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A SCIENTOMETRIC REVIEW ON LEUCISM IN WILD DOLPHINS

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RESUMO

O leucismo, uma categoria de albinismo parcial, tem sido observado em vários mamíferos marinhos, incluindo cetáceos. As mutações subjacentes, no entanto, ainda não foram identificadas, e uma grave lacuna de conhecimento sobre essa condição nesses animais foi observada. Neste contexto, o presente estudo realizou uma revisão baseada em cienciometria acerca de leucismo em golfinhos, avaliando a distribuição de casos confirmados ao redor do mundo. Registros variaram de 1929 a 2019, com um total de apenas 14 registros de casos confirmados de leucismo obtidos na literatura. Este número extremamente baixo de registros confirma a significativa lacuna de conhecimento do leucismo em golfinhos, dificultando discussões e percepções adicionais sobre as implicações ecológicas e fisiológicas dessa condição. Todos os registros relatam avistamentos de golfinhos leucísticos no hemisfério norte, exceto um, no sudeste do Brasil. As causas potenciais dessa condição são discutidas para as populações investigadas, e o papel da ciência cidadã é destacado como uma ferramenta potencial para obter mais informações sobre o assunto.

Palavras-chaves: Albinismo; Coloração anormal; Cetáceo; Análise cienciométrica; Avistamentos de golfinhos.

ABSTRACT

Leucism, a category of partial albinism, has been observed in several marine mammals, including cetaceans. The underlying mutations, however, have not yet been identified, and a severe knowledge gap concerning this condition in these animals, has, therefore, been noted. In this context, the present study performed a scientometric-based review on leucism in dolphins, assessing the distribution of confirmed cases worldwide. Reports ranged from 1929 to 2019, with a total of only 14 records on confirmed leucism cases obtained from the literature. This extremely low number of records confirms the significant knowledge gap for leucism in dolphins, hindering further discussions and insights into the ecological and physiological implications of this condition. All records report on leucistic dolphin sightings in the northern hemisphere, except for one, in southeastern Brazil. The potential causes of this condition are discussed for the investigated populations, and the role of citizen science is highlighted as a potential tool to obtain further information on the subject.
Keywords: Albinism; Abnormal coloration; Cetacean; Scienciometric analysis; Dolphin sightings.

INTRODUCTION

Excessive or deficient melanin synthesis in vertebrates leads to atypical coloration in ectoderm-derived tissues, such as skin, fur or plumage, resulting in albinism, from the Latin albus, meaning "white" (Camargo et al., 2014; Federico & Krishnamurthy, 2020). This condition is rare and can be classified as either partial or total (Alaja & Mikkola, 1997). Total albinism comprises several specific characteristics, mostly atypical coloration in skin, hair, nails and eyes (Federico & Krishnamurthy, 2020), whereas one particular category of partial albinism, leucism, presents white skin coloring but typical eye and nail coloration (Tonay et al., 2012).

The gene most likely responsible for leucism has been identified as the MC1R gene, which encodes the melanocortin 1 receptor protein (MC1R), which regulates pigment production (Bried & Haubreux, 2000; Peters et al., 2016) by encoding the receptor protein for melanocyte-stimulating hormone (MSH). Mutations in the MC1R gene can alter this receptor's activity, either over- or under-expressing it (Kopaliani, Gurielidze & Ninua, 2017). Constitutively active MC1R gene alleles are dominantly expressed, resulting in dark pigmentation, while inactive (dysfunctional) MC1R gene alleles are recessive and result in light or no pigmentation (Robbins et al., 1993; Fontanesi et al., 2006; Peters et al., 2016). For example, increased basal MC1R levels result in increased expression of several melanogenesis-related genes, such as tyrosinase, tyrosinase-related protein 1, and microphthalmia-associated transcription factor, among others, increasing eumelanin synthesis (Nishimura, 2011).

