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Original article

Parasites on the wing; two new records of marine chewing lice (Phthiraptera) on Brown booby (Suliformes: Sulidae) from Egypt with notes on genus *Pectinopygus*/boobies phylogeny

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ABSTRACT

Objectives: Little studies had been done on chewing lice of marine birds in the Middle East. Through this work, parasitic chewing lice of Brown Booby *Sula leucogaster* (Boddaert) in the Red Sea were recorded for the first time from Egypt.

Methods: One brown booby was examined for chewing lice in Giftun Island, Hurghada. A total of 27 specimens of lice were collected from this bird and phylogenetic analysis of species of genus *Pectinopygus* associated boobies has been done based on NCBI data.

Results and conclusions: Two species of marine chewing lice were identified: *Eidmanniella albescens* (Piaget, 1880) and *Pectinopygus sulae* (Rudow, 1869); diagnostic remarks for the two identified species, measurements, and material examined were provided through the manuscript. The final phylogenetic tree indicates the monophyletic origin of *Pectinopygus* spp. associated with boobies and their paraphyletic relation to other species of *Pectinopygus* that associated with other Suliformes. Also, independence of boobies' speciation from chewing louse of genus *Pectinopygus* speciation. The present work forms a small step in a long way of studying marine chewing lice of Egypt and a better understanding of marine birds/chewing lice interaction.

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1. Introduction

Many years of neglect were faced studying chewing lice fauna of the Middle East (Adly et al., 2019, 2020, Nasser et al., 2015a, 2020) and consequently, there was a lack of information concerning ectoparasites of marine bird through the area (Negm et al., 2013; Hafez and Madbouly, 1968). The chewing lice of marine birds are forming a very interesting group of insects as they form the largest hexapod fauna on the marine ecosystem (Nasser, 2015). Also, they are considered one of the most significant groups of lice which reflects a clear image about the ecology

and evolution of their host birds (Nasser et al., 2019). Especially for true marine birds like Boobies which spend most of the year on the open water (Welty and Bapista, 1990).

Boobies are large sea birds with heavily built bodies, pointed long wings, and webbed large feet. They are perfect divers whose usually get their food of fishes and squids from deep water that reaches about 15 m. They are breeding in large colonies where nests are found on the ground with few nesting materials, female usually lays 1–3 eggs. The species of boobies are distributed through tropical and subtropical open seas around the globe (Scott, 2014). There are six species of boobies, most of them are non-migrant species while masked boobies are known by their long migration (Frances, 2009). The Brown Booby is a widely distributed sea bird of order Suliformes, the order which divided from Pelecaniformes recently by several phylogenetic analyses (Boles and Christidis, 2008; Gill and Donsker, 2014). These birds are clever diver as most of them feed mainly on squids (Alderton, 2008) and they had been very known in Pantropical open oceans and warm seas and the Red Sea form a part of its range (Anonymous, 2012).

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There are two genera of chewing lice that have been listed as ectoparasites of Boobies through many parts of the world (Table 1): the genus *Eidmanniella* of suborder Amblycera and the genus *Pectinopygus* of suborder Ischnocera (Price, et al., 2003). The data about the two genera are rarely known from the Middle East. Recently, four species of chewing lice were recorded from the Gulf area infesting Suliformes: *Eidmanniella albescens* (Piaget, 1880), *Eidmanniella nancyae* Ryan & Price 1969, *Pectinopygus socotranus* Timmermann, 1964 and *Pectinopygus sulae* (Rudow, 1869) (Nasser et al., 2015b). Although the ornithological fauna of Egypt included only two recorded species of Suliformes (Brown booby, *Sula leucogaster*, and Great cormorant, *Phalacrocorax carbo*), there is no data available for their associated chewing lice.

