

# An analysis of osprey/chewing lice interaction, with a new record for Saudi Arabia

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Parasitism is a hostile relationship that helps greatly in the development and evolution of many creatures in their race for survival. Chewing lice of nestlings of the osprey *Pandion haliaetus* (L.) have been studied in Farasan Island, Saudi Arabia. All previous chewing lice records from this bird have also been reviewed. Four species of chewing lice are previously known to infest *P. haliaetus*. The nestlings of the osprey in Farasan were only infested by *Colpocephalum turbinatum* Denny, 1842. This species of chewing lice is recorded herein for the first time from the Kingdom of Saudi Arabia and its distributional pattern is very characteristic among three different avian orders (Accipitriformes, Columbiformes, and Strigiformes). *Colpocephalum turbinatum* was found mainly on terrestrial birds of the order Columbiformes and it may be transferred to predatory birds in the other two orders, but the presence of this parasite on some aquatic birds of prey like osprey may indicate that the ancestors of these birds were terrestrial hunters that acquired this louse from their prey such as doves and pigeons before their transference to aquatic life. The pattern of chewing lice distribution through their host populations and habitats may reveal some important ecological and evolutionary events that happened to their hosts in the past.

**Key words:** *Colpocephalum turbinatum* Denny, 1842, *Pandion haliaetus* (L.), Saudi Arabia, birds of prey.

## INTRODUCTION

Half of surrounding biodiversity is parasitic creatures (Hannah & Lovejoy 2003). So, the role that these organisms play in evolution and development of the life on earth is impressive. Chewing lice are such parasites that can invade mammals and bird's bodies for food and shelter, with about 4000 species worldwide. They form one of the most diversified groups of parasitic insects in the global fauna (Imms *et al.* 1977; Price *et al.* 2003). As permanent, slow-moving ectoparasites, chewing lice show some degree of host specificity that allow them to act as a clue in studying host/parasite phylogeny and coevolution (Hopkins 1941; Banks & Paterson 2004).

The chewing lice of marine birds is a very interesting group of insects which have been neglected for a long period in several parts of the world, especially in the Middle East (Negm *et al.* 2013). Recently, these creatures drew the attention of entomologists and marine biologists all over the world (Banks & Palma 2003; Palma 2012; Al-Ahmed *et al.* 2014), and this may be due to the

importance to understand their relationship with their host birds.

Osprey, *Pandion haliaetus* (L.), is a common marine fish-eating bird of prey. It is one of the most widely spread birds of prey on the planet. Its range extends to all continents except Antarctica and it is found in temperate and tropical regions, especially oceans, sea coasts and sometimes in freshwater habitats (Alderton 2008). In Saudi Arabia, the osprey is a resident breeding sea bird that is found along the coast of the Red Sea and some islands of the Gulf (Jennings 2010; Shobrak & Aloufi 2014).

Four species of lice are known to infest osprey, all of them belonging to the suborder Amblycera: *Colpocephalum napiforme* Rudow, 1869, *Colpocephalum turbinatum* Denny, 1842 and *Kurodaia haliaeeti* (Denny, 1842) of the family Menoponidae, and *Laemobothrion maximum* (Scopoli, 1763) of the family Laemobothriidae. Only *K. haliaeeti* is specific to osprey, while the other three species are known from related and non-related bird hosts



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Received 17 July 2018. Accepted 16 November 2018

ISSN 1021-3589 [Print]; 2224-8854 [Online]  
DOI: <https://doi.org/10.4001/003.027.0178>

*African Entomology* 27(1): 178–184 (2019)  
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(Price *et al.* 2003). Only a few cases of osprey/chewing lice interaction are known (Miller *et al.* 1997) so the aim of this work is to analyse the relationship between this bird and its associated chewing lice. Also, to record the chewing louse *Colpocephalum turbinatum* in Saudi Arabia for the first time.

