Parasitic arthropods as the cause of parasitoses in aquatic animals

Joanna N. Izdebska, Leszek Rolbiecki
Department of Invertebrate Zoology, University of Gdańsk, Gdynia, Al. Piłsudskiego 46, 81-378, Poland; e-mail: biojni@ug.edu.pl

Abstract

Parasitic arthropods are impressive and diverse group but only few of them live on hosts inhabiting water environment and most of them are crustaceans, which are a group originally connected with this environment. However some species of mites and insects have secondarily adapted to living in aquatic ecosystems, and consequently evolved new adaptations enabling them to live in these distinct conditions. Most parasites live in a balanced relation with the hosts and not influence remarkably their condition. However disturbance of several environmental factors, both biotic and abiotic, results in the disturbance of functioning of the parasite-host relation, which consequently can result in excessive breeding of parasites and lesions in the host.

Introduction

Quality of the immediate living environment of a host has a great influence on the type and level of infestation. This is particularly true of parasitoses observed in water environment (Combes 2004). Aquatic ecosystems cover most of the surface of the Earth, therefore offer incredibly rich and diverse living environment for animals. Still conditions of life in water environment significantly differ from those prevailing in terrestrial environment. The most important difference is density of medium, which determines size, shape and motor abilities of living organisms. Both environments differ also in thermal conditions – water is characterized by high specific heat capacity, i.e. can absorb large quantities of thermal energy while its temperature only slightly increases, therefore aquatic organisms live in relatively stable (hardly changing) temperature conditions. Moreover water strongly absorbs part of the visible light spectrum, while water turbidity (suspensions) decreases the maximal depth of light penetration. Consequently such conditions cause parasites inhabiting this environment to adapt to different physical, chemical and biological parameters of external environment, as well as to adaptation strategies of hosts living in these conditions.

Parasitic arthropods are impressive and diverse group but only few of them live on hosts inhabiting water environment and most of them are crustaceans, which are a group originally connected with this environment. However some species of mites and insects have secondarily adapted to living in aquatic ecosystems, and consequently evolved new adaptations enabling them to live in these distinct conditions.

It would be very interesting to compare adaptation strategies of parasitic arthropods from different groups, particularly those species which exert substantial pressure on the hosts.

Crustaceans as parasites of water vertebrates

Copepods (Copepoda), fish lice (Branchiura), isopods (Isopoda) and amphipods (Amphipoda) play an important role among parasitic crustaceans inhabiting water environment. They show several adaptations to parasitism. Most of them are ectoparasites, some of them can move all over the host, or even leave it and swim actively in external environment, but there are also species showing extremely modified structure and permanent fusion with the host.

Half of 11 500 described species of copepods live in symbiosis with other animals. Majority of them are most probably parasitic species or species living in various, undefined relations with other animals (Boxshall 2005). Several species of parasitic copepods can cause serious lesions in the hosts.

In the marine environment, the most common and most dangerous are the "sea lice" represented by the genera Caligus and Lepeophtheirus, and two most pathogenic species - C. elongatus von Nordmann, 1832 and L. salmonis (Krøyer, 1837). These are ectoparasites: L. salmonis of salmonids (Salmonidae), mainly of genera Salmo, Salvelinus and Oncorhynchus, while C. elongatus has broader host range (43 fish families, including salmonids) (Kabata 1979, Lester and Roubal 1995). Invasive forms are copepodits, which attach to fish by frontal filament (Piasecki and MacKinnon 1995, Tully and Nolan 2002). Both females and smaller males are parasitic. Copepods have several adaptations, which enable them to attach to the host skin. They have characteristic flattened cephalothorax with concave ventral surface and attachment organs that are clawed antennae and maxillipeds. All these and the streamlined body shape protect them against wash out by water while they are attached to the host body surface. Adults are able to freely move on the fish body surface. They also can leave the host and swim in the surrounding water or attack other fish. Sea lice pose serious threat to health of farm salmonids inhabiting waters of the northern and southern Hemisphere, and to a lesser extent to fish of brackish waters of the Mediterranean region and south-eastern Asia. They feed on epithelial tissue, which they scrape off with the mandibles protruded from the oral cone (Boxshall and Defaye 1993, Boxshall 2005).

