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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

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Kazuya Nagasawa (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. *Zoological Studies* **43**(2): 173-178. This paper reviews various aspects of the biology and effects of 2 caligid copepods, *Lepeophtheirus salmonis* and *Caligus orientalis*, on wild and farmed fish in sea and brackish waters of Japan and adjacent regions. *Lepeophtheirus salmonis* is a common parasite of wild adult chum (*Oncorhynchus keta*) and pink (*O. gorbuscha*) salmon migrating in northern Japanese waters. Masu salmon (*O. masou*) have the lowest level of infection. Juvenile chum salmon are sometimes infected. This parasite is also found on salmonids in Korean and Russian waters. The species occurs on coho salmon (*O. kisutch*) and rainbow trout (*O. mykiss*) farmed in coastal waters of northern Japan, but its infection is not a serious problem, because only young fish are reared and harvested in less than a year of culture and thus no fish are cultured during summer. This situation is very different from that in Scotland, Ireland, Norway, and Canada where *L. salmonis* causes serious damage to farms of Atlantic salmon (*Salmo salar*). *Caligus orientalis* is a parasite of coastal marine and brackish-water fish in Japan and neighboring countries (Taiwan, China, Korea, and Russia). This parasite has a wide host range and has been reported from over 20 fish species from different orders and families. It infects farmed and experimentally reared fish, such as rainbow trout in Japan, grey mullet (*Mugil cephalus*) and black porgy (*Acanthopagrus schlegeli*) in Taiwan, and Mozambique tilapia (*Oreochromis mossambicus*) in China. Heavy infection results in appetite reduction and death of fish. The parasite is one of the most important pathogens at brackish-water fish farms in Far East Asia. http://www.sinica.edu.tw/zool/zoolstud/43.2/173.pdf

Key words: Parasitic copepods, Sea lice, *Lepeophtheirus salmonis*, *Caligus orientalis*, Pathogenicity.

Sea lice are parasitic copepods of the family Caligidae, which cause serious problems in salmonid culture in Europe and North America. In particular, *Lepeophtheirus salmonis* and *Caligus elongatus* are important pathogens in these regions. Their biology and control have been intensely studied, and the information has been well compiled (Boxshall and Defaye 1993, Pike and Wadsworth 1999). Similarly, sea lice infect fish cultured in Far East Asia (Ho 2000), and they often cause disease problems in wild fish. However, the published information on Asian sea lice is scattered in various countries, and it is not easy, especially for scientists whose mother language is English, to understand the papers, most of which are written in the native language of each country. The present paper is thus intended to compile the information on various aspects of the biology and effects of 2 species, *L. salmonis* and *C. orientalis*, which are important parasites of wild and farmed fish in sea and brackish waters of Far East Asia.

Biology of *Lepeophtheirus salmonis*

Taxonomy

In Japan, this species was first described as *Lepeophtheirus uenoi* as a distinct species from *L.*

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salmonis, by Yamaguti (1939) based on the specimens from pink salmon (*Oncorhynchus* (as "*Salmo*") *gorbuscha*) collected in a brackish-water lake ("Mokoto-numa"), Hokkaido. Shiino (1952) also described the species, using the same scientific name, from the specimens from chum salmon (*O. keta*) taken near the Kurile Islands. However, Gussev (1951) regarded *L. uenoi* as a junior synonym of *L. salmonis*. Subsequently, Margolis (1958) reviewed the descriptions of *L. uenoi* by Yamaguti (1939) and Shiino (1952) and those of *L. salmonis* by earlier authors and found that Yamaguti had differentiated *L. uenoi* from *L. salmonis* due to incorrect or inadequate early descriptions of *L. salmonis*. Thus, currently *L. salmonis* has been commonly used. Kim (1998) recently redescribed the species from Korea.