## MATERIAL AND METHODS

As a part of an extensive study on the chewing lice fauna of wild birds in Saudi Arabia, we checked the breeding population of nestlings of osprey on Farasan Island, Kingdom of Saudi Arabia on 6 February 2015 (16°46'43"N 41°59'17"E). Farasan forms the largest marine protected island of archipelago in the Red Sea, which has a long hot season from April to October, with average annual temperature of 30 °C and RH 65 % to 80 %. One nest with two juvenile birds was examined for chewing lice. The bird handling occurred with permission of the Saudi Wildlife Authority. Lice were collected by visual inspection of host feathers and were preserved on 95 % alcohol. Slides were prepared using Puri's media. The lice identifications were done using Price *et al.* (2003) and Naz *et al.* (2012). All previous records of chewing lice from osprey were also revised and reviewed (Eichler 1941; Clay & Hopkins 1951; Price & Beer 1963a, b; Nelson & Price 1965; Miller *et al.* 1997; Price *et al.* 2003). These data were analysed to show the specificity of chewing lice infesting osprey and try to answer how species such as *Colpocephalum turbinatum* transferred to such a marine bird of prey. Also, the latest evolutionary studies of marine birds of prey were screened to help us answer this question (Lerner & Mindell 2005). The material collected is deposited in the King Saud University Museum of Arthropods (KSMA).

## RESULTS

Four species of chewing lice (three in the family Menoponidae and one in the family Laemobothriidae) have in the past been recorded on osprey. Only one out of the four species is recorded for the first time here from Saudi Arabia.

### Suborder Amblycera

#### Family Menoponidae

#### Genus: *Colpocephalum* Nitzsch, 1818

#### *Colpocephalum napiforme* Rudow, 1869

*Colpocephalum heterospizium* Carriker, 1963

*Known hosts.* Great black hawk (type host),

*Buteogallus urubitinga* (Gmelin); Osprey, *Pandion haliaetus* (L.); Slender-billed kite, *Rostrhamus hamatus* (Temminck); African Fish Eagle, *Haliaeetus vocifer* (Daudin); Grey-headed fish eagle, *Ichthyophaga ichthyaetus* (Horsfield); African harrier-hawk, *Polyboroides typus* Smith; Madagascan harrier-hawk, *Polyboroides radiatus* (Scopoli); Savanna hawk, *Buteogallus meridionalis* (Latham); Red-shouldered hawk, *Buteo lineatus* (Gmelin); Red-tailed hawk, *Buteo jamaicensis* (Gmelin); Crested eagle, *Morphnus guianensis* (Daudin); Harpy eagle, *Harpia harpyja* (L.).

This species is characterised by a very long mid-dorsal head seta, marginal prothorax with four long and two short setae, abdomen without row of anterior setae along tergites. This species recorded as a potential parasite of osprey on the latest world checklist of chewing lice (Price *et al.* 2003).

#### *Colpocephalum turbinatum* Denny 1842,

#### Fig. 1

*Colpocephalum ailurum* Nitzsch (in Giebel), 1861

*Colpocephalum bicinctum* Nitzsch (in Giebel), 1861

*Colpocephalum caudatum* Giebel, 1874

*Colpocephalum dissimile* Piaget, 1880

*Colpocephalum intermedium* Piaget, 1880

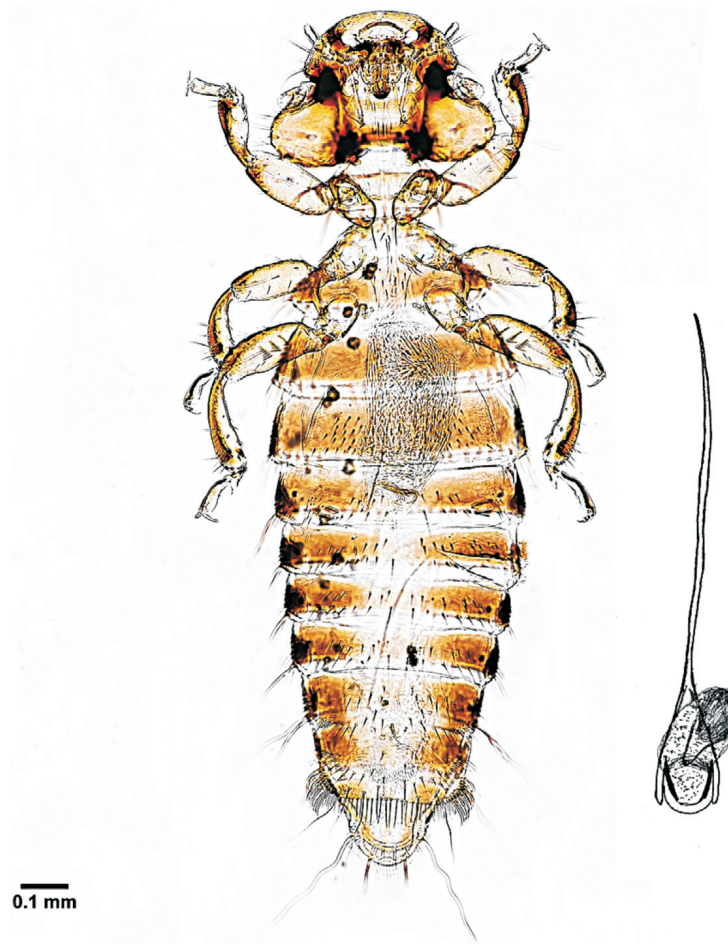
*Colpocephalum costaricense* Carriker, 1903

