

## Five Species of Parasitic Copepods (Siphonostomatoida: Pandaridae) from the Body Surface of a White Shark Captured in Morro Bay, California<sup>1</sup>

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**Abstract:** Five pandarid (Copepoda) species, *Dinemoura producta*, *D. latifolia*, *Echthrogaleus coleoptratus*, *Pandarus bicolor*, and *Achtheinus oblongus*, were collected from the external body surface of a white shark, *Carcharodon carcharias*, taken from Morro Bay in the northeastern Pacific Ocean off central California. This is the first report of parasitic copepods collected from *C. carcharias* captured in the northeastern Pacific along the West Coast of North America. It is proposed that the species-rich infections of some white sharks may be the result of the wide wanderings of individual sharks through waters inhabited by other elasmobranchs.

THE WHITE SHARK, *Carcharodon carcharias* (Linnaeus, 1758), is a widely distributed coastal and offshore species inhabiting tropical and amphitemperate continental and insular shelves (Compagno 1984a). The species is commonly infected by siphonostomatoids (Copepoda), and globally at least 18 species of these ectoparasites have been reported from *C. carcharias* (e.g., see Yamaguti 1963, Lewis 1966, Cressey 1967a,b, 1970, Hewitt 1967, 1969, 1979, Kensley and Grindley 1973, Kabata 1979, Love and Moser 1983, Hogans and Dadswell 1985, Pillai 1985, Benz 1986, Oldewage and Smale 1993). To date, all copepod species known to infect white sharks also infect other sharks. Some of these species, e.g., *Nemesis lamna* Risso, 1826, and

*Anthosoma crassum* (Abildgaard, 1794), primarily infect close phylogenetic relatives of the white shark (i.e., other members of Lamnidae or Lamniformes [e.g., see Hewitt 1969]). Other species, e.g., *Pandarus smithii* Rathbun, 1886, and *Echthrogaleus coleoptratus* (Guérin-Méneville, 1837), infect more distantly related inshore or offshore elasmobranchs that share habitat with *C. carcharias* (see Yamaguti 1963, Compagno 1984a,b).

Multiple infections of sharks by siphonostomatoids are common; however, it is unusual (G.W.B., pers. obs.) for an individual shark to be simultaneously infected by more than three species externally or by more than six species in its entirety (i.e., general body surface, olfactory sacs, and buccal and branchial chambers). Hewitt (1979) reported eight siphonostomatoid species from a white shark (three species from the branchial chamber, five species from the general body surface) caught in Pukeria Bay (Pacific Ocean near Wellington, New Zealand). Our report documents the infection of the general body surface of a white shark by five siphonostomatoid species, and it is the first report of parasitic copepods from a white shark captured along the West Coast of North America. Elasmobranch nomenclature and systematics used herein follow Compagno (1999a,b).

On 23 November 2000 a female white shark (4.33 m total length, 772 kg) was caught

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in a halibut gill net set in water 60 m deep approximately 4.8 km from shore in Morro Bay, California (35° 10' N, 120° 40' W). Upon its landing, the shark was moved and frozen, and later thawed and examined. On at least two occasions during this period copepods were collected from the external body surface of the shark; however, the exact attachment location of all parasites was not recorded. The olfactory sacs, and buccal and branchial chambers of the shark were not thoroughly examined for parasites, and it is possible that during the capture or transport period some ectoparasites may have been dislodged accidentally and lost or removed from the shark by curious bystanders. Collected copepods, fixed in 10% formalin or 70% ethanol, were sent to G.W.B. for identification. All of the specimens were identified as pandarids (Siphonostomatoida: Pandaridae), and the species and number of specimens were as follows (all specimens have been retained in the personal collection of G.W.B.).

*Dinemoura producta* (Müller, 1785): one adult female collected from about the cloaca (possibly on a pelvic fin). *Dinemoura producta* has been collected from white sharks before this report (Hewitt 1967); however, to our knowledge this is the first such report from the northeastern Pacific along the West Coast of North America. The species is well known from the Atlantic and Pacific Oceans, but according to Hewitt (1967) and Kabata (1979) it has only been reported once (from an unknown host) from the Indian Ocean. This copepod is primarily a parasite of pelagic lamniforms of the families Lamnidae and Cetorhinidae (Hewitt 1967). In northeastern Pacific waters along the West Coast of North America *D. producta* infects the shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810 (Heegaard 1945, Cressey 1968, Deets 1985), in addition to the white shark. Geographic records listed by Hewitt (1967) suggest (especially those documenting distribution within the Atlantic Ocean) that *D. producta* is more common in cooler temperate regions than its congener *D. latifolia*.

