

Epibiotic macrofauna on common minke whales (*Balaenoptera acutorostrata* Lacépède, 1804) in Icelandic waters

Droplaug Ólafsdóttir^{1,*} & Andrew P. Shinn²

¹*Marine Research Institute, Skulagata 4, IS 101-Reykjavik, Iceland;* ²*Institute of Aquaculture, University of Stirling, Stirling, FK9 4LA, UK*

Running title: Epibiotic macrofauna on common minke whales

Key words: *Caligus elongatus*, *Pennella balaenopterae*, *Cyamus balaenopterae*, *Conchoderma* spp., *Xenobalanus globicipitis*, *Udonella caligorum*, *Petromyzon marinus*

*Corresponding author:

Droplaug Ólafsdóttir

Present address: Icelandic Meteorological Office, Bústaðavegur 7-9, 150-Reykjavik, Iceland;

Email: droplaug@vedur.is

Abstract

The epibiotic macrofauna and skin lesions on 185 common minke whales (*Balaenoptera acutorostrata* Lacépède, 1804) landed in Icelandic waters between April to September 2003-2007 were determined. For each whale, the fluke and one lateral side was examined. A total of seven epibiotic species were found, namely: the caligid copepod *Caligus elongatus* (prevalence (P) = 11.9%, mean intensity (M.I) = 95.5); the pennellid copepod *Pennella balaenopterae* (P = 10.3%, M.I = 1.6); the cyamid amphipod *Cyamus balaenopterae* (P = 6.5%, M.I = 37.0); the lepadid cirripeds *Conchoderma virgatum* (P = 0.5%, M.I = 4.0) and *Conchoderma auritum* (P = 0.5%, M.I = 1.0), the balanid cirriped *Xenobalanus globicipitis* (P = 1.6%, M.I = 5.3) and the sea lamprey *Petromyzon marinus* (P = 2.7%, M.I = 1.0). In addition, the hyperparasitic monogenean *Udonella caligorum* was found on *C. elongatus* (P = 10.4%, M.I. = 3.9) on 8 of the 22 whales infected with the copepod. No significant relationship was observed between parasite intensity and host body length for neither *C. balaenopterae* nor *C. elongatus* while the proportion of infected hosts was higher in August-September than earlier in the summer for *C. balaenopterae* ($\chi^2 = 13.69$; $p < 0.01$; d.f.=1) and *C. elongatus* ($\chi^2 = 28.88$; $p < 0.01$; d.f.=1). The prevalence of *C. balaenopterae* was significantly higher on male than on female hosts ($\chi^2 = 5.08$; $p < 0.05$; d.f.=1) suggesting possible different migration routes by the sexes. A likely explanation of the occurrences of *P. marinus*, attached to the minke whales may be gradually rising sea temperature in the area in the recent years. This study represents the first known record of *C. elongatus* on a cetacean host.

Introduction

Information on the epibiotic macrofauna on large whales has been reviewed repeatedly in the cetacean literature (see Mackintosh & Wheeler, 1929; Clarke, 1966; Dailey & Brownell, 1972; Margolis & Dailey, 1972; Arvy, 1982; Raga & Sanpera, 1986; Raga *et al.*, 1987; Measures, 1993; Raga, 1994; Mignucci-Giannoni *et al.*, 1998). The epibiota reported from cetaceans consists of obligatory ectoparasites that are dependent on their hosts for survival in terms of nutrition or transport, and, of opportunistic commensals that attach onto marine hosts or flotsam and filter food particles from the marine plankton.

The abundance of epibiotic organisms on a host population is affected by a complex interaction of physical and biological factors and changes in the epibiota may serve as biological indicator of ecosystem shifts that may be difficult to observe by other means. Shifts in epibiota macrofauna on a particular host, therefore, may allude to larger and more complex environmental changes at play (Bushuev, 1990; Balbuena & Raga, 1991; Balbuena *et al.*, 1995; Araki *et al.*, 1997; Kuramochi *et al.*, 2000; Aznar *et al.*, 2005). Changes in the epibiota of cetaceans may give indications of altered migration patterns in the host population or changed proportions of seasonally overlapping populations which migrate into the study area from spatially separated grounds. Changes in abundance may also reflect changes in the parasite's ecology in terms of fluctuations in the relative abundance of alternative hosts or changes in the physical environment that may affect their survival.

Little information exists on the epibiotic macrofauna on cetaceans in Icelandic waters. Sparse historical records have been obtained from sporadic observations and, to date, no systematic studies have been conducted. Of those that are known, Hallas (1868) reported finding the caprellid *Cyamus boopis* Lütken, 1870 (Malacostraca: Cyamidae) and the cirripedes *Coronula diadema* (L.) (Maxillopoda: Coronulidae) and *Conchoderma auritum* (L.) (Maxillipoda: Lepadidae) from humpback whales (*Megaptera novaeangliae* Borowski, 1781) off the south coast of Iceland. The specimens of *C. auritum* were observed attached to the sessile barnacle *Coronula*, whilst a further single specimen was found attached directly to the skin. Later, Stephensen (1940) reported *Pennella balaenoptera* Koren et Danielsson, 1877 (Copepoda: Pennellidae) from common minke whales (*Balaenoptera acutorostrata* (syn. *rostrata*) Lacépède, 1804) in Icelandic waters.

The last known species is *Cyamus ovalis* Roussel de Vauzème, 1834 from a North Atlantic right whale (*Eubalaena glacialis* (Müller, 1776), which was listed in a catalogue of whale lice in the collections of the British Museum (Lincoln & Hurley, 1974).

Common minke whales are commonly observed in the waters off Iceland between April to November, although their abundance is at its peak in June and July (Sigurjónsson & Víkingsson, 1997). The winter distribution of the population, however, is not fully established. While some individuals may overwinter in Icelandic waters, the bulk of the population is believed to migrate to southern locations as far south as West Africa (Víkingsson & Heide-Jørgensen, 2005).

The current study, which forms part of a larger co-ordinated programme of collaborative research on the ecology and biology of common minke whales, set out to provide baseline information on the species composition, geographic distribution and abundance of the epibiotic macrofauna on minke whales in Icelandic waters during the summer period. In the light of projected environmental changes in the world's oceans in the coming decades, the information may prove valuable as a basis for future comparisons.