One of the interesting characters of Suliformes/chewing lice interaction is the special parasite/host distribution pattern. Chewing lice of cormorants show a high degree of host specificity in contrast to that infesting the boobies. Such relations need to be analyzed through the molecular level to clarifying the bases of speciation of the two groups and evaluate the impact of distribution to the picture that appears today. So, the objective of this work is to record chewing lice of Brown booby from Egypt for the first time and initially discussed the *Pectinopygus* /boobies interaction based on bioinformatics data.

2. Materials and methods

The brown booby was caught with broken wing in Giftun Island (27°13'N 33°56'E), Hurghada, Egypt. Live caught Brown Booby was examined visually and chewing lice were collected by fine forceps and placed in 95% alcohol. Then the examined booby was released at the capturing place. The collected lice were proceeded for mounting on microscopic slides for identification using the method described by Smart et al. (1965). Chewing lice were identified according to Kellogg and Kuwana (1902), Tenderio (1958), Bienko (1964), Price et al. (2003) and Nasser et al. (2015b). All specimens examined under BOECO BM-120 microscope and photographed by using S-EYE YW500 camera5mp. Measurements of specimen were taken using the same camera software in millimetres scale. Measurement abbreviations as follows: HL = Head Length; HW = Head Width; HI = Head Index; TL = Thorax Length; AL = Abdomen Length; TOL = Total Length; GL = Genitalia Length; GW = Genitalia Width. The specimens were preserved in Ain Shams University Collection (ASUC).

The database of the National Center for Biotechnology Information (NCBI) was used to study the phylogenetic relationships

among some species of *Pectinopygus*. A conservative gene (elongation factor 1-alpha (EF1alpha)) was chosen to study such relationships, based on the availability of sequences of this gene from several *Pectinopygus* species. Sequences of five species of *Pectinopygus* were extracted in Fasta format from the GenBank database: three species which known to infest boobies, one species infest Cape gannet *Morus capensis* and one species infest Pygmy cormorant *Microcarbo pygmaeus* (*Pectinopygus annulatus* “DQ482984.1”, *Pectinopygus bassani* “DQ482978.1”, *Pectinopygus excornis* “DQ482976.1”, *Pectinopygus minor* “DQ482981.1” and *Pectinopygus sulae* “AF320444.1”). The evolutionary history was inferred using the Neighbor-Joining method based on Multiple Sequence Alignment with Cluster W (Saitou and Nei, 1987). The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Maximum Composite Likelihood method (Tamura et al., 2004). Codon positions included were 1st + 2nd + 3rd + Noncoding. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There was a total of 347 positions in the final dataset. Evolutionary analyses were conducted in MEGA X (Kumar et al., 2018). For comparing the chewing lice phylogeny toward birds' phylogeny, the phylogenetic tree of host birds was modified after Patterson et al., 2011.

3. Results

3.1. Species recorded

A total of 27 chewing lice specimens representing two new records of lice species to Egyptian fauna were collected from a Brown Booby, *Eidmanniella albescens* (Piaget, 1880), and *Pectinopygus sulae* (Rudow, 1869).

- Suborder Amblycera Kellogg, 1896
- Family Menoponidae Mjöberg, 1910
- Genus: *Eidmanniella* Kéler, 1938
- Eidmanniella albescens* (Piaget, 1880:491) (Fig. 1a)
- Menopon albescens* Piaget, 1880:491
- Menopon singulans* Kellogg & Kuwana, 1902:485
- Eidmanniella sula* Tendeiro, 1958f:443

Type host: *Morus serrator* Gray, 1843, Australasian gannet.

Other hosts: *Papasula abbotti* (Ridgway, 1893), Abbott's booby; *Sula neboxii* Milne-Edwards, 1882, Bluw-footed booby; *Sula variegata* (Tschudi, 1843), Peruvian booby; *Sula dactylatra* Lesson, 1831,

Table 1
World species of boobies with their scientific name, distribution and chewing lice recorded.

