AVIAN ANATOMICAL SPECIMENS: A GEOGRAPHIC ANALYSIS OF NEEDS

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ABSTRACT.—The anatomical inventories of Wood et al. (1982a, b) indicated that nearly one-third of the world's bird species are not represented by skeletal specimens or spirit specimens. Additionally, long series of anatomical specimens, necessary for many kinds of studies, exist for only a very few species. To encourage collectors to fill in gaps in anatomical holdings, we divided the world into 60 geographic areas, developed avifaunal lists for these, and indicated what species in each area are most critically needed as anatomical specimens. The details are given by Wood and Jenkinson (1984). Various analyses indicate that collecting efforts are most needed in the following areas: Colombia, Venezuela, Bolivia-Peru-Ecuador, Brazil-Paraguay-Uruguay, Africa (except north Africa), the Indian subcontinent, Burma, New Guinea, Madagascar, Seychelles, and the islands north of Australia (except Borneo). Although collecting efforts are especially important in those areas, specimens are needed from all sites to provide series from throughout each species' range. Curators and collectors should make new or renewed efforts to increase anatomical holdings through a variety of approaches to specimen acquisition and preparation. *Received 7 May 1984, accepted 6 March 1985.*

RESEARCHERS who regularly study anatomical specimens of birds know that it often is very difficult to locate needed material. Also, they have long been concerned about the complete lack of skeletons or spirit specimens for many species and genera and the fact that few species are represented by adequate series (e.g. see Olson 1981, Martin 1983: 291). Burton (1980: 193) summarized these concerns and stated: "Curators in charge of anatomical collections of birds will no doubt be concerned to fill these gaps, but it is not always at once obvious which deficiencies are [critical]. . . . I would urge closer cooperation between ornithologists in charge of such collections, to devise a common policy aimed at providing a comprehensive stock of material for future anatomical studies."

The American Ornithologists' Union's Collections Committee shares these concerns and has addressed the matter of assessing avian anatomical holdings. Inventories of the skeletal and spirit holdings of 92 collections around the world have been published (Wood et al. 1982a, b). Zusi et al. (1982) related the history of that project and analyzed the results. The study indicated that, of 9,005 species of birds, over 2,700 are not represented as skeletons and almost 3,000 are not to be found as spirit specimens. Of the total, more than 70% are represented by fewer than 10 skeletal specimens and 78% by fewer than 10 spirit specimens. We think that these and other data indicate that existing anatomical specimens do not meet present and future research needs and that the situation must be corrected, a position we defended elsewhere (Zusi et al. 1982: 755–756).

The inventories provide a precise account of which species are lacking as anatomical specimens in the 92 collections surveyed. To encourage collectors to add important specimens, Zusi et al. (1982) summarized the inventories at the subfamily level. We analyze the results of the inventories from a geographical standpoint, so that collectors can more easily determine what specimens are most critically needed from various parts of the world. We have provided detailed information elsewhere (Wood and Jenkinson 1984) and here summarize and analyze those data.

Persons interested in purchasing the inventories or the geographical analysis should write to the Oklahoma Biological Survey, University of Oklahoma, Norman, Oklahoma 73019 USA.

METHODS

Distributional data were extracted from the literature at the Carnegie Museum of Natural History. Backup copies of all of the inventory files have been sent to the Association of Systematics Collections.

Because it was not feasible to extract precise descriptions of the distributions of over 9,000 species, we divided the world into 60 nonoverlapping geo-