Materials and methods

A study on ectoparasites, epizoics and sea lamprey marks on common minke whales was carried out in relation to a comprehensive research programme on the ecology and biology of common minke whales in Icelandic waters (MRI, 2003). Data and samples were collected from 185 animals landed between May to September 2003 to 2007 (Table 1, Fig. 3a). The whales were taken on-board a vessel about half an hour to 5 hours post mortem. The tail fluke and one lateral side of each whale were examined for epibiotic macro-organisms and skin lesions by eye immediately following the whales removal from the water. The intensity for each species in each of four body regions (Fig. 1) was recorded and qualitative sub-samples were taken for subsequent identification in the laboratory. Lamprey scars were categorised as either “fresh” or “old” based on whether the attachment wounds on the epithelium were still open or had healed (Fig. 2).

The exterior of *C. elongatus* and its monogenean hyperparasite, *U. caligorum* were examined under an Olympus SZ30 dissecting microscope. Closer evaluation of a

sub-sample of 50+ *C. elongatus* was performed using a compound Olympus BX51 microscope and, subsequently, specimens were prepared for the scanning electron microscope.

The prevalence, intensity and the mean intensity of each parasite burden was determined and follows the definitions provided by Bush *et al.* (1997). Where data was sufficient, the relationship between parasite intensity, transformed using natural logarithm, and the length of the whale was analysed using a least squares regression. Differences in prevalence of certain parasitic species between the two sexes and different time periods were investigated using chi-square tests.

Results

From the examination of 185 common minke whales, three ectoparasites *Cyamus balaenopterae* Barnard, 1931 (Amphipoda: Cyamidae) and *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae) and its monogenean hyperparasite *Udonella caligorum* Johnston, 1835 (Udonellidae) were found; one mesoparasite species, *P. balaenopterae* Koren et Danielssen, 1977 (Copepoda: Pennellidae); three epizoics, *Conchoderma virgatum* Spengler, 1790, *C. auritum* (Cirripedia: Lepadidae), and, *Xenobalanus globicipitis* Steenstrup, 1851 (Cirripedia: Balanidae). On five occasions, a single live sea lamprey, *Petromyzon marinus* L. (Pisces: Petromyzontidae), were found attached to a whale, in addition, to fresh (*i.e.* open) and old feeding / attachment wounds which were commonly seen on the flanks of the whales (see Table 2). All five *P. marinus*-infected minke whales were landed in waters to the southwest and to the southeast of Iceland in July and August 2005 and 2006 (Table 2, Fig. 3f). Four of the lampreys fell off the whales when they were hauled from the water and, therefore, it may be assumed that the prevalence of attached lampreys is underestimated in the present study with some fish possibly detaching from the host unnoticed. Fresh lamprey scars were frequently observed on the posterior part of the flank of 20 whales that were landed in waters to the west and south of Iceland, suggesting recent associations between the two ($P = 10.7\%$) (Table 2, Fig. 3f). Old scars were observed on a further 85 minke whales from all areas ($P = 42.6\%$). The force of the lamprey's attachment to its host is not strong and the fish may slip over its host's surface. A single lamprey, therefore, may be responsible for inflicting numerous

scars on a single host preventing an accurate estimation of intensity of fish based on observation of the scars.

Twenty two whales were found with a total of 2006 *C. elongatus* attached, representing the first time that this parasite has been reported from a cetacean (Table 2, Fig. 3b). The *Caligus* specimens were found distributed over the entire exterior of the whale with no apparent preference for a particular habitat ($P = 11.9\%$; M.I. = 95.5). No significant relationship between the intensity of *Caligus* and the length and / or sex of the whale was found. A significant seasonal trend in the prevalence of *C. elongatus*, however, was observed ($\chi^2 = 28.88$; $p < 0.001$; d.f. = 1) (Table 2). The copepods were principally observed on minke whales landed in August and September; they were observed on only one of the whales landed in July and no infections were observed on minke whales sampled in April to June. Closer evaluation of a sub-sample of *C. elongatus* revealed that there were at least two morphotypes of *C. elongatus* present, those where the swimming legs were separate and, a small number of sea lice, where the posterior swimming legs were fused. A full morphological and molecular study of both forms is in progress and will be presented elsewhere.

The exterior of *C. elongatus* were also infected with the eggs, juveniles and adults of a monogenean hyperparasite, *U. caligorum*. A total of 35 *U. caligorum* were found on a sub-sample of 335 *C. elongatus* that were examined ($P = 10.45\%$; M.I. = 3.89) (Table 2).

Cyamus balaenopterae was found on all body regions of the minke whales landed off the west and south coasts ($P = 6.5\%$; M.I. = 37.0) (Table 2, Fig. 3c). Twelve whales were infected with *C. balaenoptera*, although a significantly larger proportion of the males were infected than were the females ($\chi^2 = 5.08$; $p < 0.05$; d.f. = 1). Few lice were observed before August and a significant difference was observed in the prevalence of *C. balaenopterae* seen in the period April to July and those seen between August to September ($\chi^2 = 13.69$; $p < 0.001$; d.f. = 1).

A single *C. auritum* was found attached to baleen plate on a 7.9 m male minke whale from the northwest coast in August 2005 (Table 2, Fig. 3e). A second, 5.3 m female, minke whale landed off the north coast in September 2003 was infected with a specimen of *P. balaenopterae* onto which four specimens of *C. virgatum* were attached.

Pennella balaenopterae was found anchored into the flesh of 19 minke whales with a maximum intensity of 5 parasites observed on one host ($P = 10.3\%$; M.I. = 1.6). The copepod was recorded in all months that whales were sampled and from all the study areas, no infections were found on the host's head region (Table 2, Fig. 3d). . The barnacle *X. globicipitis* was found firmly attached to the tail flukes on three whales ($P = 1.6\%$; M.I. = 5.3) landed off the south and southwest coasts in July and August in 2005 and 2006 (Table 2, Fig. 3e).

