"YELLOW SPOT"—A NEW TRAIT OF GENTOO PENGUINS *PYGOSCELIS PAPUA ELLSWORTHII* IN ANTARCTICA

ROUMIANA METCHEVA[1], VLADIMIR BEZRUKOV[2], SVETLA E. TEODOROVA[3] & YORDAN YANKOV[4]

[1]*Institute of Zoology, Bulgarian Academy of Sciences, 1, Bd Tzar Osvoboditel, 1000, Sofia, Bulgaria*
[2]*Department of General and Molecular Genetics, Taras Shevchenko National University of Kyiv, 64 Volodymyrska Str, Kyiv, 01033, Ukraine*
[3]*Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72, Tzarigradsko shaussee, 1784, Sofia, Bulgaria (seteodor@tea.bg)*
[4]*Bulgarian Antarctic Institute, 15, Bd Tzar Osvoboditel, 1000, Sofia, Bulgaria*

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SUMMARY

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This article is a preliminary report regarding a new trait, a spot-like coloration of the bill, observed on the upper mandible of Gentoo Penguins *Pygoscelis papua* subspecies *ellsworthi,* that we have called "yellow spot." Three breeding colonies were investigated at three locations on the Antarctic Peninsula—Livingston Island, South Shetlands (62°38′S), Wiencke Island (64°52′S) and Petermann Island (65°10′S). The trait was found with different frequencies at these three locations: 20%, 51% and 30%, respectively. The spot varied in diameter from 1–2 mm to 20–25 mm and in colour (from white to red, with yellow, orange and pink intermediate forms). The spot was recorded among chicks more than two months old and among adult birds (normal and moulting) of both sexes. Some potential reasons for the presence of the beak spot are outlined.

Key words: Antarctic Peninsula, beak spot, Gentoo Penguin, *Pygoscelis papua ellsworthii*

INTRODUCTION

During morphology investigations on Gentoo Penguins *Pygoscelis papua ellsworthii,* a spot-like coloration that has not been described in the literature was observed at the base of the upper mandible of some individuals. It varied from clear yellow-orange to reddish.

Colour patterns of terrestrial birds have been well studied, but relatively less is known about seabird coloration (Jones & Hunter 1993, Jouventin *et al.* 2005). Among the six genera belonging to family Spheniscidae, the genus *Pygoscelis* is the most widely distributed (Del Hoyo *et al.* 1992). Three species belong to *Pygoscelis*: Chinstrap *P. antarctica,* Gentoo *P. papua* and Adélie *P. adeliae.* Gentoo Penguins breed on sub-Antarctic islands and on the Antarctic Peninsula (Stonehouse 1970). There are two subspecies of Gentoo—*P. p. papua*, J.R. Forster, 1781 and *P. p. ellsworthii*, Murphy, 1947. *P. p. papua* is distributed in the sub-Antarctic up to 60°S, and *P. p. ellsworthii* inhabits the Antarctic from 60°S up to 65°S (Del Hoyo *et al.* 1992). Compared with *P. p. papua, P. p. ellsworthii* is of smaller size and bill proportion (Martinez 1992).

Most authors that study coloration in birds tend to explain its function in terms of health, mate choice behaviour or intraspecific signalling (Stevenson & Anderson 1994, Siefferman & Hill 2005). Saks *et al.* (2003) established that brighter yellow breast feathers in male Greenfinch *Carduelis chloris* signal immunocompetence and health status. Thus, females prefer more ornamental males, able to provide parasite resistance genes for the offspring.

Some colour patches also include ultraviolet (UV) markings. Jouventin *et al.* (2005) reported UV beak spots in King Penguin *Aptenodytes patagonicus* and Emperor Penguin *A. forsteri.* They found UV peaks of reflectance overlapping with spots of colour on both sides of the lower mandible, which have appeared orange (with variations among individuals from yellow to red). The authors suggested that a UV beak spot could be an indicator of sexual maturity with a possible role in pairing. Reflective UV patches are of relevance in the context of UV vision in birds, which may also be used for foraging (Sűtari & Vűtala 2002) and hunting (Koivula *et al.* 1997, Koivula *et al.* 1999).

It would be of considerable significance to know whether such markings (colour only or colour and UV reflectivity) might appear as a consequence of environmental changes, and whether their variability depends on one or a combination of diet, biochemical disturbances or parasite infection. Similar traits could also be used for comparative population studies.

The present study also seeks to determine if this "yellow spot" on the Gentoo bill is sex- or age-dependent.