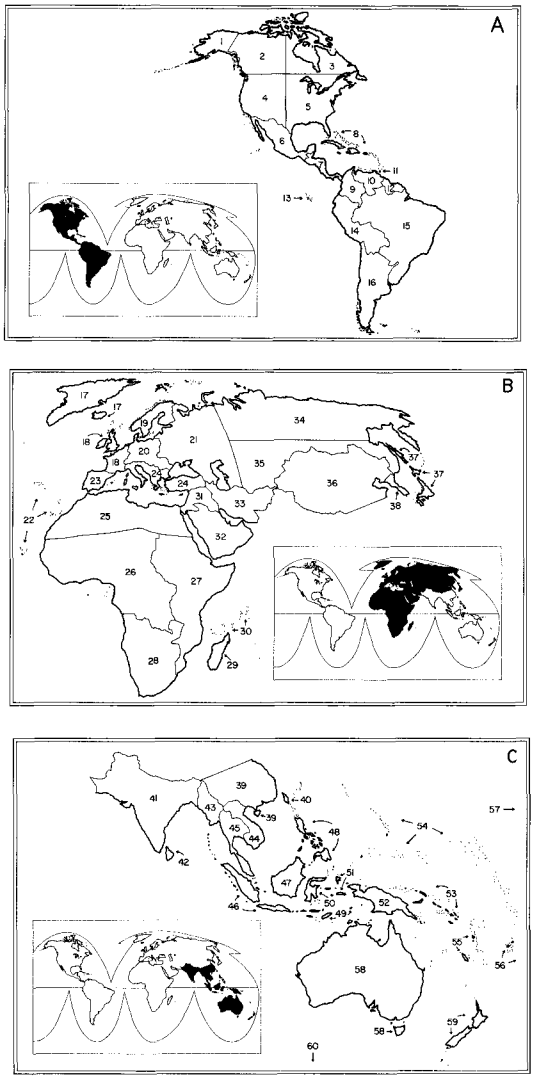

Fig. 1. The 60 geographic areas, divided into three sections, for which avifaunal lists were prepared. Section A (New World) includes areas 1–16; section B (Palearctic and Africa) includes areas 17–38; section C (Orient, Australasia, various Pacific islands, the Antarctic, and sub-Antarctic islands) includes areas 39–60. See Appendix for detailed descriptions of areas.

graphical areas (see Fig. 1 and Appendix) and developed avifaunal lists for each. We required reliable and fairly recently published reference materials for each area. Because the areas covered in these publications are usually political units, our 60 areas often follow political boundaries. However, we tried to make the areas correspond to zoogeographic units wherever possible.

The literature sources were selected by K. C. Parkes, S. M. Roble, and Wood, and the avifaunal lists were prepared by Roble, a vertebrate zoologist. Some recent additions to faunal lists no doubt were missed, but these probably would not have affected the analysis significantly. Within each of the 60 areas, we indicated (without respect to breeding status) whether each species was a permanent, summer, or winter resident, a transient, or extinct. We excluded accidental records. Summer and winter refer to the periods May–August and November–February for areas completely or mostly north of the equator, and the reverse for areas south of the equator. Our data base was a matrix of 9,007 species by 60 geographic areas [Zusi et al. (1982) analyzed 9,005 species; 2 more were inadvertently omitted in that analysis, but were included in the actual inventories].

Because the matrix was too large to be printed on one sheet, we divided the 60 areas into three sections. Section A (areas 1–16) is the New World, section B (areas 17–38) is the Palearctic and Africa, and section C (areas 39–60) includes the Orient, Australasia, various Pacific islands, the Antarctic, and the sub-Antarctic islands. We chose these sections to make the resulting three lists approximately equal in size and to reduce the number of species' names included in more than one section.

We followed the taxonomic treatment used for the inventories, as explained in Zusi et al. (1982). The list includes species that have become extinct within historical times and some that are of doubtful taxonomic status (probable hybrids, aberrant individuals, etc.). Some of the results of our analysis were affected, although slightly, by the inclusion of these species; we chose to include them rather than to make subjective decisions about which species to exclude. We did not include species described since the publication of the inventories, because of time and energy constraints.

In response to requests from various curators, we extracted as much information as possible about the geographic strengths and weaknesses of the collections of anatomical materials for which we had inventories. Many requests came from curators who were interested in exchanges, others from workers interested in particular avifaunas. We emphasize that our computer files contain no information on the collection locality of any museum specimen. Nevertheless, the species composition of a collection often can provide clues to its geographic strengths and weaknesses.

ANALYSIS

Although in our analysis we emphasize species for which few or no anatomical specimens exist, virtually all species are poorly represented (see Table 1). Present and future studies may be severely hampered by this fact. Only

15% of the 9,007 species are represented by more than 25 skeletons and only 10% by more than 25 spirit specimens.

Table 2 presents the number of species represented by no or few anatomical specimens in each of the 60 geographical areas and for the three major sections. Figures are provided for the total avifauna as well as for endemic species. The counts for all three major sections are very high. For example, for section C (Orient, Australasia, etc.), nearly one-third (1,108, 31%) of the 3,526 species are completely unrepresented by skeletal material, and almost one-third (987, 28%) are represented by only 1–5 skeletons. Data for the other two areas and for spirit specimens in all three are similar. The situation is worse for endemics. For section C, 45% of the 1,672 endemic species are completely unrepresented by skeletons and 44% are unrepresented by spirit specimens. Again, similar figures exist for the other sections.

