EFFECTS OF PARASITES ON MARINE MAMMALS

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INTRODUCTION

Parasites of marine mammals have been the focus of numerous reports dealing with taxonomy, distribution and ecology (Defyamure, 1955). Descriptions of associated tissue damage are also available, with attempts to link severity of disease with morbidity and mortality of individuals and populations. This paper is not intended to duplicate that literature. Instead we focus on those organisms which we perceive to be pathogenic, while tempering some of the more exaggerated interpretations.

We deal with life cycles by emphasizing unusual adaptations of selected organisms, and have necessarily limited our selection of the literature to highlight that theme. For this discussion we address the parasites of cetaceans—baleen whales (mysticetes), and toothed whales, dolphins and porpoises (odontocetes); pinnipeds—true seals (phocids), fur seals and sea lions (otariids) and walruses (odobenids); sirenians—manatees and dugongs, and the diminutive sea otter.

ECTOPARASITES

We use the term “ectoparasite” loosely, when referring to organisms ranging from algae to fish which somehow cling to the surface of a marine mammal, and whose mode of attachment, feeding behavior, and relationship with the host or transport animal are sufficiently obscure that the term parasite cannot be excluded. What is clear is that these organisms damage the integument in some way.

For example, a whale entering the cold waters of the Antarctic can acquire a yellow film over its body. Blue whales so discolored are known as “sulfur bottoms”. The organisms responsible are diatoms, principally morphs of Cocconeis ceticoia and Navicola spp. (Hart, 1935) which attach to the surface by innocuous sucker-like valves, but on occasion penetrate the epidermis and become saprophytic (Hart, 1935). The film is shed when the whales return to warmer waters.

Several arthropods also injure the integument of whales by burrowing to secure firm anchorage. Such are the sessile barnacles (Cirripedia) Coronula diadema and Cryptolepas rhachianecti which attach so deeply onto their respective hosts, the humpback whales, Megaptera novaeangliae, and gray whales, Eschrichtius gibbosus (Andrews, 1914; Clarke, 1966), that when the organisms are shed or removed, a pit remains which eventually becomes a scar (Scheffer, 1939). Similarly, aberrant sessile barnacles, Xenobalanus globicipitis, burrow deeply in odontocetes, leaving characteristic star-shaped scars (Bane & Zullo, 1980). They align in such a way along the trailing edges of fins and flukes, that host dolphins long ago became known as “tassle-fins” (True, 1891).

An equally decorative, but more serious tissue-invader is Penella balaeopteridarum (family Pennellidae), one of the largest parasitic copepods. It penetrates the skin of mysticetes and anchors within the blubber (Clarke, 1966). The attachment is so “clean” as to be envied by population biologists seeking to devise a permanent percutaneous mark for whales.

Whale lice (Amphipoda: Cyamidae) are less ornamental, and in fact are among the more unsightly surface dwellers. Those of odontocetes are cosmopolitan, while on mysticetes they are more host-specific (Leung, 1970). Cyamids reside in fissures and crevices, around sessile barnacles, and on the callosities on the heads of right whales, (Leung, 1976; Scheffer, 1939). They are assumed to graze on algae, and probably ingest exfoliating epidermal cells as well (Leung, 1976).

Marine mammals are also parasitized by more conventional lice and mites. Sucking lice belonging to the
family Echinophtheridae (Siphunculata: Anopleura) concentrate on the head, neck, and flippers of pinnipeds (Kim, 1972), causing little more than mild irritation (Fay, 1982). Transmission of lice, and reproduction on the host occur when seals are out of water (Murray, 1964). Thus, heavy infestations provide a clue that seals have spent an inordinate amount of time on land—a behaviour normally associated with illness. Not surprisingly then, we find heavy infestations of *Echinophthirius horridus* associated with poor body condition in harbor seals, *Phoca vitulina*. Quite apart from any direct effect, *E. horridus* can also serve as an intermediate host of the heartworm *Dipetalonema spirocauda* (Geraci, Fortin, St. Aubin & Hicks, 1981).

Mites (*Demodex* sp.) can cause mange-like lesions in captive California sea lions, *Zalophus californianus* (Nutting & Dailey, 1980). As in other species, the clinical condition may be an expression of lowered immune function associated with the captive environment of the host. No similar infections have been noted in the wild.