*Colpocephalum bruptofasciatum* Mjöberg, 1910

*Neocolpocephalum wetzeli* Eichler, 1941

*Colpocephalum wernecki* Orfila, 1959

*Known hosts.* Rock dove (type host), *Columba livia* Gmelin; Pied imperial-pigeon, *Ducula bicolor* (Scopoli); White-winged dove, *Zenaida asiatica* (L.); White-tailed kite, *Elanus leucurus* (Vieillot); Brahminy kite, *Haliastur indus* (Boddaert); Whistling kite, *Haliastur sphenurus* (Vieillot); Black kite, *Milvus migrans* (Boddaert); Red kite, *Milvus milvus* (L.); Bateleur, *Terathopius ecaudatus* (Daudin); Western marsh harrier, *Circus aeruginosus* (L.); Spotted harrier, *Circus assimilis* Jardine & Selby; Swamp harrier, *Circus approximans* Peale; Northern harrier/hen harrier, *Circus cyaneus* (L.); Brown goshawk, *Accipiter fasciatus* (Vigors & Horsfield); African goshawk, *Accipiter tachiro* (Daudin); Dark chanting goshawk, *Melierax metabates* Heuglin; Galapagos hawk, *Buteo galapagoensis* (Gould); Red-tailed hawk, *Buteo jamaicensis* (Gmelin); Roadside hawk, *Buteo magnirostris* (Gmelin); Swainson's hawk, *Buteo swainsoni* Bonaparte; Prairie falcon, *Falco mexicanus* Schlegel; Wedge-



**Fig. 1.** Female *Colpocephalum turbinatum* Denny 1842 with a drawing of male genitalia to the right.

tailed eagle, *Aquila audax* (Latham); Bald eagle, *Haliaeetus leucocephalus* (L.); White-bellied sea eagle, *Haliaeetus leucogaster* (Gmelin); Pallas's fish eagle, *Haliaeetus leucoryphus* (Pallas); African fish eagle, *Haliaeetus vocifer* (Daudin); Little eagle, *Hieraaetus morphnoides* (Gould); Booted eagle, *Hieraaetus pennatus* (Gmelin); Long-crested eagle, *Lophaetus occipitalis* (Daudin); Martial eagle, *Polemaetus bellicosus* (Daudin); Mountain hawk-eagle, *Spizaetus nipalensis* (Hodgson); Eurasian buzzard, *Buteo buteo* (L.); Jackal buzzard, *Buteo rufofuscus* (Forster); Long-tailed buzzard, *Henicoperis longicauda* (Garnot); Laughing falcon, *Herpetotheresca chinnans* (L.); Osprey, *Pandion haliaetus* (L.); European honey buzzard, *Pernis pivoorus* (L.); Oriental honey buzzard, *Pernisptilo rhyncus* (Temminck); Barred eagle-owl, *Bubo sumatranus* (Raffles); Brown fish-owl, *Ketupa zeylonensis* (Gmelin); Barking owl, *Ninox connivens* (Latham); Barn owl, *Tyto alba* (Scopoli); Cinereous vulture, *Aegyptius monachus* (L.); African white-backed vulture, *Gyps africanus* Salvadori; Indian white-backed vulture, *Gyps bengalensis* (Gmelin);

Cape griffon, *Gyps coprotheres* (Forster); Griffon vulture, *Gyps fulvus* (Hablizl); Indian vulture, *Gyps indicus* (Scopoli); Ruppell's griffon, *Gyps rueppellii* (Brehm); Hooded vulture, *Necrosyrtes monachus* (Temminck); Egyptian vulture, *Neophron percnopterus* (L.).

*Remarks.* This species was collected from fluffy feathers on the abdomen of juvenile osprey.