Booby common name	Booby scientific name	Distribution	Chewing lice recorded
Blue-footed booby	<i>Sula neboxii</i> Milne-Edwards, 1882	East Pacific especially south coast of North America and North coast of south America	<i>E. albescens</i> <i>P. minor</i>
Brown booby	<i>Sula leucogaster</i> (Boddaert, 1783)	All tropical open seas	<i>E. albescens</i> <i>P. annulatus</i> <i>P. garbei</i> <i>P. sulae</i>
Masked booby	<i>Sula dactylatra</i> Lesson, 1831	Tropical pat of pacific and Atlantic ocean and some regions of Indian oceans	<i>E. albescens</i> <i>P. annulatus</i> <i>P. sulae</i>
Nazca booby	<i>Sula granti</i> Rothschild, 1902	Eastern pacific and Galápagos Islands	---
Peruvian booby	<i>Sula variegata</i> (Tschudi, 1843)	Chilean and Peruvian coast	<i>E. albescens</i> <i>P. annulatus</i>
Red-footed booby	<i>Sula sula</i> (Linnaeus, 1766)	Through tropical open seas	<i>E. albescens</i> <i>P. annulatus</i> <i>P. garbei</i> <i>P. sulae</i>

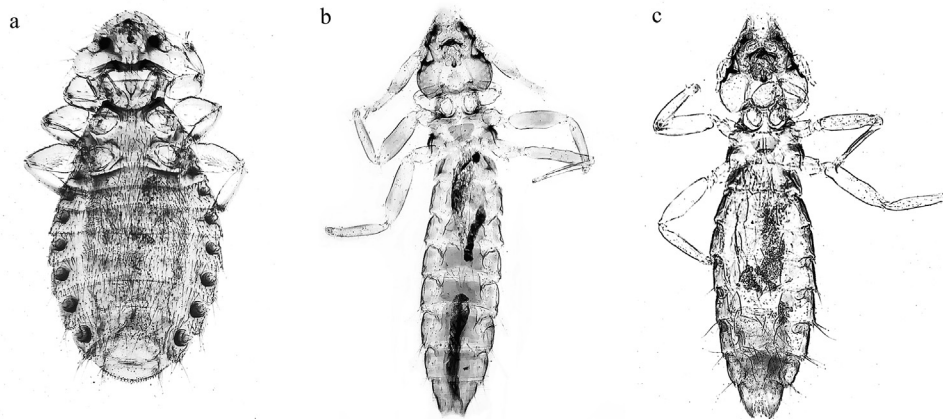


Fig. 1. a. Female *Eidmanniella albescens*; b. Male *Pectinopygus sulae* & c. Female *Pectinopygus sulae*.

Masked booby; *Sula sula* (L., 1766), Red-footed booby; *Sula leucogaster* (Boddaert, 1783), Brown booby (Suliformes: Sulidae).

Local host: *Sula leucogaster* (Boddaert, 1783), Brown booby.

Remarks: This is the first record of *Eidmanniella albescens* from Egypt. The *Eidmanniella albescens* dislocated from downside of wing feathers and abdomen feathers of brown booby.

Description: Body medium; head semicircular, broad with pre-ocular slit, well developed hypopharyngeal sclerite, fourth segmented antennae with terminally distinctive club shape, temple with four medium setae; thorax with characteristic hexagon prothorax shape with numerous short setae on margins; meso and metathorax normally flattened; length of legs nearly equal; abdomen well-distinguish with stretched oval shape; The key characters that distinguish *Eidmanniella albescens* from other *Eidmanniella* spp.; the hypopharyngeal well-developed sitophore sclerite, the posterior margin of last tergite with short blunt spiniform setae.

Material examined: 3 females and 1 nymph of chewing lice from *Sula leucogaster* at Giftun Island, Egypt June 2019.

Measurements: Female HL: 0.44 (0.40–0.47); HW: 0.77 (0.72–0.83); HI: 0.57 (0.56–0.67); TL: 0.73 (0.70–0.75); AL: 1.46 (1.43–1.50); TOL: 2.63 (2.53–2.72).

