Gull, Pohlsche Heide, Germany, 6th October 2009. Parentage confirmed by microsatellite markers. Both parents were hybrids, trapped at the nest and identified in the hand by phenotype; the female parent had an intermediate genotype. Ringed as a chick in Włocławek, central Poland, 11th May 2005. Unlikely to be separated from Herring Gull with confidence, while pure Caspian can be excluded on the basis of the P10 pattern (very short tongue), the head shape and facial expression (notably the very pale eye). However, signs of Caspian genes include the longish legs, relatively slim bill and nearly all-white head, despite the fact that the moult to winter plumage is more or less finished. Despite it not being possible to calculate a total score for this bird (P4 and P5 patterns not visible), it must have been higher than 12 (this was the partial score without inclusion of P4 and P5). This score reflects the bird's similarity to Herring (see fig. 6).

across the underwing; on some birds there is also a similar band across the lesser underwing-coverts. Consequently, on the medium and darker Caspian Gulls, the pattern is rather contrasting (e.g. birds *d* and *e*) and so can be similar to the banding seen on some Yellow-legged Gulls. While the underwing of Herring Gull varies in overall darkness, the key point is that it is much more uniform, with little contrast between the darker and paler feathers. On Caspian Gull the long rear axillaries are often (but not always) the most strongly marked part of the underwing, although the actual pattern varies: some birds have heart-shaped spots (bird *m*), others coarse barring (bird *j*) and some fine barring (birds *f*, *h* and *i*) on the axillaries. The wing fold line along the upper flank is often contrastingly pale (e.g. birds *b*, *d* and *o*).

PUSZ (bird *a*) is the darkest example we have of a proven Caspian Gull (it was ringed as a chick in Ukraine). The brown on the underwing of such birds is very cold and dark in tone and the barring is very dense, producing an underwing that is at least as dark as typically seen on Yellow-legged Gull.

Grzegorz Neubauer

Grzegorz Neubauer

408. 5CY backcross hybrid Caspian x Herring Gull, Włocławek, central Poland, 21st May 2008. Mother known as hybrid Caspian x Herring, father as a pure Caspian. Ringed as a chick on 9th May 2004 in Włocławek. Given its age, this bird shows rather a surprisingly brownish alula and primary coverts. With a score of 10, it falls closer to Caspian than Herring, as expected given that Caspian genes predominate. Its hybrid origin is unlikely to be detected in the field, and most likely this bird would be identified as Caspian if unringed. In the right-hand photo it is paired with a female Herring.

Grzegorz Neubauer

409. 5CY backcross hybrid Caspian x Herring Gull, Włocławek, central Poland, 26th April 2008. Mother known as hybrid Caspian x Herring, father as Herring. Ringed as chick in Włocławek on 18th May 2004. This bird is inseparable from Herring: it retains a deep and short bill, short legs, and its bill coloration is intense.

Grzegorz Neubauer

410. 5CY female backcross hybrid Caspian x Herring Gull (right), Włocławek, central Poland, 26th April 2008. Mother Herring, father hybrid Caspian x Herring. Ringed as chick in Włocławek on 19th May 2004. Paired with male Caspian. Although the plumage is not fully adult yet (note the brown-spotted wing-coverts), its iris is non-spotted and the eye-ring yellow, both matching Herring Gull. As in other backcrosses, hybrid origin is hardly detectable in the field (evident only in the bill, which is slimmer than usual for Herring). Its alert stance makes it look long-necked and small-headed.

Grzegorz Neubauer

411. Adult Caspian Gull, Selitba Lake, Penza district, SE European Russia, May 2010. An example of a bird with a *thayeri* pattern on P9 and a typical Caspian pattern on P10.

Marcin Sidelnik/Michał Rycak

Marcin Sidelnik/Michał Rycak

412. 6CY F2 or backcross hybrid Caspian x Herring Gull, Vistula, near Warsaw, Poland, May 2011. Mother known as hybrid, father unknown. Ringed as chick on 18th May 2006 in Włocławek, central Poland. This bird is actually very Herring-like, as all trait scores correspond to Herring Gull (e.g. unmarked eye, strong bill and the P10 pattern (more black than white). The Caspian influence is barely detectable – if at all.

If seen in Britain, such birds would most likely cause considerable debate. Notice that on some birds the dark markings are coarse and sit over a pale ground colour (e.g. birds *c*, *e* and *j*), while on others the feathers have a buffy-brown ground tone with paler stippling over this (i.e. the reverse pattern, bird *g*). Thus, while the paler Caspian Gulls separate clearly from Herring and Yellow-legged Gulls, there are no simple character traits that separate the darker birds. An important point is that there is a strong correlation between the underwing markings and the extent of streaking on the head and body. Heavily streaked birds are likely also to have relatively dark underwings, as shown by PUSZ (also shown in plate 422).

Identification of 1CY birds in August and September

First-calendar-year Caspian Gulls are now turning up regularly in Britain in July and August. On such early dates the post-juvenile moult has either not begun or barely started and so these birds retain a more or less full set of relatively fresh, first-generation feathers. At this time they can look extremely different from how they appear later in the autumn and winter, when moult and wear have turned them into much more distinctive birds. Some fully juvenile Caspian Gulls can easily be overlooked by the unwary, and so are worth discussing here, even though we have not scored them quantitatively.

