# 3.2.14 Sea Lice Parasitism

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## A. Name of Disease and Etiological Agent

The term sea lice is commonly used to refer to several species of marine ectoparasitic copepods of the family *Caligidae* (order *Copepoda*: suborder *Siphonostomatoida*) that infect salmonids. These species include *Caligus clemensi*, *Caligus curtus*, *Caligus elongatus*, *Caligus rogercresseyi*, *Caligus orientalis*, *Lepeophtheirus cuneifer* and *Lepeophtheirus salmonis*. Other species in the family Caligidae are parasites of a wide variety of marine fishes. Emphasis here is only on those species that affect salmonids.

Synonyms include: salmon louse, salmon lice, sea louse, white spot, and summer lesion syndrome. The use of the term "salmon louse" should be restricted to the common name for *L. salmonis*.

## B. Known Geographical Range and Host Species of the Disease

**1. Geographical Range**

Sea lice have been reported on wild and farmed salmonids in the North Atlantic and North Pacific, South Atlantic, South Pacific oceans and adjacent seas. The sea lice species found on sea-farmed salmonids vary according to geographic region, as follows:

a. *C. clemensi*
Found in the Pacific coast of Canada (British Columbia) and probably the northwest coast of the United States (Washington).

b. *C. curtus*
Found in the Atlantic coast of Canada (Bay of Fundy).

c. *C.elongatus*
Found in the Atlantic coast of Canada, Ireland, and Scotland.

d. *C. orientalis*
Found in coastal marine and brackish-waters of Japan, Taiwan, China, Korea, and Russia.

e. *C. rogercresseyi*

Found in the Pacific coast of southern Chile and Atlantic coast of Argentina.

f. *L. cuneifer*
Found in the Pacific coast of Canada (British Columbia).

g. *L. salmonis*
Found in the Pacific coast of Canada, Atlantic coast of Canada and Northern United States, Japan, Korea, Russia, Ireland, Scotland, and Norway.

Although highly morphologically similar in form, recent genetic studies provide strong evidence for Pacific and Atlantic Ocean forms of *L. salmonis*.

**2. Host Species**

The species of *Caligus* and *L. cuneifer* occur naturally on a wide variety of teleost and elasmobranch hosts. *L. salmonis* is essentially limited to salmonids.

**a. *C. clemensi***

Salmonid hosts include: pink salmon *Oncorhynchus gorbuscha*, chum salmon *Oncorhynchus keta*, coho salmon *Oncorhynchus kisutch*, sockeye salmon *Oncorhynchus nerka*, Chinook salmon *Oncorhynchus tshawytscha*, Atlantic salmon *Salmo salar* and rainbow or steelhead trout *Oncorhynchus mykiss*.

Other hosts include: Pacific herring *Clupea harengus pallasii*, three spine stickleback *Gasterosteus aculeatus*, greenling *Hexagrammos* sp., Pacific ratfish *Hydrolagus colliei*, copper rockfish *Sebastes caurinus*, and walleye pollack *Theragra chalcogramma*.

**b. *C. curtus***

Salmonid hosts include: Atlantic salmon.

Other hosts include: generally considered a parasite of gadid fishes, but has a broad host range, including more than 35 species of teleosts and elasmobranchs.

**c. *C. elongatus***

Salmonid hosts include: Atlantic salmon, rainbow trout, brown or sea trout *Salmo trutta* and brook trout *Salvelinus fontinalis*.

Other hosts include: a very broad host range, with more than 80 species of teleost and elasmobranch hosts reported.

**d. *C. orientalis***

Salmonid host: rainbow trout.

Other hosts include: a very broad host range, with more than 22 species of teleost hosts reported.

**e. *C. rogercresseyi***

Salmonid hosts include the following species which were introduced into Chile (Atlantic salmon, coho salmon, and rainbow trout) and Argentina (brown or sea trout).

Other hosts include: Patagonian blennie *Eleginops maclovinus*; Chilean silverside *Odontesthes regia*; and Chilean or small-eyed flounder *Paralicthys microps*.

**f.** ***L. cuneifer***
Salmonid host: Atlantic salmon, rainbow trout.

Other hosts include: both teleost and elasmobranch hosts including the big skate *Raja binoculata* and rock greenling *Hexagrammos lagocephalus*.