Head smoky brown with six pitchy dark spots with frontal pair small, antenna not completely covered, palpi and antennae protruding especially apical segment, pre-antennal margin with six setae, three of them slightly longer, temple rounded with numerous small setae; thorax with characteristic shape, prothorax rhombus with two posterior setae on each side and clear large coxa, med and metathorax somewhat triangular with a spinelike seta in the middle, legs equal in length, marginal bands of all legs paler than any other species in the genus, fore legs with enlarged tibia, hind femora with three clear spiny combs on ventral side; abdomen elongated in female, rounded in male, characterised by faint lateral



spots on widest segments I and II, large patchy dark spots appear from III segment to VII, lateral setae appear through the abdominal segment ending in female with tuft-like lateral hairs on segment IX, the posterior margin of sternum of segment IX with a row of bristle-like setae, abdominal tip rounded in female with two long setae and two small spines, in male genitalia with very small parameres. This species was recorded as a potential parasite of osprey in the world checklist of lice (Price *et al.* 2003).

*Material examined* (1). *Pandion haliaetus* (L.): 1♀, 6 Feb. 2015.

*Measurements.* Head length 0.3 mm; head widest 0.47 mm; head index 0.64 mm; thorax length 0.33 mm; abdomen length 1.17 mm; total length  $1.8 \pm 0.2$  mm.

### ***Kurodaia haliaeti* (Denny, 1842)**

*Colpocephalum haliaeti* Denny, 1842

*Colpocephalum pachygaster* Giebel, 1874.

*Known hosts.* Osprey (Type host) *Pandion haliaetus* (L.).

This species is specific to osprey and has never recorded from any other hosts. It can be easily distinguished from any other species in the genus *Kurodaia* by the weakly developed hypopharyngeal sclerite, characteristic chaetotaxy of female terminalia and unique male genitalia with wide flattened structure. This is the most common species in the genus, with a large number of individuals having been collected from osprey, especially from North America (Price & Beer 1963a).

## **Family Laemobothriidae**

### **Genus *Laemobothrion* Nitzsch, 1818**

#### ***Laemobothrion maximum* (Scopoli, 1763)**

*Pediculus maximus* Scopoli, 1763

*Laemobothrion giganteum* Nitzsch, 1818

*Known hosts.* Eurasian buzzard (Type host), *Buteo buteo* (L.); Pacific baza, *Aviceda subcristata* (Gould); Osprey, *Pandion haliaetus* (L.); Hook-billed kite, *Chondrohierax uncinatus* (Temminck); European honey buzzard, *Pernis apivorus* (L.); Mississippi kite, *Ictinia mississippiensis* (Wilson); Red kite, *Milvus milvus* (L.); Black kite, *Milvus migrans* (Boddaert); Whistling kite, *Haliastur sphenurus* (Vieillot); Brahminy kite, *Haliastur indus* (Boddaert); White-bellied sea eagle, *Haliaeetus leucogaster* (Gmelin); African fish eagle, *Haliaeetus*

*vocifer* (Daudin); Grey-headed fish eagle, *Ichthyophaga ichthyaetus* (Horsfield); Short-toed eagle, *Circaetus gallicus* (Gmelin); Brown snake eagle, *Circaetus cinereus* Vieillot; Western marsh harrier, *Circus aeruginosus* (L.); Swamp harrier, *Circus approximans* Peale; Northern harrier/hen harrier, *Circus cyaneus* (L.); Montagu's harrier, *Circus pygargus* (L.); African harrier-hawk, *Polyboroides typus* Smith; Madagascan harrier-hawk, *Polyboroides radiatus* (Scopoli); Dark chanting goshawk, *Melierax metabates* Heuglin; Pale chanting goshawk, *Melierax canorus* (Thunberg); Shikra, *Accipiter badius* (Gmelin); Levant sparrow hawk, *Accipiter brevipes* (Severtzov); Cooper's hawk, *Accipiter cooperii* (Bonaparte); Black sparrow hawk, *Accipiter melanoleucus* Smith; Northern goshawk, *Accipiter gentilis* (L.); White-eyed buzzard, *Butastur teesa* (Franklin); Grey-faced buzzard, *Butastur indicus* (Gmelin); Harris's hawk, *Parabuteo unicinctus* (Temminck); Black-collared hawk, *Busarellus nigricollis* (Latham); Roadside hawk, *Buteo magnirostris* (Gmelin); Swainson's hawk, *Buteo swainsoni* Bonaparte; Red-tailed hawk, *Buteo jamaicensis* (Gmelin); Long-legged buzzard, *Buteo rufinus* (Cretzschmar); Ferruginous hawk, *Buteo regalis* (Gray); Rough-legged buzzard, *Buteo lagopus* (Pontoppidan); Augur buzzard, *Buteo augur* (Ruppell); Jackal buzzard, *Buteo rufofuscus* (Forster); Indian black eagle, *Ictinaetus malayensis* (Temminck); Tawny eagle, *Aquila rapax* (Temminck); Golden eagle, *Aquila chrysaetos* (L.); Verreaux's eagle, *Aquila verreauxii* Lesson; Wahlberg's eagle, *Hieraaetus wahlbergi* (Sundevall); Bonelli's eagle, *Hieraaetus fasciatus* (Vieillot); Booted eagle, *Hieraaetus pennatus* (Gmelin); Little eagle, *Hieraaetus morphnoides* (Gould); Martial eagle, *Polemaetus bellicosus* (Daudin).