Suborder Ischnocera Kellogg, 1896

Family Philopteriidae Burmeister, 1838

Genus: *Pectinopygus* Mjöberg, 1910

Pectinopygus sulae (Rudow, 1869) (Fig. 1b, c)

Lipeurus sulae Rudow, 1869

Lipeurus helleri Kellogg & Kuwana, 1902:479

Lipeurus tuberculatus Piaget, 1885:61

Type host: *Sula leucogaster* (Boddaert, 1783), Brown booby.

Other hosts: *Sula dactylatra* Lesson, 1831, Masked booby; *Sula sula* (L., 1766), Red-footed booby (Suliformes: Sulidae).

Local host: *Sula leucogaster* (Boddaert, 1783), Brown booby.

Remarks: This report constitutes a new geographical record of *Pectinopygus sulae* from Egypt. All specimens of *Pectinopygus sulae* were located on head and neck feathers of host. & feathers of wing and tail.

Description: Body elongated, female wider and shorter than male, head conic shape with numerous setae around margin of hyaline, antennae sexually dimorphic with male scape enlarged; thorax slightly narrower than head, trapezoidal in shape, fore legs very shorter than other two pairs of legs; abdomen elongated, tergites with characteristic chitinized margin and with two centrals short setae, four short setae in each sternum. The open of anus of female angularly with many setae, asymmetric curved genitalia of male with granulated club shaped head and pointed end.

Material examined: 11 males, 6 females and 6 nymphs of chewing lice from *Sula leucogaster* Giftun Island, Egypt June 2019.

Measurements: Male HL: 0.78 (0.75–0.79); HW: 0.66 (0.64–0.67); HI: 2.38 (2.35–2.41); TL: 0.50 (0.48–0.53); AL: 2.30 (2.28–2.32); TOL: 3.58 (2.58–2.64), female HL: 0.75 (0.73–0.78); HW: 0.66 (0.62–0.69); HI: 2.22 (2.19–2.25); TL: 0.44 (0.41–0.47); AL: 2.13 (2.11–2.16); TOL: 3.32 (3.30–3.34); GL: 1.03 (1.02–1.04); GW: 0.21 (0.20–0.22).

3.2. Phylogeny of Boobies' chewing lice of genus *Pectinopygus*

The sequence data of elongation factor 1-alpha (EF1alpha) gene of Boobies' chewing lice of Genus *Pectinopygus* were used to construct an evolutionary tree (Fig. 2). The produced tree indicated the monophyletic relation of the three recorded chewing lice species of Genus *Pectinopygus* which infested boobies and their paraphyletic relation toward other *Pectinopygus* spp. which infest other Suliformes. *Pectinopygus sulae* appears to the last recently developed species of the group while *Pectinopygus bassani* of Cape gannet *Morus capensis* was the oldest.

Comparing the produced tree to host bird phylogeny (Fig. 3) indicated independence of boobies' evolution from the *Pectinopygus* chewing lice evolution. Only the *Pectinopygus minor* has a specific relation with blue-footed booby (*Sula nebouxii*) of the Pacific Ocean, while *Pectinopygus annulatus* and *Pectinopygus sulae* recorded from four and three species of boobies respectively. Such results indicated sympatric speciation of Genus *Pectinopygus* through boobies' population around the globe.

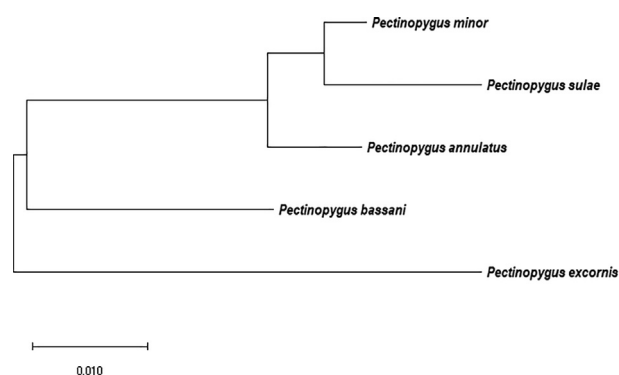


Fig. 2. Annotated tree illustrates phylogenetic relations among *Pectinopygus* spp. based on Neighbor-Joining method of elongation factor 1-alpha (EF1alpha) sequence.