The data for the 60 geographic areas vary widely. In most North American and European areas, species generally are represented by at least a few anatomical specimens, but South American, Asian, and African areas need much better coverage. Ten of the 60 areas have more than 150 species that are unrepresented by anatomical specimens [areas 9 (Colombia), 10 (Venezuela), 14 (Bolivia-Peru-Ecuador), 15 (Brazil-Paraguay-Uruguay), 26–28 (Africa, except north), 41 (Indian subcontinent), 43 (Burma), and 52 (New Guinea)]. These parts of the world have large avifaunas and are important areas for collectors to focus on.

Another measure of the situation is the percentage of species in each area lacking anatomical specimens. Our data show that in 15 areas, more than 20% of the species have no anatomical specimens. These include the above-mentioned areas except 10 and 26, plus areas 29, 30, and 48–53 (Madagascar, Seychelles, and the islands north of Australia except Borneo).

If endemic species are considered, the figures are even worse. Of the 2,707 species for which no skeletons exist, 1,537 (57%) are endemic to one of our areas, and for the 2,958 species that have no spirit specimens, 1,625 (55%) are endemics. The areas where collecting of endemics is critical are essentially the same ones as listed above.

In virtually all of the above-mentioned areas, various habitats are disappearing rapidly, a fact that makes intensive collecting efforts in the immediate future all the more critical. In some areas political unrest threatens present or future access by investigators.

TABLE 1. Numbers of species represented by various amounts of anatomical material.[a]

Numbers of specimens	Preparation	
	Skeletons	Spirit specimens
0	2,707	2,958
1	920	1,028
2–5	1,757	1,949
6–10	1,026	1,086
11–25	1,216	1,128
26–50	614	501
51–100	364	237
101–200	214	89
>200	189	31

[a] Slightly modified from Table 4 of Zusi et al. (1982).

Almost all of the reported percentages would be much higher if we were considering only those specimens taken in the areas in question. For example, 553 skeletons exist for the Common Barn-Owl (*Tyto alba*), a geographically widespread and variable species that occurs in 41 of the 60 areas. It is possible, and quite likely, that most of the specimens of this species were taken from a very limited portion of its range. Thus, our estimates of geographic coverage for anatomical materials of widely distributed species are overly optimistic. Further analysis is not possible at this time because we have no collection locality data in our files for individual specimens.

Although collecting efforts at "prime" localities might be the most rewarding, any collector at any locality can assist significantly. All collectors and curators need to remember that, in addition to filling gaps for species missing from the inventories, more anatomical specimens are needed for species already represented, so that adequate series and specimens from throughout the species' ranges are available.

The burden of collecting is not distributed equally. Of the 92 museums participating in the inventory (which includes all but a very few of the world's significant collections of anatomical avian material), 49 are in geographic section A (virtually all of which are in North America), 31 are in section B (most in Eurasia, 4 in Africa), and 12 are in section C. Section A has the most species (3,826), but it also has the best representation of anatomical specimens and, apparently, the most museums that are ac-

TABLE 2. Distribution of species in the 60 geographic areas and representation by anatomical specimens.

Geographic area[a]	All species					Endemics		
		Number represented by:					Number represented by:	
		Skeletons		Spirit specimens			Skeletons	Spirit specimens
	Total	0	1–5	0	1–5	Total	0	0
Section A: New World	3,826	746 (19%)	988 (26%)	981 (26%)	1,235 (32%)	1,116	396 (35%)	495 (44%)
1. Alaska	214	1	1	2	15	0	0	0
2. Western Canada	321	0	1	1	19	0	0	0
3. Eastern Canada	241	1	0	2	9	0	0	0
4. Western USA	481	0	2	4	40	4	0	0
5. Eastern USA	461	2	9	6	30	11	0	0
6. Mexico	926	22	93	57	191	87	10	18
7. Central America	1,047	66	169	135	247	89	22	37
8. West Indies	437	21	57	35	82	148	13	29
9. Colombia	1,502	217	381	334	457	70	53	64
10. Venezuela	1,286	187	283	241	388	57	43	34
11. Trinidad and Tobago	331	0	32	18	49	0	0	0
12. The Guianas	742	72	144	116	208	9	6	6
13. Galapagos Islands	79	3	3	7	8	21	2	2
14. Bolivia, Peru, Ecuador	1,954	292	575	442	697	286	87	129
15. Brazil, Paraguay, Uruguay	1,514	288	388	374	506	253	143	156
16. Argentina, Chile	858	87	189	132	282	81	17	20
Section B: Palearctic and Africa	2,775	671 (24%)	777 (28%)	734 (26%)	886 (32%)	896	413 (46%)	421 (47%)
17. Greenland, Iceland	96	0	0	1	7	0	0	0
18. Great Britain, France, Benelux	325	0	16	2	32	0	0	0
19. Scandinavia	265	0	6	1	23	0	0	0
20. Central Europe	322	1	17	7	38	0	0	0
21. European USSR	442	13	56	17	101	2	0	0
22. Atlantic Islands	159	6	10	6	17	9	5	6
23. Iberian Peninsula	305	2	20	4	38	0	0	0
24. Mediterranean	384	11	44	19	70	2	2	1
25. North Africa	402	20	49	20	76	6	4	4
26. Central and West Africa	1,074	173	277	175	279	201	92	83
27. East Africa	1,386	253	360	297	395	292	147	148
28. South Africa	860	92	200	180	229	168	48	68
29. Madagascar	231	53	66	46	77	94	35	29
30. Seychelles, etc.	179	46	31	42	37	51	38	29