*Laemobothrion maximum* is the type species of the genus *Laemobothrion*. This genus was erected by Nitzsch when he examined samples of this species giving it a new name *Laemobothrion giganteum* Nitzsch, 1818. The new name of Nitzsch was synonymised by Clay & Hopkins (1951). Eichler (1941) provided a very good photograph for this species and designated a neotype. The first record of this species from osprey was by Nelson & Price (1965) from samples collected in North America. *Laemobothrion maximum* is characterised by the very large body, characteristic hypopharyngeal sclerite and unique, very simple male genital structure with mace shape.

## DISCUSSION

The chewing lice/osprey interaction forms a very interesting host/parasite relationship. Four species of the suborder Amblycera were recorded before from this bird (Price *et al.* 2003). The absence of Ischnocera from osprey is very questionable. Members of this suborder are common through many other species of Accipitriformes and these birds are hosts for many ischnoceran species in several genera including *Aegypocercus* spp., *Craspedorrhynchus* spp., *Degeeriella* spp. and *Falcolipeurus* spp. (Kellogg 1914; Bedford 1931; Clay 1958). As the lice of the suborder Ischnocera are sluggish and show a high degree of host specificity, we expect that scientists will discover very characteristic new species of ischnoceran chewing lice from osprey in the future.

From the faunistic point of view, *Kurodaia haliaeeti* (Denny, 1842) of family Menoponidae is the only specific louse of osprey while the other three chewing lice species which were recorded on it before showed a wider range of host relations. *Colpocephalum napiforme* Rudow, 1869 and *Laemobothrion maximum* are known from several species of raptors including many of aquatic birds such as African Fish Eagle and Grey-headed fish eagle, while *Colpocephalum turbinatum* occurs mainly on Columbiformes and transfer to their hosts on order Accipitriformes and Strigiformes (Clay 1976). The occurrence of *Colpocephalum turbinatum* on marine birds of prey such as osprey needs more analysis of osprey evolution to get a complete understanding of this relation.

Although there are good fossil records of many aquatic ancestors of modern osprey (Mayr 2006), the new molecular phylogenetic analysis indicated that lineage of osprey evolution is separated from other Accipitridae and occurs as paraphyletic to it (Fig. 2). The whole cluster shares a common ancestor, and scientists think that this ancestor was a completely terrestrial bird of prey (Lerner & Mindell 2005). The other Falconiformes occurs as out group of this cluster so ornithologists induced new order Accipitriformes from this part of old Falconiformes (Christidis & Boles 2008).

Although the complex distribution of the genus *Colpocephalum* among bird groups, testing the distribution pattern of *Colpocephalum turbinatum* among birds of prey indicated that the restriction of this distribution is to Accipitridae and its closely related osprey. This could prove that the ancestor of this louse was transferred from of Columbi-

