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Case Report

Anomalous Coloration of Indo-Pacific Humpback Dolphins off Southern China

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Abstract: The Indo-Pacific humpback dolphin is characterized by a particular ontogenic change in body color from dark gray at birth to pure white (or with a few dark-gray spots) after reaching adulthood. Here, we report a spectrum of anomalous body color patterns observed on Indo-Pacific humpback dolphins off southern China. The occurrence of hypopigmentation and hyperpigmentation was described and compared among six putative dolphin populations. Low rates of anomalies in body color patterns were observed (<1%), except for hypopigmentation, which was prevalent in dolphins residing in the mid-Pearl-River-Delta region (3.3%).

Keywords: anomalous coloration; Chinese white dolphin; leukoderma; Sousa chinensis; piebaldism

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1. Introduction

To date, four species of humpback dolphin are recognized under the genus *Sousa* [1], including: the (1) Indo-Pacific humpback dolphin (*S. chinensis*, also known as the Chinese white dolphin), (2) Australian humpback dolphin (*S. sahulensis*), (3) Indian Ocean humpback dolphin (*S. plumbea*), and (4) Atlantic humpback dolphin (*S. teuszii*). These four species differ substantially in both their morphological and genetic characteristics [2], e.g., the presence/absence of a humpback [1]. Unlike the other three species that present a gray body color throughout their life, the Indo-Pacific humpback dolphin presents a unique ontogenic body discoloration process, with calves being born dark gray but gradually losing their body color until reaching pure white skin (or with a few dark spots) at an older stage (ca. 20 years or sometimes more) [3,4]. The unique light color of adult Indo-Pacific humpback dolphins makes them highly distinguishable in the field. From the mid-Guangdong coast (Pearl River Delta region or PRD) to the Leizhou Peninsula at the south end of the province, these dolphins are called "Wu Baak Gei" by fishermen, which refers to the black and white unfortunate or catastrophic symbols in Cantonese.

Jefferson first examined the link between Indo-Pacific humpback dolphins' ages and body colors in Hong Kong's waters (part of the PRD region) and categorized the dolphins into six classes (unspotted calves, UC; unspotted juveniles, UJ; spotted juveniles, SJ; spotted sub-adults, SS; spotted adults, SA; and unspotted adults, UA) [3]. The spotted sub-adults class was later renamed to "mottled" [5], likely due to the uncertainty in defining the reproductive stage of dolphins associated with the individual or sexual heterogeneity in their discoloration process. More recently, Guo et al. [4] aged 37 carcasses stranded in the PRD region and rigorously estimated the correlation between dolphins' body color patterns and ages, and confirmed that the discoloration speed was relatively faster amongst females than males. The six age categories proposed by Jefferson and recently updated have been frequently used to infer the age of humpback dolphins at several locations in

Chinese waters [6–8]. However, Tang et al. [9] examined the body color pattern of free-ranging humpback dolphins from four locations and proposed a varying discoloration process between populations, with a relatively faster discoloration process for dolphins from the PRD region and Leizhou Peninsula compared with those from the Beibu Gulf and southwestern Hainan Island. Even though the research effort is much lower for the conspecific populations outside Chinese waters, it has been suggested that the discoloration process may be even slower amongst the Indo-Pacific humpback dolphins from Southeast Asia and the Indian Ocean [10].

Intra-population variation in the discoloration process was also noted in Indo-Pacific humpback dolphins. For instance, a long-term photo-identification (photo-ID) survey reported two slightly different discoloration processes in the PRD population [4]. For some of the dolphins, the gray skin of juveniles will lighten on parts of the body, leaving extensive dark spots on the rest of the body region, while, for other dolphins, the gray skin of juveniles first lightens throughout the trunk, but dark spots will soon merge, seemingly due to the increase in dark-colored pigments (see details in [4]). As the dark spots will be continuously and gradually lost by dolphins in both discoloration processes, the difference between these two processes is only observable before the dolphins reach maturity. Despite the inter- and intra-population variations in the discoloration process, both the dark and white spots formed during the discoloration process commonly exhibit spindle or oval shapes with regular sizes ranging from a few mm up to ca. 5 cm in length.

