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Invited Review

Endo- and ectoparasites of large whales (Cetartiodactyla: Balaenopteridae, Physeteridae): Overcoming difficulties in obtaining appropriate samples by non- and minimally-invasive methods

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ABSTRACT

Baleen and sperm whales, belonging to the Order Cetartiodactyla, are the largest and heaviest existent mammals in the world, collectively known as large whales. Large whales have been subjected to a variety of conservation means, which could be better monitored and managed if physiological and patho-physiological information, such as pathogen infections, could already be gathered from free-swimming animals instead of carcasses. Parasitic diseases are increasingly recognized for their profound influences on individual, population, and even ecosystem health. Furthermore, a number of parasite species have gained importance as opportunistic neozoan infections in the marine environment. Nonetheless, traditional approaches to study parasitic diseases have been impractical for large whales, since there is no current routine method for the capture and handling of these large animals and there is presently no practical method to obtain blood samples remotely from free-ranging whales. Therefore, we here not only intend to review the endo- and ectoparasite fauna of large whales but also to provide new insights in current available methods for gathering parasitological data by using non- or minimally invasive sampling techniques. We focus on methods, which will allow detailed parasitological studies to gain a broader knowledge on parasitoses affecting wild, free-swimming large whale populations.

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1. Introduction

Over the last two centuries, most large whale species were subjected to severe overexploitation by commercial whaling to the point of becoming almost extinct (Clapham et al., 1999). Fortunately, since the international moratorium on commercial whaling, that has been in place since 1986, some populations have slowly recovered, although most populations have not yet recuperate their historical numbers, and others are still under threat or seriously endangered (Kraus et al., 2005; Freeman, 2008; Reynolds et al., 2009; IUCN, 2012). Moreover, large whales still experience numerous anthropogenic pressures, which warrant closer investigations from a conservation physiology perspective in order to better understand their resilience and ability to recover from overexploitation. Even with the cessation of commercial whaling in most countries, large whales still face chronic exposure to toxins and pollutants, global climate change, as well as several pathologies including naturally occurring parasite infections but also from water contamination by human activities (Van Bressem et al., 2009; Kleinertz et al., 2014b; Moore, 2014).

Large cetaceans can be affected by a wide range of endo- and ectoparasites, which have been the focus of numerous reports mainly dealing with taxonomy, distribution and ecology. Furthermore, a number of parasite species have gained importance as opportunistic neozoan infections in the marine environment. This review focuses on those organisms which we perceive as pathogenic for baleen and sperm whales (known collectively as large whales) as well as on new emerging and neglected neozoan parasites, mainly protozoan parasites. Nonetheless, traditional approaches to studying parasitic diseases have been impractical for large whales, because there is no current routine method for capturing the largest whale species and there is presently no practical method for obtaining blood samples remotely from free-ranging whales. Thus, here we intend, additionally, to review current available methods for gathering parasitological information by using a variety of non- and minimally-invasive sample collection techniques. The following five types of non-(minimally) invasive sample collections are discussed: faecal samples, vomitus samples, respiratory samples, skin/blubber samples and photograph monitoring.

2. Endoparasites of large whales (Physeteridae, Balaenopteridae)

Sperm whales (*Physeter macrocephalus*) are the largest of the toothed whales and it is the only living member of the family Physeteridae. Sperm whales are apex predators and have a catholic diet: females preferentially prey upon mesopelagic cephalopods, in addition to cephalopods, and males consume demersal fish species including gadoids, sharks and rays (Whitehead, 2009). A wide range of helminths including mainly cestodes, nematodes, trematodes and acanthocephalan parasite species can parasitize sperm whales (see Table 1).

The cestode fauna of sperm whales consists of species from the Tetrabothriidae, Diphyllobothriidae and Phyllobothriidae: *Tetrabothrius curilensis*, *Tetrabothrium wilsoni*, *Trigonocotyle* sp., *Priapocephalus grandis* (Rees, 1953), *Diplogonoporus* sp. (Gubanov, 1951; Rees, 1953; Delyamure, 1955), *Hexagonoporus physeteris* and *Phyllobotrium delphini* (Baylis, 1932). Most of the tapeworms belonging to the families Tetrabothriidae and Diphyllobothriidae were found in the small intestine of sperm whales, with the exception of the genus *Diplogonoporus*, which may also reside in the bile ducts. Infections with mature pseudophyllideans, mainly *Diphyllobotrium* spp. are usually innocuous (Arundel, 1978), but may also cause debilitation and even death of heavily infected animals. Adult cestodes have been described to occasionally encyst within the intestine mucosa or to block the gut lumen (Cordes and O'Hara, 1979; Geraci and St Aubin, 1987). Moreover, plerocercoids cysts of *Phyllobotrium* spp. are the most commonly encountered parasites in cetaceans worldwide (Ruhnke and Workman, 2013). The definitive hosts of adult *Phyllobotrium* cestodes are several sharks as described elsewhere (Ruhnke and Workman, 2013; Kuris et al., 2015).

Table 1
Groups of endo- and ectoparasite species and their site of infection in large whale species (Balaenopteridae, Physeteridae).

Parasite	Whale species				Site of infection
	Blue whale	Sei whale	Fin whale	Sperm whale	
Protozoa					
Giardia		+	+		Small intestine
Entamoeba	+	+	+		Large intestine
Balantidium			+		Large intestine
Trematoda					
Zalophotrema				+	Liver/pancreas
Ogmogaster	+	+	+		Stomach/intestine
Lecithodesmus	+	+	+		Stomach/intestine
Nasitrema	+	+	+		Nasal sinuses
Cestoda					
Tetrabothrium	+	+	+	+	Small intestine
Tetrabothrius	+	+	+	+	Small intestine
Trigonocotyle	+	+	+	+	Small intestine
Priapocephalus	+	+	+	+	Small intestine
Diplogonoporus	+	+	+	+	Liver/intestine
Hexagonoporus	+	+	+	+	Small intestine
Phyllobotrium	+	+	+	+	Subdermis
Acanthocephala					
Bolbosoma	+	+	+	+	Stomach/intestine
Corynosoma				+	Stomach/intestine
Nematoda					
Anisakis	+	+	+	+	Stomach
Contracaecum	+	+	+		Stomach
Porrocaecum	+	+	+		Stomach
Placentonema				+	Uterus/kidney
Crassicauda	+	+	+		Uterus/kidney
Stenurus	+	+	+		Lungs
Arthropoda					
Coronula	+	+	+	+	Skin/subdermis
Xenobalanus	+	+	+		Skin/subdermis
Penella	+	+	+		Skin/subdermis
Cyamus	+	+	+	+	Skin
Neocyamus	+	+	+	+	Skin
Agnatha (fish)					
Entosphenus	+	+	+	+	Skin/subdermis