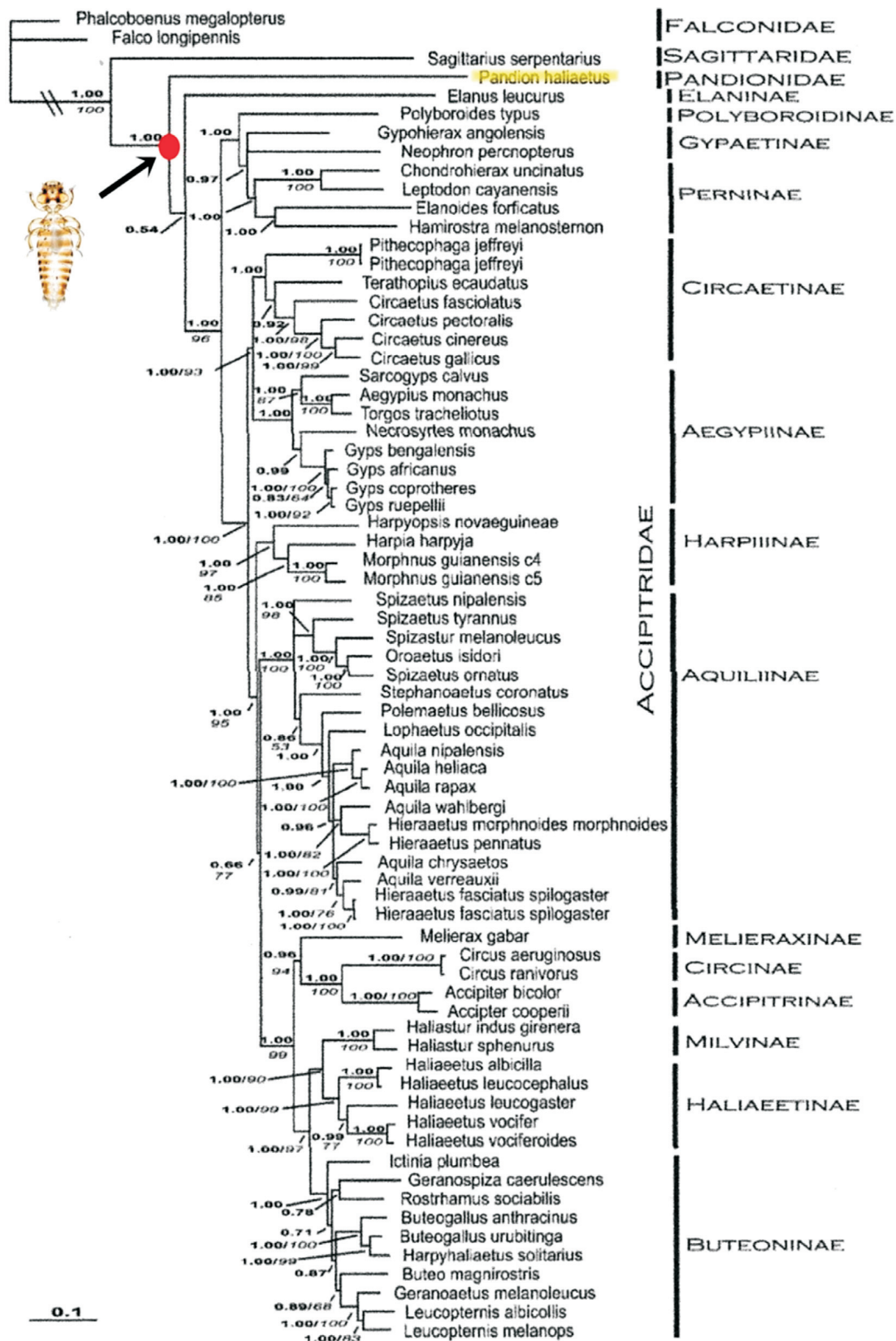
formes to the terrestrial common ancestor of Accipitridae group several millions of years ago (Fig. 2). The most interesting point about this relationship is the relation of *C. turbinatum* with only birds of Accipitriformes and absence of other birds of prey of order Falconiformes. This fact supports the molecular investigation and separation of the new order Accipitriformes.

The most important question now is why the bird ancestor of Accipitriformes radiated and separated into many different species while the chewing louse *Colpocephalum turbinatum* did not? The answer to this question lies in the nature of this species of louse itself. *Colpocephalum turbinatum* is a cosmopolitan species found everywhere and parasitises a huge number of bird species through three bird orders Accipitriformes, Columbiformes and Strigiformes (Adly *et al.* 2019). Also, this species of louse ventures outside its host and it was recorded through their host habitat before (Clay 1948). Combining these facts indicates that *Colpocephalum turbinatum* could support one gene pool that prevents its members from isolation and consequently speciation. The migration of host birds also supports the stability of this gene pool over a long period of time.