Changes in body color throughout life cycles have been reported for some cetacean species [3,4,11,12]. In addition, anomalous body color is not unusual in cetaceans [13–16]. One of the most famous cases of body color anomaly may be the pure white humpback whale (*Megaptera novaeangliae*, https://www.migaloo.com.au, accessed on 29 November 2022) named "Migallo", whose color allows biologists to easily find and identify this individual and to collect data when sightings occur [17]. Such data have been used to examine the site fidelity and ranging pattern of humpback whales off the east Australian coast [18]. In comparison, anomalous skin color that involves only parts of the body of individuals is more difficult to notice and, therefore, less documented in cetacean species [14,19–21], and has attracted much less research attention.

Over the past decade, an ongoing photo-ID survey effort has been made to track over 3500 Indo-Pacific humpback dolphins off the coast of southern China. Here, we report anomalous color patterns that were observed in six populations of Indo-Pacific humpback dolphins, including hyperpigmentation and piebaldism corresponding to the darkening or loss of color of an area of the body, respectively. This report aims to: 1. describe the anomalously pigmented individuals observed in Chinese waters; 2. quantify the percentage of anomalously pigmented individuals in each population; and 3. analyze the long-term development of anomalous body pigmentation throughout the discoloration process of dolphins. The results of this work constitute the first report of anomalous body pigmentation for the most "colorful" cetacean species in the world.

2. Materials and Methods

2.1. Study Areas and Field Survey

The present study examined six populations of Indo-Pacific humpback dolphins off southern China, including Xiamen Harbor (XM), the coastal waters off Shantou City (ST), the Pearl River Delta region (PRD) extending from the Lingding Sea in the east to the waters surrounding Chuanshan Islands in the west, the east coast of Leizhou Peninsula (LZP), the southwestern coast of Hainan Island (HN), and the Dafeng River Estuary and its surrounding waters (DRE, Figure 1). Photographs of dolphins' dorsal regions were collected using CANON MARK IV, 7D II, or X cameras equipped with 100–400 mm lenses through regular photo-identification surveys carried out year-round from 2014 to 2022 using small vessels powered by two- or four-stroke outboard engines [9,22].