Importance of parasitic copepods increased with the intensification of fish breeding in the farms (maricultures). Fish crowding in limited water volume provides conditions favourable for parasite transmission leading to high parameters of prevalence, and most of all high intensity level, which results in intensified lesions and finally the mass death (Nagasawa 2004, Piasecki and Sękowska-Jakubowska 2005). Losses of the fish farms due to parasitism of "sea lice" can reach 10% of total production. The costs include not only those directly connected with fish death but also the applied chemotherapy and lower quality of fish intended for sale (Boxshall and Defaye 1993).

Sphyrion lumpi (Krøyer, 1845) (Fig.1, 2) is another marine pathogenic copepod highly adapted to parasitism. This species inhabits mainly the North and South Atlantic Ocean, and prefers representatives of the genus Sebastes as hosts. These are large

copepods – females can reach nearly 8 cm. Males are dwarf, they are only up to 2 mm long, sometimes they can be found attached to female. Females, most probably in copepodid stage, settle on the host and generate in frontal part of cephalothorax appendages called sphyrna or hammer, which enable them to anchor to fish muscles. Such shape of attachmnet organ causes that the parasite is attached to the host permanently. Only thin neck, long (part of cephalothorax) and so called pereon with abdominal appendages and egg-sacks hang outside. After some time sphyrna becomes tightly encysted (defence reaction) by the host tissue, which completely separates it from the food source. Before generation of this attachment organ and encystment, parasite feeds mainly on blood cells. After some time isolated, mature individual dies leaving large tumour: up to 5 cm in diameter filled with remains of decomposing copepod. This undoubtedly has an influence on quality of fish meat, moreover quite often several copepods are found on one fish. Only low-infected meat, after removal of tumours can be suitable for consumption. When infection is high the meat is not suitable for further processing, because it becomes uneconomic – production costs can be increased even by 80%. In such cases fish are designed for fish meal or used as food for other animals (Jara 1961, Kabata 1979, Grabda 1991).

In fresh water environments, more rarely brackish, serious and common parasites are copepods of the genus Ergasilus. In their life-cycle, development stadia from nauplius to adult sexually mature individuals are free-living; males after mating die, while fertilized females are parasitic. E. sieboldi von Nordmann, 1832 is one of the most pathogenic representatives of this genus. It was recorded on over 60 species of fish, while prefers cyprinids, esocids, salmonids and the percids. It is characterized by a very high reproduction rate. In Central Europe two, sometimes three generations of this copepod are noted. Theoretically one female can produce even 8 millions of new parasites (Kabata 1979, Lester and Roubal 1995, Rolbiecki 2003, 2004, Piasecki et al. 2004). E. sieboldi attach to the gills with clawed antennae. The parasite feeds on blood and epithelial tissue of the gills. E. sieboldi can be noted on fish with a very high infestation, reaching even several thousands of specimens, which together with other stressors (e.g. oxygen decrease during summer) can result in fish death (Lester and Roubal 1995, Hoole et al. 2001).

Figure 1. *Sphyrion lumpi*, female

Figure 2. Female of *Sphyrion lumpi* in fish

Fish lice (Branchiura) are entirely parasitic group of aquatic crustaceans, which includes 176 species. Most of them (134 species) are representatives of the genus *Argulus,* out of which most well-studied are *A. foliaceus* (Linnaeus, 1758), *A. japonicus* Thiele, 1900 and *A. coregoni* Thorell, 1865. *A. japonicus* noted in fresh water, mainly on the Crucian carp and common carp, originally inhabited only Asia, but later with aquarium fish has expanded all over the world. *A. foliaceus* inhabits fresh and brackish waters and is a parasite of various fish (e.g. cyprinids, salmonids, gobies and other), sometimes also frogs and turtles. *A. coregoni* is noted in fresh, brackish and marine waters mostly on the salmonids (Yamaguti 1963, Boxshall and Walter 2010). Fish lice are ectoparasites, which can leave the host and become free-living. Because they are dorsoventrally flattened and their attachment organs, i.e. maxillule - are transformed to a sucker they easily attach to the host skin. Both females and males are parasitic, while larvae are the invasive forms right after the hatch; sometimes (*Chonopeltis*) copepodid-like larva occurs, which lives on intermediate host. The common fish louse *A. foliaceus* is regarded as the most pathogenic species. Similarly to other branchiurans its mouthparts form proboscis, which is used to feed on host blood and tissue fluids. During heavy invasion fish become apathetic, lean and susceptible to other infections. Because the common fish lice are haematophagic and are able to leave the host, they are vectors of various pathogens, e.g. virus of the septicaemia, or even nematodes *Skrjabillanus scardinii* Molnár, 1966 (Grabda 1991, Lester and Roubal 1995, Moravec 1994).