By far the largest organisms that attach to the surface of marine mammals are fish. Whalesuckers, *Remilegia australis*, are obligate commensals (Rice & Caldwell, 1961), which can fasten firmly enough to withstand the aerobatics of spinner dolphins, *Stenella longirostris*, and leave oval lesions in the host’s epidermis. Whalesuckers typically do not feed on host tissue, though Rice and Caldwell (1961) found epidermal tissue in the stomachs of two specimens. Lampreys, *Entosphenus tridentatus*, on the other hand rely on cetacean skin as a source of nutrients. Attached by the teeth of its sucking disc, the lamprey uses a rasping tongue to abrade the epidermis down to the blubber (Pike 1951). As such, it can be regarded as the most voracious marine mammal parasite.

**Protozoa**

Internal parasites of marine mammals tend to be less specialized to the marine environment than those which colonize the surface. While their location and pathogenicity may be more predictable, their life cycles are generally obscure, if not enigmatic. An example can be drawn from sarcosporidians which infect muscle tissues of pinnipeds (Migaki & Albert, 1980) and cetaceans (Akao, 1970). On land, infection with this parasite requires that the animal consume fecal sporocysts of the genus *Sarcocystis*. Yet no sexual stages of *Sarcocystis* are reported from marine organisms, and only *Eimeria* sp. are known from marine mammals (Hsu, Melby & Altman, 1974; Lainson, Naiff, Best & Shaw, 1983). Marine bird droppings contain *Isospora*-type oocysts which may prove to be those of *Sarcocystis* sp. (Pellerdy, 1974), but any proposed transmission in and out of a seal or whale would require still unexplained feeding patterns.

Equally curious is the finding of toxoplasma-like organisms in a harbor seal, *Phoca vitulina*, which had never contacted feral or domestic felids, or their fecal material (Van Pelt & Dieterich, 1973). The seal, taken from the wild as a newborn pup, was thought to have acquired the organism through the placenta. Still unresolved is the source of the original infection in the mother.

An unusual adaptation is that of free-living holotrich ciliates in the upper respiratory tract of bottlenose dolphins, *Tursiops truncatus* (Woodard, Zam, Caldwell & Caldwell, 1969). Dolphins along the Florida coast harbor these protozoa, apparently without ill effect. Under certain conditions, the organism can invade the lung and result in pneumonia. As far as we know, this is the only facultative endoparasite of marine mammals.

**Arthropods**

Normally associated with the exterior surface of marine mammals, arthropods also parasitize the nasal passages, trachea, and bronchi of pinnipeds. Nasal mites (*Acarina: Gamasidae*) of the genus *Halarachne* infest phocid seals (Arundel, 1978) and occasionally sea otters, *Enhydra lutris* (Kenyon, Yunker & Newell, 1965); the genus *Orthohalarachne* is found in otariids and walruses, *Odobenus rosmarus* (Kim, Haas & Keyes, 1980; Fay & Furman, 1982). Mites can cause enough damage to mucous membranes to affect an animal’s health adversely. Paroxysmal coughing and nasal contact transmit motile larvae concentrated in the anterior portions of the airways (Kim *et al.*, 1980). Adult mites anchor to mucosal surfaces and, unlike sucking lice, cannot survive outside the moist environment of their host. They are truly endoparasites.

**Cestodes**

Marine mammals host adult and larval stages of cestodes. Infections with mature pseudophyllideans, principally *Diphyllobothrium* sp., are usually innocuous (Arundel, 1978), but in extreme circumstances can result in debilitation and death of the host. The parasites can encyst in the colonic wall, or as a mass weighing more than 1 kg, can obstruct the lumen of the gut (Cordes & O’Hara, 1979).
Larval tetraphyllideans of the genera *Phyllobothrium* and *Monorygma* are distributed ubiquitously among cetaceans and pinnipeds (Testa & Dailey, 1977). The parasites are presumed to complete their life cycle in sharks (Delyamure, 1955), which either prey on marine mammals (Wood, Caldwell & Caldwell, 1970), or consume their remains (Clarke & Merrett, 1972). *Phyllobothrium* larvae encyst in blubber; those of *Monorygma* localize in abdominal musculature or append to viscera. Their concentration in abdominal tissues (Geraci, Testaverde, St. Aubin & Loop, 1978) probably reflects migration from the gut, and offers some advantage in transmission to sharks, which show a predilection for attacking this vulnerable area.

The unusual finding of larval stages of *Taenia solium* in a Cape fur seal, *Arctocephalus pusillus*, signals exposure to human fecal material, perhaps indirectly by consumption of a fish which had recently fed on a gravid proglottid (De Graaf, Shaughnessy, McCully & Verster, 1980). Alternatively, the seal might have been infected by feeding on contaminated invertebrates or carrion.