Discussion

Caligus elongatus was found on 11.9% of the minke whales investigated in this study; principally from those landed off the west and north coasts of Iceland. Although *C. elongatus* has been recorded from a wide spectrum of fish hosts in temperate waters (Margolis & Arthur 1979; Kabata, 1992; McDonald & Margolis, 1995; Boxaspen, 2006), the current finding of specimens on minke whales, is to the authors knowledge, the first time these have been found on a cetacean host. Although *Caligus* sp. larvae have been observed on young cod, *Gadus morhua* L., in Icelandic waters (Eydal *et al.*, 2005), detailed information on their distribution on the fish species inhabiting Icelandic waters awaits further examination. *Caligus elongatus* adults, however, are good swimmers and occur in the plankton as well as attached to hosts (Boxhall, 1974; Neilsson *et al.*, 1987 cited in Heuch *et al.*, 2007) Studies on pen reared Atlantic salmon, *Salmo salar* L., and southern bluefin tuna, *Thunnus maccoyii* (Castelnau, 1872), have shown that adult *Caligus* on wild fish that are attracted to the sea cages transfer onto the cage held stock (Tully *et al.*, 1996; Hayward *et al.*, 2008). It is also probable, therefore, that free swimming adult *Caligus* attach to whales rather than infections establishing from larvae attaching to whales. A parallel analysis of the stomach contents of individual whales sampled in the current study, revealed the frequent occurrence of *Caligus* sp. (Víkingsson *pers. comm.*), suggesting that common minke whales may become infected when filter feeding on infected fish. Although some specimens of *C. elongatus* were observed to have material within their guts, suggesting they had recently fed, the source of this material is not known. Stable isotope studies on the gut contents of the *Caligus* specimens

found on whales, however, would help answer whether this material is of whale origin or whether their fate is to starve on the whale host (Schell *et al.*, 2000).

The prevalence and mean intensity of *C. elongatus* on wild fish in southern Norway have been shown to increase from spring to autumn as result of faster development in the warm summer months and formation of multiple generations throughout the summer (Schram *et al.*, 1998; Heuch *et al.*, 2007). This is in line with the higher prevalence of *C. elongatus* observed on the minke whales landed late in the summer in the present study, suggesting the local origin of the infections and real seasonal shifts rather than inter-annual fluctuations due to different sampling distribution between years (see Table 1).

Cyamus balaenopterae was found on all body regions of the minke whale off the west and south coasts in the present study. The species is an obligatory parasite foraging on the whale's skin (Schell *et al.*, 2000) and is found globally on baleen whales (Margolis, 1959; Leung, 1967; Lincoln & Hurley, 1974; Raga & Sanpera, 1986; Kuramochi *et al.*, 2000; Uchida & Araki, 2000). Studies on *C. scammoni*, a related species found on the gray whale (*Eschrichtius robustus* Lilljeborg, 1861), revealed that they have a one year long direct life-cycle (Leung, 1976). The larvae hatch from eggs in autumn, with the young remaining in the female's brood pouch for two to three months. The juveniles were released from the pouch in mid-winter and fastened to the soft skin on the belly or shielded itself from the water current in scars on the host's surface or in the orifices of the cirriped *Cryptolepas rachianecti*. Most of the lice observed in Leung's study had reached maturity in March and possessed a full brood by the time the whales arrived at the summer grounds. The life-cycles of two other *Cyamus* species, *C. kessleri* and *C. ceti*, parasitising gray whales, displayed similar life cycle patterns (Leung, 1976).

The low prevalence of *C. balaenoptera* observed in the early summer months in the present study may suggest that either the appearance and development of *C. balaenopterae*, in Icelandic waters, is later than that of *C. scammoni* or that given the smaller size of *C. balaenopterae* in the early summer they were overlooked, sheltering within pores on the whale, which are preferred sites among Cyamidae species (Berzin & Vlasova, 1982).

A tentative explanation of the significantly larger proportion of male minke infected with *C. balaenoptera* than females in the present study may be due to the different migration routes taken and the geographic segregation of the sexes during the potential period of infection.

Studies of the Antarctic minke whale (*Balaenoptera bonaerensis* Burmeister, 1867) revealed a positive relationship between the occurrence of *C. balaenopterae* and the number of corpora in the ovaries of adult females (Bushuev, 1990). This may be interpreted as increased abundance with larger host size. In the present study, however, there was no significant relationship between lice prevalence and whale body length.

Pennella balaenopterae has a global distribution and is reported on wide range of cetacean species (Margolis & Dailey, 1972; Arvy, 1982; Raga & Sanpera, 1986; Kuramochi *et al.*, 2000). It is the only *Pennella* species parasitising cetaceans whereas other species of the genus are found embedded in the flesh of a wide range of marine hosts (Hogans, 1987). The life-cycle *P. balaenopterae* is poorly understood and only the adult female and the first naupliar stage have been identified with certainty (Hogans, 1987; Arroyo *et al.*, 2002). Observations of the copepod in all months, years and areas of the present study show that the parasite can survive in the colder waters and contradicts Mackintosh and Wheeler (1929) suggesting that the parasite falls off their host during migrations into colder waters.

A single *C. auritum* found attached to the baleen plate of a minke whale landed on the northwest coast in August. This cirripid species is commonly found attached to ships and floating objects in tropic and warm temperate waters indicating that the settlement on whales moving into Icelandic waters occurs during winter migrations at lower latitudes. The higher prevalence of *C. auritum* observed on female, rather than male, sperm whales in the south Pacific further indicates that they are picked up in warmer water. Part of the sperm whale males migrate to higher latitudes whereas the females remain in waters below a latitude of 40° all year around (Clarke, 1966). *Conchoderma auritum* rarely attaches directly to the skin of cetaceans and is mainly reported to be epizoic on hard surfaces including sessile *Coronula* barnacles, and occasionally on the teeth and baleen plates of whales (Clarke, 1966; Christensen, 1986). Most *C. auritum*, therefore, are reported from humpback whales carrying settlements of *Coronula* spp. Other baleen

whales appear to be rare hosts for *C. auritum* and there is only one previous record of this barnacle attaching to a minke whale, where a cluster of *C. auritum* was observed attached to the damaged baleen plates of a minke whale caught off the coast of East Greenland in 1984 (Christensen, 1986). The study, however, found no *C. auritum* infection on the 1317 minke whales that were examined from the North Atlantic over the period 1972 to 1984, further emphasizing the rarity of these incidences. In addition, very low prevalences of *C. auritum* on blue, *Balaenoptera musculus* (L.), fin, *Balaenoptera physalus* (L.), and sei, *Balaenoptera borealis* Lesson, 1828, whales have been reported (see Clarke, 1966).

