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ARTICLE

The relationship between the feather tuft of the uropygial gland and terrestrial/aquatic birds

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ABSTRACT: The bird´s uropygial gland has a papilla in its caudal end and it can also show a feather tuft. These feathers may have a raquis or not. The purpose of our study was to compare the number, dimensions and types of the tuft´s feathers in aquatic and terrestrial birds, as well as to investigate whether the potential differences are related or determined by their dissimilar habitats. The uropygial glands were removed and the tuft´s feathers were extracted and then measured, prepared for magnifying glass observation and photo shoot. Aquatic birds were found to have not only a larger number of feathers in the tuft but also longer feathers than terrestrial birds. However, the length ratio between calamus/raquis was higher in terrestrial birds. Almost all the species under study presented the same type of feathers except for the three penguin species that showed a peculiar type. The differences found between the tuft´s feathers of the studied species are related with the environment. Aquatic birds have a longer length of the feather tuft because they may produce a greater amount of secretion than terrestrial birds.

KEY-WORDS: down, environment, preen gland, semiplumes

INTRODUCTION

The uropygial is a sebaceous and compact gland placed dorsally over the caudal vertebrae at the base of the bird´s tail (Jacob & Ziswiler 1982). When preening, the lipid secretion is spread over the feathers. It has been suggested that this gland is well developed in aquatic birds, whose uropygial secretion would play an essential role in feather waterproofing (Spearman & Hardy 1985). However, other authors found a lack of correlation between the uropygial gland size and the degree of exposure to water (Montalti & Salibián 2000).

Jacob & Ziswiler (1982), Johnston (1988) and Montalti & Salibián (2000) found that the uropygial gland was heavier in aquatic bird species. Within terrestrial birds, the uropygial gland´s size shows substantial variations (Lucas & Stettenheim 1972) and in some groups it can be vestigial or absent (Struthionidae, Rheidae, Casuariidae, Dromaiidae and in some species of Columbidae and Psittacidae) (Johnston 1988).

The physiologic role of this gland seems to be diverse since it has been attributed to feather waterproofing, pheromone production, prevention of microorganisms growth, preservation of the feather's physical structure, pesticide and pollutant excretion and changes in the plumage appearance related to sex (Jacob & Ziswiler 1982, Kozulin & Pavluschick 1993, Gutiérrez *et al.* 1998, Piersma *et al.* 1999, Montalti & Salibián 2000, Moyer *et al.* 2003, Montalti *et al.* 2005, Reneerkens *et al.* 2005).

Regarding the external morphology, the uropygial gland is a bilobate organ provided with a papilla in its caudal end, which can have at least two ducts in most avian species. Surrounding these ducts, there is usually a feather tuft (Jacob & Ziswiler 1982). The calamus of the tuft´s feathers is completely embedded in the skin (Chandler 1914) and they differ from the typical down feathers because they are briefer (due to the shorter length of the barbs) and the calamus is longer than down feathers (Lucas & Stettenheim 1972).

A classification of the uropygial gland was made on the basis of the presence or absence of the feather tuft. Three types of glands were described based on the degree of development of the tuft: 1.- "naked" (no feathers observable, even with magnification); 2.- "minutely tufted" (feathers visible only with magnification); and 3.- "tufted" (feathers observable without magnification) (Johnston 1988). Most non Passerines birds have tufted glands, while all Passerines and some groups of Non Passerines have naked glands (Johnston 1988).

The tuft´s feathers have been described as "down", "modified down" or "semiplumes", and these may have a raquis or not. Johnston (1988) proposed three types of tuft's feathers: Type I, "down" and Type II and IIa "semiplumes" (which have a raquis). The difference between these "semiplumes" is the disposition of the barbs along the raquis.

There is a tendency for water birds to have many tuft feathers than terrestrial birds (Jacob & Ziswiler 1982), however, there are no studies related to the dimensions and the types of the tuft feathers related to aquatic or terrestrial birds.

The purpose of our study was to compare the amount, dimensions and types of the tuft´s feathers in aquatic and terrestrial birds, and to investigate whether the potential differences are related or determined by the different environments that birds inhabit.

MATERIALS AND METHODS

We used 12 aquatic bird species and 9 from terrestrial environments. The aquatic birds included: Gentoo Penguin (*Pygoscelis papua*), Adelie Penguin (*P. adeliae*), Chinstrap Penguin (*P. antarcticus*), Neotropic Cormorant (*Phalacrocorax brasilianus*), Night Heron (*Nycticorax nycticorax*), Chilean Flamingo (*Phoenicopterus chilensis*), Black-Necked Swan (*Cygnus melanocoryphus*), Yellow-Billed Pintail (*Anas georgica*), Giant Wood-Rail (*Aramides ypecaha*), South Polar Skua (*Stercorarius maccormicki*), Grey-Headed Gull (*Chroicocephalus cirrocephalus*) and Kelp Gull (*Larus dominicanus*).