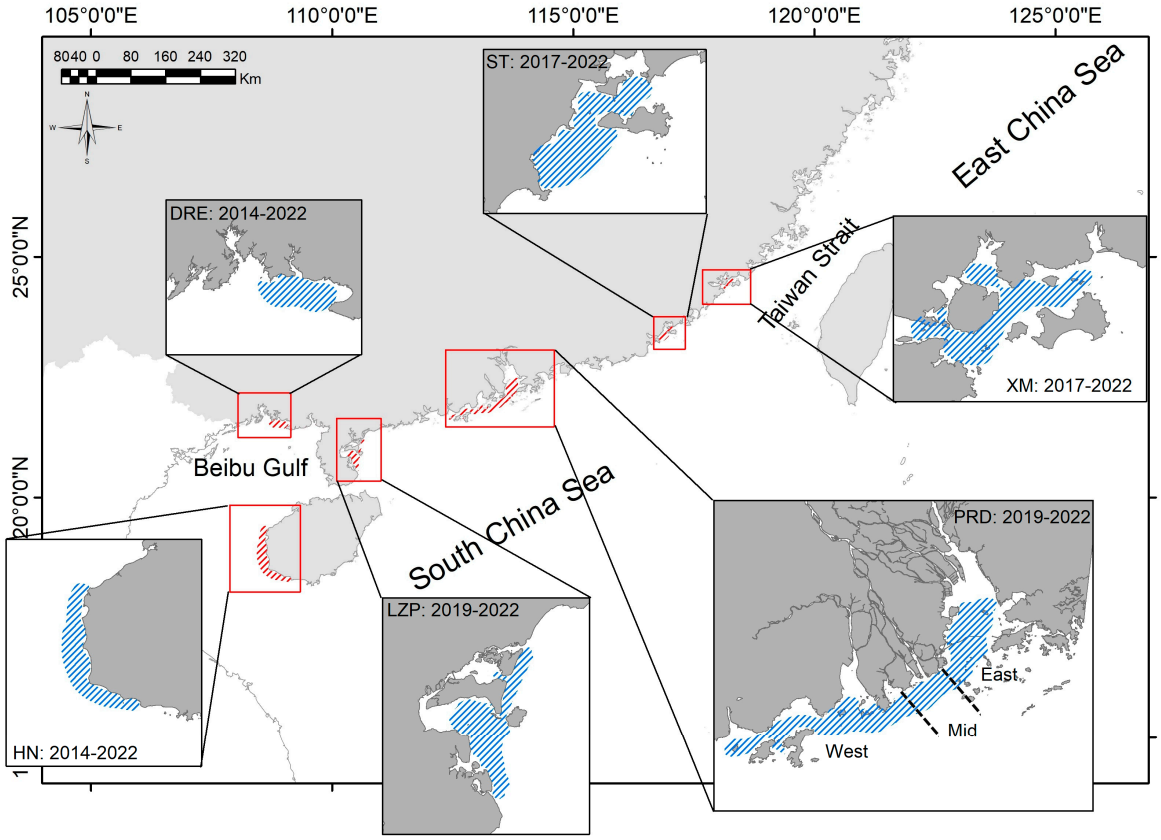

Figure 1. Six Indo-Pacific humpback dolphin populations off southern China covered by this study effort, including: Xiamen Habor (XM), the coastal waters off Shantou City (ST), the Pearl River Delta region (PRD, which was further divided into the East, Mid, and West sections by the dashed lines), the east coast of Leizhou Peninsula (LZP), the southwestern coast of Hainan Island (HN), and the Dafeng River Estuary and its surrounding waters (DRE). The sampling periods are indicated for each location.

2.2. Anomalous Pigmentation

As Indo-Pacific humpback dolphins experience a discoloration process, they naturally exhibit color spots (Figure 2A). These color spots generally exhibit spindle or oval shapes with varying, yet highly comparable, sizes (Table 1). In the present study, anomalous pigmentation was defined as a lack (hypopigmentation) or an excess (hyperpigmentation) of melanin on part of the dolphin's body (usually >20 cm, Figure 2B), the color of which therefore differed substantially from the rest of the body of an individual. (De-) pigment spots exhibiting an unusually large size (e.g., >5 cm but <10 cm in length) and a usual smooth shape were not categorized as anomalous, but were more likely to be merged/overlapping discoloration spots occurring due to individual variation (Figure 2C,D). Hypopigmentation associated with physical scars (such as rope scars, propeller trauma, biting scars, etc., Figure 2E) was also excluded from the analysis (Table 1).

Table 1. Characteristics used to distinguish normal pigmentation, abnormal skin coloration due to physical injuries, and anomalous body color used in this study.

Categories	Size (in Length)	Shape	Skin Lesion
Normal pigmentation	Ranges from a few mm to 5 cm	Regular dot, spindle, or oval shape	Not relevant
Anomalous pigmentation	Usually >20 cm	Irregular patchy shape	Not relevant
Physical scars	Irregular size	Stripe, usually with concave skin	Presence and relevant