In the current study, four *C. virgatum* were found attached to a single *Pennella* on a minke whale off the north coast. The barnacle is found attached to flotsam and on ships, as a hyperepizoic on *Pennella* or on the stalked barnacle *C. auritum* and has been reported from several large whale species, including minke whales (Clarke, 1966). The distribution of *C. virgatum* is circum-global in tropical and subtropical waters and its occurrence on whales in colder areas may be explained by migration from warmer seas. The finding of *C. virgatum* on whales late in the feeding season in the colder waters off the north coast of Iceland in the present study suggests that the barnacle may survive in the colder waters. The completion of its life-cycle though is most likely restricted to warmer areas.

The barnacle *X. globicipitis* has been reported from a number of cetacean species inhabiting tropical to temperate waters (Rajaguru & Shantha, 1992; Karuppiyah *et al.*, 2004; Kane *et al.*, 2008). This barnacle species is typically found attached to the trailing edge of cetacean flukes and fins; its morphology is well adapted to the strong currents generated by the swimming movements of its host (Orams & Schuetze, 1998; Berland *et al.*, 2003). The average swimming speed of the host does not appear to be a factor affecting barnacle settlement, whereas diving to great depths may reduce settlement of the larvae (Kane *et al.*, 2008).

Attempts have been made to use *X. globicipitis* as a biological tag to trace migration routes and the delineation of host populations. Spatial differences in the prevalence of *X. globicipitis* on Antarctic minke whales examined in summer, suggests that these whales also have separate winter grounds where the exposure to the barnacle is different (Bushuev, 1990). A study on Mediterranean striped dolphins, *Stenella*

coeruleoalba (Meyen, 1833), concluded that an increased prevalence of *X. globicipitis* on certain individuals was due a viral epizootic in the population predisposing individuals to infection (Aznar *et al.*, 1994; Aznar *et al.*, 2005). Previous records of the species from Greenland and Finnmark in northern Norway (Rajaguru & Shantha, 1992) together with the present study probably represent the northern limits of their distribution in the North Atlantic. These northern records were all from balaenopterid hosts that most likely carried the barnacle from winter grounds at lower altitudes.

Kane *et al.* (2008) commented that ocean productivity and therefore the availability of feed for filter feeding barnacle species like *X. globicipitis* may cause spatial variation in their distribution. More information on the host selection criteria, environmental tolerance limits and early life history strategies is needed to determine the utility of *X. globicipitis* as a biological tag for cetaceans.

Petromyzon marinus is the only lamprey species reported in Icelandic waters (Jónsson & Pálsson, 2006). It attaches to the surface of its host using an array of small teeth and burrows into the skin using a rasping tongue which can create an open lesion in the skin that leaves a pale scar when it heals (Pike, 1951). Both the fresh and old scars seen on the minke skin, therefore, can be attributed to the activity of this one fish species. The distribution of *P. marinus* is limited to temperate waters in the North Atlantic and until recently, findings of this fish in Icelandic waters were rare (Jónsson & Pálsson, 2006). An unusual abundance of free swimming lampreys, however, were noted in southwest Iceland in 2004 (Hjartarson & Ólafsdóttir, 2005) and lesions on salmonid fish in south Icelandic rivers have increased in recent years (Jónsson & Jóhannsson, 2008). A photo-identification based study on killer whales, *Orcinus orca* L., inhabiting the waters around the Vestmannaeyjar archipelago to the south of Iceland in July 2009, found two *P. marinus* attached to whales and the presence of shallow marks suggesting other attachment events (Samarra *et al.*, 2012). Re-sightings of the same individuals showed, evidently, that the attachments were of local origin and that the shallow marks were not permanent. Working through the photo-ID catalogue of whales in the area dating back to 1980, revealed no indication of lamprey marks in previous years. The finding of lampreys on minke whales, in the current study, relatively late in the summer further suggest that *P.*

marinus can survive in the area and do not fall off their host during migration to the summer grounds, at least in the warmer waters off the south and southwest coasts.

The apparent change in distribution of *P. marinus* in recent years is presumably related to rising sea temperatures (Ástþórsson & Pálsson, 2006), however, there is no evidence to suggest that lampreys complete their life-cycle in Iceland by spawning in Icelandic freshwaters (Jónsson & Jóhannsson, 2008).

Mackintosh and Wheeler (1929) assumed that epizoid barnacles and *Pennella* fell off their hosts as they migrated into colder waters. The low prevalence of these epizoids observed in the present study prevents any firm conclusions being drawn. *Pennella balaenopterae* was found on minke whales that were landed in each month although the barnacles were found relatively late in the season; *C. virgatum* in mid-September, *C. auritum* in August, *X. globicipitis* in late July and August. This shows that at least some epizoid barnacles stay attached on the whale host throughout the feeding season in Icelandic waters. Lack of information on the epizoid species found on minke whales from the winter grounds prevents a comparison with those found on whales in the summer grounds and, therefore, a concluding statement on whether the observed low prevalences in Icelandic waters are due to unfavourable conditions that are fatal to the barnacles.

The long term impact of increased sea temperatures as observed in the world's oceans in recent years and projected subsequent rise in the near future (Bindoff *et al.*, 2007) on the biota in the northern North Atlantic is an unknown. Potential future changes in the epibiotic macrofauna on common minke whales may indicate the altered migration route of the host population or alterations to the survival rate of the epizoid species.

Acknowledgements

This study forms part of a comprehensive research programme on the ecology and biology of minke whales in Icelandic waters. The programme was granted a special permit to sample up to 200 minke whales by the government of Iceland according to article VIII of the Convention of the International Whaling Commission (IWC). All details of the survey described comply with the current laws of the Republic of Iceland. The authors would like to thank Mr Gísli A. Víkingsson at the Marine Research Institute,

Iceland who kindly gave access to unpublished information on the stomach contents of common minke whales.

Authors' contributions

DO made all the sample collections, analysed the data and wrote the initial draft. APS subsequently identified the *Caligus elongatus* and *Udonella caligorum* specimens, intellectually supported the study and corrected the manuscript drafts. Both authors read and approved the final manuscript.