Among isopods (Isopoda) parasites are represented by Cymothoidae (Fig. 3), Epicaridea and Gnathiidae. Most of them are marine species. Cymothoidae (larval and adult stages) and Gnathiidae (larval stages; adult free-living individuals do not feed at all) are fish parasites, while Epicaridea (larval and adult stages) are crustacean parasites (Ostracoda, Cirripedia, Copepoda, Decapoda, Isopoda). Most of them are ectoparasites; they attach to skin, fins, gill and oral cavities with their thoracic legs with claws; only some of Epicaridea are endoparasites. In some Cymothoidae with the growth of the parasite, hollows (pockets) are formed in the fish skin. After some time parasites are closed/immobilized there and cannot leave their host. Parasitic isopods feed on fish

blood. As these are large parasites (even 5 cm in length), they can cause anaemia, which could lead to inhibition of fish growth, leanness and finally death. Feeding parasites often leave bleeding wounds on fish skin, therefore highly infested individuals can only be designed for fish meal (Grabda 1991, Lester and Roubal 1995).

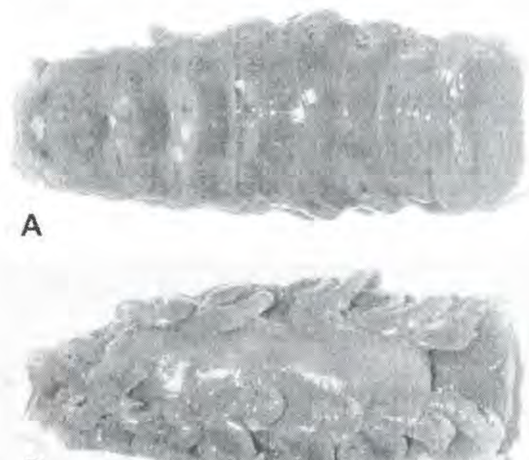

Figure 3. Cymothoidae, A – dorsal view, B – ventral view

Amphipods (Amphipoda) of the suborder Caprellidea include parasitic whale lice Cyamidae. They are dorsoventrally flattened with strongly reduced pleon. Whale lice are external parasites, found in skin lesions, genital folds, nostrils, and eyes of marine mammals of the order Cetacea. These include not only whales but dolphins and porpoises as well. Heavy infestation even of such huge hosts as cetaceans, results in skin lesions (Lützen 2005).

Mites and insects as parasites of water vertebrates

Most representative insects and mites, largest taxons of arthropods, are terrestrial, which means they live on land. A few groups, including parasites, have only secondarily adopted to living in aquatic environment. They are mainly species, which as closely bound with the host travelled evolutionary way from forms typically land, through the different degree of the connection with the aquatic environment, after secondarily water. It is forming with creation diverse morphological, anatomical, or physiological modifications, concerning, e.g. the way of breathing but also the adaptation of the reproduction and the development to new conditions of lives. And so amongst insects and mites of water animals many interesting models exist to deliberations above cospeciation and coevolution. However birds or mammals are also associated with the aquatic environment attacked by parasites on the land, where they are resting or nesting. Some arthropods adapted even their periods of the activity, or life cycles to customs of this peculiar host group.