An extremely dark-looking, well-streaked

Armin Deutsch

Armin Deutsch

413. 4CY (left) and 5CY (right) backcross or F2 hybrid Caspian x Herring Gull, Pohlsche Heide, Germany, 17th December 2009 (left) and 14th January 2010 (right). Mother known as hybrid Caspian x Herring, father unknown. Ringed as a chick in Włocławek on 20th May 2006. This bird is very Herring-like and has a high score (20). The P10 pattern, with a short tongue and thick black band within the white tip, is outside that seen in any pure Caspian in our sample. Perhaps the only Caspian sign is seen in the bill, which is relatively slim with only a slight gonydeal angle.

Chris Gibbins

414. 2CY Caspian Gull, Riga, Latvia, March 2009. This bird has a rather robust bill (trait score 2), which overlaps with Herring Gull. Such large (presumed) male birds can appear very unlike the caricatured image sometimes painted of Caspian Gull. Its plumage is very typical of Caspian Gull – for example, its greater coverts have a trait score of 1, a pattern seen in 63% of birds. This bird has an overall score of 19, very close to the average for the species (18.2).

Chris Gibbins

415. 2CY Herring Gull, Peterhead, North-east Scotland, March 2011. This is an example of a bird with moderately long legs (trait score 1) and a fine bill that lacks a marked gonydeal angle (score 1). Its plumage, however, is typical. Its overall score is 32, very close to the average for this species (33.0) and therefore some odd structural traits do not affect its sum score markedly.

Chris Gibbins

416. 2CY Caspian Gull, Mamaia, Romania, January 2011. This is an extremely short-legged individual (trait score 2), but otherwise it is perfectly typical. Its overall score is 18. Of the Caspian Gulls in the sample, 52% were truly long-legged (trait score 0), with many (46%) having only medium or moderately long legs (trait score 1).

juvenile, especially if it has heavily marked wing-coverts, may not immediately strike observers as a Caspian Gull. However, this combination of traits does occur in pure Caspian Gull, as indicated by the Ukrainian birds depicted in plates 430, 431 & 433 (ring codes PUHP and PUNP). PUHP is unusual in its overall darkness (trait score 4) and heavily notched greater coverts (score 3) as well as in having a tertial pattern more like that of a Yellow-legged Gull (score 1). In fully juvenile plumage, PUHP looks rather like some Lesser Black-backed Gulls *L. fuscus* and in Britain may be passed off as such. However, later in the autumn such birds can become more typical-looking (plate 431). PUNP (plate 433) also looks dark but actually is rather typical of how many fresh 1CY Caspian Gulls look. Once we accept that such Caspian Gulls occur, the identification of unringed dark individuals as this species becomes more palatable.

Discussion

This paper represents the first fully quantitative analysis of patterns of phenotypic variability in adult and first-winter Caspian Gulls, relative to Herring Gulls and hybrids between these species. We scored more than 400 birds using plumage, moult and structural traits and analysed patterns of variability in individual traits and sum scores. We used PCA to plot pure and hybrid birds in multivariate phenotypic space and assess the traits most responsible for the intra- and interspecific variability observed in our sample.

The main point about the scoring system is that it has allowed us to quantify the patterns of variability in individual traits and the extent of overlap between species. However, the system may also be useful for records committees, should they feel it appropriate in their area, to help with assessment of less typical birds. These two points are elaborated in the discussion that follows.

Trait scores and the use of the scoring system

The frequency statistics in tables 3 and 4 allow birders to determine how unusual a trait present in a candidate bird actually is. This is a critical starting point for tackling the identification of a less typical individual. Particularly for first-winter birds, the data show that some traits, traditionally thought to be useful for separating the species, are not wholly reliable on their own because of the degree of overlap. Rather than necessarily seeing this overlap as a problem for field identification, we prefer to use it to suggest that certain criteria used in record assessment should be relaxed. Perhaps most obviously, it is clear that a virtually unmarked white head and body should not be a prerequisite for a record of first-winter Caspian Gull – many Caspian Gulls (16% of our sample) were actually rather well streaked (trait score 3). Similarly, some first-winters had heavily chequered greater coverts, so this feature alone should not automatically rule out a candidate bird. Bill structure, leg length and the presence of a ventral bulge are all useful features for identification of typical birds, but the statistics show a considerable overlap; for example, a bird a with a typical Herring Gull-like bill (trait score 2) can easily be a Caspian. For adults, there was much overlap in the extent of black within the white tip of P10 and across P5, so neither of these traits should be seen as being critical for field identification.

Despite the overall success of the approach we have used, it must be stressed that it remains simplistic. This simplicity was dictated primarily by the need to ensure its application to birds seen in the field. With trapped birds, more detailed measurements permit the application of more sophisticated and powerful approaches (for example, those used in Gay *et al.* 2007 and Neubauer *et al.* 2009). It is clear that individual observers might score the same bird slightly differently; as a consequence, while we have developed an approach that allows a bird's phenotype to be characterised as objectively as possible, there remains an element of subjectivity. Polarised scoring systems are essentially linear and, through careful choice of traits and their scores, are capable of representing the transition (in scores) from one species to another and of identifying the points across this transition occupied by hybrids between the two. By their very nature they are not able to assess the similarity of a third species to these two if it does not sit somewhere on the same overall transition line. In essence, this is

Chris Gibbins

417. 1CY Caspian Gull, Sijazan, Azerbaijan, September 2011. The greater coverts are heavily chequered, quite unlike those of a textbook Caspian. Birds such as this one, in the species' core range, show that individuals far from the hybrid zone can exhibit such traits. This bird and those in plates 418 & 419 were excluded from the sample because they were photographed before the completion of post-juvenile moult.