Terrestrial birds comprised: Red-Winged Tinamou (*Rhynchotus rufescens*), Spotted Nothura (*Nothura maculosa*), American Kestrel (*Falco sparverius*), Kalij Pheasant (*Lophura leucomelanos*), Scarlet Macaw (*Ara macao*), Monk Parakeet (*Myiospsitta monachus*), Nanday Parakeet (*Nandayus nenday*), Budgerigar (*Melopsittacus undulatus*), and Field Flicker (*Colaptes campestris*) (Table 1).

Most birds were captured in their natural habitats in different localities of Buenos Aires province (permission of the Dirección Provincial de Gestión, Control Agroalimentario y Uso de los Recursos Naturales y Pesqueros, Ministerio de Asuntos Agrarios de la Provincia de Buenos Aires Nº DIP 138/04). Antarctic birds (penguins, skuas) were found dead in Potter peninsula, King George Island and others came from the Botanical Garden and Zoo of La Plata City. All birds were preserved in plastic bags at -20ºC. The gland was removed as described by Montalti *et al.* (1998). The

TABLE 1. Amount of tuft feathers, total length and length ratio between calamus/raquis of aquatic and terrestrial birds. Species are in taxonomic order (Remsen *et al.* 2013) and values are shown as mean ± SD.

Species	Nº of individuals	Amount of feathers	Total length	Calamus/raquis ratio
Rhynchotus rufescens	3	4	12,13±0,17	0,56±0,04
Nothura maculosa	6	3,83±0,41	8,43±0,52	0,47±0,05
Cygnus melancoryphus	2	23±4,24	20,7±0,63	0,14±0,01
Anas georgica	6	25±3,74	10,6±0,32	0,15±0,02
Lophura leucomelanos	1	6	7,11±0,11	0,45±0,01
Phoenicopterus chilensis	3	32,67±4,62	13,42±1,13	0,22±0,02
Pygoscelis papua	3	32±2,83	28,71±1,99	0,25±0,03
P. adeliae	4	30,5±4,95	21,45±0,44	0,22±0,01
P. antarcticus	4	27,5±2,12	20,73±1,41	0,21±0,012
Phalacrocorax brasilianus	2	72±9,89	11,14±0,11	0,21±0,03
Nycticorax nycticorax	2	10,5±2,12	6,48±0,30	0,29±0,07
Aramides ypecaha	2	13,5±0,71	12,18±0,29	0,33±0,08
Stercorarius maccormicki	2	28,5±2,12	18,30±0,31	0,15±0,005
C. cirrocephalus	18	19,33±2,90	10,64±0,45	0,15±0,009
Larus dominicanus	15	22,31±2,39	20,13±1,58	0,09±0,014
Colaptes campestris	6	7,66±2,33	3,99±0,96	0,32±0,04
Falco sparverius	3	10±2,65	7,04±0,14	0,24±0,03
Ara macao	1	13	19,1±0,17	0,71±0,05
Nandayus nenday	1	7	8,24±0,33	0,41±0,02
Miyopsitta monachus	6	6±1,09	8,55±0,42	0,33±0,03
Melopsittacus undulatus	4	9±0,82	5,23±0,13	0,34±0,02

feathers were counted after manual extraction, and then their total length, the calamus length and the raquis length (if present; for Type I feathers we consider the barb portion as raquis) were measured using a digital caliper (accuracy 0.01 mm). For each species some feathers were fixed with Canada Balm and mounted on microscope slides for magnifying observation and photo shoot. By observing the feathers, the types were established following classification of Johnston (1988). Also, the length ratio between calamus and raquis was calculated for each studied species.

The mean values of the amount of feathers and of the length ratio between calamus/raquis were obtained and the results were expressed as mean ± standard deviation. A One-way ANOVA test was used for statistical analysis of results; P values < 0.01 were considered as highly significant and $P < 0.05$ as significant. The statistical analyses were performed with STATISTICA 7.0 program.

RESULTS

All studied bird species had tufted glands. The tuft´s feathers of the three penguins (*Pygoscelis* sp.) showed a raquis with barbs along all its extension and also a "downy" region originated in the calamus zone, starting just before the raquis onset. We called this feather Type IIb (Figure 1). In the remaining studied species, Type I feathers were documented (Figure 2).