Anyway chewing lice *(Phthiraptera: Amblycera, Ischnocera) and many groups of mites* (e.g., Ixodidae, Argasidae, Rhinonyssidae, Halarachnidae, Hypoderatidae, Syringophilidae, Trombiculidae, Alloptidae, Avenzoariidae, Psoroptidae, Freyanidae, Kramerellidae, Ptiloxenidae, Xolalgidae, Apionacaridae, Dermoglyphidae, Syringobiidae, Dermationidae, Epidermoptidae, Laminosioptidae) inhabit water birds (e.g., Wilson 1970, Dabert 2005, Fryderyk and Izdebska 2009). From among this group, chewing lice penguins are deserving the particular attention. In 17 penguin species, 15 species of lice of the genera *Austrogoniodes* and *Nesiotinus* (Ischnocera, Philopteridae) were described, which they constitute unusual model for the research on cophylogenetic relationships between penguins and their parasites (Clay 1967, Mey et al. 2002, Banks and Paterson 2004, Banks et al. 2006). Other typical ectoparasite of penguins is a seabird tick *Ixodes uriae* White, 1852, noted on many species of hosts from polar areas, peculiarly of sea birds (Block 1984, Gauthier-Clerc et al. 2003). In case of penguins this tick is able to adapt its life cycle and the span of the parasitic phase precisely to their season of the reproduction, associated with the land environment. A survey of the temporal pattern of population structure and feeding activity of *I. uriae* was conducted in two host species colonies - king penguin and macaroni penguin; the life cycle of the seabird tick was investigated over 3 years in a king penguin colony and 2 years in a macaroni penguin colony. There was a marked seasonal feeding activity pattern of ticks in both host species, connected with the presence of birds during the breeding season. Consequently, *I. uriae* probably completed its life cycle over 3 years in king penguin colonies; this life cycle could be shortened to 2 years in macaroni penguin colonies, as a result of a different timetable of the presence of birds for breeding and moulting (Frenot et al. 2001). High tick densities in penguin or other seabird colonies have been implicated in desertion and chick mortality. The adverse effects of seabird tick infestation for king penguins has been reported on adult health, breeding success and pathogen transmission (Gauthier-Clerc et al., 1998, 2003, Mangin et al. 2003).

A very rich fauna of parasitic arthropods is appearing in land mammals, however not numerous species adapted to living at water mammals. Specific host groups are marine mammals - cetaceans and pinnipeds. The sea mammals are host for several group of parasitic arthropods, especially sucking lice (Phthiraptera, Anoplura, Echinophthiriidae), skin mite – hair follicle mites (Acari, Prostigmata, Demodecidae) and scabies (Acari, Astigmata, Sarcoptidae); additionaly Halarachnid mites (Acari, Mesostigmata, Halarachnidae), which inhabit the respiratory tract of mammals, mainly the nasal passages. Echinophthiriidae and Acari are not found in cetaceans and sirenians. The lack of hair to attach the eggs and a proper surrounding environment are clear reasons for the absence of lice and mites in cetaceans (e.g., Aznar et al. 2001).

It seems that greatest chance for adaptation to life in water mammals have skin mites, living in skin of hosts. Especially Demodecidae that living in hair follicles and glands of skin, however so far they were noted only in small number of water mammals. Demodecidae are represented on the eared seal family Otariidae (Dailey and Nutting 1979) and the earless seals Phocidae (Desch et al. 2003). The hair follicle mites and itch mite were found in the harbor seal (*Demodex phocidi* Desch, Dailey & Tuomi, 2003), in the grey seals (*D. phocidi, Sarcoptes scabiei* Linnaeus, 1758), in the California sea lion (*D. zalophi* Dailey & Nutting, 1980) (e.g., Dailey and Nutting 1979, Desch et al. 2003, Izdebska 2006). *D. zalophi* cause alopecia and thickening of the skin over the genitalia, flippers and ventral body in California sea lions (Dailey and Nutting 1979). All life stages of *D. phocidi* inhabit the sebaceous glands of the hair follicles. Mites were discovered from areas of persistent hyperkeratosis on the dorsum of female atlantic harbor seal (Desch et al. 2003). Probably unknown demodecid species may be discovered in another Pinnipedia.