*Dinemoura latifolia* (Steenstrup & Lütken,

1861): four adult females, one of which was collected from about the cloaca (possibly on a pelvic fin). *Dinemoura latifolia* has been collected from white sharks before this report (Lewis 1966, Hewitt 1967, Benz 1986); however, to our knowledge this is the first such report from the northeastern Pacific along the West Coast of North America. This copepod has been reported from the Atlantic, Pacific, and Indian Oceans and it is primarily a parasite of pelagic lamnids (Cressey 1967a, Hewitt 1967). In northeastern Pacific waters along the West Coast of North America *D. latifolia* infects the salmon shark, *Lamna ditropis* Hubbs & Follett, 1947, and the shortfin mako (Wilson 1935, Cressey 1968, Deets 1985) in addition to the white shark.

*Echthrogaleus coleoptratus* (Guérin-Ménéville, 1837): one immature female collected from about the cloaca (possibly on a pelvic fin). *Echthrogaleus coleoptratus* has been reported from white sharks before this report (Yamaguti 1963, Hewitt 1967, 1979); however, to our knowledge this is the first such report from the northeastern Pacific along the West Coast of North America. This copepod has been collected in the Atlantic, Pacific, and Indian Oceans, where it has been reported from squaliforms, lamniforms, and carcharhiniforms, with most reports linking it to pelagic hosts (e.g., see Yamaguti 1963, Kabata 1979, Pillai 1985). In addition to the white shark, in northeastern Pacific waters *E. coleoptratus* has been reported from the leopard shark, *Triakis semifasciata* Girard, 1854, off California by Russo (1975); from the salmon shark off British Columbia by Bere (1930); from the blue shark, *Prionace glauca* (Linnaeus, 1758), off California by Pappas (as reported in Love and Moser 1983) and Deets (1985); and from the smooth hammerhead, *Sphyrna zygaena* (Linnaeus, 1758), off California by Deets (1985).

*Pandarus bicolor* Leach, 1816: one adult female (partial specimen consisting of cephalothorax and thorax) collected from about the cloaca (possibly on a pelvic fin). *Pandarus bicolor* has been reported from the white shark before this report (Hewitt 1979); however, to our knowledge this is the first such report

from the northeastern Pacific along the West Coast of North America. This copepod has been collected in the Atlantic, Pacific, and Indian Oceans, where it has been reported from squaliforms, lamniforms, and carcharhiniforms (Barnard 1955, Yamaguti 1963, Hewitt 1967, Kabata 1979). In addition to the white shark, in northeastern Pacific waters *P. bicolor* has been reported from the piked dogfish, *Squalus acanthias* Linnaeus, 1758, by Wilson (1935) and Deets (1985); from the leopard shark by Russo (1975); from the broadnose sevengill shark, *Notorynchus cepedianus* (Peron, 1807), by Russo (1975) and Ebert (1989); from the tope shark, *Galeorhinus galeus* (Linnaeus, 1758), by Russo (1975); and from the bluntnose sixgill shark, *Hexanchus griseus* (Bonnaterre, 1788) by Ebert (1986).