**Acanthocephala**

*Botbosoma* and *Corynosoma* are two of the principal genera (subfamily Corynosomatinae) of acanthocephalans which localize in the intestine of marine mammals (Arundel, 1978; Golvan, 1959). The worms cause little more than local irritation with occasional ulceration at the site of attachment, and are usually of little pathological significance despite the occurrence in some hosts of thousands of parasites. Heavy infestations in sea otters (*Enhydra lutris*) have been associated with ulceration and perforation of the intestinal wall (Morejohn, Ames & Lewis, 1975).

**Digenea**

Digeneans parasitize the gastrointestinal system of marine mammals, and also the nasal and cranial sinuses of small cetaceans. Within the lumen of the gut or in nasal passages, they have little impact on the host, but within the parenchyma of organs. They can be destructive. In the extreme, errant migrants from the cranial sinuses somehow reach the brain, leading inevitably to the death of infected dolphins.

Throughout the gastrointestinal system, digeneans have adapted to a broad spectrum of microenvironments. One of the more interesting is *Labicola elongata* (Monostromata: Labicolidae) which resides in abscesses in the upper lip of dugongs, *Dugong dugon* (Blair, 1979). Tracts connecting the abscesses to the labial mucosa presumably allow for the release of ova. Further along the alimentary canal, other digeneans form similar cysts in the walls of the stomach and intestine. *Braunina cordiformis* (Strigeata: Brauninidae) attaches to the lining of the second and third stomach compartments of odontocetes, and becomes nearly enveloped by an outgrowth of vascularized connective tissue (Schryver, Medway & Williams, 1967). *Pholetter gastrophilus* (Fasciolata: Troglotrematidae) resides within fibrotic nodules in the submucosa of the stomach, and elicits an intense inflammatory reaction (Woodard et al., 1969).

In the pancreas and hepato-biliary system of nearly all marine mammals, members of the genera *Camplula*, *Zalophotrema*, *Oschmarinella*, and *Orthosplanchnus* induce necrosis of parenchymal tissue, and chronic fibrosis and hyperplasia of ducts (Woodard et al., 1969; Fleischman & Squire, 1970). *Camplula oblonga* infects virtually all mature harbor porpoises, *Phocoena phocoena*, stranded along the New England coast of the United States. In many of these animals, we have noted pancreatic fibrosis that was sufficient to extensively compromise digestive and endocrine function, and we therefore presume that this condition is a significant factor leading to natural mortality.

Other digeneans which have a major impact on small cetaceans are members of the genus *Nasitrema* (Nasitremaeidae). Normally an innocuous inhabitant of cranial sinuses (Neilland, Rice & Holdin, 1970), the organism can invade the brain and cause extensive necrosis (Ridgway & Dailey, 1972). A similar condition occurs in Amazon River dolphins, *Inia geoffrensis*, in which the campulid *Hunterotrema macrosoma* is associated with both pulmonary and cerebral lesions (Woodard et al., 1969; Dailey, 1971). Cerebral infection with *Nasitrema* sp. is a major factor in natural mortality of common dolphins along the Pacific coast of the United States (Dailey & Walker, 1978), and is one of the few examples of parasitism linked directly to stranding.

**Nematoda**

The most popular hypothesis advanced to explain cetacean mass strandings is that the metastrongylid nematodes *Stenurus minor* and *S. globicephalae* lodge in the middle ear, and interfere with echolocation and orientation (Delyamure, 1955). The evidence is fragmentary. Many whales and dolphins harbor *Stenurus* sp. (Arnold & Gaskin, 1975), yet there are no reports of associated lesions. In stranded Atlantic white-sided dolphins, *Lagenorhynchus acutus*, we have found as many as 3,300 worms densely clustered in the cranial sinuses and extending into the middle ear (Geraci et al., 1978). For the most part, the
nematodes elicit low grade inflammation of the mucous membranes, and rarely purulent sinusitis. The condition, while likely to cause discomfort, would probably not impair hearing, unless the nematodes or some toxic excretion were to penetrate into the inner ear. Because sound conduction in cetaceans depends only partially on the movement of auditory bones (McCormick, Wever, Palin & Ridgway, 1970), the mere presence of nematodes on those structures would not necessarily impede hearing—and by extension echolocation. It seems that Stenurus has been implicated in cetacean strandings more by the desire for a simplistic answer than through any accumulated scientific evidence.