Finally, the information concerning host/parasite interaction and distribution is very valuable to study birds' phylogeny and evolution (Hafner & Nadler 1988). The record of *C. turbinatum* from osprey could reveal the nature of the ancestor of this bird that was a terrestrial hunter. Also, it helps the ornithologists to confirm their phylogenetic analysis and improve their wariness about the evolution and ecology of these host birds.

## ACKNOWLEDGEMENTS

This work forms part of a Ph.D. study of the first author on the diversity of chewing lice associated with the bird fauna of Saudi Arabia, supported by a graduate student grant from King Abdulaziz City for Science and Technology (No. 0003-13-T-A). We are gratefully for kind support and help given to this study by the King Saud University, Deanship of Scientific Research and College of Food and Agriculture Science Research Center. Our appreciation also goes to HH Prince Bander Bin Saud Bin Mohammad, the president of Saudi Wildlife Authority, for his sponsorship of the study of ectoparasites of wild birds in the kingdom. Also, we would like to thank the Saudi Wildlife Committee for supporting this study in the field.



**Fig. 2.** Phylogeny of Acciptridae and some other Falconiformes, including osprey (yellow highlighting), based on mitochondrial Cyt-b, ND2 and nuclear  $\beta$ -fibrinogen intron 7 sequences. From this tree we can recognise osprey as being paraphyletic to the Acciptridae, but it is very close to the family; this led to new classification of birds of prey by extracting this group of raptors from the Falconiformes and erecting a new order Accipitriformes that includes osprey. *Colpocephalum turbinatum* chewing louse, which is common among Accipitriformes, might have been transferred to the terrestrial ancestors of these groups millions of years ago from their terrestrial prey, namely the ancestors of pigeons (red dot). (Adapted from Lerner & Mindell 2005.)