Chris Gibbins

418. 1CY Caspian Gull, Klaipeda, Lithuania, September 2010. This bird's second-generation scapulars score 0 (uniformly silvery-grey, patterning absent or faint). Although regarded as the 'textbook' scapular pattern, it is actually not common – only 8% of Caspian Gulls show this pattern. This bird was excluded from the sample because it was photographed in September and had not completed its post-juvenile moult.

Chris Gibbins

419. 1CY Caspian Gull, Sijazan, Azerbaijan, September 2011. Another bird with textbook colour and pattern in its second-generation scapulars. The number of wing-coverts included in the post-juvenile moult varied from 0 to more than 75% in our sample of Caspian Gulls; this bird shows a typical pattern, with some new inner greater coverts and a scattering of new median coverts.

420. 2CY Caspian Gull, Riga, Latvia, March 2009. The second-generation scapulars show a typical pattern – a mixture of some darker, well-marked feathers and others which are rather silvery grey and lightly marked. This is quite different from the more uniform overall impression given by Herring Gulls, which generally have the same or a very similar pattern across all of their scapulars.

Chris Gibbins

421. 2CY Caspian Gull, Mamaia, Romania, January 2011. A darker-bodied bird than average for January, but the ground colour to the head and body remains white. The scapulars show a mix of well-marked and clean grey feathers while the wing-covert colour tone and pattern are typical of Caspian Gull – e.g. the greaters have dark bases and a pale band along the tip. Its overall score is 18, close to the average for Caspian.

Chris Gibbins

422. 1CY Caspian Gull, Denmark, October 2010. PUSZ (ringed as a chick in Ukraine in June 2010) is an example of a dark plumage type seen only rarely in Caspian Gulls of this age, yet this bird, from the core range in eastern Europe, confirms that a heavily streaked body and dark eye-mask are not necessarily signs of mixed genes. The juvenile greater coverts and tertials show perfect patterns for a Caspian (both trait score 0).

Lars Adler Krogh

Armin Deutsch

423. 1CY hybrid Caspian x Herring Gull, Germany, 5th December 2007. Ringed as a chick in Poland on 9th May 2007, parents known as Herring (mother) and Caspian (father). It has some Caspian traits (greater-covert and tertial patterns, replaced wing-coverts), but the head- and body-streaking is heavier and more extensive than shown by any pure Caspian in December. Its overall score was 26, outside the range of pure individuals of both species.

Armin Deutsch

424. 2CY backcross hybrid Caspian x hybrid Caspian x Herring Gull, Germany, 22nd March 2006. Ringed as chick in Poland on 11th May 2005, parents known as Caspian (mother) and hybrid Caspian x Herring (father). This bird combines Caspian-like jizz and moult (note the new inner greater covert) with some plumage traits that are more like Herring or Yellow-legged Gull. Its score was 26, outside the limits of pure Caspian or Herring Gull.

Jörgen Bernsmo

425. 1CY backcross hybrid Caspian x Herring Gull, Sweden, 26th September 2006. Ringed as a chick in Poland on 17th May 2006, mother known as Caspian, father as a hybrid Caspian x Herring Gull. This is a very difficult bird, combining Caspian jizz (long legs, slender bill) with aspects of plumage and moult that are more like Herring. Its score (25) is too high for Caspian and low for Herring and should flag it as a possible hybrid.

because the full set of traits used to separate two species are not the same set used to separate a third species from each of these. Consequently, it has not been possible to incorporate Yellow-legged Gull in our system.

Application of the scoring system ideally requires that all traits are visible in photographs or at least have been recorded in the field. If not, then observers or committees may have to judge whether, without full details, a bird is acceptable. A full discussion of this issue is beyond the scope of this paper, but it may still be possible to use the system to score such a bird partially and to use that score to help reach a decision. For example, if the partial score (primary projection not seen) of a first-winter gull is 19 (with its score not including a value for primary projection), that bird would in any event fall within the range of Caspian Gull, since the upper limit for Caspian is 25 and the primary projection score runs from 0 to 3.

Defining boundaries for the safe identification of Caspian Gull

There is frequent debate on internet forums over 'problem birds'. In many cases these debates go unresolved because the views being put forward lack an objective or quantitative basis – opinion and counter opinion fuel interesting but ultimately inconclusive debate. Although we recognise that many birders will not find the statistical approach outlined in this paper to their liking, it does provide an objective basis to allow such debates to be resolved. We stress that rather than amounting to 'identification by numbers' it merely formalises a process that we already attempt when confronted with a less typical individual gull; the formalisation is required because we cannot otherwise deal with multiple traits simultaneously and quantitatively, especially when it comes to subtle hybrids. Thus, we prefer to see our system as a supportive tool, rather than a fundamental shift in the approach to bird identification. Records committees have discussed such formalisation previously, for other species groups, but for a variety of reasons have generally retained more traditional approaches to record assessment. However, because they are so individually variable, and because of the issues posed by hybrids, we feel that a more quantitative approach is justifiable for assessing Caspian Gull records.