While the effect of Stenurus remains in doubt, there is little question that other pseudalid nematodes can cause severe pulmonary infection in cetaceans. The Atlantic harbor porpoise can become host in the extreme, with Pseudalidus inflexus, S. minor, Torynurus convolutus, and Halocercus invaginatus all crowding the main-stem bronchi (Arnold & Gaskin, 1975). There are always some associated lesions, particularly with Halocercus sp. Adult worms, with coiled cephalic ends lodged firmly within bronchioles, induce mucopurulent bronchitis and pneumonia (Cowan & Walker, 1979). Larvae in the sputum may be destined for direct transfer to another host (Woodard et al., 1969) while adults eventually die and either liquify or become enveloped in firm fibrous or calcified nodules. The consequence of infection can only be surmised. Pneumonia must place a stiff burden on diving mammals compelled to keep pace with the herd. Many do, as evidenced by the high prevalence of parasitic lesions in the lungs of robust free-ranging cetaceans (Cowan, 1966; Conlogue et al., 1985). Others die as a direct effect, or through bacterial and cardiovascular complications (Andersen, 1974), or hypersensitivity to the parasites (Sweeney & Ridgway, 1975).

Hypersensitivity reaction is also associated with Parafilaroides decorus (Fleischman & Squire, 1970) infection in California sea lions, Zalophus californianus (Sweeney & Gilmartin, 1974). Larvae induce acute bronchitis, and bronchopneumonia (Nicholson & Fanning, 1981), and stimulate mucous secretion which can lead to asphyxiation. P. decorus is the only pseudalid parasite of marine mammals for which a life cycle is proposed, and the first metabaryngid found to utilize a vertebrate (a small tidal-pool fish, Girella nigricans) as a single intermediate host (Dailey, 1970).

Parafilaroides sp. also infect phocid seals, but only the large crenosomatid nematode, Otostrongylus circumlitus, has been associated with clinical disease, primarily in young harbor seals and ringed seals, Phoca hispida. The parasite obstructs Airways, causing bronchitis and pneumonitis, and can penetrate pulmonary vessels to emerge in the right ventricle (Van Den Broek & Wensvoort, 1959). Among 800 harbor seals stranded along the New England coast, O. circumlitus was most prevalent in animals under two years of age. It is not clear whether this pattern of infection relates to a change in food (intermediate host) preference, acquired immunity, or early mortality of infected animals.

Captive harbor seals (Medway & Wieland, 1975) and sea lions (Forrester, Jackson, Miller & Townsend, 1973) can be infected with Dirofilaria immitis, the heartworm of other canids. However, the heartworm that infects free-ranging seals is Dipetalonema spirocauda (Van Den Broek & Wensvoort, 1959; Schroeder et al., 1973). The louse E. horridus is a natural vector (Geraci et al., 1981) for the worms which, as adults, reside in the right heart and pulmonary arteries. Here, they and their microfilariae induce proliferation and necrosis of vascular endothelium, and form verminous emboli leading to granulomatous pneumonia (Dunn & Wolke, 1976). We might expect that pulmonary and cardiovascular complications associated with heartworm would seriously reduce a seals’ ability to dive and feed. However, we have no direct measurement of diving performance in infected animals.

One of the most devastating parasites of pinnipeds is Uncinaria lucasi, the hookworm responsible for mass mortalities among the pups of fur seals, Callorhinus ursinus (Olsen, 1958). It is one of the few nematodes transmitted in milk. Infective third stage larvae, possibly influenced by hormones in the pregnant cow (Lyons & Keyes, 1978), migrate from the belly blubber to the mammary glands. Newborn pups can consume as many as 1500 larvae with the first meal of milk, and two weeks later develop potentially fatal hemorrhagic diarrhea and anemia. Eggs shed by survivors hatch in late summer, or in spring after overwintering, and develop eventually into soil-borne free-living third-stage larvae. These penetrate the skin of seals of all ages, migrate to the belly blubber, and become a threat only to the next generation of suckling pups. The tissue phase of the parasite affords protection from the hazards of overwintering in the soil when temperatures can be lethal and seals are unavailable (Olsen & Lyons, 1965).

The most cosmopolitan of marine mammal parasites are the anisakine nematodes, Phocanema decipiens, and several species of the genera Contracaecum and Anisakis. The worms can be found free within the stomach or attached to the gastric mucosa. Penetration by larvae (Young & Lowe, 1969) and adults (McClelland, 1980) can lead to ulcers (Schnieder & Wegeforth, 1933), perforation into the abdominal cavity (Fiscus, Baines & Wilke, 1964), and gastritis which may have an allergic component. Infections are generally not serious to the host. However, marine mammals shed larvae which eventually infect commercially valuable fish. People who eat the fish become ill (Margolis, 1977), and seals, for their role, become targets of organized culls. In that sense, the parasite can indeed be fatal!
The only other organism which rivals the public health importance of the anisakine nematodes is the Arctic form (Britov, 1977; Dick & Chadee, 1983) of *Trichinella spiralis*. Polar bears, *Ursus maritimus*, and walruses, and to a lesser extent ringed seals and beluga whales, *Delphinapterus leucas*, are among the many northern species infected (Rausch, 1970) by eating contaminated carrion and prey, including marine amphipods (Fay, 1967) and fish (Kozlov, 1971). The literature on “Arctic trichinosis” is dominated by reports of periodic outbreaks among native people (Margolis, Middaugh & Burgess, 1979). We know of no description of the effect of the organism on the host marine mammal, which is surprising in light of its known pathogenicity in other species.