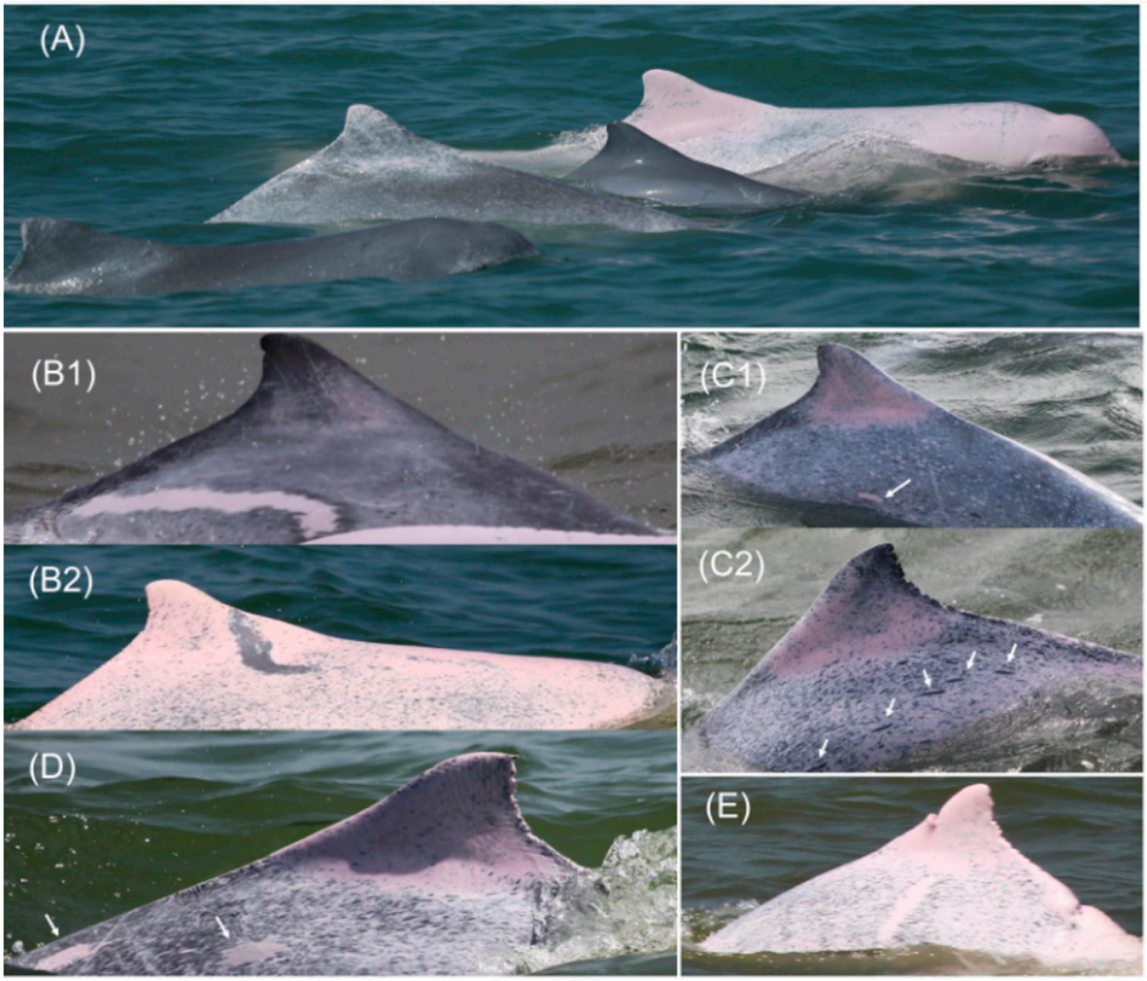

Figure 2. Typical and atypical skin coloration patterns of Indo-Pacific humpback dolphins. Typical color patterns: (**A**) life-cycle discoloration from calf to adult. Atypical color patterns: (**B1**) hypopigmentation and (**B2**) hyperpigmentation. Unusual, but not considered anomalous, color patterns (part of normal inter-individual variation): (**C1, C2**) unusual white or dark spots, (**D**) merging dots, (**E**) depigmentation due to physical trauma.