Besides lung mites of two genera of Halarachnid mites are parasitic in several pinnipeds species (Fay and Furman 1982). Lung mites are common parasites of the nasal passages, trachea, bronchi, and bronchioles (Moeller 2003). Both seals and sea lions are affected *Halarachne* is confined to the true earless seals, while *Orthohalarachne* is found in the eared seals (sea lions) and walruses (Domrow 1962). The most common mites observed are *Orthohalarachne diminuata* (Doetschman, 1944)

and *O. attenuata* (Banks 1910) (cf. Dailey 2001). *O. diminuata* inhabits the airways of the lung, and *O. attenuata* are found in the nasopharynx. The nasal mite, *Halarachne miroungae* Ferris, 1925, has been observed in sea otters. Hosts reported for this mite are the southern elephant seal, the northern elephant seal, the harbor seal, the sea otter and Gentoo penguin (Wilson 1970). Clinically, these mites do not cause any serious problems, however, they might cause copious amounts of mucus in the upper respiratory tract and nose, nasal discharge, dyspnea, and coughing.

Anopluran (sucking) lice of Echinophthiridae family are parasite of Pinnipedia and Mustelidae. Their body is covered with stout setae, under which air bubbles can accumulate – these are useful when the seal is under the water surface (Fig. 4, 5). Moreover these lice evolved prehensile legs well-adapted to grasp hair of the head – part of the body that most probably is submerged for the shortest time (e.g., Scherf 1963, Izdebska and Fryderyk 2008).

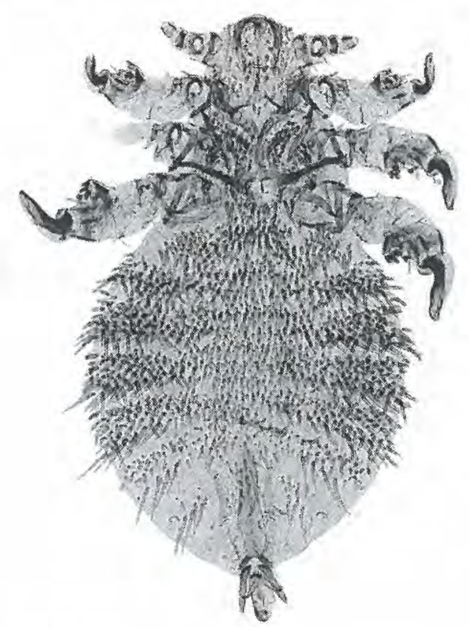

Figure 4. *Echinophthirius horridus*

The seal louse *Echinophthirius horridus* (Olfers, 1816) noted from six seal species: ringed seal, harp sea, grey seal, bearded seal, hooded seal and harbor seal (e.g., Durden and Musser 1994); in Poland – only in the grey seal (Kadulski 2001). Prevalence of infection of the seals is very differentiated, e.g. Lehnert et al. (2007) noted 4% infected harbor seals wheather Thompson et al. (1998) - 39%. High burdens of lice *E. horridus* may compromise diving ability of seals. The epidemiology of the seal louse was studied in which their harbour seal hosts experienced marked inter-annual changes in food availability. Burdens were highest on immature seals, but both prevalence and intensity of infestation were significantly higher in years when food availability was low. No significant differences were found in the haematological parameters of infected and uninfected hosts. Nevertheless, there was a significant negative correlation between intensity of infection and several erythrocyte parameters, suggesting that high burdens of lice may compromise diving ability (Thompson et al. 1998). Probably high infestation may cause anemia – Lehnert at al. (2007) report on one severely infested harbor seal, that was found to have died of anaemia. Further the seal louse is believed to an intermediate host of the filarioid nematode *Acanthocheilonema spirocauda* (Leidy, 1858) (cf. Geraci et al. 1981, Lehnert et al. 2007).

Another louse *Antarctophthirus trichechi* (Bohemann, 1865) noted in walrus and louse *A. microchir* (Trouessart and Neumann, 1888) – in American sea lion (e.g., Durden and Musser 1994). *A. microchir* is a common louse noted on sea lion pups (Aznar et al. 2009). Lice cause alopecia in infected hosts. An arbovirus (*Alphavirus*) has been isolated from the elephant seal louse, *Lepidophthirus macrorhini* Enderlein 1904, which implies that these lice can transmit viral infections from one animal to the other.