Mutations in the MC1R gene associated to pigmentation alterations have been noted in humans and several domestic animals, such as pigs, cows, chickens, horses and dogs (Peters et al., 2016) (and references therein) and in wild animal populations, in ca. 20 species comprising three mammalian orders, five avian orders, and lizards (Hoekstra, 2006). However, the genetic polymorphisms responsible for different color morphs, including leucism, have not yet been elucidated in many wild vertebrate species (Peters et al., 2016). For example, hypopigmentation cases, including leucism, have been observed in several marine mammals, including 25 cetacean species (Acevedo et al., 2009) and seven pinniped species (Peters et al., 2016), but the underlying mutations have not yet been identified (Peters et al., 2016).

It has been hypothesized that hypopigmentation may result in several negative effects, such as higher predation rates (Sandoval-Castillo et al., 2006; Acevedo, Aguayo-Lobo & Torres, 2009); increased sun sensitivity; reduced heat absorption, decreased mating success or inbreeding (Fertl & Rosel, 2009; Keener et al., 2011; Prado-Martinez et al., 2013; Robinson & Haskins, 2013; Peters et al., 2016). However, other studies have indicated that a higher than normal frequency of unusually colored individuals is not associated to negative consequences in a specific habitat (Kopaliani, Gurielidze & Ninua, 2017; Sokos et al., 2018).

Some assessments indicate that environmental factors may play a role in leucism, such as low-quality habitat, low-quality diets (Owen & Skimmings, 1992; Peles, Lucas & Barrett, 1995) or environmental pollution (Yauk & Quinn, 1996; Ellegren et al., 1997; Møller & Mousseau, 2001). Furthermore, some studies speculate that hypopigmentation cases have become more common due to climate change, although studies are still severely lacking for marine mammals (Forcada & Hoffman, 2014; Mikkola, 2017). A severe knowledge gap concerning hypopigmentation in cetaceans, has, therefore, been noted in the literature (Fertl et al., 2004). In this context, the present study aimed to perform a scientometric-based review on leucism in dolphins, assessing the distribution of confirmed cases worldwide and carry out a discussion of potential causes of this condition.

MATERIAL AND METHODS

The scientometric technique was applied to generate qualified information on leucism in dolphins from scientific publications indexed on the Google Scholar, Pubmed and Scopus (Elsevier) scientific databases. This technique is applied in the mapping of diverse scientific fields to identify the current state of research in certain areas and allow researchers to identify and undertake new lines of research (Battisti and Salini, 2013).

After manual screening of titles and abstracts and excluding duplicates and articles that did not report leucism data, a total of 14 records were selected and included in the final quantitative analyses. Citations within the reports were also investigated and added when adequate. During a second screening, all selected articles were thoroughly read and, those matching the following selection criteria, were included. Records that did not state eye color, that reported only "anomalous color patterns" or those assessing captive animals with no capture location data were excluded. Table 1 depicts the scientometric search strategy applied herein.

Table 1. Applied scientometric search strategy concerning leucism in dolphins applied in the present study.

Scientometric search strategy	
Subject	Leucism reports in dolphins
Scientific databases	Google Scholar (Google), Pubmed (NCBI), Scopus (Elsevier)
Descriptors and Boolean operators	Leucis* AND dolphin; leucism AND dolphin
Language	English
Document types	All types of reports except personal communications
Research areas	All research areas
Timespan	All years

RESULTS

A total of 172 results were found for the search comprising the terms "leucis*" AND "dolphin", while a total of 61 results were found for the search comprising the terms "leucism" AND "dolphin". After manually reading all papers and excluding those not dealing with leucism, a total of 14 reporting confirmed leucistic cases in dolphins were included in the final quantitative analyses (Table 2). This low amount of hits obtained in the scientometric search and selection indicate that leucism reports in dolphins are extremely scarce.