The results of our study are perhaps fully satisfying for a statistician, owing to the very different mean values and virtually non-overlapping distributions of the sum scores of pure individuals. For birders interested in the identification of problem birds, this indicates that separation of the vast majority of pure Caspian and Herring Gulls should be possible using sum scores. At the same time, our data represent the classic picture of hybrid intermediacy very well – all proven hybrids had sum scores roughly in between the pure species. However, given the range of the scores of pure individuals, it is also clear that there is very little 'space' remaining for hybrids to fit into. Consequently, one would have to be fortunate to find a hybrid that fell neatly between the distributions of pure Herring and Caspian Gulls.

The number of hybrids included in our sample was constrained by their abundance in the study colonies. Despite the limited sample size, however, hybrids showed a degree of variability comparable with pure individuals. What we infer from this is that, because there is little sum-score space left between pure individuals of the two species, the true distribution of hybrid scores must overlap considerably with Herring and Caspian. While this is an interesting finding in its own right, it can also be used to define safe boundaries for the identification of pure individuals. For adult birds, it is clear (fig. 6) that a bird with a score of less than 9 should be pure Caspian, while one with a score of 9 or more is not safely identifiable as a Caspian. For first-winter birds (fig. 8), the upper limit for pure Caspian was 25, while the lowest score for a proven hybrid was 22. Thus, we suggest that 21 should mark the upper limit of safe first-winter Caspian (as birds with scores of 22–25 could be either pure Caspian Gulls or hybrids).

The application of these values would mean that some pure individuals (those with scores overlapping with those of hybrids) would not be considered acceptable. Such birds appear from our sample data to be rare in populations, so we might expect that western Europe is visited far more frequently by 'safe' Caspian Gulls (i.e. adults with scores

Ruud Altenburg

426. 1CY presumed hybrid Caspian x Herring Gull (7P48), Amsterdam, Netherlands, 25th September 2004. Parentage unknown, but ringed in a mixed colony at middle Vistula, SE Poland on 15th May 2004. Note the Caspian-like jizz combined with heavily notched greater coverts and tertials. This combination means that few birders would identify this as a pure Caspian Gull.

Chris Gibbins

427. 2CY presumed hybrid Caspian x Herring Gull, Riga, Latvia, April 2009. Ringed as a chick in a colony in eastern Lithuania where c. 50% of pairs are mixed, though its parents are uncertain. It occupies phenotypic space (fig. 9) that fits neither pure Caspian nor pure Herring Gull and its overall trait score of 26 reflects this. In the field it looked noticeably bulky, with a robust head and bill and relatively short legs.

Marco Basso

428. 2CY backcross or F2 hybrid from central Poland, father known as hybrid Caspian x Herring, mother unknown. Ringed as a chick on 20th May 2005, photographed on the Adriatic coast in Italy, where it spent its first winter. It occupies space on the PCA biplot (fig. 9) which is distant from any Caspian Gull and outside the space occupied by Herring Gull. Its trait score is 27 – too high for Caspian and below that of any pure Herring.

429. 2CY backcross or F2 hybrid Caspian x Herring Gull, Włocławek, Poland, 19th April 2007. Ringed as a chick on 20th May 2006 at Włocławek, mother a hybrid, father unknown. Although it is rather pale and has a slim bill, this bird is inseparable from Herring Gull with any confidence. PCA (fig. 9) indicates that, phenotypically, it sits in the space occupied by pure Herring Gull, with a trait score of 30.

Grzegorz Neubauer

430. Juvenile Caspian Gull, Poland, 16th July 2010. Ringed in the Caspian Gull core range in Ukraine in June 2010. It is in very fresh juvenile plumage and thus extremely dark on the head and body; broad white notches on the greater coverts (score 3) are more indicative of Herring, but the plumage is otherwise typical for fresh juvenile Caspian. This bird flew c. 1,300 km to the northwest a month after it was ringed (see plate 431).

Marcin Sowa

431. First-winter Caspian Gull (centre), Switzerland, 22nd December 2010. This shows the same bird as plate 430, now in first-winter plumage – evidence of just how much birds can change in a few months. By December the wing-coverts and tertials are heavily worn, while the mantle and scapulars show a typical Caspian pattern. The greater coverts now look more classically Caspian-like because of wear. To the right is a 2CY Caspian.

Ernst Weiss

432. Variation in the underwing colours and pattern in 1CY (first-winter) Caspian Gull. *All photographs Chris Gibbins, except bird a (by Lars Adler Krogh)*

less than 9, first-winters with scores less than 22) than by these extreme individuals from the tails of the distribution. Given that the phenotype of known hybrids shows considerable variation (i.e. the maximum and minimum values in figs. 6 and 8), we suggest that safe identification of Caspian Gull, at least in areas where it constitutes a rarity or scarce migrant, should be accompanied by scores.