3. Results

3.1. Frequency and Spatial Distribution of Anomalies

Of the total 3636 humpback dolphins included in this study, only 42 individuals exhibited anomalous pigmentation (Table 2). Hypopigmentation was the more frequently observed type (61.9% of the individuals with anomalous skin color) compared with hyperpigmentation (38.1%). In all populations, the proportion of anomalous pigmentation was low $\leq$1%, with an exception for the XM population, which was particularly small in size (48 dolphins), leading to a high proportion, even though only one dolphin exhibited anomalous pigmentation (2.1%). No spatial pattern was observed for hyperpigmentation, but 20 out of the 24 cases with hypopigmentation were documented in the mid-PRD region (Table 2). When averaged over the population/sample sizes, 3.3% of the mid-PRD humpback dolphins presented hypopigmentation, which was significantly higher than the values found in the other populations/regions ($\chi^2 = 21.0$, $p < 0.001$). Interestingly, the proportion of hypopigmentation at the two flanking zones of the PRD was low and highly comparable to that of other conspecific populations (West-PRD: $\chi^2 = 1.1$, $p = 0.29$; East-PRD: $\chi^2 = 1.5$, $p = 0.21$).

Table 2. Summary of the anomalous body color patterns documented amongst Indo-Pacific humpback dolphins from the Xiamen harbor (XM), the waters off Shantou city (ST), the east coast of Leizhou Peninsula (LZP), the Dafeng River Estuary and its surrounding waters (DRE), the southwestern coast of Hainan Island (HN), and the Pearl River Delta region (PRD).

Categories	XM	ST	LZP	DRE	HN	PRD		
						West	Mid	East
Dolphin records	48	14	692	204	212	973	603	889
Hypopigmentation	1	0	0	0	1	4	20	0
Hyperpigmentation	0	0	4	1	0	6	4	1

3.2. Ontogeny of Hypopigmentation

Among the dolphins exhibiting hypopigmentation, most presented the anomaly since their first sighting, including three calves < six months old (see examples in Figure 3A,B). The only exception was observed for 2294-JrMosquitoII, who experienced a continuous depigmentation process. 2294-JrMosquitoII was first sighted as a juvenile with normal pigmentation, but its dorsal region (including the dorsal fin) partially turned light-gray around age 2 (Figure 4A). For this individual, the depigmentation process sped up abnormally and hypo-pigmented patches were formed at < 18 months, a phase during which 2294-JrMosquitoII exhibited no sign of behavioral or physical disorder. These observations seemingly suggest that the anomalous skin color might be formed within a short time period during the early life stage of humpback dolphins (from a few months to dozens of months after birth).