Most reports were on white harbour porpoises (*Phocoena phocoena*) (N=9, 64.2%), followed by Atlantic spotted dolphins (*Stenella frontalis*) (N=2, 14.2%) and bottlenose dolphins (*Tursiops truncatus*) (N=1, 7.1%), short-beaked common dolphins (*Delphinus delphis*) (N=1, 7.1%) and Risso's dolphins (*Grampus griseus*) (N=1, 7.1%).

The coordinates of each sighting were plotted on a map (Figure 1). All sightings occurred in the Northern hemisphere, except for one case in Brazil.

Table 2. Articles reporting confirmed leucistic dolphins in the scientific literature worldwide.

Paper ID	Title	Publication year	Authors
1	First leucistic Bottlenose Dolphin (*Tursiops truncatus*) sighting registered in the Gulf of California, Mexico	2019	Perez-Puig et al
2	Rough-Toothed Dolphins (*Steno bredanensis*) along Southeastern Brazil: Report of an anomalous pigmented juvenile and description of social and feeding behaviors	2019	Cardoso et al.
3	Records of harbour porpoise (*Phocoena phocoena*) in the mouth of the Douro River (Northern Portugal) with presence of an anomalous white individual	2019	Gil et al.
4	Records of anomalously white harbour porpoises and atypical pigmented short-beaked common dolphin in the Georgian Black Sea Waters	2017	Kopaliani et al.
5	Rare records of hypo- and hyper-pigmented individuals in two delphinid species off Madeira Island	2017	Alves et al.
6	Three Cases of Anomalously White Risso's Dolphins *Grampus griseus* in Japan	2017	Funasaka et al.
7	Anomalously White Atlantic Spotted Dolphins (*Stenella frontalis*, Cuvier, 1892) Off the Azores	2016	dos Santos, et al.
8	Rare sighting of an anomalously white harbour porpoise (*Phocoena phocoena*) in the Moray Firth, north-east Scotland	2013	Robinson and Haskins
9	First records of anomalously white harbour porpoises (*Phocoena phocoena*) in the Turkish seas with a global review	2012	Tonay et al.
10	First records of anomalously white Harbor Porpoises (*Phocoena phocoena*) from the Pacific Ocean	2011	Keener et al.
11	Mammals of the Black Sea and the Sea of Azov. Results of joint biological-commercial dolphin whaling studies [Translated from Russian by the Translation Bureau Multilingual Services Division Department of the Secretary of State of Canada, 1978]	1956	Kleinenberg
12	Über einem weißen Tümmler [On a Bottlenose Dolphin, in German]	1929	Peters
13	Some rare cases of albinism in animals	1913	Prince
14	On a white porpoise	1912	Mcintosh

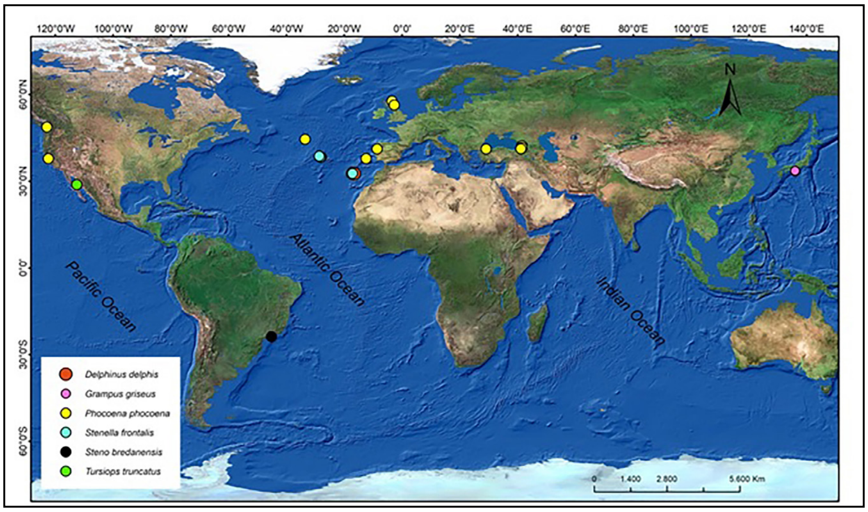

Figure 1. Plotted coordinates of each confirmed leucistic dolphin sightings around the globe reported in the literature.