TABLE 2. Continued.

Geographic area[a]	All species					Endemics		
		Number represented by:					Number represented by:	
		Skeletons		Spirit specimens			Skeletons	Spirit specimens
	Total	0	1–5	0	1–5	Total	0	0
31. Israel to Iraq	374	20	49	22	80	1	1	1
32. Arabian Peninsula	392	37	51	27	85	8	6	6
33. Iran, Afghanistan	451	35	79	37	120	2	2	1
34. Asiatic USSR, north	304	1	6	7	27	2	0	0
35. Asiatic USSR, south	554	29	93	30	166	1	0	0
36. NW China, Mongolia	670	111	139	116	211	41	24	32
37. Japan	419	30	60	49	90	16	9	13
38. Korea	325	18	54	20	88	0	0	0
Section C: Orient, Australasia, etc.	3,526	1,108 (31%)	987 (28%)	1,088 (31%)	1,135 (32%)	1,672	728 (45%)	709 (44%)
39. SE China, Hainan	754	117	191	122	236	14	11	12
40. Taiwan	309	20	62	35	71	12	2	6
41. Indian subcontinent	1,085	254	283	255	358	82	56	60
42. Sri Lanka	327	41	68	55	84	21	14	18
43. Burma	920	181	257	182	308	17	15	17
44. Laos, Cambodia, Vietnam	777	142	218	131	264	17	12	11
45. Thailand, Malay Peninsula	861	134	268	133	302	4	4	3
46. Greater Sunda Islands	640	89	208	120	196	50	22	39
47. Borneo	494	73	156	75	162	32	24	18
48. Philippine Islands	483	111	123	78	128	149	83	46
49. Lesser Sunda Islands	344	55	80	83	67	59	37	54
50. Sulawese	338	64	97	95	72	71	26	56
51. Moluccas	336	82	73	92	68	64	52	48
52. New Guinea	643	163	168	151	216	320	131	116
53. Bismarck, Solomon islands	314	122	47	76	85	119	102	65
54. Micronesia, etc.	145	11	32	23	25	39	9	20
55. New Caledonia, etc.	129	17	24	13	18	31	12	8
56. South Pacific	172	46	39	29	38	78	40	27
57. Hawaiian Islands	153	18	13	20	21	41	18	16
58. Australia, Tasmania	687	58	138	63	177	325	47	46
59. New Zealand	221	14	26	30	60	69	9	22
60. Antarctic, sub-Antarctic	65	3	9	4	19	13	2	1
Totals	9,007	2,707	2,677	2,958	2,977	3,639	1,537	1,625

[a] See Appendix for full descriptions of areas.

TABLE 3. Numbers of species occurring in any given number of areas.[a]

Number of areas	Number of species									
1–10	3,639	1,601	1,136	612	498	324	230	190	123	98
11–20	90	66	45	50	41	31	25	26	15	17
21–30	16	15	12	9	4	9	4	6	5	4
31–40	10	7	5	5	2	3	2	2	7	0
41–50	3	2	2	0	0	2	2	0	0	1
51–60	0	1	1	0	1	2	0	2	0	0

[a] For example, 3,639 species occur in only 1 area, 1,601 in 2 areas, and only 2 in as many as 58 areas.

tive in obtaining anatomical material. Section C has 3,526 species, but it has the poorest representation of anatomical material and the fewest museums with a tradition of collecting anatomical material. Comments made by curators participating in the inventory project indicate that new or renewed efforts to incorporate anatomical specimens are being made by some South African, New Zealand, and Australian museums.