The proximity of arrows on a PCA biplot shows how strongly correlated the variables are. For first-winter birds, we ran the Caspian Gull data on its own through a PCA to assess the degree of correlation between traits. This analysis indicated that, of the plumage traits, scapular pattern and overall darkness scores are correlated. Consequently, a Caspian Gull which has lots of dark streaking on the head and body is statistically likely to have strongly marked second-generation scapulars too. This is highly relevant for field identification. When confronted with a bird that appears rather too heavily streaked on the head and body to be a likely candidate, it is logical to look at some other traits to help with the identification. If the bird also has heavily marked scapulars, the temptation might be to dismiss it because it shows two 'atypical' traits. However, the PCA indicates that these characters tend to go hand in hand, and that the combination of a dark head and body and heavily marked scapulars does not automatically rule out Caspian.

In general, adult hybrids had a shorter bill and more black in P10 than Caspian Gulls, and frequently the spotting on their irides was so delicate that they would look pale-eyed in the field. Scores for many of the individual traits overlapped between pure Caspian and pure Herring Gulls. In effect this means that, for individual traits, there are no intermediate scores that are characteristic of hybrids (as such scores can also be shown by pure individuals). The phenotypic intermediacy of hybrids was evident only when multiple traits were examined simultaneously. The PCA indicated that in terms of their overall phenotype, some hybrids really are intermediate, so extreme caution is needed when tackling them in the field. One known and two presumed adult backcross hybrids were extremely similar to parental phenotypes. While the adult F1 hybrids were rather uniform in phenotype, F2 hybrids and backcrosses must show a higher degree of phenotypic variation because of recombination and segregation. In these hybrids, new combinations of genotypes arise, ones that are never present in the parental or F1 hybrid generation, as well as genotypes identical to parental ones (see Price 2008). Therefore, both F2 hybrids and backcrosses are likely to look either like pure species or like intermediates. It seems very likely that such birds simply go undetected in the field.

Knowledge gaps

Our understanding of Caspian Gull has improved dramatically thanks to the pioneering work undertaken in the 1990s by Ronald Klein, Lars Jonsson, Martin Garner and others. Research published since then has provided further insights into the ecology, genetics and identification of Caspian and related gulls. Despite the advances, these gulls still present challenging biological questions (for example, related to their evolution; Liebers *et al.* 2004) and for birders they will no doubt continue to pose challenging identification problems. While this paper will not allow birders to identify all the problem Herring/Caspian Gulls they encounter, we hope that it at least provides a structured framework that can be used to reach objective decisions about which ones are identifiable and which are not. It is certainly the case that many of the hybrids in our sample look intuitively odd, appearing neither like pure Herring nor like Caspian. Birders who spend time regularly looking at large gulls are most likely to sense this overall intermediacy; the scoring system allows this to be quantified and reported objectively.

In terms of describing patterns of variability, this paper should be seen as a first step. It is largely the result of informal observation and analysis, rather than funded, professional scientific research. Constraints on the locations we have been able to visit, relative to the full range of the species, mean that we cannot present a complete picture of intra- and interspecific variability, nor the variability of hybrids. Specific issues related to this, and other aspects of large gull identification that require further work, are discussed below.

1. Hybrids and sample size

Although we included as many hybrids in our sample as possible, the numbers are small and that sample is unlikely to capture the full variability in the appearance of hybrids. More work is needed to record the appearance of hybrids and assess the extent to which our data are representative. Heterospecific pairs, where the partners represent pure individuals of different species, constitute only a minority in mixed colonies because of the isolation mechanisms which limit mixed-species pairing (Neubauer *et al.* 2009) – and because of that it is clear that a full understanding of the phenotypic variation of hybrid individuals is some way away.

2. Yellow-legged Gull

The scoring system we have developed does not deal with Yellow-legged Gulls. Generally, this species is not a major cause of confusion for observers faced with a putative Caspian Gull in Britain, but some birds create problems. Work is needed to develop a scoring system to separate Yellow-legged from Caspian Gulls, and hybrids between these two.

3. Long-term studies and the identification of other age groups

We have dealt only with adult and first-winter birds and there is a need to collect data on other age groups. While most birds will not be problematic, others are genuinely difficult and a quantitative approach is most likely to provide the insights needed to resolve the identification of the more difficult pure individuals of various immature age classes, and hybrids.

If the plumage and plumage development of these long-lived birds is to be studied in nature, research is required in the hybrid zones. So far it seems that intensive colour-ringing of the offspring of mixed pairs yields the most insightful results. Several ringed immature birds have been observed in Europe, and are sufficiently well documented by photographs that details of their phenotype can be studied (e.g. plate 434). The central problem with this approach is that the average probability of recovering a ringed bird is low. Moreover, only a minority of reports of colour-ringed individuals are accompanied by photographs, and very few of these have the quality necessary to provide

Michał Rycak

433. Juvenile Caspian Gull, Łubna, Poland, 9th August 2010. Ringed at Dnepr River, Ukraine in June 2010. This bird has textbook jizz and plumage patterns, but overall it looks rather dark. This darkness on the head and body is actually rather regular in fresh juveniles (note that just the first feathers in the mantle and scapulars have been replaced), but British birders used to seeing Caspian Gulls in midwinter might be thrown by how they appear in summer.