The number of tuft feathers (Table 1) in aquatic birds was significantly higher as compared with that of the terrestrial birds (27.75 ± 15.6 vs. 7.22 ± 3.07; $p < 0.001$). Similar findings were demonstrated with the total length of the feathers (Table 1); in fact, feathers in birds related to aquatic environments were longer than in terrestrial birds (15.75 ± 6.3 vs. 8.8 ± 4.25 mm; $p < 0.01$).

Regarding the length ratio between calamus/raquis (Table 1), it was greater in terrestrial species (0.43 ± 0.14 vs. 0.20 ± 0.07; $p < 0.0001$).

FIGURE 1. Tuft feather of the uropygial gland of an Adelie penguin (*Pygoscelis adeliae*). Photograph taken with a Summar 80 mm objective, scale 10 mm.

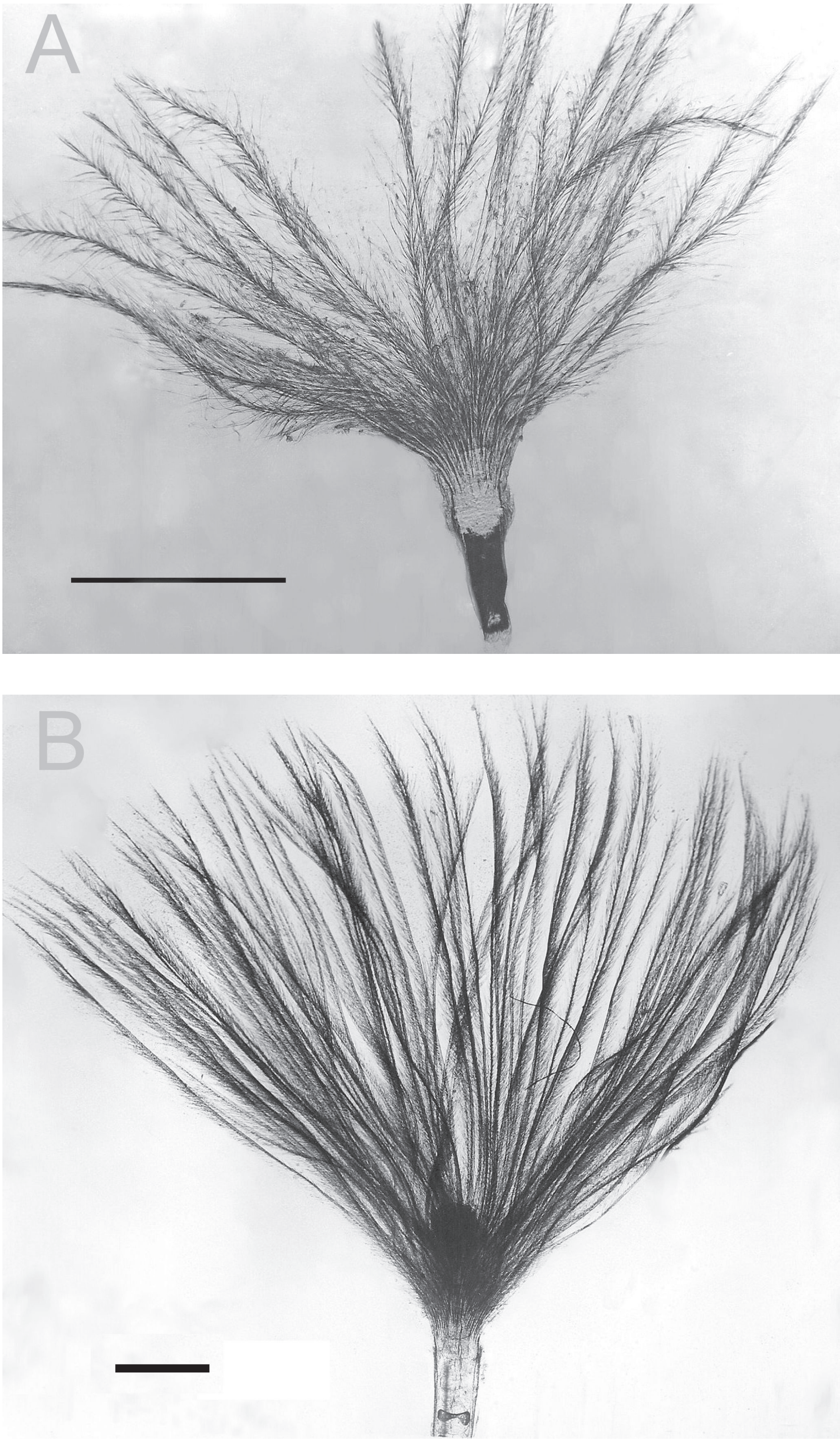

FIGURE 2. Tuft feather of the uropygial gland of: **A)**. Terrestrial bird, Field Flicker (*Colaptes campestris*), photograph taken with Leitz Plan 4 objective, scale 1 mm; and **B)**. Aquatic bird, Neotropical Cormorant (*Phalacrocorax brasilianus*), photograph taken with Luminar 63 mm objective, scale 1 mm.