Because of the criteria used in selecting our geographic areas, considerable biogeographic information can be extracted from our files (see Table 3). Most species are rather restricted in distribution; 40% (3,639) are endemic to 1 area, 71% are found in no more than 3 areas, and 91% (8,230) occur in only 8 or fewer areas. The Whimbrel (*Numenius phaeopus*) and Ruddy Turnstone (*Arenaria interpres*) are the most widespread, occurring in 58 of the 60 areas.

DISCUSSION AND RECOMMENDATIONS

Many museums and collectors do not have a tradition of preparing anatomical specimens. Austin (1967: 119) stated that William Brewster felt "intense disgust" that Frank M. Chapman (in 1890) had skeletonized a specimen of the Ivory-billed Woodpecker (*Campephilus principalis*; only four skeletons of this species are now known to exist). Elliott Coues (1903: 48–49) presented a fairly enlightened view for his day when he stated that it was "highly desirable to obtain more information of birds than their stuffed skins can ever furnish." But he also implied that preservation of a bird in fluid generally should be considered only when the specimen could not be anatomically examined "on the spot," when more birds had been collected than could be put up, or when the plumage was too poor to warrant a skin. Osteologically, Coues considered the skull and sternum to be valuable enough to keep, even though "to save a skull . . . is to sacrifice a skin." But again, "mutilated or decayed specimens . . . are very profitably utilized in this way." The paucity of anatomical specimens in today's collections suggests that some more recent curators and collectors have not advanced much beyond this view. Although specimens of all kinds are needed, we think workers must accept the fact that, for many species, anatomical specimens are often more important than study skins. We do not mean to imply that there is no justification for collectors making traditional skins; our purpose is to encourage preparation techniques that result in anatomical materials. Following are some things we think a collector or curator should consider when making decisions about the acquisition and preparation of bird specimens, as well as some general comments that are appropriate for all ornithologists.

(1) Many curators seem to assume that the three main forms of preparation (study skins, skeletons, spirit specimens) are mutually exclusive. However, some research questions can be answered only if the skeleton and plumage of individual birds can be studied simultaneously, and these studies are virtually impossible to do with present museum materials. An essentially complete skeleton and skin can be prepared from one specimen, with only the bill lacking from the skin and the distal skeletal elements of one wing and one leg being retained with the skin. Such skins can be prepared as traditional "round" skins, or they can be left flat. Traditional skins are aesthetically more pleasing and easier to integrate into existing skin collections. They also permit easier study of the ventral plumage than flat skins, and they may be sturdier. Flat skins, however,

require less storage space and can be easily packed for shipment. They greatly facilitate studies of molt and pterylography, as well as the detection of brood patches. All traditional skin measurements (except those requiring the bill) can still be taken, and many of those using the bill can be made if the rhamphotheca is left on the skeleton. Bill measurements can be taken prior to preparation. Presently, at least two museums routinely save essentially complete skeletons and skins (the Royal Ontario Museum and the Thomas Burke Memorial Museum at the University of Washington).

If skeletal preparation precludes saving a full skin (because of time or expense), portions of the skin should be saved. It is particularly useful to save one wing, dried in a spread position. This allows studies of color patterns and molt of remiges or coverts, for example, that are difficult or impossible with traditional skins. Saving at least portions of the skin also may permit verification of the identification of a skeleton.

Spirit preparations preserve the skeleton and the skin as well as the rest of the bird. If necessary, skins or skeletons can be prepared from such specimens, although it is considerably more difficult and often less satisfactory than with fresh material. Since extreme color changes can occur in bird feathers after storage in formalin or alcohol, spirit specimens cannot be used for some studies.

(2) The cost of preparation for a specimen varies considerably among types of preparation, with skeletal specimens probably being the most expensive to prepare. Skeletons require more time per specimen if numbering the elements with a catalogue number is included, but such work can be done by less-skilled workers than are needed for study-skin preparation. Maintenance of a dermestid colony or maceration of specimens takes much time, but if many skeletons are prepared simultaneously, the time involved for each specimen is reduced. The expense of preparing spirit specimens, by comparison, is trivial, especially if done in quantity.