Figure 5. *E. horridus* - body is covered with stout setae

Summary

Parasitic arthropods of aquatic vertebrates are very diverse group, of different origin, adaptation strategies, range of host and site specificity, and importance to hosts. Most parasites live in a balanced relation with the hosts and not influence remarkably their condition. However disturbance of several environmental factors, both biotic and abiotic, results in the disturbance of functioning of the parasite-host relation, which consequently can result in excessive breeding of parasites or replacing one parasite with another more pathogenic species and parasitoses in the host. A perfect example is a comparison of infestation with parasitic copepods of fish in natural water reservoirs and fish-breeding ponds, where high density of hosts favours transmission and parasite breeding, and consequently parasitoses development. Similar effect is a result of the climate changes, particularly warming during winter, which guarantees higher survival of parasites and increases their pressure on the hosts.

References

Aznar F. J., Balbuena J. A., Fernandez M., and Raga J. A. 2001. Living together: The Parasites of Marine Mammals. In: P. G. H. Evans, Raga J.A (eds.), Marine mammals: Biology and Conservation. Kluwer Academic/Plenum Publishers, New York: 385-423.

Aznar F.J, Leonardi M.S, Berón Vera B., Vales D.G., Ameghino S., Raga J.A., Crespo E.A. 2009. Population dynamics of *Antarctophthirus microchir* (Anoplura: Echinophthiriidae) in pups from South American sea lion, *Otaria flavescens*, in Northern Patagonia. Parasitology 136: 293-303.

Banks J. C., Paterson A.M. 2004. A penguin-chewing louse (Insecta: Phthiraptera) phylogeny derived from morphology. Invertebr. Systematics 18: 89-100.

Banks J. C., Palma R. L., Paterson A. M. 2006. Cophylogenetic relationships between penguins and their chewing lice. J. Evolution. Biol. 19: 156–166.

Block W. 1984. Terrestrial microbiology, invertebrates and ecosystems. In: P. Laws (ed.), Antarctic ecology. Academic Press, London, 1: 163–326.

Boxshall G. 2005. Copepoda (copepods). In: Rhode K. (ed.), Marine parasitology. CABI Publishing, Wallingford, United Kingdom: 123-169.

Boxshall G.A., Defaye D. (eds) 1993. Pathogens of wild and farmed fish. Sea lice. Ellis Horwood, Chichester, 375 pp.

Boxshall G., Walter T. C. 2010. Branchiura. In: Walter T.C., Boxshall G. (eds), World Copepoda database. Accessed through: Costello M. J., Bouchet P., Boxshall G., Arvantidis C., Appeltans W. European Register of Marine Species, http://www.marbef.org.

Clay T., Moreby C. 1967. Mallophaga (biting lice) and Anoplura (sucking lice). Part II: Keys and Locality of Mallophaga and Anoplura. Antarctic Res. Ser. 10 (Entomol. Antarctica): 157–196.

Combes C. 2004. Parasitism: The Ecology and Evolution of Intimate Interactions. Chicago University Press. Chicago, 552 pp.

Dabert J. 2005. Acari (mites and ticks). In: Rhode K. (ed.), Marine parasitology. CABI Publishing, Wallingford, United Kingdom: 216-222.

Dailey M. D., Nutting W.B. 1979. *Demodex zalophi* sp. nov. (Acari: Demodicidae) from *Zalophus californianus*, the California sea lion. Acarologia 21: 423-428.

Dailey M. D. 2001. Parasitic Diseases. In: L. A Dierauf, F. M. D. Gulland (eds), CRC Handbook of marine mammal medicine: health, disease, and rehabilitation. CRC Press: Boca Raton, FL: 357-379.

Desch C.E., Dailey M.D., Tuomi P. 2003. Description of a hair follicle mite (Acari: Demodecidae) parasitic in the earless seal family Phocidae (Mammalia: Carnivora) from the harbor seal *Phoca vitulina* Linnaeus, 1758. Int. J. Acarol. 29: 231-235.

Domrow R. 1962. Halarachne miroungae Ferris redescribed (Acarina: Laelaptidae). Pac. Insects 4: 859-863.

Durden L. A., Musser G.G. 1994. The sucking lice (Insecta, Anoplura) of the world: A taxonomic checklist with records of mammalian hosts and geographical distributions. B. Am. Mus. Nat. Hist. 218:1–90.

