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The first record of a rare blue phenotype in the brown spiny lobster *Panulirus echinatus* Smith, 1869 (Decapoda: Palinuridae)

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Abstract. We are reporting a blue phenotype in the brown spiny lobster *Panulirus echinatus* captured in Alagoas, Brazil. In the blue phenotype, a dark blue color replaced the original brownish color throughout the body, and the peculiar lines and spots remained white.

Key words: color anomaly, crustacean, Brazil.

Resumo: O primeiro registro de um fenótipo azul raro na lagosta espinhosa marrom *Panulirus echinatus* Smith, 1869 (Decapoda: Palinuridae). Relatamos um fenótipo azul da lagosta espinhosa marrom *Panulirus echinatus* capturada em Alagoas, Brasil. No fenótipo azul, a cor acastanhada original foi substituída por um azul escuro no corpo e as linhas e manchas permaneceram brancas.

Palavras-Chave: anomalia de cor, crustáceo, Brasil.

Among reef invertebrates, spiny lobsters are one of the largest and most profitable fisheries in the world (Holthuis 1991). In Brazil, there are three species of spiny lobster: *Panulirus echinatus* Smith, 1869, *Panulirus laevicauda* (Latreille, 1817) and *Panulirus meripurpuratus* Giraldes & Smyth, 2016. The last two species are the most abundant and commercially relevant, and are intensively caught by commercial and artisanal fishing in deeper offshore sites. *P. echinatus* is less important in Brazilian fisheries, and it is mainly captured in coastal reefs by artisanal and recreational fishers (George 2005, Giraldes & Smyth 2016).

Commonly known as the brown spiny lobster due to the brownish color of its exoskeleton, *P. echinatus* is a tropical species that inhabits the coast of Brazil (from Ceará to Rio de Janeiro) and offshore Central Atlantic islands (Holthuis 1991, Coelho *et al*. 2007, Faria-Júnior *et al*. 2013, Gaeta *et al*. 2015, Giraldes & Smyth 2016). Inhabiting accessible shallow reefs, *P. echinatus* has been intensively captured in Brazilian coastal and oceanic islands (Pinheiro *et al*. 2003), and other Central Atlantic oceanic islands, such as Cabo Verde (Freitas 2002, Freitas *et al*. 2007) and the Canary Islands (González-Pérez 1995, Moro *et al*. 2014, Riera *et al*. 2014). Despite its economic importance, there are only a few population biology studies on *P. echinatus* available for coastal Brazil (Barreto *et al*. 2003, Giraldes *et al*. 2015). The majority of studies are in oceanic islands, such as São Pedro and São Paulo archipelago (Pinheiro *et al*. 2003, Pinheiro & Lins-Oliveira 2006), and Rocas Atoll (Silva *et al*. 2001, Gaeta & Cruz 2019a and b). Recently two different *P. echinatus* fishing stocks were genetically identified, indicating that this species needs to be managed according to the ecological factors and different pressures in each of these stocks (Gaeta *et al*. 2020). According to the identification key, *P. echinatus* differs from the congeners by the presence of a single pair of strong thorns in the antennular plate; the tail is covered by distinct rounded spots; the antennulae and legs are streaked with longitudinal lines; the membranous part of the telson and uropod are dark blue, and the pleopods are black with a white border (Holthuis 1991, Giraldes & Smyth 2016). Crustaceans, including spiny lobsters, have a wide range of species-specific shell colors and patterns, which are used for protection through cryptic coloration, reproduction, and communication (Rao 1985, Bliss 1990, Horst & Freeman 1993). The crustacyanin (CRCN) and the carotenoid astaxanthin combine to form a multimeric protein complex that is critical to the array of external shell colors in lobsters (Wald *et al*. 1948, Cianci *et al*. 2002, Wade *et al*. 2009). The CRCN gene is a crustacean-specific genomic innovation and many CRCN orthologs have been identified in decapod crustacean species, suggesting a diversification of this gene within this arthropod lineage (Wade *et al*. 2009).