METHODS

Populations studied

Field measurements were carried out on adult, non-moulting and moulting Gentoo Penguins, inhabiting Livingston Island (62°38′ S, 60°24′ W; South Shetland Islands), Wiencke Island (64°49′ S, 63°30′ W; Palmer Archipelago), and Petermann Island (65°10′ S, 64°10′ W). The birds were measured during the Antarctic summer, from January to March, at Livingston Island in years 2002–2005, at Petermann Island in 2002/03 and at Wiencke Island in 2003/04. At Livingston Island, the studied colony varied between 84 and 110 pairs; at Petermann and Wiencke islands, the colonies were larger—about 1000 nests per island. Additionally, at Livingston Island, 12 marked pairs of *P. p. ellsworthii* and offspring in crèches were observed in December 2005 to January 2006.

The penguins were captured using a hand net, inspected and marked. After inspection, morphologic traits were measured according to the Commission for the Conservation of Antarctic Marine Living Resources–Ecological Monitoring Programme (CCAMLR EMP) recommendations (CCAMLR 2004). All the penguins were marked with implanted glass-encapsulated TROVAN identification electronic transponders. The TROVAN system provides long-lasting marking, automatic detection of birds and quick identification (Clarke & Kerry 1998).

Blood samples for DNA analysis

Blood sampling for sex identification and DNA analysis was performed in two different ways according to the CCAMLR EMP Standard Methods. Approximately 1 mL blood was drawn from the cubital vein with a syringe and placed into tubes with K_3·EDTA or into tubes containing heparin. DNA was extracted using a standard phenol-chloroform method as described by Sambrook *et al.* (1989). Sex determination was performed by polymerase chain reaction as described by Itoh *et al.* (2001).

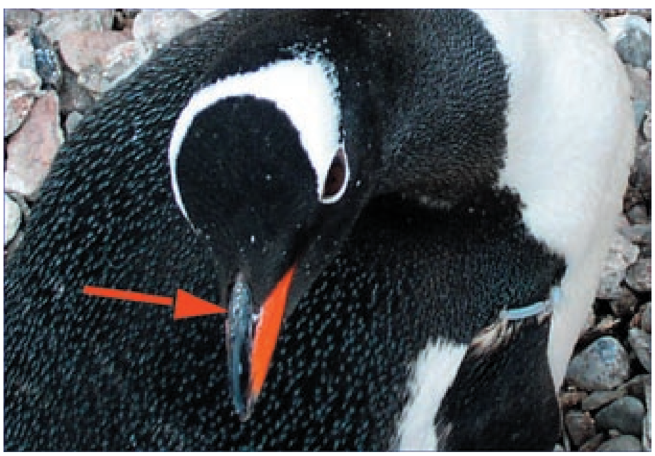

Fig. 1. Adult Gentoo Penguin *Pygoscelis papua ellsworthii* without spot on the beak.

Fig. 2. Adult Gentoo Penguin *Pygoscelis papua ellsworthii* with spot on upper mandible.

Statistical treatment

The percentages of spotted individuals from Livingston Island, Wiencke Island and Petermann Island were compared statistically for their significance. Differences in the trait distribution between males and females were tested using the χ^2 criterion for 2×2 tables. Trait distribution in the penguins at various locations was tested with the Fisher exact test (for two-tailed probability of type II error; Sokal & Rohlf 1995, Y. Dubrova pers. comm.).

RESULTS

Gentoo Penguins from the Antarctic Peninsula (Fig. 1) were examined for the presence of beak spot (Figs. 1 and 2) as follows: 157 individuals at Livingston Island (or about 81% of the breeding colony), 114 at Wiencke Island (11% of the colony) and 201 at Petermann Island (20% of the colony). The spot is located on the upper mandible of the bird (Fig. 3) and begins at the flashy cere and extends onto the hardened part of the beak.

The spot size in various individuals ranged from very small (1–2 mm) to quite large (20–25 mm). The largest spots spread over almost all the upper surface of the bill. Although we named the observed new trait "yellow spot" after its typical colour, the colour of the spot varied from white (yellowish) to red with yellow, orange and pink intermediate forms in various birds. The scheme in Fig. 3 gives a picture regarding size and colour variations of the spot. Other visible peculiarities in body or feather coloration of beak-spotted Gentoo Penguins were not recorded.

All the penguins were checked for appearance of the yellow spot on the beak when they were marked. The trait was observed year round, not only during moult. Over the observation period, the spots did not change their appearance. The yellow spot was observed in both adults and chicks. Among adult birds, the frequency of this trait was approximately twice that seen in chicks.