Fay F.H., Furman D.P. 1982. Nasal mites (Acari: Halarachnidae) in the spotted seal, *Phoca largha* Pallas, and other pinnipeds of Alaskan waters. J. Wildlife Dis. 18: 63-68.

Frenot Y., de Oliveira E., Gauthier-Clerc M., Deunff J., Bellido A., Vernon B. 2001. Life cycle of the tick *Ixodes uriae* in penguin colonies: relationships with host breeding activity. Int. J. Parasitol. 31: 1040-1047.

Fryderyk S., Izdebska J.N. 2009. Birds as a living environment for parasitic arthropods. In: J. Wišček, M. Polak, M. Kucharczyk, G. Grzywaczewski, L. Jerzak (eds), Birds-Environment-Threats-Conservation. Select issues in avian ecology. LTO, Lublin: 61-69.

Gauthier-Clerc M., Clerquin Y., Handrich Y., 1998. Hyperinfestation by ticks Ixodes uriae: a possible cause of death in adult King Penguins, a long-lived seabird. Colon. Waterbirds 21: 229-233.

Gauthier-Clerc M., Mangin S., Le Bohec C., Gendner J.P., Le Maho Y. 2003. Comparison of behaviour, body mass, haematocrit level, site fidelity and survival between infested and non-infested king penguin *Aptenodytes patagonicus* by ticks *Ixodes uriae*. Polar. Biol. 26: 379–382.

Geraci J R., Fortin J. F., Aubin D. J. St., Hicks B. D. 1981. The seal louse, *Echinopthirius horridus*: an intermediate host of the seal heartworm, *Dipetalonema spirocauda* (Nematoda). Can. J. Zool. 59: 1457-1459

Grabda J. 1991. Marine fish parasitology. An outline. VCH, Weinheim, 306 pp.

Hoole D., Bucke D., Burgess, P., Wellby, I. 2001. Diseases of carp and other cyprinid fishes. Blackwell Science, Oxford, 264 pp.

Izdebska J.N. 2006. Roztocze skórne z rodziny Demodecidae (Acari, Prostigmata) u ssaków wodnych. Streszczenia i wystąpienia, XX Zjazd Hydrobiologów Polskich, 5-8 września 2006, Toruń: 107.

Izdebska J.N., Fryderyk S. 2008. Morphological differentiation and interesting adaptations to parasitism in sucking lice and biting lice (Insecta, Phthiraptera). In: A. Buczek, Cz. Błaszak (eds), Arthropods. Influence on host. Akapit, Lublin: 21-28.

Jara Z. 1961. Sphyrion lumpi (Krøyer). Wiad. Parazyt. 7: 596-599.

Kabata, Z. 1979. Parasitic Copepoda of british fishes. The Ray Society, London, 468 pp.

Kadulski S. 2001. *Echinophthirius horridus* (Olfers, 1816) (Anoplura) rzadki pasożyt fok. Wiad. Parazyt. 47: 269-271.

Lehnert K., Raga J.A., Siebert U. 2007. Parasites in harbour seals (*Phoca vitulina*) from the German Wadden Sea between two Phocine Distemper Virus epidemics. Helgol. Mar. Res. 61: 239–245.

Lester R.J.G., Roubal F.R. 1995. Phylum Arthropoda. In: Woo P.T.K. (ed.), Fish diseases and disorders. Protozoan and metazoan infection. CAB International, Wallingford, UK. 1: 475-598.

Lützen J. 2005. Amphipoda (amphipods). In: Rhode K. (ed.), Marine parasitology. CABI Publishing, Wallingford, United Kingdom: 165-169.

Mangin S., Gauthier–Clerc M., Frenot Y., Gendner J. & Le Maho Y. 2003. Ticks *Ixodes uriae* and the breeding performance of a colonial seabird, King Penguin *Aptenodytes patagonicus*. J. Avian Biol. 30: 30–34.

Mey E., Chastel O., Beaucournu J.C. 2002. A 'penguin' chewing louse Nesiotinus on a Kerguelen Diving-petrel (*Pelecanoides urinatrix exsul*): an indication of a phylogenetic relationship? J. Ornithol. 143: 472-476.