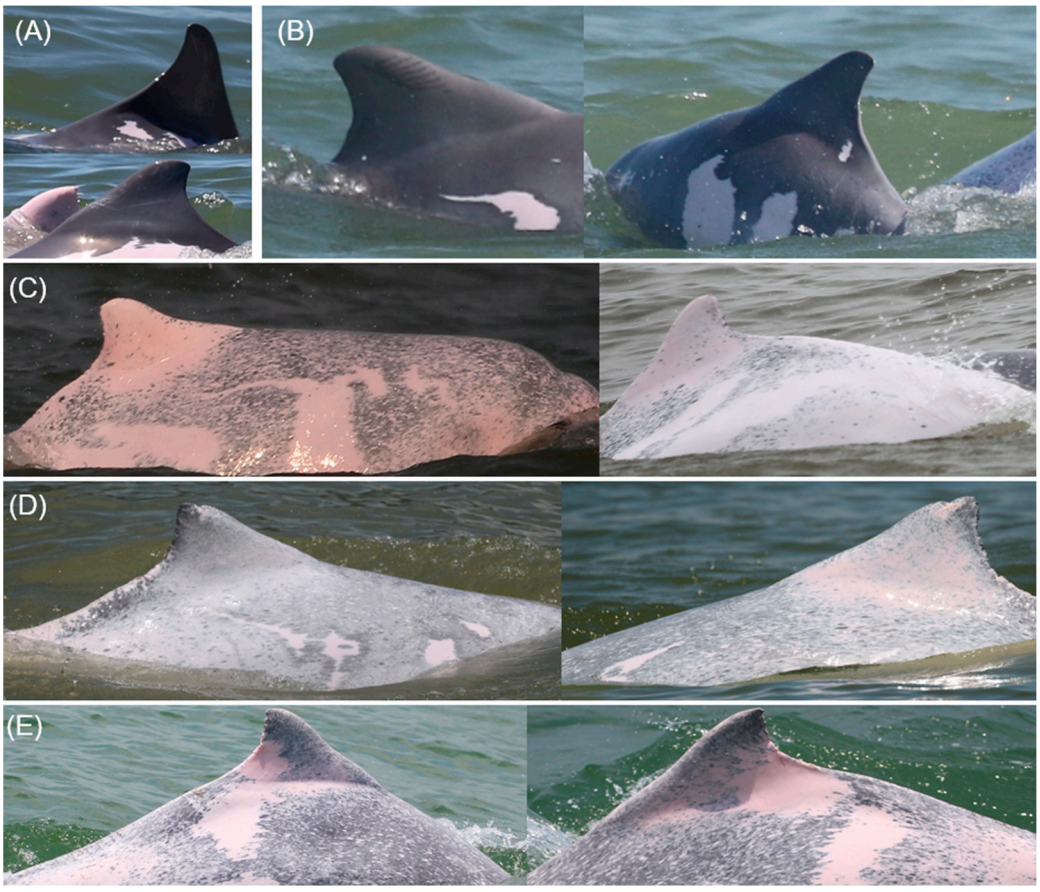

Figure 3. Examples of the hypopigmentation cases in young and adult Indo-Pacific humpback dolphins. Each panel represents the two body sides of the same individual. (**A**,**B**) Hypopigmentation on both sides of two calves < six months old; (**C**–**E**) hypopigmentation on both sides of three adults.

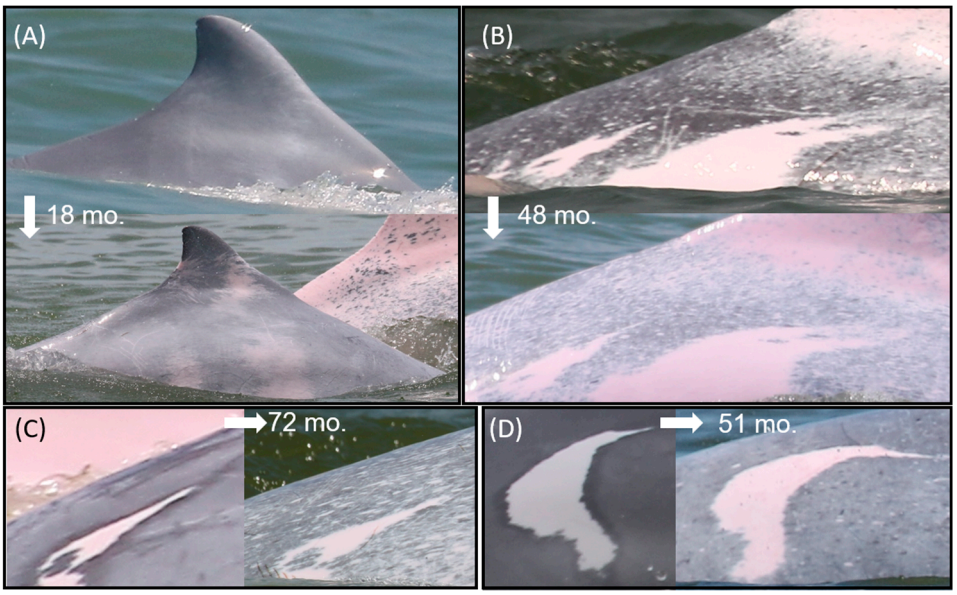

Figure 4. Ontogeny of the hypopigmentation of an Indo-Pacific humpback dolphin. (**A**) Continuous depigmentation process for a weaning juvenile; (**B**–**D**) examples of constant hypopigmentation observed for most of the individuals.