Hosts

The hosts of *L*epeophtheirus *salmonis* are usually salmonids (family Salmonidae). In Japan, the following 7 species of 2 genera, *Oncorhynchus* and *Salvelinus*, are known as hosts: chum salmon (*O. keta*, Shiino 1952 1959, Nagasawa 1985, Gresty and Warren 1993); pink salmon (*O. gorbuscha*, Yamaguti 1939, Nagasawa and Takami 1993); masu salmon (*O. masou*, Nagasawa and Takami 1993); chinook salmon (*O. tshawytscha*, Nagasawa and Yanagisawa 1992); coho salmon (*O. kisutch*, Nagasawa and Sakamoto 1993, Urawa et al 1998, Ho and Nagasawa 2001); rainbow trout (*O. mykiss*, Nagasawa and Sakamoto 1993, Urawa et al. 1998, Ho and Nagasawa 2001); and white-spotted charr (*S. leucomaenis*, Nagasawa et al. 1994). Of these salmonids, coho salmon and rainbow trout are cultured fish, but the others are wild.

The parasite occurs on chum and masu salmon in Korea (Kim 1998) and also on chum, pink, and chinook salmon in Far Eastern Russia (e.g., Akhmerov 1955, Smirnova 1971, Panasenko et al. 1986).

As non-salmonid hosts, 2 cyprinids are known: Japanese dace (*Tribolodon hakonensis*, Nagasawa et al. 1994, Kim 1998) and Far Eastern dace (*Leuciscus brandti*, Gussev 1951). These species are euryhaline and can inhabit coastal marine waters where they become infected.

Geographical distribution and occurrence on wild fish

In Far East Asia, *L. salmonis* is distributed in the western North Pacific, the Sea of Okhotsk, and the Sea of Japan. Its distribution range well corresponds to the migration range of Pacific salmon (*Oncorhynchus* spp.) inhabiting the cold subarctic waters (Nagasawa 1987 2001, Nagasawa et al. 1993). However, as an exceptional record, the parasite was found on a chinook salmon taken from as far south as the coastal waters on the Pacific side of central Japan (33°36'N, Nagasawa and Yanagisawa 1992).

In Japanese waters, 3 salmonids, chum, pink, and masu salmon, are the most abundant. Infection level of *L. salmonis* varies among these host species (Nagasawa 1985, Nagasawa and Takami 1993). Chum salmon are most frequently and heavily infected, followed by pink salmon. Masu salmon have the lowest level of infection. Juvenile chum salmon are sometimes infected (Nagasawa et al. 1994). On adult mature chum salmon, *L. salmonis* is found mainly in the perianal and dorsal regions (Nagasawa 1985).

Lepeophtheirus salmonis is principally a parasite of sea-migrating salmon, but it is also found on those mature salmon that have just arrived in rivers and coastal brackish-water lakes from the ocean (Yamaguti 1939, Akhmerov 1955, Shiino 1959, Smirnova 1971, Panasenko et al. 1986).

Infection of farmed fish and treatment

Lepeophtheirus salmonis infects farmed salmonids as well (Nagasawa and Sakamoto 1993, Urawa et al. 1998, Ho and Nagasawa 2001). On the Pacific coast of northern Honshu, Japan, coho salmon are cultured in net pens, and rainbow trout are also raised on a much smaller scale. The parasite is not a serious problem with coho salmon farming because they are more resistant to infection, only young fish are reared and harvested in less than a year of culture, and no fish are cultured during summer (Fig. 1, Ho and Nagasawa 2001). This situation is very different from that in Scotland, Ireland, Norway, and Canada where *L. salmonis* causes serious damage to the farming of Atlantic salmon (*Salmo salar*, Boxshall and Defaye 1993, Pike and Wadsworth 1999). At salmon farms in Japan, all *L. salmonis* disappear in summer, and transmission of the species occurs in fall from infected, returning mature chum salmon to cultured salmonids (Fig. 1).