Moeller R. 2003. Pathology of marine mammals with special reference to infectious diseases. In: J. G. Vos, G. D. Bossart, M. Founier, T. J. O'Shea (eds.). Toxicology of marine mammals. Taylor & Francis, New York: 3-37.

Moravec F. 1994. Parasitic nematodes of freshwater fishes of Europe. Academia, Praha, 473 pp.

Nagasawa K. 2004. Sea Lice, *Lepeophtheirus salmonis* and *Caligus orientalis* (Copepoda: Caligidae), of Wild and Farmed Fish in Sea and Brackish Waters of Japan and Adjacent Regions: A Review. Zool. Stud. 43: 173-178.

Piasecki W., MacKinnon B.M. 1995. Life cycle of a sea louse, *Caligus elongatus* von Nordmann, 1832 (Copepoda, Siphonostomatoida, Caligidae). Can. J. Zool. 73: 74-82.

Piasecki W., Goodwin A.E., Eiras J.C., Nowak B.F. et al. 2004. Importance of Copepoda in freshwater aquaculture. Zool. Stud. 43: 193-205.

Piasecki W., Sękowska-Jakubowska A. 2005. Epizootiologiczne i epidemiologiczne znaczenie widłonogów (Arthropoda: Crustacea: Copepoda). In: A. Buczek, Cz. Błaszak (eds), Stawonogi, różnorodność form i oddziaływań. Koliber, Lublin: 305-310.

Rolbiecki L., 2003. Diversity of the parasite fauna of cyprinid (Cyprinidae) and percid (Percidae) fishes in the Vistula Lagoon, Poland. Wiad. Parazyt. 49: 125-164.

Rolbiecki L. 2004. Preferencje siedliskowe pasożytniczego widłonoga *Ergasilus sieboldi* (Ergasilidae) u troci jeziorowej *Salmo trutta m. lacustris* (Linnaeus, 1758) z jeziora Wdzydze In: A. Buczek, Cz. Błaszak (eds), Stawonogi, interakcje pasożyt-żywiciel. Liber, Lublin: 87-92.

Scherf H. 1963. Ein Beitrag zur Kenntnis zweier Pinnipedierläuse (*Antarctophthirus trichechi* Boheman und *Echinophthirius horridus* Olfers). Parasitol. Res. 23: 16-44.

Thompson P.M, Corpe H.M., Reid R.J. 1998. Prevalence and intensity of the ectoparasite *Echinophthirius horridus* on harbour seals (*Phoca vitulina*): effects of host age and inter-annual variability in host food availability. Parasitology 117: 393-403.

Tully O., Nolan D.T. 2002. A review of the population biology and host-parasite interaction of the sea louse *Lepeophtheirus salmonis* (Copepoda: Caligidae). Parasitology 124: 165-182.

Wilson N. 1970. Acarina: Mesostigmata: Halarachnidae, Rhinonyssidae of South Georgia, Heard and Kerguelen. Pac. Insects Monograph 23: 71-77

Yamaguti S. 1963. Parasitic Copepoda and Branchiura o fishes. Interscience Publishers, New York, 1104 pp.

Stawonogi.
Ekologiczne i patologiczne aspekty układu pasożyt – żywiciel

ARTHROPODS
Ecological and pathological aspects of parasite- host relationships

Edited by

Alicja Buczek

Czesław Błaszak

AKAPIT

LUBLIN 2010

STAWONOGI

Ekologiczne i patologiczne aspekty układu pasożyt- żywiciel

Pod Redakcją

Alicji Buczek
Katedra i Zakład Biologii i Parazytologii
Uniwersytet Medyczny w Lublinie

Czesława Błaszaka
Zakład Morfologii Zwierząt
Uniwersytet im. Adama Mickiewicza w Poznaniu

AKAPIT
LUBLIN 2010

PROJEKT OKŁADKI: SEBASTIAN BUCZEK
COVER DESIGN: SEBASTIAN BUCZEK

WYDANIE DOFINANSOWANE PRZEZ KOMITET ZOOLOGII PAN

ISBN 978-83-896160-7-4

AKAPIT
Lublin, ul. Węglowa 3

www.kleszcze.pl

Spis Treści