References

- Araki, J., Machida, M., Nagasawa, K., Kuramochi, T. & Uchida, A. (1997) A note on the parasite fauna of the western North Pacific minke whale (*Balaenoptera acutorostrata*). *Reports from the International Whaling Commission*, **47**, 565-569.
- Arroyo, N.L., Abuanza, P. & Preciado, I. (2002) The first naupliar stage of *Pennella balaenopterae* Koren and Danielssen, 1877 (Copepoda: Siphonostomatoida, Pennellidae). *Sarsia*, **87**, 333-337.
- Arvy, L. (1982) Phoresies and parasitism in cetaceans: a review. In: Pilleri, G. (ed.) *Investigations on Cetacea*, **14**, 233-335.
- Ástþórsson, Ó.S. & Pálsson, J. (2006) New fish records and records of rare southern fish species in Icelandic waters in the warm period 1996–2005. *ICES, Copenhagen, CM 2006/CM20*, 22 pp.
- Aznar, F.J., Balbuena, J.A. & Raga, J.A. (1994) Are epizoites biological indicators of a western Mediterranean striped dolphin die-off? *Diseases of Aquatic Organisms*, **18**, 159-163.
- Aznar, F.J., Perdiguero, D., del Olmo, A.P., Repulles, A., Agusti, C. & Raga, J.A. (2005) Changes in epizoic crustacean infestations during cetacean die-offs: the mass mortality of Mediterranean striped dolphins *Stenella coeruleoalba* revisited. *Diseases of Aquatic Organisms*, **67**, 239-247.
- Balbuena, J.A. & Raga, J.A. (1991) Ecology and host relationships of the whale-louse *Isocyamus delphini* (Amphipoda: Cyamidae) parasitizing long-finned pilot whales (*Globicephala melas*) off the Faroe Islands (Northeast Atlantic). *Canadian Journal of Zoology*, **69**, 141-145.

Balbuena, J.A., Aznar, F.J., Fernández, M. & Raga, J.A. (1995) Parasites as indicators of social and stock identity of marine mammals. In: Blix, A.S., Walløe, L. & Ulltang, Ö. (eds.) *Whales, Seals, Fish and Man*. Elsevier Science, pp. 133-139.

Berland, B., Krakstad, J-O., Nöttestad, L., Axelsen, B.E., Vaz-Velho, F. & Bauleth-D'Almeida, G. (2003) *Xenobalanus globicipitis* (Crustacea: Cirripedia) on dusky dolphins (*Lagenorhynchus obscurus*) off Namibia: Hitch-hiker's guide to the seas. *Proceedings of the 15th Biennial Conference on the Biology of Marine Mammals, Dec. 14-19, 2003, Greensboro, NC, USA*.

Berzin, A.A. & Vlasova, L.P. (1982) Fauna of the Cetacea Cyamidae (Amphipoda) of the World Ocean. *Investigations on Cetacea*, **13**, 149-164.

Bindoff, N.L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S., Hanawa, K., Le Quéré, C., Levitus, S., Nojiri, Y., Shum, C.K., Talley, L.D. & Unnikrishnan, A. (2007) Observations: oceanic climate change and sea level. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, H.L. (Eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Boxaspen, K. (2006) A review of the biology and genetics of sea lice. *Journal of Marine Science*, **63**, 1304-1316.

Boxshall, G.A. (1974) Infections with parasitic copepods in North Sea marine fishes. *Journal of the Marine Biological Association of the UK*, **54**, 355-372.

Bush, A.O., Lafferty, K.D., Lotz, J.M. & Shostak, A.W. (1997) Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology*, **83**, 575-583.

Bushuev, S.G. (1990) A study of the population structure of the southern minke whale (*Balaenoptera acutorostrata* Lacépède) based on morphological and ecological variability. *Reports from the International Whaling Commission*, **40**, 317-324.

Christensen, I. (1986) First record of gooseneck barnacles (*Conchoderma auritum*) on a minke whale (*Balaenoptera acutorostrata*). *Fauna Norvegica, Ser. A*, **7**, 15-16.

Clarke, R. (1966) The stalked barnacle *Conchoderma*, ectoparasitic on whales. *Norsk Hvalfangsttid*, **55**, 153-168.

Dailey, M.D. & Brownell Jr., R.L. (1972) A checklist of marine mammal parasites. In: Ridgway, S.H. (ed.) *Mammals of the Sea, Biology and Medicine*. Chapter 9. Charles C. Thomas Publ., Springfield, pp. 528-589.

Eydal, M., Helgason, S., Kristmundsson, Á. & Bambir, S.H. (2005) Species parasitizing young Atlantic cod *Gadus morhua* in Icelandic waters. *Bulletin of the Scandinavian-Baltic Society for Parasitology*, **14**, 55-56.

Hallas, S. (1868) Optegnelser om nogle paa et hvalfangst-tog i havet omkring Island iagttagne hvaler. *Videnskabelige Meddelelser Dansk Naturhistorisk Forening*, **1**, 150-177.

Hayward, C.J., Aiken, H.M. & Nowak, B.F. (2008) An epizootic of *Caligus chistos* on farmed southern bluefin tuna *Thunnus maccoyii* off south Australia. *Diseases of Aquatic Organisms*, **79**, 57-63.

Heuch, P.A., Øines, Ø., Knutsen, J.A. & Schram, T.A. (2007) Infection of wild fishes by the parasitic copepod *Caligus elongatus* on the south east coast of Norway. *Diseases of Aquatic Organisms*, **77**, 149-158.

Hjartarson, Á. & Ólafsdóttir, D. (2005) Náttúrufarsannáll 2004. *Náttúrufræðingurinn*, **73**, 119-123.

Hogans, W.E. (1987) Morphological variation in *Pennella balaenopterae* and *P. filosa* (Copepoda: Pennellidae) with review on the genus *Pennella* Oken, 1816 parasitic on Cetacea. *Bulletin of Marine Science*, **40**, 442-453.

Jónsson, B. & Jóhannson, M. (2008) Research on settlement of sea lamprey (*Petromyzon marinus*) in Iceland [Rannsóknir á landnámi sæsteinsuga (*Petromyzon marinus*) á Íslandi]. Institute of Freshwater Fisheries, Iceland, Reykjavik, VMST/08019, 11 pp. [In Icelandic]

Jónsson, G. & Pálsson, J. (2006) Icelandic fishes [Íslenskir fiskar]. Vaka-Helgafell, Reykjavik, 336 pp. [In Icelandic]

Kabata, S. (1992) *Copepods Parasitic on Fishes: Keys and Notes for Identification of the Species*. Linnean Society, London. 264 pp.