Concerning maturity, only one of the articles recorded a calf, while the others reported both juvenile and adult specimens, and two did not state this information. Data on species and maturity for each of the reported individuals of the 14 assessed studies are shown in Table 3.

DISCUSSION

Several negative leucism effects have been postulated, such as reduced countershading, in turn increasing detection by predators or prey species and prey avoidance (Sandoval-Castillo, Mariano-Meléndez & Villavicencio-Garayzar, 2006; Acevedo, Aguayo-Lobo & Torres, 2009); increased chances of sunburn or skin cancer; reduced heat absorption, leading to thermoregulatory limitations in cold waters, reduced attractiveness to the opposite sex, leading to decreased mating success, or inbreeding, since some assessments in mammals have reported a possible link between coloration and inbreeding, where affected individuals could be at a fitness disadvantage due to inbreeding depression (Fertl & Rosel, 2009; Keener et al., 2011; Prado-Martinez et al., 2013; Robinson & Haskins, 2013; Peters et al., 2016).

However, both juvenile and adults were reported in the 14 articles investigated herein. This corroborates several previous assessments in marine mammals, indicating evident survival and relative longevity of leucistic individuals (Forestell et al., 2001; Tonay et al., 2012; Robinson & Haskins, 2013; Gil et al., 2019), both male and females, in line with studies indicating no associations to negative consequences in a specific habitat for several species (Abreu et al., 2013; Kopaliani et al., 2017). For example, Antarctic fur seals (*Arctocephalus gazella*) from Bird Island, South Georgia, displaying hypopigmentation attributed to leucism were identified as homozygous for a nonsynonymous mutation within the MC1R gene.This results in the substitution of serine with phenylalanine at an evolutionarily highly conserved structural domain. In the aforementioned study, both wild-type and hypopigmented individuals did not differ significantly in their standardized multilocus MC1R heterozygosity (which would otherwise be indicative of low genome-wide heterozygosity) (Peters et al., 2016). The authors, thus, indicate that this lack of association implies that hypopigmented individuals are unlikely to suffer disproportionately from inbreeding depression, and are, therefore, are not at a selective disadvantage in the wider population in this context. In another assessment, leucism in bats did not seem to negatively affect their reproductive potential, as leucistic pregnant females and males in reproductive conditions have been reported in the literature (García-Morales et al., 2013). Although studies in dolphins are scarce, the fact that adult dolphins of a reproductive age were reported in most of the reports seems to indicate that a leucistic condition does not negatively affect dolphin survival, although further studies are required in this regard.

Comparatively, a high number of leucistic dolphin have been sighted in the Black Sea, even considering only confirmed leucistic cases. This has been commented on in previous assessments (Kopaliani, Gurielidze & Ninua, 2017), with regard

Table 3. Species and maturity data for each of the 14 leucistic dolphin cases reported in the scientific literature worldwide.

Paper ID	Species	Common name	Maturity
1	*Phocoena phocoena*	White harbour porpoise	Calf* Calf* N.A.
2	*Tursiops truncatus*	Bottlenose dolphin	Subadult
3	*Stenella frontalis*	White Atlantic Spotted dolphin	Adult Juvenile Juvenile Juvenile
4	*Delphinus delphis**	Short-beaked common dolphin	Adult** Adult**
	Stenella frontalis	Atlantic spotted dolphin	Adult
5	*Grampus griseus*	Risso's dolphin	Adult Juvenile Juvenile
6	*Steno bredanensis*	Rough-Toothed dolphin	Juvenile
7	*Phocoena phocoena*	White harbour porpoise	Adult Adult*** Adult*** Adult***
8	*Phocoena phocoena*	White harbour porpoise	Adult
9	*Phocoena phocoena*	White harbour porpoise	Adult
10	*Phocoena phocoena*	White harbour porpoise	Adult Adult
11	*Phocoena phocoena*	White harbour porpoise	Juvenile
12	*Phocoena phocoena*	White harbour porpoise	Juvenile
13	*Phocoena phocoena*	White harbour porpoise	N.A.
14	*Phocoena phocoena*	White harbour porpoise	Juvenile