Spirit specimens require the least preparation time in the field and study skins the greatest. Preparing a full skeleton and skin from one specimen may be less time-consuming than preparing a skeleton and skin from separate specimens. In remote areas, unlikely to be revisited, it is most important for the collector to maximize the total number of specimens prepared, given that anatomical preparations are included. For rare species, skin and skeletal combinations, or skins with carcasses preserved in formalin, should be the preparation of choice.

Shipping costs are highest for spirit specimens because of their weight. Skins and spirit specimens require careful and time-consuming packing. Roughed-out skeletons weigh little and can be packed fairly easily.

(3) Storage and maintenance of anatomical specimens is also expensive, although often less than the cost of acquisition and preparation, and probably less than storage of skins in airtight specimen cases. Museums with extensive skeleton collections often have custom-made, heavy-duty storage boxes, but many box manufacturers offer a large selection of satisfactory and less expensive boxes. One especially useful size is a standard earring box, which will hold disarticulated skeletons of most birds smaller than the Northern Cardinal (*Cardinalis cardinalis*). Glass vials can be used for storing small specimens; the labels can be read and contents viewed without opening the vials and risking loss of an element. Plastic medicine vials with snap-on tops are inexpensive and easy to obtain, but the lids can break upon impact, which causes shipping problems, and some plastics react with some fumigants. Museums with large skeletal collections often are willing to make joint purchases of custom-made boxes with smaller collections. Skeletons of small birds occupy approximately the same space as their study skins, but skeletons of large specimens often use much less space. Skeletons also require less maintenance (e.g. fumigation) than skins.

After initial preparation, the costs involved in maintaining a spirit collection include containers with good seals, replacement alcohol as evaporation occurs, and good shelving (ideally in fireproof cabinets).

(4) Many collectors seem to consider it difficult to take supplies into the field for preservation of spirit specimens. However, herpetologists have amassed vast numbers of such specimens from fairly remote places. Formalin can be purchased at many local pharmacies, and powdered paraformaldehyde is available (see Huheey 1963; premixed, buffered, and powdered paraformaldehyde can be obtained from the Carolina Biological Supply House). After thorough preservation, specimens can be

wrapped in moist cotton or cloth, stored in plastic sacks, and shipped in comparatively light containers to the museum for further processing. Because preparation time is so short, many more specimens can be procured in the often limited time available to collectors, an especially important consideration in remote locations.

(5) A few published sources that give techniques for preparing and caring for anatomical specimens are available (see, for example, Hall and Russell 1933, Zweifel 1966, Hildebrand 1968, Feduccia 1971, Quay 1974, Sommer and Anderson 1974, Williams et al. 1977, Valcarcel and Johnson 1981, Cumbaa 1983). An up-to-date publication that deals specifically and thoroughly with techniques for preparation of avian anatomical material is badly needed.

We think that all curators have an obligation to learn the techniques for preparing and maintaining anatomical specimens. Collectors who are unable to prepare anatomical specimens thoroughly should learn the few initial steps that are required and donate the specimens to an appropriate museum for final processing.

We also urge workers who are preparing specimens of any kind to remember the importance of DNA hybridization studies to our understanding of avian phylogenies (see Diamond 1983) and to preserve tissue and blood samples, whenever possible, for these studies. The procedures are given by Sibley and Ahlquist (1981); Charles G. Sibley (pers. comm.) states that 75–80% ethanol is now the preferred concentration for preservation of tissue samples.

(6) There are far fewer skilled collectors today than there were a decade or two ago, and few students are being taught the techniques of collecting and preparing specimens. This makes it all the more imperative that the few active collectors increase the number of anatomical specimens they prepare. It is particularly important that skeletal specimens be collected by workers who are thoroughly competent in field identification, because it is difficult, and often impossible, to correct a misidentification of a skeleton if no skin has been saved.

(7) Many collectors are discouraged by the difficulties encountered in obtaining collecting permits. This complex problem deserves fuller attention than we can give here. We hope, however, that collectors can use this report as strong support for their applications for such permits. The report of the American Ornithologists' Union's ad hoc Committee on the Scientific and Educational Use of Wild Birds (A.O.U. 1975) also might be useful.

(8) Although many important anatomical specimens can be added to collections without extensive fieldwork, it is clear that major funding is needed for many collecting trips. Both private and government funds are needed, and we hope that the anatomical inventories and the present geographical analysis will help institutions obtain such funds. Also, many researchers who rely heavily on museum specimens (both traditional skins and anatomical materials) are not collectors and are not associated with a museum. They should seriously consider ways in which they can help museums obtain and preserve the research specimens they require.