There is an increase in the prevalence and mean intensity of infection by *L. salmonis* on coho salmon and rainbow trout during the culture period (from Nov. to July). Rainbow trout are highly sus-

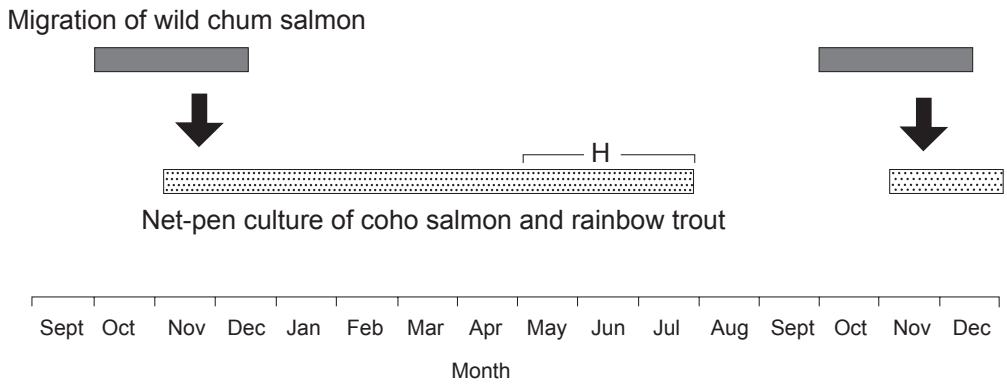

Fig. 1. Transmission of *Lepeophtheirus salmonis* (indicated by the arrows) from returning chum salmon to salmonids cultured in a bay on the Pacific coast of northern Honshu, Japan. The strippled bar indicates the time period in a year when the salmonids are cultured and harvested (H). The dark bar signifies the time period when the infected wild chum salmon pass through the bay on their return to their native river (from Ho and Nagasawa 2001, with permission from the Crustacean Society).

ceptible to *L. salmonis*, and the intensity of infection can reach as high as 51 copepods/fish in July. In the net pens where rainbow trout are reared, the parasite reproduces twice, in Jan. and May. Interestingly, even under these conditions, coho salmon harbor only preadult and adult stages of *L. salmonis*, indicating that, due to the resistance of this salmon to the parasite, infective copepodids from nearby net-pens where rainbow trout are being raised are prevented from either settlement or growth into the chalimus stage (Ho and Nagasawa 2001).

No treatment or control is performed on *L. salmonis* because its infection is not a serious problem with coho salmon farming in Japan.

Effects on host fish

In wild and farmed salmonids, the sites of heavy infection by *L. salmonis* show abrasion and hemorrhage. The skin near the anal fin is usually heavily infected. Kimura (1970) suggested that the pathogenic bacteria, *Aeromonas salmonicida masoucida*, invade the fish through the skin damage induced by *L. salmonis* and cause a disease in masu and pink salmon kept in fresh waters for maturation.

Biology of *Caligus orientalis*

Taxonomy

This species was originally described by Gussev (1951) from various coastal marine fish collected in Peter the Great Bay on the Japan Sea coast of Russia. Without referring to Gussev's paper, Shen (1957) described 2 new species, *Caligus communis* and *C. laticorpus*, from plankton collected in coastal waters of China. *Caligus communis* was also found on grey mullet (*Mugil cephalus*). However, Yin (1962) suggested that the 2 species described by Shen are synonymous with *C. orientalis*, which was supported by Hwa (1965). In a monograph on *Caligus*, Margolis et al. (1975) also treated *C. communis* and *C. laticorpus* as junior synonyms of *C. orientalis*. However, a recent study has revealed that *C. communis* is conspecific with *C. punctatus* (Lin and Ho 1998a). In addition, *C. japonicus* has been regarded as a junior synonym of *C. orientalis* (Margolis and Parker 1966).

Urawa et al. (1979) made a detailed redescription of *C. orientalis* from Japan, and the species was also described from Korea by Kim (1998) and from Taiwan by Lin and Ho (1998a). The fine structures on legs 1 and 4 and the male antenna of the species were examined with a scanning electron microscope (Lin and Ho 1998b).