Armin Deutsch

434. Second-winter (3CY) backcross hybrid Caspian x Herring Gull (same bird as in plate 408), Detmold, Germany, 3rd November 2006. Currently, we have too little information to develop identification criteria for hybrids of this age class. This bird has more uniform grey on its upperparts than on a typical Herring of this age, a longish bill but moderate (too heavy for Caspian) streaking on the head. The iris is much paler than typical in Caspian of this age.

insights into subtle plumage or structural details. Another difficulty is that of confirming the identification of both parents of ringed chicks. This requires lots of time spent observing adults at nests and trapping more problematic individuals. Hence, while following the plumage development of hybrids ringed as chicks will likely yield the required information, this work will inevitably be slow.

4. Geographic variability and hybridisation in areas of overlap

There is discussion in the literature about the geographic variability of Caspian Gull (summarised in Malling Olsen & Larsson 2003) but little or no published quantitative data on the subject. So-called 'eastern' Caspian Gulls reportedly have more black and less white in the wing-tip than western birds and so potentially complicate interpretation of the wing-tip trait scores presented here. The relatively invariant P10 pattern found in our Caspian sample (less black than white on P10) refers to western, *ponticus*-type birds. Despite statements in the literature, Caspian Gulls observed by us farther east on the breeding grounds have shown the same P10 pattern, with a whitish and deep tongue, pure white tip and less black than white, indicating stability of the basic characters of P10. During visits to southeast European Russia and southwest Siberia (May–June 2010, e.g. plate 436), Caspian Gulls were found breeding in colonies along with birds phenotypically identical to 'Steppe Gulls' *Larus [cachinnans] barabensis*; some intermediate individuals were also observed and photographed (GN unpubl. data). Presumed mixed colonies were reported from southern Siberia some years ago (Panov & Monzikov 2000). This evidence suggests that Steppe Gull is expanding its breeding range westwards and that hybridisation with Caspian is already taking place (Filchagov 1996). As a consequence of hybridisation, 'eastern Caspian Gulls' with blacker wing-tips could in fact be yet another type of hybrid – between Caspian and Steppe Gulls. The influence of the latter is likely to be expressed, for example, in more black in the wing-tips of otherwise Caspian-like birds, as was observed in Siberia in 2010. Clearly, gull studies in SE Europe and western Asia are badly needed to resolve the complex relationships between these taxa.

Much of the evidence for hybridisation between Caspian and Yellow-legged Gulls comes from Poland, where they now breed in a number of mixed colonies (Neubauer *et al.*

Armin Deutsch

435. Adult backcross hybrid Caspian x Herring Gull (same bird as in plates 408 and 434), 13th October 2011, Pohlsche Heide, Detmold, Germany). This interesting plate shows 4P46 as an adult (7CY), nearly in full winter plumage (primaries still regrowing). The head-streaking, especially the shadowing around the eye, is too heavy for any normal Caspian Gull, and perhaps would be the first clue to it being a probable hybrid. Note than in this photograph the bill is slightly open and so looks deceptively deep.

Grzegorz Neubauer

436. Eastern Caspian Gull or intergrade with Steppe Gull *Larus [cachinnans] barabensis*, Obalykol Lake, Russia, May 2010. This individual has slightly darker upperparts than most western birds, with more black on P10. However, unlike typical Steppe Gull, it shows a long, nearly all-white tip to P10 (score 1). The rest of the plumage and jizz are like Caspian.

2006, 2009; Beran *et al.* 2010). However, the evidence from Poland is rather different from that from other areas of overlap (e.g. the Black Sea coast of Romania), where these species apparently do not hybridise (Klein & Buchheim 1997; Neubauer *et al.* 2010). There are other areas of potential overlap between these species, notably along the eastern and southeast shoreline of the Black Sea, and our understanding of the relations between Caspian and Yellow-legged Gulls would benefit from work there. The Black Sea is further interesting because the more easterly populations of Yellow-legged Gull found there appear to differ in a number of respects from western ones, including some traits that make them more similar to Caspian Gulls (e.g. more frequently a fully white tip to P10 and a longer tongue than on western birds). There remains scope for work describing quantitatively the plumage traits of eastern Yellow-legged Gulls so that the extent to which they overlap with those of other species or hybrids can be established.

5. Call and posture

Long call and long-call posture are important in the identification of Caspian Gull (details in Gibbins *et al.* 2010). However, there are no published data on the call or call posture of hybrids. Consequently, work is needed to determine what hybrids sound like and the posture they adopt when long-calling. Sonogram analysis, as used for example to assess the songs of Common Chiffchaff *Phylloscopus collybita*, Iberian Chiffchaff *P. ibericus* and suspected hybrids, would most likely prove insightful (Collinson & Melling 2008).

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Brian J. Small

Field sketches of a juvenile Caspian Gull *Larus cachinnans*, Suffolk, 20th August 1999.

Identification of Caspian Gulls: phenotypic variability and the field characteristics of hybrids

Summary of key findings

- Overall trait scores (i.e. the sum of individual trait values) for pure Herring and pure Caspian Gulls showed little (adult) or no (first-winter) overlap (figs. 6 & 8). Frequency statistics indicate that these scores can be used to separate even the most extreme (atypical) first-winter birds and the vast majority (c. 99%) of adults with confidence.