DISCUSSION

The tuft´s feathers have been classified according to their structure and the presence or absence of a raquis (Johnston 1988). The results of this study indicate that the terrestrial birds have the same type of feathers reported by Johnston (1988) for species of the same families. This also happened for aquatic birds except for the three analyzed penguin species. Johnston (1988) reported that these penguin species had tuft's feathers Type IIa, implying that the middle part of the raquis lacks barbs. Our analysis of the tuft's feathers characteristics in the studied penguin species indicates that some differences do exist. The "downy" region of these feathers (afterfeather named as a cluster of barbs by Lucas & Stettenheim 1972) might have the same function of the cobert's afterfeathers, that is, to increase the bird´s isolation from the environment. In fact, this downy region of the penguin´s feathers may amplify the tuft´s area. Lucas & Stettenheim (1972) observed a hyporaquis in the tuft´s feathers of chickens and kingfishers, and a distinct aftershaft in the plumules of grouses and sandpipers. Conversely, Johnston (1988) did not find afterfeathers in any of the tuft´s feathers he analyzed.

One of the most relevant functions of the uropygial gland is to maintain the feather structure as a mean of preserving its waterproofing properties (Moyer *et al.* 2003) and its isolation from the environment. Aquatic birds have a greater amount of tuft´s feathers and also longer than in terrestrial birds. These results agree with data reported by Jacob & Ziswiler (1982), either for same species or for different species of the same families. It had been observed that this tuft was always saturated with gland secretion (Schumacher 1919), therefore these feathers could not have thermoregulatory functions; this function would be carried out by down feathers that surround the gland. It may be speculated that the feather tuft might act as a container of certain amount of uropygial secretion, which is available when required without the need of extracting the secretion constantly. Therefore, the uropygial gland secretion can be at disposal for the brief periods that aquatic birds spend out of the water for preening activities.

Terrestrial birds have a longer length ratio between calamus/raquis than aquatic birds. As a result, they have less feather area to contain secretion and less raquis area to act as a container. Actually, terrestrial species used to squeeze the uropygial gland to obtain the secretion every time they need because they preen more often than aquatic birds and for this reason the feather tuft is smaller than in aquatic species.

Some terrestrial birds have a longer ratio between calamus/raquis than others. In our material, the Scarlet Macaw (Psittaciformes) had the longest length ratio between calamus/raquis (0.71); to be noted that this specie lives in tropical forests where it is well protected from rain. Other Psittaciformes, such us the Monk Parakeet, with a smaller length ratio between calamus/raquis (0.33), are more exposed to the inclemency of the weather (*e.g.* rain) because they inhabit open areas (Collar 1997). Furthermore, the Red-Winged Tinamou, which lives in more enclosed environment, had a calamus/raquis relation of 0.56, while a smaller calamus/raquis ratio value (0.47) was found in the Spotted Nothura that inhabits in a more exposed region (Cabot 1992).

The differences found for the calamus length/raquis length in aquatic birds might be attributed to different degrees of exposure to water. Penguins (calamus/raquis relation 0.23) spend most of their time inside the water and they only come to the coast during the breeding and moulting seasons (Williams 1995). Therefore, they do not need to preen as often as gulls (0.12) or skuas (0.15) do. In fact, these species obtain their food without having much contact with water (Burger & Gochfeld 1996) and can return to land after getting wet to preen their plumage. Thus, their calamus/raquis ratio values are smaller than that of the penguins. Comparably, herons only have their legs in contact with water (Martínez-Vilalt & Motis 1992) and an observed length ratio between calamus/raquis of 0.296.

As a conclusion, the differences found in the amount and length of the tuft´s feathers and the length ratio between calamus/raquis in different bird's species can be related to the environment; aquatic birds have a larger development of the feather tuft (amount and length of feathers) which might act as a container of uropygial secretion being available when needed. On the other hand, the development of these feathers is less pronounced in terrestrial birds, because they do not need to store secretion since they squeeze the uropygial gland to get secretion whenever it is necessary.

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