(9) Ornithologists might take advantage of the bird specimens easily available to them. Accidentally killed birds (e.g. road kills, window and TV-tower casualties) are frequently in suitable condition for at least one kind of preparation. Museums often obtain old mounted birds that are in poor condition or worse. Sometimes these are species that are impossible to obtain today, and curators should consider "sacrificing" the mount to remove the remaining skeletal elements (flight feathers should be saved). The University of Kansas Museum of Natural History has recently added partial skeletons of two Whooping Cranes (*Grus americana*) and one Eskimo Curlew (*Numenius borealis*) in this manner.

State and federal fish and game officials frequently do not realize that museums are interested in skeletons of birds and thus discard confiscated birds not suitable for skins. In the last few years, the University of Kansas Museum of Natural History has added skeletons of several Golden Eagles (*Aquila chrysaetos*) to its collection after indicating to officials that it was possible to remove feathers for American Indian use and simultaneously preserve a skeleton. Because of the frequent turnover of personnel in many fish and game departments, contacts with these workers must be renewed regularly.

We cannot overemphasize the need for reconsideration of current avian preparation practices and the need for much more avian anatomical material in museum collections. Investigators who wish to examine more than just

the external features of birds cannot always be expected to acquire their own material. Without adequate museum collections of anatomical specimens, certain research will remain impossible. Fortunately, some museums seem to be willing to give high priority to anatomical collections. We hope more will do so in the future.

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APPENDIX. Geographic areas and literature sources used in the analysis.

Section A

1. Alaska (Robbins et al. 1966, Armstrong 1980)
2. Canada north of 50°N and west of 100°W (Godfrey 1966, Robbins et al. 1966, Peterson 1980, A.O.U. 1983)
3. Canada north of 50°N and east of 100°W (same as for area 2)
4. USA and Canada south of 50°N and west of 100°W (same as for area 2)
5. USA and Canada south of 50°N and east of 100°W, and Bermuda (same as for area 2)
6. Mexico (Peterson and Chalif 1973, A.O.U. 1983)
7. Central America except Mexico (Ridgely 1976, A.O.U. 1983)
8. West Indies (Bond 1980)
9. Colombia (Meyer de Schauensee 1964, Meyer de Schauensee and Phelps 1978, Vaurie 1980)
10. Venezuela and Netherlands Antilles (Meyer de Schauensee and Phelps 1978, Vaurie 1980)
11. Trinidad and Tobago (ffrench 1973)
12. Guyana, Surinam, and French Guiana (Meyer de Schauensee 1966, Snyder 1966, Haverschmidt 1968, Delacour and Amadon 1973, Forshaw 1973, Davis 1979, Vaurie 1980)
13. Galapagos Islands (Harris 1974)
14. Bolivia, Peru, and Ecuador (Bond and Meyer de Schauensee 1942, 1943; Gyldenstolpe 1945; Meyer de Schauensee 1966; Pearson 1975; Butler 1979; Parker et al. 1980; Remsen and Ridgely 1980; Cardiff and Remsen 1981; Parker et al. 1982; Schulenberg and Remsen 1982; Remsen and Traylor 1983)
15. Brazil, Paraguay, and Uruguay (Meyer de Schauensee 1966, Delacour and Amadon 1973, Forshaw 1973, Gore and Gepp 1978, Vaurie 1980)
16. Argentina, Chile, Falkland Islands, and Pacific Islands west of Chile to Easter Island (Olrog 1963, Johnson 1965–1972, Delacour and Amadon 1973, Forshaw 1973, Woods 1975, Vaurie 1980)

Section B

17. Greenland and Iceland (Voous 1960, Robbins et al. 1966, Harrison 1982)
18. British Isles, France, Belgium, Netherlands, and Luxembourg (Harrison 1982)
19. Norway, Sweden, and Finland (Harrison 1982)

APPENDIX. Continued.