- There was considerable overlap between pure Caspian and pure Herring Gulls in virtually all of the individual phenotypic characteristics examined. Consequently, traits have to be used *in combination* to help resolve the identification of difficult individuals.

- For adult Caspian Gulls, the most stable traits were the balance of black and white in P10 and the colour of the pale tongue on this feather. Our analysis indicates that any gull showing more black than white in P10 and a tongue of similar shade to the mantle should not be identified as a Caspian Gull.

- First-winter Caspian Gulls varied enormously, with few stable traits. The traits most useful for separation from Herring Gull were bill shape (length:depth ratios), greater-covert pattern, scapular moult and primary projection. Nonetheless, species' scores for each of these traits overlapped to some degree, indicating that they should not be used in isolation.

- Many first-winter Caspian Gulls were well streaked on the head and body and had heavily marked scapulars. Many birds also had rather dark underwings. Despite the variability of these traits, resulting in some birds having high scores for one or two of them, the sum scores did not overlap between species. This indicates that the scoring system is robust to the variability of individual traits.

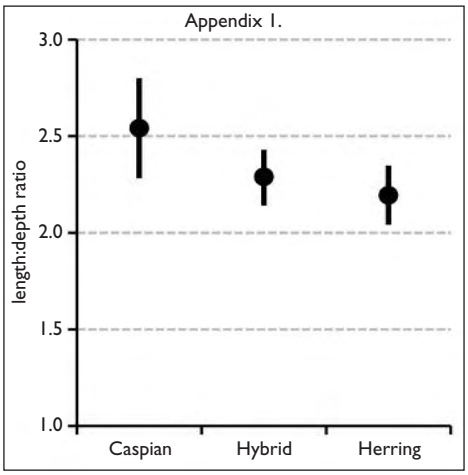
- Many of the F1 hybrids had intermediate sum scores and occupied intermediate multivariate space. By combining sum scores and evidence from the PCA, it should be possible to establish whether a given bird is phenotypically outwith the range of pure species and hence should not be identified as either Herring or Caspian Gull. However, some F1 and most F2 hybrids and backcrosses fell within the space occupied by pure individuals. It is likely that at least some of these birds would simply go undetected. At the moment it seems that there is no way of confidently recognising them in the field.

- There was considerable variability in our small sample of hybrids, such that this sample is likely to be insufficient to fully establish their true heterogeneity. Given this and the limited multivariate space remaining between pure species, we conclude that in reality there must be considerable overlap between hybrids and pure individuals.

- The problem posed by hybrids (as indicated by their trait scores) suggests that a conservative approach to field identification is warranted. Specifically, we recommend that only adult gulls with a sum trait score of less than 9 and first-winters scoring less than 22 are safely identifiable as Caspian outside its main range. These conservative values will mean that a minority of pure individuals will not be considered acceptable. These thresholds, however, may be refined in the future as our understanding of the phenotypic characteristics of hybrids improves, and/or refinements to the scoring system are made.

Appendices

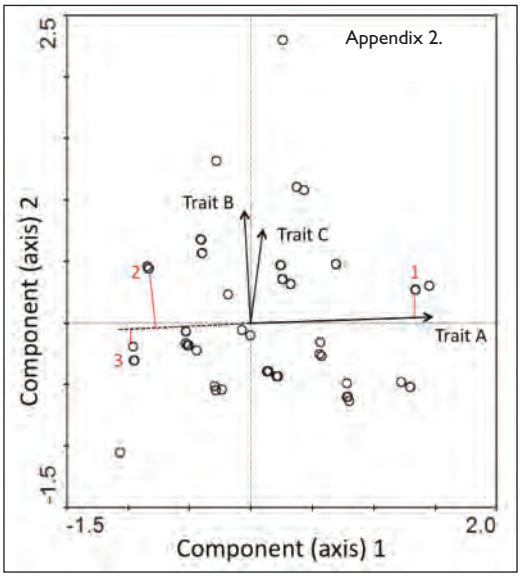
Appendix 1. Bill length:depth ratios (mean and standard deviation) for first-winter birds.



Appendix 2. Principal Component Analysis (PCA).

PCA is a method of data reduction and has been used widely to help understand patterns in complex (multivariate) datasets. It integrates variation (information) contained in pure, raw variables (e.g. measurements) into fewer, synthetic variables called Principal Components (PCs). It finds linear combinations of the raw measurements which maximise the variation present within them, and summarises this in PCs (the first two of which are represented as axes on a two-dimensional diagram). In essence, it finds an optimum way of capturing the variability in multidimensional data and represents this in a smaller number of dimensions. Some unavoidable information loss occurs during the process of computing principal components, and so it is necessary to provide the percentage of the total variation 'explained' (captured) within particular components. Typically, the first few components (axes) are the most important in terms of explaining the original variation: PC1 explains the largest amount of variation contained in the original data, the second (PC2) explains less, and so on. The ideal situation is when PC1 and PC2 (i.e. axes 1 and 2 on the diagram) together capture most of the total variation in the data. A key advantage of PCA is that it does not require the data to be normally distributed (Zuur *et al.* 2007).