Hosts

One of the most important features of *C. orientalis* is the low host specificity. This species has been so far recorded from 22 species of fish belonging to 8 orders and 13 families (hosts are systematically shown): milkfish (*Chanos chanos*, Lin 1996, Lin and Ho 1998a 1998b) in the Chanidae; deepbodied crucian carp (*Carrasius cuvieri* (as "*C. auratus*"), Suzumoto 1974), silver crucian carp (*C. auratus langsdorfi*, Suzumoto 1974), common carp (*Cyprinus carpio*, Suzumoto

1974, Matumoto 1980), Japanese dace (*Tribolodon hakonensis*, Urawa and Kato 1991), and Far Eastern dace (*Leuciscus brandti*, Gussev 1951) in the Cyprinidae; Japanese smelt (*Hypomesus nipponensis* (as "*H. transpacificus*"), Urawa and Kato 1991) in the Osmeridae; rainbow trout (*Oncorhynchus mykiss*, Urawa and Kato 1991) and Sakhalin taimen (*Hucho perryi*, Urawa and Kato 1991) in the Salmonidae; soiuy mullet (*Mugil soiuy*, Gussev 1951, Yin 1962), grey mullet (*M. cephalus*, Urawa and Kato 1991, Lin 1996, Lin and Ho 1998a 1998b, Kim 1998), soiny mullet (*Liza haematocheila*, Yoda 1973, Lin 1996), and largescale mullet (*L. macrolepis* (as "*L. akame*"), Urawa et al. 1979, Muroga 1979, Lin 1996, Lin and Ho 1998a 1998b) in the Mugilidae; Japanese halfbeak (*Hyporhamphus sajori*, Gussev 1951) in the Hemiramphidae; rockfish (*Sebastes* (as "*Sebastodes*") *taszanowskii*, Gussev 1951) in the Scorpaenidae; masked greenling (*Hexagrammos* (as "*Hexagrammus*") *octogrammus*, Gussev 1951) in the Hexagrammidae; giant perch (*Lates calcarifer*, Lin 1996, Lin and Ho 1998a 1998b) in the Latidae; Malabar rockcod (*Epinephelus malabaricus*, Lin 1966, Lin and Ho 1998a 1998b) in the Serranidae; black porgy (*Acanthopagrus schlegeli*, Lin 1996, Lin and Ho 1998a 1998b) and yellowfin seabream (*A. latus*, Lin 1996, Lin and Ho 1998a 1998b) in the Sparidae; Mozambique tilapia (*Oreochromis mossambicus* (as "*Tilapia mossambica*"), Hwa 1965, Lin 1996, Lin and Ho 1998a 1998b) in the Cichlidae; and yellowfin sole (*Limanda aspera*, Gussev 1951) in the Pleuronectidae.

Based on the low host specificity, it is likely that the number of host fish will increase with future parasitological surveys of coastal marine and brackish-water fish in Far East Asia.

Geographical distribution and occurrence on wild fish

Caligus orientalis has been reported mainly from coastal temperate regions of Japan, Russia, Korea, China, and Taiwan, including the Sea of Japan, the Seto Inland Sea, the Gulf of Po-hai, the Yellow Sea, and the East China Sea (cf. Hwa 1965). Exceptionally, Urawa and Kato (1991) found this species on the Okhotsk Sea coast of Hokkaido, northern Japan, but this location is strongly affected by a warm current from the Sea of Japan during summer and fall.

There was an outbreak of *C. orientalis* on deepbodied crucian carp in the summer of 1973 in Lake Shinji on the Japan Sea coast of western Japan (Suzumoto 1974). The intensity of infection varied between host individuals, but the mean intensity of adults was recorded as high as 462 copepods/fish for large fish (1.0-1.1 kg body weight (BW)) and 183 copepods/fish for small fish (0.2-0.3 kg BW). The copepods were found mainly on the head, skin, and fins of fish. Many fish died and were stranded on the beach from late Aug. to late Oct. The outbreak was induced by increased salinity in the lake due to a small amount of rainfall during that summer.