As a preliminary investigation of a possible heritable basis and to estimate the age-related process of spot appearance, commencing with hatching, we made some additional observations of three pairs

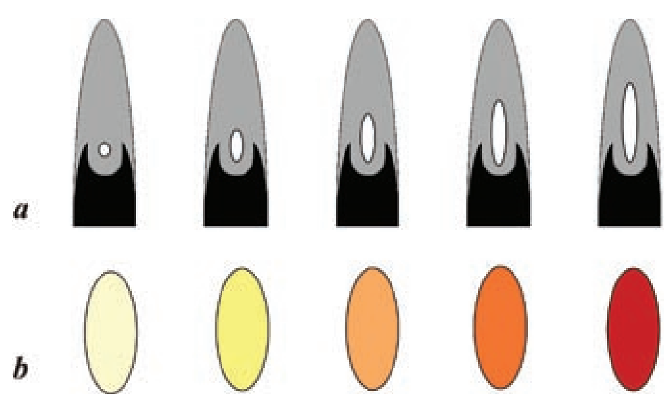

Fig. 3. A scheme of the "yellow spot" observed on the upper mandible of Gentoo Penguins *Pygoscelis papua ellsworthii*: (a) location on the mandible and size variations, and (b) colour variations.

with spots (both of parents), two pairs without spots and seven mixed pairs (with only one spotted parent) at Livingston Island in December 2005 to January 2006. From the beginning of hatching to about three weeks of age, no beak spot was found in the offspring. Similar data were obtained at the other locations (Petermann and Wiencke islands), where recently hatched chicks with beak spots were not found. However, spots were observed in two-month chicks (Livingston colony), when they had formed a crèche. Among 75 juveniles, three chicks two-months of age (4%) exhibited a small spot in the base of the upper mandible.

Table 1 presents the distribution of the spot among males and females. The DNA analysis was carried out for 93 individuals in the Livingston colony and for 185 individuals in the Petermann colony. The analysis revealed that, at Livingston Island, 37 of the samples were females, and the remaining 56 were males. At Petermann Island, 94 of the penguins were females, and 91 were males. Among all inspected females, 31% exhibited a beak spot, and among all inspected males, a colour spot on the beak was observed in 27% of individuals. There was no statistically significant difference in the frequency of spot appearance between sexes (Table 1).

Table 2 presents the distribution of the trait in the three Gentoo colonies investigated during 2002–2005 (without those observed in the summer season 2005/06). All inspected birds were divided into two categories on the basis of the presence or absence of beak spot. Spot size, number and colour were ignored in this assay. The average frequency of spotted individuals was 32%. The differences in the percentages of spotted individuals were statistically significant between all three colonies (Table 2).

The frequency of spot appearance did not correlate with the distances between the colonies. The highest frequency of the trait was found in the colony on Wiencke Island (situated between Livingston and Petermann islands) followed by the colonies of Petermann and Livingston (the most distant locations; Table 2). At Wiencke Island, half of the observed penguins had the spot. The lowest percentage of investigated individuals exhibiting a spot was recorded at Livingston Island, the most northern of the three locations. Thus, the existing data do not support the idea of a cline.

TABLE 1

Distribution of the "yellow spot" between male and female Gentoo Penguins *Pygoscelis papua ellsworthii*

Location	Sex	n (all inspected)	Beak spot				χ^2	*P*
			Yes		No			
			(n)	(%)	(n)	(%)		
Livingston Island	Male	56	15	27	41	73		
	Female	37	9	24	28	76	0.069	0.98
	Total	93	24	26	69	74		
Petermann Island	Male	91	25	27	66	73		
	Female	94	31	33	63	67	0.66	0.78
	Total	185	56	30	129	70		
All groups	Male	147	40	27	107	73		
	Female	131	40	31	91	69	0.37	0.93
	Total	278	80	29	198	71		

TABLE 2

Distribution of the "yellow spot" in the three colonies of Gentoo Penguins *Pygoscelis papua ellsworthii* inhabiting different Antarctic areas. Frequencies (%) of spotted individuals and statistical significance are given.

Population	Location	Total	Beak spot			Statistical significance (Fisher exact test)	
			Yes (n)	No (n)	Yes (%)	Population comparison	Two-tailed probability
Livingston Island	62°38′ S 60°24′ W	157	31	126	20	Livingston–Peterman	0.014
Wiencke Island	64°52′ S 63°30′ W	114	58	56	51	Peterman–Wiencke	0.0004
Petermann Island	65°10′ S 64°10′ W	201	61	140	30	Livingston–Wiencke	0.00012
All		472	150	322	32		