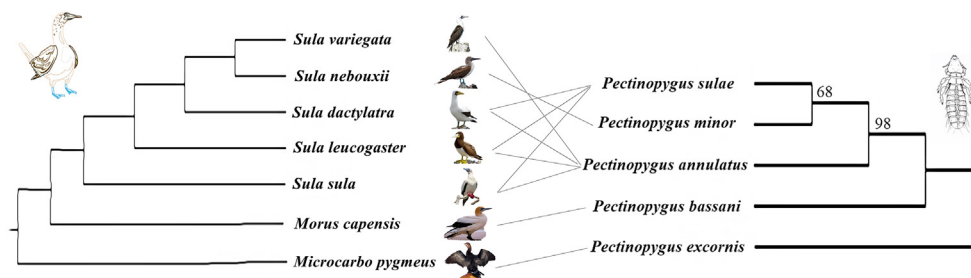


Fig. 3. Comparing the phylogenetic relations among *Pectinopygus* spp. toward their host birds' phylogeny "the phylogenetic tree of birds was modified after Patterson et al., 2011"

4. Discussion

The diversity of Marien birds' ectoparasites is not completely understood through different parts of the world, as many new species and new records are discovered every year (Shobrak et al., 2015; Nasser, 2015). This is not far from the data about chewing lice of Egypt that are very old and not compatible with the great diversity of avifauna of the country (Adly et al., 2019). So, the present work forms a small step to better understanding chewing lice/marine birds' association to the region. *Eidmanniella* Kéler, 1938 of the suborder Amblycera, and *Pectinopygus* Mjöberg, 1910 of the suborder Ischnocera are two newly recorded genera to Egyptian fauna with the two species *Eidmanniella albescens* and *Pectinopygus sulae* from brown booby. Several previous studies have revised the information on chewing lice of these two species and recorded them on brown booby from different parts of the world (Kellogg and Kuwana, 1902; Timmermann, 1967; Ryan and Price, 1969; Nasser, et al., 2015b).

The chewing lice/boobies interaction indicates the absence of clear parasitic specificity except for *Pectinopygus minor* on blue-footed booby (*Sula neboxii*) of the Pacific Ocean. This is maybe due to the niche overlapping of boobies' species through pantropic seas and oceans. Such host distribution pattern could confirm parasite transfer through different species of boobies' population and preventing chewing lice specificity and speciation. The phylogenetic analysis of *Pectinopygus* spp. support such hypothesis and indicated sympatric speciation of the three *Pectinopygus* spp. infesting boobies. On the other hand, each species of the genus *Pectinopygus* parasitizes a unique species of a cormorant as usually there is a clear geographical isolation pattern of cormorant species populations (Price et al. 2003). More studies are needed to get a complete understanding of interactions between Suliformes and their associated chewing lice, especially on the molecular level. Also, knowledge of the diversity of chewing lice from wild birds in Egypt is still very sparse and great efforts are needed to end their survey.

5. Conclusion

A significant lack of information about ectoparasites of marine birds around the world especially in the Middle East region. A total of 27 specimens of lice were collected from Brown Booby *Sula leucogaster* (Boddaert) in Giftun Island, Hurghada, Red Sea, Egypt. Two species of marine chewing lice (*Eidmanniella albescens* (Piaget, 1880) and *Pectinopygus sulae* (Rudow, 1869)) were identified for the first time in Egypt. Also, we did a bioinformatic analysis of genus *Pectinopygus* associated with boobies to produce a phylogenetic tree that indicated the independence of boobies' speciation from chewing louse of genus *Pectinopygus* speciation. A lot of effort is needed for this important point of the study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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