On 29th April 2019, a blue color phenotype specimen of *P. echinatus* was collected from the coastal waters of Maragogi, a fishing village on the northern coast of Alagoas state, Brazil (8° 59’ 57” S; 35° 10’ 49” W; Fig. 1). The specimen was captured at night by a fisherman using a net in shallow waters on a coral reef. Due to the curious color of the specimen, the fisherman who captured it took photos. Photographs were used to identify the specimen through specialized literature (Holthuis 1991).

The blue specimen has the key morphological characteristics of *P. echinatus*, including the pattern of thorns in the antennular plate, the same longitudinal lines on the legs, the same spots on the tail, the black pleopods with white borders, and the blue membranous part of the telson and uropod. A dark blue color throughout the body replaced the original brownish color, and the peculiar lines and spots are white (Figs. 2 and 3).

The most likely explanation for this color anomaly is a mutation in a gene affecting some aspect of the biochemical synthesis pathway in pigmentation. It seems to be operative, as verified in the Malacostraca Class in crustaceans (Hayes & Reimer 1975, Black & Huner 1980, Cianci *et al*.

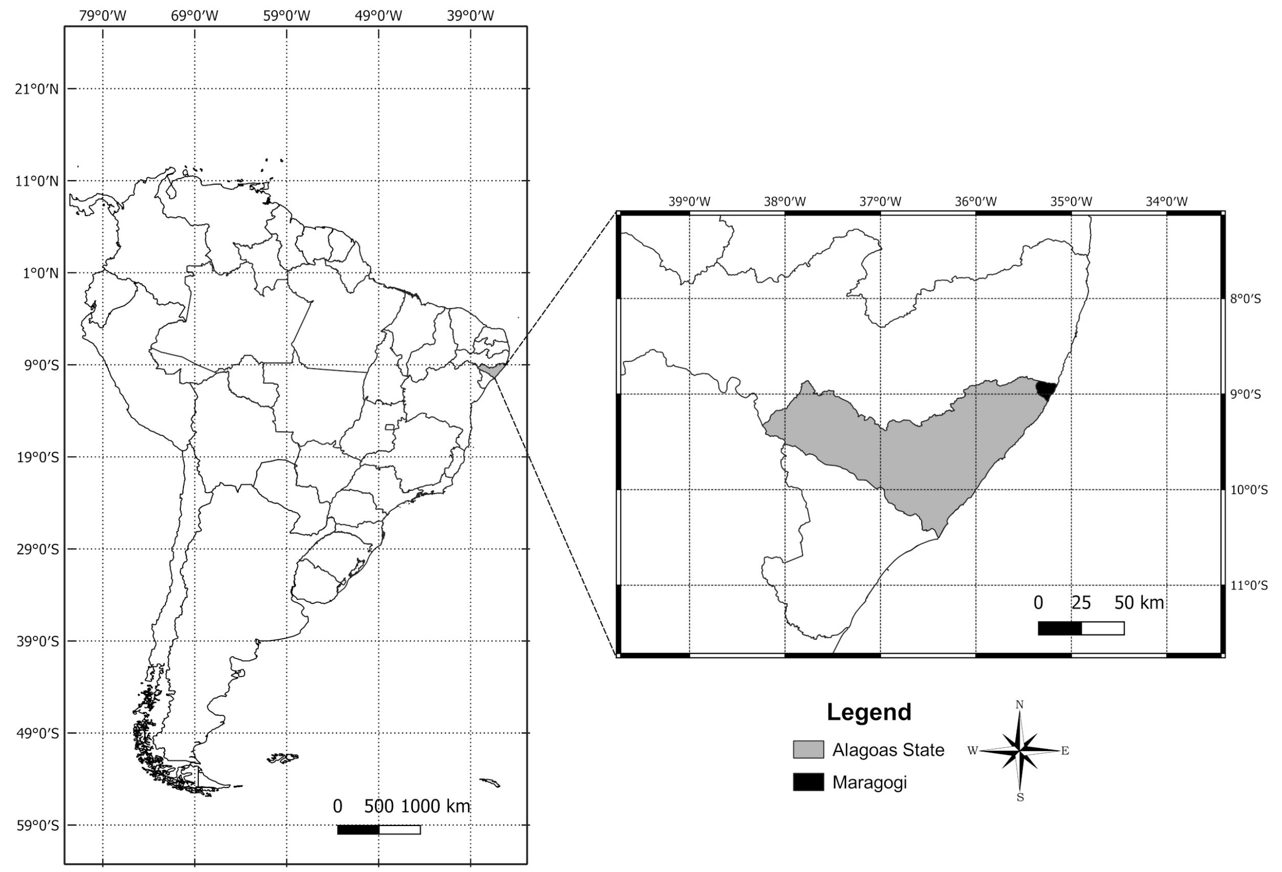

Figure 1. Collection location of the brown spiny lobster *Panulirus echinatus* Smith, 1869 anomalous specimen on the northern coast of Alagoas state along the Brazilian coast in the South Atlantic Ocean, on April 2019.

Figure 2. Typical color and pattern of the brown spiny lobster *Panulirus echinatus* Smith, 1869 in the same location of capture as the blue specimen (Photos: Cláudio L. S. Sampaio).

Fig. 3: Blue color phenotype in a specimen of the brown spiny lobster *Panulirus echinatus* Smith, 1869 captured on the northern coast of Alagoas state along the Brazilian coast in the South Atlantic Ocean, on April 2019 (Photos: José Valdemar de Oliveira).

2002, vanWijk *et al*. 2005), and as observed in *Panulirus cygnus* and *P. versicolor* (Wade *et al*. 2009). Within lobsters, CRCN forms multimeric complexes that have the potential to generate the diversity of colors observed in crustacean carapaces (Chayen *et al*. 2003, Wade *et al*. 2009). The binding of the carotenoid astaxanthin (AXT) in the protein multimacromolecular complex crustacyanin (CRCN) is responsible for blue coloration in a lobster carapace (Cianci *et al*. 