20. Denmark, Germany, Poland, Czechoslovakia, Switzerland, Austria, Hungary, and Romania (Harrison 1982)
21. European USSR (Harrison 1982)
22. Azores, Madeira, Canary, and Cape Verde islands (Bannerman 1963, Bannerman and Bannerman 1965–1968)
23. Spain, Portugal, and Balearic Islands (Harrison 1982)
24. Italy, Yugoslavia, Bulgaria, Albania, Greece, Turkey, and islands of the Mediterranean except Balearic Islands (Harrison 1982)
25. Africa north of the Sahara: Morocco to Egypt (Étchécopar and Hüe 1967)
26. Mauritania and Liberia east to Chad and south to Gabon and Zaire; Ascension and St. Helena islands (Hall and Moreau 1970; Mackworth-Praed and Grant 1970, 1973; Snow 1978)
27. Sudan and Somalia south to Malawi and Mozambique (Mackworth-Praed and Grant 1955, 1957, 1962, 1963; Hall and Moreau 1970; Snow 1978)
28. Angola and Zambia south to South Africa (same as for area 27)
29. Madagascar (Rand 1936, Milon et al. 1973)
30. Seychelles, Comoros, and Mascarenes (Meinertzhagen 1912, Berlioz 1946, Benson 1960, Niven 1965, Hall and Moreau 1970, Penny 1974, Snow 1978)
31. Israel, Jordan, Lebanon, Syria, and Iraq (Harrison 1982)
32. Arabian Peninsula (Meinertzhagen 1954, Bundy and Warr 1980, Gallagher and Woodcock 1980, Jennings 1981, Harrison 1982)
33. Iran and Afghanistan (Harrison 1982)
34. Asiatic USSR north of 55°N (Voous 1960, Dement'ev and Gladkov 1966–1968, Harrison 1982)
35. Asiatic USSR south of 55°N (same as for area 34)
36. China north of a line from junction of Burma-India-China, to the border of Shandong and Jingsu provinces; Mongolia (Cheng 1976; Étchécopar and Hüe 1978, 1983; Wild Bird Society of Japan 1982)
37. Japan; Bonin and Ryukyu islands (Wild Bird Society of Japan 1982)
38. Korea (Gore and Won 1971, Wild Bird Society of Japan 1982)

Section C

39. China south of a line from junction of Burma-India-China, to the border of Shandong and Jingsu provinces; Hainan (Cheng 1976; Étchécopar and Hüe 1978, 1983; Wild Bird Society of Japan 1982)
40. Taiwan (Chang 1980)
41. India, Pakistan, Nepal, Sikkim, Bhutan, Bangladesh, and Maldives (Ripley 1961)
42. Sri Lanka (Phillips 1975)
43. Burma; Andaman and Nicobar islands (Smythies 1953)
44. Laos, Cambodia, and Vietnam (King and Dickinson 1975)
45. Thailand, Malay Peninsula, and Singapore (Lekagul and Cronin 1974, Medway and Wells 1976)
46. Sumatra, Belitung, Java, Bali, and islands east and south to Christmas and Cocos islands (Delacour 1947, Medway and Wells 1976)
47. Borneo and satellite islands (Smythies 1960)
48. Philippine Islands (duPont 1971, 1976b)
49. Islands from Lombok to Tanimbar (Rensch 1931; Mayr 1944; Paynter 1963; McKean et al. 1975; White 1975, 1976, 1977)
50. Celebes (Stresemann 1936; van Bemmel and Voous 1951; White 1975, 1976, 1977; Escott and Holmes 1980)
51. Moluccas (van Bemmel and Hoogerwerf 1940, van Bemmel 1948; van Bemmel and Voous 1953, White 1975, 1976, 1977)
52. New Guinea and nearby islands (Rand and Gilliard 1968)
53. Bismarck Archipelago; Solomon and Admiralty islands (Mayr 1945a, b, 1949, 1955; Cain and Galbraith 1956; Gilliard and LeCroy 1967; White 1975, 1976, 1977; Hadden 1981)
54. Mariana, Caroline, Marshall, Phoenix, Gilbert, Ellice, and Line islands; Wake Island (Mayr 1945b, Baker 1951, Gallagher 1960, Bakus 1967)
55. New Caledonia and Vanuatu (New Hebrides); Loyalty and Santa Cruz islands (Delacour 1966)
56. Fiji, Samoa, Tonga, Tokelau, Cook, Society, Tubuai, Marquesas, Tuomatu, and Henderson islands (duPont 1976a)
57. Hawaiian Islands (Berger 1981)
58. Australia, Tasmania, and satellite islands (Pizzey 1980)
59. New Zealand, Lord Howe, Norfolk, and Kermadec islands south to Chatham, Auckland, and Campbell islands (Ornithol. Soc. New Zealand 1970, 1980; Falla et al. 1978; Mayr and Cottrell 1979)
60. Antarctica, southern islands from South Georgia to Ile Amsterdam to Macquarie Island (Watson 1975)