DISCUSSION

Given that the frequency of the beak spot in *P. p. ellsworthii* does not differ significantly in males and females (Table 1), it may safely be said that this trait is not sex related. Much attention has been paid to the significance of colour and UV phenomena in avian intrasexual competition or intrasexual selection. Jouventin *et al.* (2005) established that recently paired King Penguins had shown higher UV reflectance than courting ones. These authors therefore considered the UV ornaments to be a factor that plays a role in the pairing of breeding males and females and could serve as an indicator of sexual maturity. Also Mougeot & Arroyo (2006) noted that UV signals play key roles in social and sexual signalling in birds. European Starlings *Sturnus vulgaris* (Benett *et al.* 1997), Blue Tits *Parus caeruleus* (Anderson *et al.* 1998, Hunt *et al.* 1998) and Bluethroats *Luscinia s. svecica* (Anderson & Amundsen 1997) use UV-reflecting plumage cues in mate choice. On the other hand, there are studies indicating that UV vision in birds plays an essential role in foraging and hunting behaviour. Black Grouse *Tetrao tetrix* prefer UV-reflecting berries (S˝utari & V˝utala 2002), and kestrels are attracted to the vole urine and faeces marks that reflect UV light (Viitala *et al.* 1995, Koivula *et al.* 1999, Zampiga *et al.* 2006). The hunting success of nocturnal owls is best during clear nights because of the visibility of scent markings in UV light (Koivula *et al.* 1997).

We have not yet collected data supporting a heritable basis of the trait. The fact that no spot was recorded in Gentoo chicks below two months of age suggests a possible correlation between spot appearance and age. Such an assumption is reasonable, taking into account that in the crèche only 4% of the two-month chicks exhibited a small spot and that in adult birds the frequency of the spot was about twice the frequency seen in juveniles.

Gentoo Penguin populations of the Antarctic Peninsula have been studied with respect to foraging behaviour (Trivelpiece *et al.* 1986), morphometry (Stonehouse 1970), UV reflectance (Jouventin *et al.* 2005) and more. However, this trait (“yellow spot”) has not been reported before. A possible reason could be that it has been induced by a recent rapid change in the Antarctic environment (e.g. the increase in ozone depletion). Some environmental factors could be reflected in a change in the synthesis of melanin or carotenoid pigments; however, no targeted investigation has been carried out.

Melanin availability (black colour) may explain the presence or absence of the spot. Melanin is an essential component in bill structure, and incorporation of melanin granules into the bill keratin increases the hardness of the bill (Bonser & Witter 1993). The attachment of cisteine to DOPA–chinon after oxidative cyclisation and polymerisation results in the formation of reddish pigments (Angelov *et al.* 1995). DOPA–chinon is the third step in the melanin synthesis chain beginning with tyrosine. Such a reaction may occur in the case of an increase of the concentration of cisteine, taking part in detoxification processes.

Red, orange and yellow coloration is usually related to the carotenoid pigment type. Saks *et al.* (2003) established that plumage coloration in male Greenfinches, signalizing their immunocompetence and health status, is carotenoid-based. The combination of carotenoid pigments and proteins generates many colours, from brilliant yellow to red, in crustaceans, fish and birds. The general distribution and metabolic pathways of carotenoids have been investigated in detail (Katayama *et al.* 1971, Goodwin 1984, Davis 1985, Matsuno & Hirao 1989). However, there are reports regarding the potential for melanin to produce yellow coloration in birds’ plumage (McGraw *et al.* 2004). These authors have not detected carotenoid pigments in feathers of five avian species, including King Penguins and Macaroni Penguins *Eudyptes chrysolophus.* Moreover, McGraw *et al.* (2004) suggested that the yellow appearance of penguin and domestic chick feathers might be attributed to a new form of plumage pigment, never before described from bird feathers. We have not analyzed the Gentoo Penguin beak biochemically, but it seems reasonable to suppose at least a partial carotenoid contribution in beak coloration because of their diet. It consists of about 50%–80% crustaceans, mainly krill, which are a rich source of carotenoids (Berrow *at al.* 1999).

A possible cause for the variation in spot coloration could be also endoparasitism (McGraw & Hill 2000). Saks *et al.* (2003) found that coccidian infection reduces the expression of plumage coloration in Greenfinches by creating a deficiency of carotenoids available for deposition in ornamental feathers. Golemanski (2002) first described intestinal coccidiosis in *P. papua* (Livingston Island).

If it turns out that the Gentoo beak spot has no role in pairing, is not environmentally based or is caused by disease (of any origin), this trait could be a polymorphic characteristic—in which case, it will be of interest to study its genetic architecture. Analyses of Gentoo Penguin populations are important today because these populations are indicator species of the Antarctic ecosystem (Zhu *et al.* 2005) and a comparison of trait frequencies in various populations could be useful for population studies and monitoring programs.

Finally, four reasons for the newly observed beak spot in Gentoo Penguins could be suggested:

- The beak spot plays some role in mate choice
- The trait occurs because of changes in the synthesis of melanin or carotenoid pigments, which could be related to some environmental changes in Antarctica.
- The trait may be the result of parasite infection.
- The trait could be a phenotypic characteristic.

Longer studies are required to determine the most probable cause or causes for the appearance of this trait and to clarify its possible function.

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