2002). CRCN accumulates in the outer layer of the hypodermis and is deposited in a discrete band in the outer margin of the exoskeleton only in the color regions of the carapace or exoskeleton (Wade *et al*. 2009). Changes in the primary sequence of CRCN and differences in CRCN subunits have the potential to change the binding affinities with astaxanthin, astaxanthin distortion, forces exerted on the end rings of AXT, effects on the dimeric and multimeric subunit formation, and conformation in functional α-CRCN (Wade *et al*. 2009).

According to Griffiths *et al*. (2000), albinism is a genetic mutation on the gene that codifies an enzyme and results in losing the capacity to synthesize the color pigment that is responsible for skin and hair color in animals. Therefore, the anomaly causes the organisms to adopt a white skin and hair coloration, such as the case of partial albinism observed in the blue spiny lobster *Panulirus inflatus* (Landa-Jaime *et al*. 2018). The blue phenotype is a different mutation that affects subunits of the CRCN. This alteration occurs in one of the three shell layers that do not show one of the pigmented layers. Thus, the unique layer that is visible is the blue layer (Cianci *et al*. 2002). Therefore, it would benefit scientific understanding and the management of lobster species that blue lobsters like this are captured and taken to scientific research centers, so genetic analyzes can be carried out to assess whether the mutation is genetically rare. Moreover, it is important to evaluate if the blue phenotype directly results in the low abundance of organisms with this color anomaly, or if these organisms are ecologically disadvantaged in the adaptive process. Predation could be increased and interfere in this rare phenotype since the cryptic coloration involved in camouflage are not present in this specimens or it could change elements of behavioral characteristics as suggested by Wade *et al*. (2009). The cryptic coloration frequently comprises the first line of an animal's defense against predators. The blue color could affect the establishment success after the first ontogeny, which is represented by the puerulus post larvae as suggested for other marine species (Beingesser & Copp 1985, Palma *et al*. 2003, Duarte *et al*. 2017). According to Duarte *et al*. (2017), the color change involves a suite of mechanisms and selection pressures that result in the ultimate appearance and adaptive value of color formations, and there is still a lot left to understand in this subject.

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