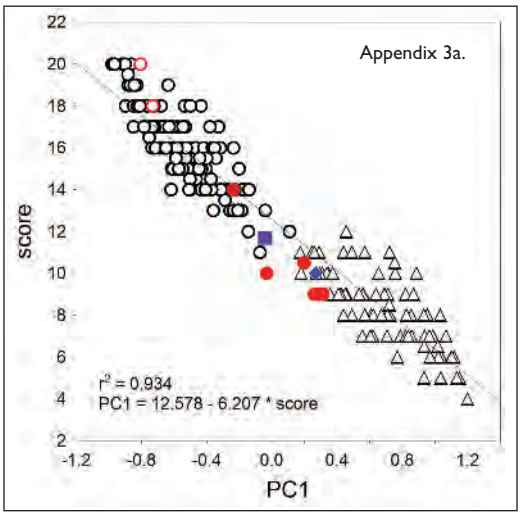
Output from a hypothetical Principal Component Analysis is shown in the diagram below. It visualises the distribution of a number of sample birds (dots) and the traits (arrows A–C) used to characterise each one. In this example, trait A can be interpreted as being the most important one in driving the overall differences between the birds, because it has the longest arrow. Conversely, trait C, because it has the shortest arrow, varies least between the birds and so is not responsible for the major differences between them. Trait B is intermediate, but clearly less important than A and rather similar to C in the proportion of the overall variance that it explains. Trait A lies nearly parallel with the horizontal axis (PC1) and so the separation of birds from left to right in the diagram relates to their values of this trait. The arrowheads point in the positive direction of the trait values; thus, if trait A was the overall size of the bird, then larger birds would be to the right. For example, bird 1 in the figure is a large bird as it sits close to the end of the trait arrow (where it falls on the arrow is shown by the vertical red line). Traits radiate from the origin (0,0), and by convention are shown only in their increasing (positive) direction. The equivalent part of the trait arrow going in the opposite direction, on the other side of the origin, is not normally shown. This decreasing part of the arrow has to be visualised as the 180° projection of the increasing one, back through the origin. Just



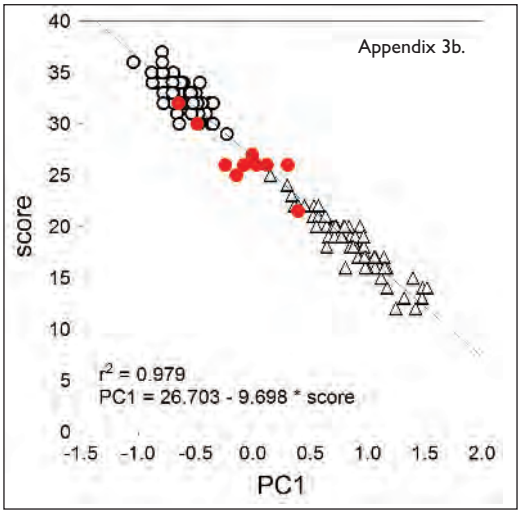
for illustrative purposes here, this decreasing line for trait A is shown as a dashed line in the figure. Birds 2 and 3 sit at the extreme end of this negative line and so have the lowest values in the sample for this trait (i.e. they are the smallest birds). Arrows for traits B and C lie very close together. This indicates that these two traits are correlated, i.e. those birds which have high values for trait B will also have high values for trait C. If they were traits related to bill and leg brightness, for example, the analysis would show that the birds with the brightest legs also have the brightest bills, and vice versa. These traits point tangentially (more or less 90°) to trait A. This means that they are not correlated, i.e. there is no relationship between bare-part brightness and the size of the bird.

Appendix 3. Relating trait scores to multivariate space.

The figures below show the relationships between the sum of the trait scores for individual birds and their positions on axis 1 of respective PCAs. By reading from the fitted regression lines, it is possible to use these figures to convert a sum trait score derived for a candidate Caspian Gull to a component score. In this way it is possible to use the diagrams to see where a candidate bird plots on PCA-defined multivariate space, e.g. a first-winter bird scored as 15 should have an axis 1 score of 1.2 and hence sit perfectly in the space occupied by Caspian, while a bird scored as 25 will have an axis 1 score of 0 and hence sit within the area occupied by hybrids. By converting sum to axis 1 scores, these diagrams should allow field observers to reach a well-informed decision about the identification of a problem bird, based on its position in true multivariate space.



3a. Relationship between PCA axis 1 and trait scores for sample adult gulls. The principal component value can be approximated by the equation given on the scatter; while the correlation is not ideal (as some portion of original variation was captured by further principal components), it is very high and sufficient to show that scores characterise phenotype well enough to detect between-species differences. By reading from the regression line, it is possible to convert a sum trait score to a PC1 position, and thus locate a bird within multivariate space. Known hybrids are given by red and blue symbols: they all have one or two known parents (most birds of the latter group), are offspring of different pairs and have been scored as adults. Red circles are known F1 hybrids (offspring of Caspian × Herring Gull pairs in both combinations), the square is an F2 hybrid (offspring of two Caspian × Herring hybrids), while the diamond is a backcross to Caspian. Empty red circles within the Herring Gull group are F2 hybrids or backcrosses, with one parent known as being hybrid in both cases; they are apparently impossible to separate from pure species (Herring Gull in this case).



3b. Relationship between PCA axis 1 and trait scores for sample first-winter birds. Triangles show Caspian Gulls, open circles Herring Gulls and red circles hybrids.