Legend: * Same individual seen twice in report 1; ** Possibly the same individual seen twice in report 4; *** Same individual seen thrice in report 7.

to different factors. These include: (i) the fact that the Black Sea harbour porpoise's population is small and isolated populations due to long-term isolation (at least 9,000 ya) (Fontaine et al., 2007, 2010, 2012) from the nearest Atlantic harbour porpoises' populations and consequent inbreeding (Kopaliani et al., 2017), with consequent loss of genetic variability, favoring the appearance of recessive alleles, increasing leucism frequency (Łopucki & Mróz, 2011); (ii) the fact that the harbour porpoise is an apex Black Sea ecosystem predator, with no natural predators, so pigmentation would not be a protective countershading factor in this regard (Kopaliani et al., 2017); (iii) the relatively high water turbidity and limited surface light penetration would negate potential advantages of normal pigmentation (i.e. countershading) (Kopaliani et al., 2017). Therefore, the authors indicate that this high number of records of atypically pigmented dolphins may be associated with a relaxed selection pressure in this area when compared to the Mediterranean or Atlantic basins (Kopaliani et al., 2017), even though the available data is insufficient to conclude if atypically colored individuals in the Black Sea are in fact more frequent than in other marine basins (Kopaliani et al., 2017). Other factors, however, may be at play here, and the high sighting rates may be due to increased field efforts compared to other areas, especially the southern hemisphere, due to financial constraints, especially in developing countries (Smith & Reeves, 2000; Smith & Hobbs, 2002; Daura-Jorge & Simões-Lopes, 2017). These relatively frequent reports in the northern hemisphere seem to indicate that these animals seem not to display any issues regarding thermoregulatory limitations in cold waters, as temperatures in the region are lower than in many other areas around the globe.

Concerning the association between environmental factors and leucism, some reports have speculated that climate change may play a role in increased leucism frequency (Mikkola, 2017), as reported, for example, for declining fur seal populations (Forcada & Hoffman, 2014), where this environmental variable selects for heterozygosity. Studies in this regard, however, are almost nonexistent, hampering discussions on climate change effects concerning leucism in dolphins. Regarding the role of environmental pollution, studies on birds have postulated that the higher frequency of leucistic animals in these environments compared to rural areas may be due to higher mutagen (pollution) concentrations in cities (Yauk & Quinn, 1996; Møller & Mousseau, 2001), while studies carried out in Chernobyl have made this same association between birds and radioactivity (Moller, 1993). In addition, low-quality habitats have also been implicated in leucism in geese (Owen & Skimmings, 1992). Mammal assessments are, again, rare, and only one study was found associating environmental factors, i.e. low-quality diets, to leucism in mammals (voles) inhabiting high quality grassland habitat (Peles et al., 1995).

As indicated almost two decades ago (Fertl et al., 2004), a very low number of papers is found on the subject of hypopigmentation in cetaceans, even less so for leucism in particular, indicating the significant knowledge gap in this regard and hindering further discussions and insights into the ecological and physiological implications of this condition. Therefore, we recommend further monitoring efforts in this regard be carried out by both scientists and applying the concept of citizen science, which has been proven a powerful tool in cetacean studies worldwide (Embling et al., 2015; Lodi & Tardin, 2018), especially in the southern hemisphere, which still lacks these types of assessments.

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