Kane, E.A., Olson, P.A., Gerrodette, T. & Fiedler, P.C. (2008) Prevalence of the commensal barnacle *Xenobalanus globicipitis* on cetacean species in the eastern tropical Pacific Ocean, and a review of global occurrence. *Fisheries Bulletin*, **106**, 395-404.

Karuppiah, S., Subramanian, A. & Obbard, J.P. (2004) The barnacle *Xenobalanus globicipitis* (Cirripedia, Coronulidae), attached to the bottle-nosed dolphin, *Tursiops truncatus* (Mammalia, Cetacea) on the Southeastern coast of India. *Crustaceana*, **77**, 879-882.

Kuramochi, T., Araki, J., Uchida, A., Moriyama, N., Takeda, Y., Hayashi, N., Wakao, H., Machida, M. & Nagasawa, K. (2000) Summary of parasite epizoot investigations during JARPN surveys 1994-1999, with reference to stock structure analysis for the western North Pacific minke whales. Paper SC/F2K/J19 presented to the IWC Scientific Committee Workshop to review Japanese whale research programme under special permit for North Pacific minke whales (JARPN), Tokyo, 7-10 February 2000 (unpublished).

Leung, Y.M. (1967) An illustrated key to the species of whale-lice (Amphipoda, Cyamidae), ectoparasites of Cetacea, with a guide to the literature. *Crustaceana*, **12**, 279-291.

Leung, Y.M. (1976) Life-cycle of *Cyamus scammoni* (Amphipoda: Cyamidae), ectoparasite of gray whale, with remark on the associated species. *The Scientific Reports of the Whales Research Institute*, **28**, 153-160.

Lincoln, R.J. & Hurley, D.E. (1974) Catalogue of the whale-lice (Crustacea: Amphipoda: Cyamidae) in the collections of the British Museum (Natural History). *Bulletin of the British Museum of Natural History (Zool.)*, **27**, 65-72.

Mackintosh, A.A. & Wheeler, J.F.G. (1929) Southern blue and fin whales. *Discovery Reports*, **1**, 257-540.

Margolis, L. (1959) Records of *Cyamus balaenopterae* Barnard and *Neocyamus physteris* (Pouchet), two species of whale-lice (Amphipoda), from the Northeast Pacific. *Canadian Journal of Zoology*, **37**, 895-897.

Margolis, L. & Arthur, J.R. (1979) Synopsis of the parasites of fishes of Canada. *Bulletin of the Fisheries Research Board of Canada*, **199**, 1-269.

Margolis, L. & Dailey, M.D. (1972) Revised annotated list of parasites from sea mammals caught off the west coast of North America. NOAA, Seattle, WA, SSRF-647, 24 pp.

McDonald, T.E. & Margolis, L. (1995) Synopsis of the parasites of fishes of Canada: Supplement (1978-1993). *Can. Spec. Publ. Fish. Aquat. Sci.*, **122**, 1-265

Measures, L.N. (1993) Annotated list of metazoan parasites reported from the blue whale, *Balaenoptera musculus*. *Journal of the Helminthological Society of Washington*, **60**, 62-66.

Mignucci-Giannoni, A., Hoberg, E., Siegel-Causey, D. & Williams, J.E.H. (1998) Metazoan parasites and other symbionts of cetaceans in the Caribbean. *Journal of Parasitology*, **84**, 939-946.

MRI (2003) A programme for a two year feasibility study on cetaceans in Icelandic waters. Paper SC/55/O2-revised, presented to the IWC Scientific Committee, Berlin, May 2003, 1-63 (unpublished).

Orams, M.B. & Schuetze, C. (1998) Seasonal and age / size-related occurrence of a barnacle (*Xenobalanus globicipitis*) on bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal Science*, **14**, 186-189.

Piasecki, W. & MacKinnon, B.M. (1995) Life-cycle of a sea louse, *Caligus elongatus* von Nordmann, 1832 (Copepoda, Siphonostomatoida, Caligidae). *Canadian Journal of Zoology*, **73**, 74-82.

Pike, G.C. (1951) Lamprey marks of whales. *Journal of the Fisheries Research Board of Canada*, **8** (4), 275-280.

Raga, J.A. & Sanpera, C. (1986) Ectoparasitos y epizoitos de *Balaenoptera physalus* (L., 1758) en aguas Atlánticas Ibericas. *Investigacion Pesquera*, **50**, 489-498.

Raga, J.A. (1994) Parasitismus bei den Cetacea. In: Robineau, D., Duguy, R. & Klima, M. (eds.) *Handbuch der Säugertiere Europas. Teil IA: Wale und Delphine I*. Chapter A12. Aula-Verlag, Wiesbaden, pp. 132-179

- Raga JA, Petter AJ, Duguy R (1987) Catalogue des parasites de Cetaces des collections du musee oceanograpique de La Rochelle. *Bulletin du Muséum National d'Histoire Naturelle. Section A, Zoologie, Biologie et Écologie Animales*, **9**, no.1, 159-168.
- Rajaguru, A. & Shantha, G. (1992) Association between the sessile barnacle *Xenobalanus globicipitis* (Coronulidae) and the bottlenose dolphin *Tursiops truncatus* (Delphinidae) from the Bay of Bengal, India, with a summary of previous records from cetaceans. *Fisheries Bulletin*, **90**, 197-202.
- Rice, D.W. (1998) Marine mammals of the world, systematics and distribution. *Special Publications of the Society for Marine Mammalogy*, **4**, 231 pp
- Samarra, F.I.P., Fennell, A., Aoki, K., Deecke, V.B. & Miller, P.J.O. (2012) Persistence of skin marks on killer whales (*Orcinus orca*) caused by the parasitic sea lamprey (*Petromyzon marinus*) in Iceland. *Marine Mammal Science*, **28** (2), 395–401.
- Schell, D.M., Rowntree, C.J. & Pfeiffer, C.J. (2000) Stable-isotope and electron-microscope evidence that cyamids (Crustacea: Amphipoda) feed on whale skin. *Canadian Journal of Zoology*, **78**, 721-727.
- Schram, T.A., Knutsen, J.A., Heuch, P.A. & Mo, T.A. (1998) Seasonal occurrence of *Lepeoptheirus salmonis* and *Caligus elongatus* (Copepoda: Caligidae) on sea trout (*Salmo trutta*), off southern Norway. *ICES Journal of Marine Science*, **55**, 163-175.
- Sigurjónsson, J. & Víkingsson, G.A. (1997) Seasonal abundance of and estimated food consumption by cetaceans in Icelandic and adjacent waters. *Journal of Northwest Atlantic Fisheries Science*, **22**, 271-287.
- Stephensen, K. (1940) Parasitic and semiparasitic Copepoda. *The Zoology of Iceland*, **3** (34), 1-34.