*Achtheinus oblongus* Wilson, 1908 (sensu Ho 1975): one young adult and 12 adult females, three of which were collected from a pelvic fin and nine collected from about the cloaca (possibly on the pelvic fins). Cressey (1967a) placed *Achtheinus* Wilson, 1908, as a junior synonym of *Perissopus* Steenstrup & Lütken, 1861, and in doing so he grouped 10 *Achtheinus* spp. as one species that he referred to as *Perissopus oblongatus* (Wilson, 1908). Some lapsus prevented Cressey (1967a) from mentioning an eleventh species of *Achtheinus*—*A. armatus* (Dana, 1852) (see Oldewage 1992). Ho (1975) resurrected *Achtheinus* based on specimens that he referred to as *A. oblongus*, the original species epithet spelling of Wilson (1908). Ho (1975) justified this action based on substantial differences between the dorsal plates and leg armature of *Achtheinus* and *Perissopus* species. However, to date no one has reexamined type specimens representing the junior synonyms erected by Cressey (1967a) to determine if his action to lump all *Achtheinus* spp. as one was well founded. We agree with Ho's (1975) assessment of *Achtheinus*, and we further note (G.W.B., pers. obs.) that adult female representatives of *Achtheinus* attach to the host by embedding their antennae deeply in the skin whereas those representing *Perissopus* attach by cementing the enlarged myxal region of their maxillipeds to the host's placoid scales.

In assigning an identity to our specimens and in the remarks that follow we consider *A. oblongus* sensu Ho (1975). *Achtheinus oblongus* has been reported (Barnard 1955) from the white shark in Table Bay (Atlantic Ocean off Cape Town, South Africa); however, we believe this to be the first such report from the northeastern Pacific Ocean off the West Coast of North America. *Achtheinus oblongus* has been collected in the Atlantic, Pacific, and Indian Oceans, where it has been reported from hexanchiforms, squaliforms, pristiphoriforms, lamniforms, carcharhiniforms, rhinobatiforms, and rajiforms, with most reports linking it to benthic-dwelling nearshore hosts (see Yamaguti 1963). In addition to the white shark, in northeastern Pacific waters (including the Gulf of California) *A. oblongus* has been reported from the broadnose sevengill shark by Wilson (1912); the thresher shark, *Alopias vulpinus* (Bonnaterre, 1788), by Wilson (1921); the piked dogfish by Deets (1985); the gray smooth hound, *Mustelus californicus* Gill, 1864, by Ho (1975) and Deets (1985); the brown smooth hound, *M. henlei* (Gill, 1863), by Russo (1975); the sicklefin smooth hound, *M. lunulatus* Jordan & Gilbert, 1883, by Wilson (1921); the leopard shark by Wilson (1908) and Deets (1985); the smooth hammerhead by Wilson (1944); the shovelnose guitarfish, *Rhinobatos productus* Girard, 1854, by Ho (1975); and the big skate, *Raja binoculata* Girard, 1854, by Wilson (1911).

This report and that of Hewitt (1979) demonstrate that although species-rich infections of sharks by siphonostomatoids are generally unusual, they may not be so regarding the white shark. Four of the five copepod species reported herein were also reported by Hewitt (1979) from the collections he examined. Regarding our report, it is possible that a thorough examination of the shark's buccal and branchial chambers would have resulted in collections of two additional siphonostomatoids, *Nemesis lamna* and *Anthosoma crassum*, because these species are known to infect these body regions on white sharks collected elsewhere (e.g., see Hewitt 1979), and they are known to exist along the West

Coast of North America on other lamnids (Love and Moser 1983).

What facilitates the species-rich infections of individual white sharks by siphonostomatoids remains unknown. This phenomenon cannot be explained by the large size that white sharks can attain, because the whale shark, *Rhincodon typus* Smith, 1828, and the basking shark, *Cetorhinus maximus* (Gunnerus, 1765), each grow to be considerably larger (Compagno 1984*a,b*) and yet they are not known to be similarly infected. Furthermore, from a phylogenetic perspective, the basking shark and white shark are close relatives (Compagno 1999*a*) and their ranges overlap considerably (Compagno 1984*a*); hence it might be expected that these species would be infected by the same species of copepods. We feel that it is significant that, together, all of the copepod species reported from *C. carcharias* are known to infect a wide phylogenetic and ecological range of elasmobranchs. Based on this and on a recent report (Boustany et al. 2002) of the extremely large home ranges of at least some white sharks that span a variety of inshore and offshore provinces, we propose that the species-rich infections of some white sharks may be the result of the wide wanderings of individual sharks through waters inhabited by other elasmobranchs. Unfortunately, to date too little is known about the biogeography and genetics of the siphonostomatoids that infect the white shark to understand if occurrence patterns and molecular techniques might allow these parasites to be used as biological tags to help in studies of shark movements.

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