*Placentonema* and *Crassicuuda* (subfamily Crassicaudinae) are the largest nematodes of cetaceans. They were once prominent for that fact, but are now being reconsidered for their role as pathogens. The parasites are peculiarly adapted to embed their cephalic ends into soft tissues, frequently those of the urogenital system. Their posterior ends hang freely within a lumen, providing a mechanism for discharging fertilized eggs into the sea. Thus the 9-m long *P. gigantissima* infects the uterus of the sperm whale. *Physester catodon*, early in pregnancy, and matures in the placenta of the developing fetus (Skjabin, Sobolev & Ivashkin, 1967). *Crassicuuda* sp. are found in rorqual whales, entwined within genital tissues (Gibson, 1973), and in kidneys where they induce the formation of large fibrous digitate structures (Cockrill, 1969) that extend into the vena cava and hepatic portal vein (Gibson, 1973). In small cetaceans, immature forms of *C. grampicola* migrate in fascia beneath the blubber and emerge in mammary glands where they destroy functional secretory tissue. While the ova-rich milk presents no threat of infection to the newborn, the effect of reduced lactation may lead to lower calf survival and herd productivity (Geraci, Dailey & St. Aubin, 1978).

Adult *Crassicuuda* sp. also appear in the soft tissue of the cranial sinuses, and are associated with lesions particularly in the developing pterygoid bone of juvenile dolphins (Walker & Cowan, 1981). The absence of residual osseous lesions in older animals is strong evidence that parasitic infection is fatal in young dolphins (Perren & Powers, 1980; Walker & Cowan, 1981). Further studies are likely to reveal that *Crassicuuda* sp. constitutes a significant factor in natural mortality of these and other (Raga, Barbonell & Raduan, 1982) small odontocetes.

**SUMMARY**

This report examines the broad range of organisms which can parasitize marine mammals, and identifies those which we feel have the greatest impact on individuals and populations. Many parasites colonize and damage the integument in some way. Only the sucking lice of seals are associated with debilitating disease. In addition, at least one species, *E. horridus* can serve as intermediate host of the seal heartworm, *D. spirocauda*.

Of the few protozoa, the one deserving most attention is *Sarcocystis* sp. Its ubiquitous distribution challenges our understanding of coccidial life cycles as currently perceived.

Acanthocephalans and cestodes are rarely associated with clinically significant illness. It is intriguing that cetaceans and pinnipeds serve as mammalian intermediate hosts for larval tetraphyllidians destined to mature in elasmobranchs.

Digeneans occupy the gastrointestinal tract and severely damage liver and pancreas of cetaceans. *Naistrema* sp. infects cranial sinuses of small odontocetes, and enters the brain, thereby leading to stranding and death in selected populations.

Nematodes represent the broadest group of parasites. Pseudaliids often infect the respiratory system, causing sufficient damage to affect survival. There is no evidence that *Stenurus* sp., a pseudaliid inhabiting the cranial sinuses of some whales and dolphins, plays any role in mass strandings, as has been popularly suggested. Filarioids are highly pathogenic in pinnipeds and are probably responsible for significant mortality, especially in young animals. Anisakine nematodes in the stomach are of little consequence to the host. The role of marine mammals in transmitting the parasites to commercially exploited fish stocks is a public health issue. The only other parasite which represents a threat to humans is *Trichinella spiralis*, which is widespread in Arctic mammals.

The Crassicaudinae are the largest nematodes in cetaceans. Evidence is accumulating that the damage they cause in cranial bone, mammary tissue and the urinary tract may influence productivity and survival among certain groups.

Most of our understanding of the parasites of marine mammals derives from studies on specimens which come ashore. The information is fragmentary, and suffers from our inability to follow the progress of infection and the overall condition of the parasitized animal. Yet we might conclude that the parasitism we see is as advanced as can be tolerated by the host. Weak animals retreat from the protection of the herd, become vulnerable to predators, and probably cannot survive in an environment which places heavy demands on thermoregulation, respiration and mobility.
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