Infection of farmed fish and treatment

Caligus orientalis often causes serious problems at fish farms in brackish-water regions of Japan, Taiwan, and China.

In a farm on the Japan Sea coast of Japan, common carp became heavily infected when the rearing water was introduced from a brackish-water lake (Matumoto 1980). All age-0 fish and many age ≥ 1 fish died due to the infection. Urawa and Kato (1991) reported a case of heavy infection of pen-cultured rainbow trout (320 g mean BW) in a brackish-water lake on the Okhotsk Sea coast of Hokkaido. The infection occurred in mid-Aug. (with a sea surface temperature of 16-23°C and a maximum salinity of around 32‰). Totals of 128 and 188 copepods were found respectively on the 2 fish examined. The copepods were attached to the body surface and fins. The fish appeared to have reduced their appetites, and most fish died within 1 month. The authors thought that infective larvae of *C. orientalis* were transmitted from some wild fish (Japanese dace, Japanese smelt, or grey mullet) to the rainbow trout. In addition, soiny mullet reared at a fisheries research station facing the East China Sea in Kyushu, southern Japan, became infected with *C. orientalis* in mid-June (with a sea surface temperature of 24-25°C) and 15% of the fish had died by the end of June (Yoda 1973).

In Taiwan, *C. orientalis* has been reported from the following 8 species of fish cultured in coastal brackish-water ponds (Lin 1996, Lin and Ho 1998a 1998b, Ho 2000): milkfish, giant perch, Malabar rockcod, yellowfin seabream, black porgy, Mozambique tilapia, largescale mullet, and grey mullet. On these hosts, the parasite was frequently found together with *C. punctatus*, *C. epidemicus*, or *C. acanthopagri* and caused a problem in the culture of grey mullet in Chi-Ku Village, Tainan County (Lin and Ho 1998a).

In China, Mozambique tilapia reared in coastal ponds at a fisheries research institute in Xiamen were heavily infected by *C. orientalis* and died (Hwa 1965).

For eradiating *C. orientalis*, infected rainbow trout were transferred to a freshwater pond (Urawa and Kato 1991). On the 5th day, the appetite of the fish had recovered, but a few copepods still survived, indicating that repeated treatment is necessary to completely remove the parasite.

Effects on fish

Heavy infection by *C. orientalis* causes reduced appetite and death of the fish (Hwa 1965, Yoda 1973, Suzumoto 1974, Matumoto 1980, Urawa and Kato 1991). At the attachment sites, the skin epidermal tissues are destroyed by the feeding activity of the parasite (Urawa and Kato 1991), and hemorrhage is found (Suzumoto 1974). In a study on the ulcer disease of largescale mullet found in the estuary of the Ashida River, western Japan, Muroga (1979) suggested that the wounds inflicted by *C. orientalis* are a foothold for invasion by various bacteria.

Future Research

In Japanese coho salmon farming conducted on the Pacific coast of northern Honshu, *L. salmonis* is not a problem at present. This is because all salmon are harvested in early summer before water temperatures increase and because coho salmon are resistant to the parasite infection. However, with the future development of farming of other salmonids in colder regions, it is likely that *L. salmonis* becomes a constantly occurring parasite even in Japanese waters.

Based on the above information, *C. orientalis* is considered to be a dangerous pathogen in coastal brackish-water aquaculture in Japan, Taiwan, and China. Ho (2000) has suggested that three species of *Caligus*, *C. epidemicus*, *C. orientalis*, and *C. punctatus*, are the potential major pathogens in the development of cage culture in Asia. *Caligus orientalis* sometimes seriously affects wild fish populations as well. Despite these situations, much remains unknown on the biology of this parasite. Although the life history of the species is known (Hwa 1965), other aspects of the biology have never been examined. We need to study the ecology of the parasite, including its seasonal occurrence and maturation, population dynamics and transmission mechanisms, in order to prevent and control the outbreak of the species in brackish-water fish farming in Far East Asia.

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