Tully, O., Daly, P., Lysaght, S., Deady, S. & Varian, S.J.A. (1996) Use of cleaner-wrasse (*Centrolabrus exoletus* (L.) and *Ctenolabrus rupestris* (L.)) to control infestations of *Caligus elongatus* Nordmann on farmed Atlantic salmon. *Aquaculture*, **142**, 11-24.

Uchida, A. & Araki, J. (2000) The ectoparasites and endoparasites in the minke whale, *Balaenoptera acutorostrata* from the western north Pacific Ocean. *Journal of the Japan Veterinary Medical Association*, **53**, 85-88.

Víkingsson, G.A. & Heide-Jørgensen, P.P. (2005) A note on the movements of minke whales tracked by satellite in Icelandic waters in 2001-2004. IWC SC/57/O9, 3pp.

Table 1. Spatial and temporal distribution of the common minke whales (*Balaenoptera acutorostrata* Lacépède, 1804) (n = 185) examined in the current study for their epibiotic macrofauna during their summer migrations in Icelandic waters over the period 2003 to 2007.

Years	2007	2007	2004, 2006, 2007	2004, 2005, 2006, 2007	2003, 2005, 2006, 2007	2003, 2007	
Months	April	May	June	July	August	September	Total
1		3	8	11	17	7	46
2	3	1	4	6	13	3	30
3			7	5	2		14
4			8	4	2	1	15
Geographic areas†	5		4	4	2	1	11
6		2	7	6	6	2	23
8				2	1		3
9		1	2	14	8	2	27
10			9	1	4	2	16
Total	3	7	49	53	55	18	185

†Geographic areas are detailed in Figure 3a.

8 Table 2. Infection statistics for the ectoparasites and epizootics recovered from one lateral flank and one fluke of each common minke
 9 whale (*Balaenoptera acutorostrata* Lacépède, 1804) (n = 185) landed in Icelandic waters during the period April to September 2003-
 10 2007.

				Regression of body length against ln (intensity)		Chi test prevalence on females vs. males (df = 1)		Chi test prevalence in April- July vs. Aug-Sep. (df = 1)	
	Habitat†	P (%)	M.I	r	p	χ^2	p	χ^2	P
Phylum Arthropoda									
Fam. Caligidae									
<i>Caligus elongatus</i>	all	11.9	95.5	0.23	0.32	1.45	0.23	28.88	<0.001
Fam. Pennellidae									
<i>Pennella balaenopterae</i>	B, C, fluke	10.3	1.6	-	-				
Fam. Cyamidae									
<i>Cyamus balaenopterae</i>	all	6.5	37.0	0.19	0.59	5.08	0.02	13.69	<0.001
Fam. Lepadidae									
<i>Conchoderma virgatum</i>	B, C (*)	0.5	4.0	-	-				
<i>Conchoderma auritum</i>	A (baleen plate)	0.5	1.0	-	-				
Fam. Coronulidae									
<i>Xenobalanus globicipitis</i>	fluke	1.6	5.3	-	-				
Phylum Chordata									
Fam. Petromyzontidae									
<i>Petromyzon marinus</i> attached	B, C	2.7	1.0	-	-				
<i>P. marinus</i> fresh scars	B, C	10.7	na						
<i>P. marinus</i> old scars	A, B, C	42.6	na						
Class Monogenea									
Fam. Udonellidae									
<i>Udonella caligorum</i> **	all	10.4	3.9						

11 Abbreviations: M.I., mean intensity; p, probability; P, prevalence; r, regression coefficient; χ^2 , chi.

12 †For a description of the “Habitat” regions see Figure 1; * Attached to *P. balaenopterae*; ** Infection statistics on *C. elongatus* based on the microscopic
 13 evaluation of a sub-sample of 335 *C. elongatus*.

Figures

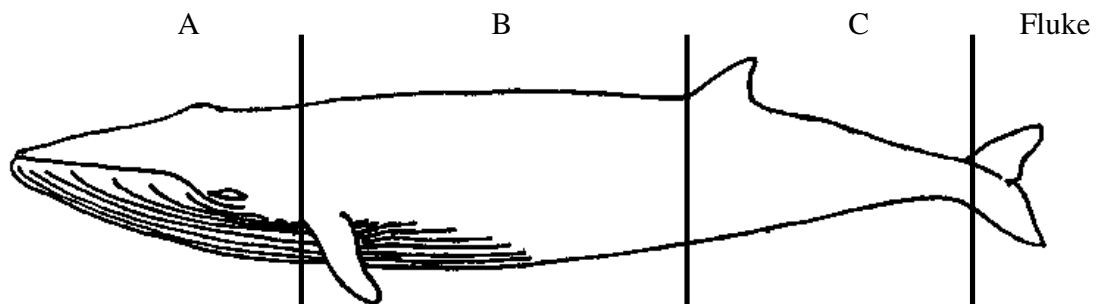


Figure 1. Division of the common minke whale's, *Balaenoptera acutorostrata* Lacépède, 1804, body into zones used for the epibiotic macrofauna study.