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## REFERENCES

- ADLY, E., NASSER, M., SOLIMAN, D., GUSTAFSSON, D.R. & SHEHATA, M. 2019. New records of chewing lice (Phthiraptera: Amblycera, Ischnocera) from Egyptian pigeons and doves (Columbiformes), with description of one new species. *Acta Tropica* **190**: 22–27.  
<https://doi.org/10.1016/j.actatropica.2018.10.016>
- AL-AHMED, A., SHOBRACK, M. & NASSER, M. 2014. Chewing lice (Phthiraptera: Amblycera, Ischnocera) from red seagulls with new host-parasite records. *Zootaxa* **3790**: 567–576.
- ALDERTON, D. 2008. *The World Encyclopaedia of Birds and Birdwatching*. Hermes House, London, U.K.
- BANKS, J.C. & PALMA, R.L. 2003. A new species and new host records of *Austrogoniodes* (Insecta: Phthiraptera: Philopteridae) from penguins (Aves: Sphenisciformes). *New Zealand Journal of Zoology* **30**: 69–75.
- BANKS, J.C. & PATERSON, A.M. 2004. A penguin-chewing louse (Insecta: Phthiraptera) phylogeny derived from morphology. *Invertebrate Systematics* **18**: 89–100.
- BEDFORD, G.A.H. 1931. New genera and species of Mallophaga. *Report of the Director of Veterinary Services and Animal Industry, Union of South Africa* **17**: 283–297.
- CHRISTIDIS, L. & BOLES, W.E. 2008. *Systematics and Taxonomy of Australian Birds*. CSIRO Publishing, Sydney, Australia. pp. 50–55.
- CLAY, T. 1948. Relationships within the Sternidae as indicated by their mallophagan parasites. *Ibis* **90**: 141–142.
- CLAY, T. & HOPKINS, G.H.E. 1951. The early literature on Mallophaga. Part II, 1763–1775. *Bulletin of the British Museum (Natural History), Entomology* **2**: 1–36.
- CLAY, T. 1958. Three new species of *Degeeriella* Neumann (Mallophaga) from the Falconiformes (Aves). *Proceedings of the Royal Society of London B, Biological Science Series B* **27**: 1–7.
- CLAY, T. 1976. Geographical distribution of the avian lice (Phthiraptera): a review. *Journal of the Bombay Natural History Society* **71**: 536–547.
- EICHLER, W. 1941. Zur Klassifikation der lauskerfe (Phthiraptera Haeckel: Rhynchophthirina, Mallophaga und Anoplura). *Archiv für Naturgeschichte* **10**: 345–398.
- HAFNER, M.S. & NADLER, S.A. 1988. Phylogenetic trees support the coevolution of parasites and their hosts. *Nature* **332**: 258–259.  
DOI: [10.1038/332258a0](https://doi.org/10.1038/332258a0)
- HANNAH, L.J. & LOVEJOY, T.E. 2003. *Climate Change and Biodiversity: Synergistic Impacts*. Centre for Applied Biodiversity Science at Conservation International (CABSCI), Arlington, VA, U.S.A.
- HOPKINS, G.H.E. 1941. Stray notes on Mallophaga – III. *Annals and Magazine of Natural History* **7**: 35–50.
- IMMS, A.D., RICHARDS, O.W. & DAVIES, R.G. (Eds). 1977. *Imms' General Textbook of Entomology. Volume 2: Classification and Biology*. Springer Science+Business Media, Dordrecht, Netherlands.
- JENNINGS, M.C. 2010. Atlas of the breeding birds in the Arabian Peninsula. *Fauna Arab* **25**: 751.
- KELLOGG, V.L. 1914. Mallophaga from birds of the South Atlantic. In: Murphy, R.C. A report on the South Georgia Expedition. *Science Bulletin of the Museum of the Brooklyn Institute of Arts and Sciences* **2**: 80–89.
- LERNER, H.R. & MINDELL, D.P. 2005. Phylogeny of eagles, Old World vultures, and other Accipitridae based on nuclear and mitochondrial DNA. *Molecular Phylogenetics and Evolution* **37**: 327–346.
- MAYR, G. 2006. An osprey (Aves: Accipitridae: Pandioninae) from the early Oligocene of Germany. *Senckenbergiana lethaea* **86**: 93–96.
- MILLER, M.J.R., EWINS, P.J. & GALLOWAY, T.D. 1997. Records of ectoparasites collected on ospreys from Ontario. *Journal of Wildlife Diseases* **33**: 373–376.
- NAZ, S., SYCHRA, O. & RIZVI, S.A. 2012. New records and a new species of chewing lice (Phthiraptera, Amblycera, Ischnocera) found on Columbidae (Columbiformes) in Pakistan. *ZooKeys* **174**: 79.
- NEGM, M.W., NASSER, M.G., ALATAWI, F.J., AL AHMAD, A.M. & SHOBRACK, M. 2013. Feather mites of the genus *Zachvatkinia* Dubinin, 1949 (Astigmata: Analgoidea: Avenzoariidae) from Saudi Arabia: a new species and two new records. *Zootaxa* **3710**: 61–71.
- NELSON, R.C. & PRICE, R.D. 1965. The *Laemobothrion* (Mallophaga: Laemobothriidae) of the Falconiformes. *Journal of Medical Entomology* **2**: 249–257.
- PALMA, R.L. 2012. Three new species of the louse genus *Saemundssonina* (Insecta: Phthiraptera: Philopteridae). *Zootaxa* **3478**: 38–48.
- PRICE, R.D. & BEER, J.R. 1963a. The genus *Kurodaia* (Mallophaga: Menoponidae) from the Falconiformes, with elevation of the subgenus *Falcomenopon* to generic rank. *Annals of the Entomological Society of America* **56**: 379–385.
- PRICE, R.D. & BEER, J.R. 1963b. Species of *Colpocephalum* (Mallophaga: Menoponidae) parasitic upon the Falconiformes. *Canadian Entomologist* **95**: 731–763.
- PRICE, R.D., HELLENTHAL, R.A., PALMA, R.L., JOHNSON, K.P. & CLAYTON, D.H. 2003. *The Chewing Lice: World Checklist and Biological Overview*. Illinois Natural History Survey Special Publication 24.
- SHOBRACK, M.Y. & ALOUFI, A.A. 2014. Status of breeding seabirds on the Northern Islands of the Red Sea, Saudi Arabia. *Saudi Journal of Biological Sciences* **21**: 238–249.
- SHOBRACK, M., ALAHMED, A., PALMA, R., ALMALKI, M. & NASSER, M.G. 2015. New records of species of *Saemundssonina* (Insecta: Phthiraptera: Philopteridae) infesting breeding terns in the Arabian Peninsula, with notes on their phylogeny and ecology. *Parasitology Research* **114**: 2587–2597.