The mean sampling period for an individual presenting anomalous pigmentation (N = 26) was 45.1 months (range: 1.0–89.2 months), with the longest record being 7.3 years. The patchiness of the anomalous skin color seemed to be stable, as no change in size or shape was recorded during our study period (Figure 4B–D). It is noteworthy that once the hypopigmentation occurred in a relatively large size (ca. over a quarter of the dolphin's girth), it was generally found on both sides of the dolphin's body, with comparable patch sizes, general shapes (belt-like, patch-like, or lighting shapes), and positions, but not exact shapes (Figure 3).

To evaluate whether the hypopigmentation was inherited, we also examined the body color of three mothers of the calves/juveniles with anomalous coloration; however, they displayed no signs of similar patterns.

4. Discussion

Even though anomalies in skin color have been reported for a wide range of cetacean species, their prevalence has rarely been examined [14,19–21], likely due to the low frequency of occurrence. Here, anomalous color patterns were found in <1% of the examined humpback dolphins. An exception was found for dolphins from the mid-PRD region, who presented a rate of 3.3% of dolphins exhibiting hypopigmentation. This value was considered unnaturally high compared with the other populations or sub-populations examined in the present study.

The probability of recording any anomalous pigmentation patterns might be biased by the natural depigmentation process of humpback dolphins. Empirical studies suggest that PRD humpback dolphins generally exhibit a densely dark, spotted skin color after reaching maturity that will gradually depigment until they lose all or most of their body color around age 20 [4]. Therefore, hypopigmentation should be visible on calves/young juveniles with a uniform gray color, speckled juveniles/sub-adults, and some adults exhibiting dark spots (age range between 10 to 20), while hyperpigmentation should be easily spotted amongst most of the adults. Therefore, the actual proportions of hyperpigmentation and hypopigmentation could be higher than the presently reported values.

Unlike the depigmentation associated with physical injuries, the anomalous depigmentation as described in the present study was found exclusively on smooth skin, without any skin bulges or phymata that are generally associated with infection or physical trauma [4,23].

No skin lesions that might be associated with an anomalous skin color pattern were documented during our over-ten-year field study across the species' range in the nation. As such, the hypopigmentation of humpback dolphins resembles congenital leukoderma (loss of pigment on the trunk, stable throughout life) [24].

Mice models have suggested that the pigmentation process is regulated by multiple genes [25], such as KIT, which encodes the transmembrane receptor tyrosine kinase. Mutations in KIT and many other genes cause the malfunction of melanin synthesis and ultimately lead to pigment disorders, such as piebaldism. In cetaceans, Polanowski et al. [19] suggested that a mutation in the tyrosinase-coding gene (TYR) led to a truncated TYR protein, which resulted in a malfunction of the tyrosinase enzymatic activity of a white humpback whale. Moreover, the regulation of skin color is determined by multiple steps, starting from the melanoblast's migration to the skin at the embryonic stage [26]. Damage in this very first step will cause the loss of melanocytes in the ventral skin of humans, and may have been the cause of the hypopigmentation observed on both sides of humpback dolphins, including unweaned calves.

The disproportionate distribution of hypopigmentation between locations indicates a possible prevalence of a mutation of related gene(s) in the mid-PRD region. In human society, 75% of piebaldism cases are due to mutations in the KIT gene [27]. Anomalous body color, such as albinism, may make the individual more susceptible to predation, or conversely, may reduce the success rate of predation, therefore playing a role in the spread of the anomaly (i.e., the anomaly has less chance to be transmitted to offspring if the animal has a short lifespan). For cetacean species, it has been suggested that the loss of melanin pigments is correlated with a higher probability of UV damage [19]. Nevertheless, it is plausible to assume that humpback dolphins' fitness is mildly impacted by their body color, as they search for their prey primarily through echolocation and should not be susceptible to sunburn due to the low transparency of the brackish waters of their estuarine/bay habitats. To support this hypothesis, no apparent evidence of emaciation or physical disorder was observed on the humpback dolphins presenting anomalous pigmentation. However, the potential effects of anomalous pigmentation on these dolphins' lives [28], including social relationships or reproductive success, remain to be investigated.

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