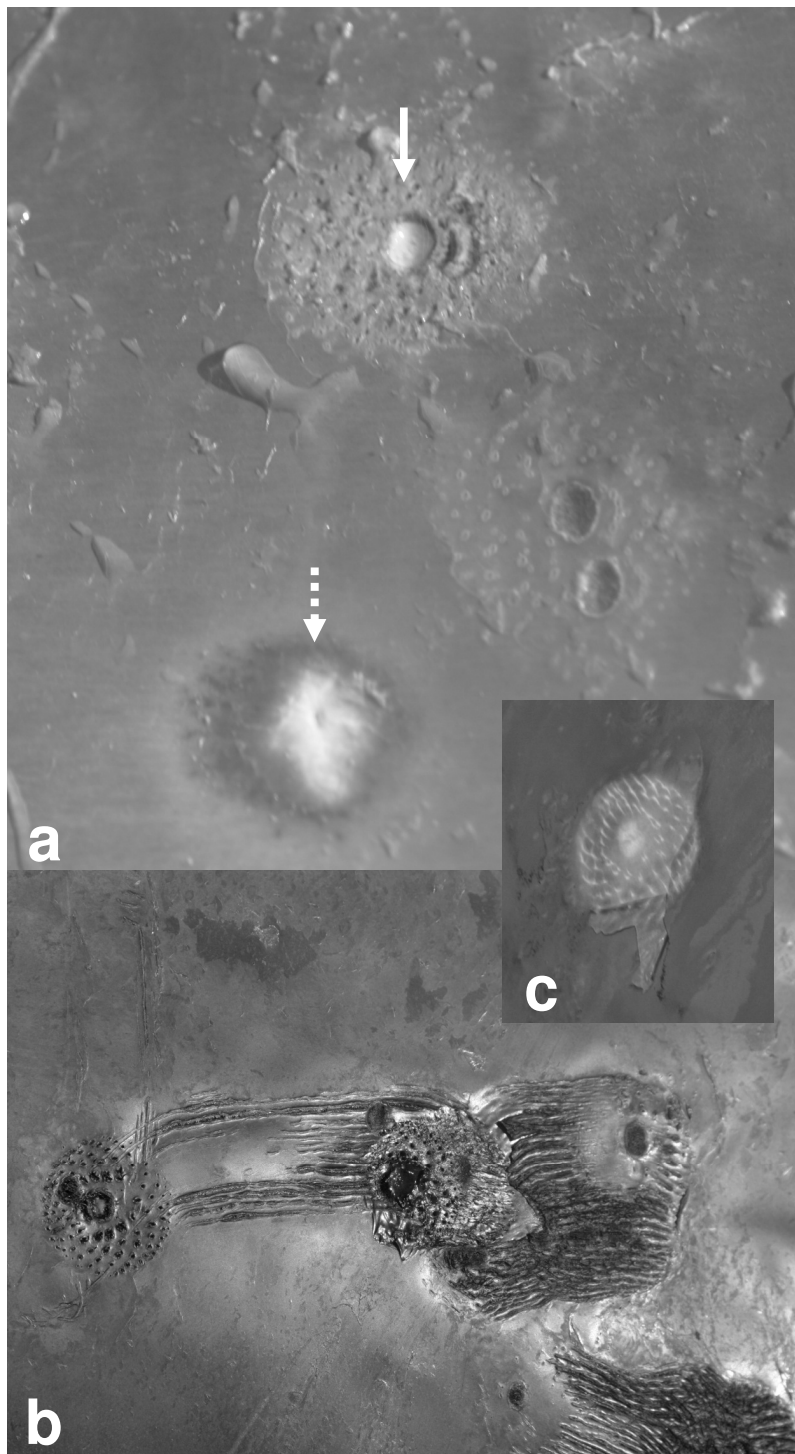
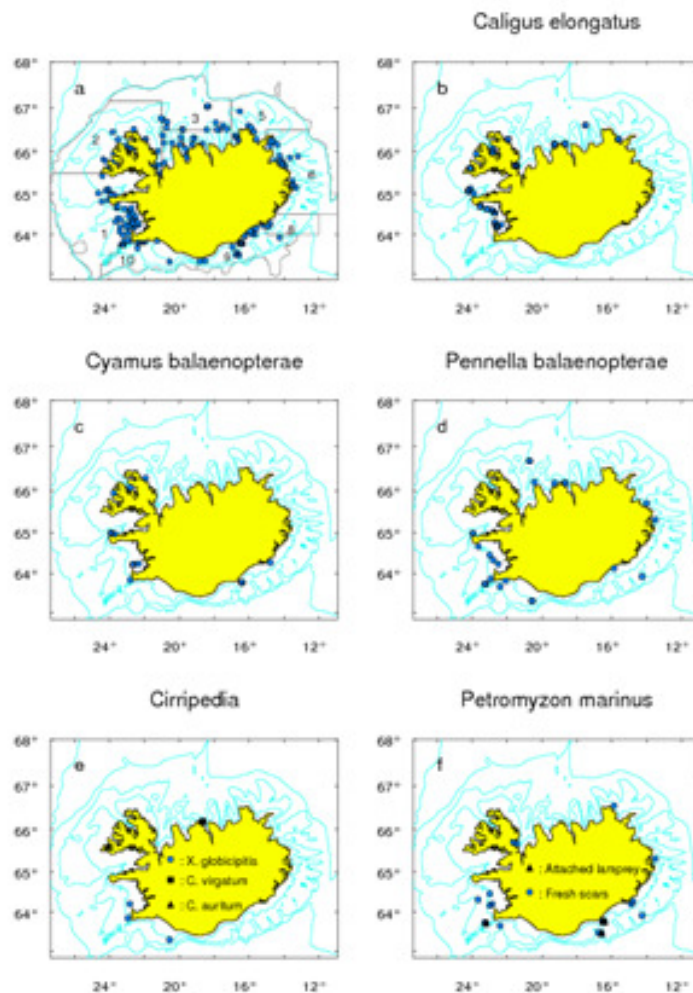


Figure 2. Lamprey, *Petromyzon marinus* L., scars on the skin of common minke whales, *Balaenoptera acutorostrata* Lacépède, 1804. a) Recent (solid arrow) and old (dotted arrow) feeding wounds; b) dentition marks and scores left in the skin left by an attached lamprey; c) dentition pattern following the removal of a live lamprey.



26
 27 Figure 3. Maps of Iceland showing the landing point of each common minke whale
 28 (*Balaenoptera acutorostrata* Lacépède, 1804) that was examined for their epibiotic
 29 macrofauna (a) and for each epibiot that was subsequently found; b) *Caligus elongatus*
 30 von Nordmann, 1832, c) *Cyamus balaenopterae* Barnard, 1931, d) *Pennella*
 31 *balaenopterae* Koren et Danielsson, 1877; e) cirriped barnacles; and, f) sites where
 32 whales that were landed had either live lampreys, *Petromyzon marinus* L., attached or
 33 bore fresh lamprey scars.