**g.** ***L. salmonis***
Salmonid hosts include: pink, chum, coho, sockeye, Chinook, Atlantic, cherry or masu salmon *Oncorhynchus masou*, rainbow trout, coastal cutthroat trout *Oncorhynchus clarkii*, brook trout and brown or sea trout.

Other hosts include: Far East rudd *Leuciscus brandti*, flag rockfish *Sebastes rubrivinctus*, sand lance *Ammodytes hexapterus*, three-spine stickleback and white sturgeon *Acipenser transmontanus*.

There are significant differences in susceptibility to sea lice between salmonid species that are related to the magnitude of the host response to infection. For example, coho salmon have been demonstrated to be less susceptible to infection with *L. salmonis* and *C. rogercresseyi* when compared to Atlantic salmon and rainbow trout.

# C. Epizootiology

## 1. Conditions Under Which Disease Occurs

*L. salmonis* has 10 developmental stages in its life cycle, whereas *Caligus* spp. are reported to have, depending on species, 8 or 9 developmental stages. These stages include two free-living planktonic nauplius stages, one free-swimming infectious copepodid stage, four attached chalimus stages, two preadult stages (except for *Caligus* spp.), and one adult stage. The life cycle of *L. cuneifer* has not been described. All stages except the nauplii feed on mucus, skin, and blood using rasping mouthparts contained within the oral cone. The adults usually cause the most serious disease state.

Egg-bearing female *C. clemensi*, *C. elongatus*, *C. rogercresseyi* and *L. salmonis* can be present throughout the year. Hatching of the eggs and development to the infective copepodid stage occurs at temperatures as low as 5$^{o}$C for *L salmonis* and *C. elongatus*, and as low as 4.2$^{o}$C for *C. rogercresseyi*. Low salinity (<20 parts per thousand) conditions result in lower *C. rogercresseyi* and *L. salmonis* settlement rates on hosts due to reductions in hatchability of eggs and survival of the naupliar and copepodid sages.

In general, prevalence of sea lice increases with higher temperatures, independent of time of season. Generation times of sea lice are temperature dependent. *C. elongatus* is reported to have a generation time of approximately 5 weeks at 10 to 13$^{o}$C. *C. rogercresseyi* has a generation time of 6.4 weeks at 10.3°C, 4.6 weeks at 12.5°C and 3.7 weeks at 15.2$^{o}$C. The generation time of *L. salmonis* is approximately 6 weeks at 9 to 12$^{o}$C and 7.5 weeks at 10$^{o}$C.

Sea lice are commonly found on all species of wild and farmed salmonids in the marine environment. Sea lice infections can be acquired at any time following seawater entry; however the highest numbers are generally found on maturing salmon in coastal waters.

There have been few reports of disease caused by sea lice in wild salmon. *L. salmonis* has been reported to cause disease and morbidity in wild Atlantic salmon, brown/sea trout, sockeye salmon and pink salmon. Juvenile wild pink salmon that were heavily infected with *C. clemensi* were reported to have severe fin erosion and fin loss.

Most regions where salmonids are farmed have reported serious disease caused by sea lice. In these regions, sea lice populations are controlled on the farms to prevent disease using therapeutants and management practices. The exception is British Columbia, where sea lice disease on salmon farms has been rarely seen. Although there is a treatment threshold for sea lice in British Columbia for Atlantic salmon farms, these treatments are used to reduce exposure of juvenile wild salmon to sea lice being shed from the farms rather than to protect farmed fish from disease.

The relationship of the number of sea lice to severity of the disease is dependent on 1) size and age of the fish, 2) the general state of health of the fish, and 3) the species and developmental stages of the sea lice present. However, even when present in low abundance, sea lice may cause sublethal effects on the physiology and behaviour of their hosts. The magnitude of such effects and their impacts, especially on wild salmon, at the individual and population levels continues to be widely debated in social media, scientific forums and publications.

Important environmental, biological and farm management/husbandry factors that may determine the severity of infections include: 1) environmental factors such as currents, water temperature and salinity, 2) biological factors such as presence of reservoir salmonid and non-salmonid hosts (wild and net pen-reared), and 3) farm management/husbandry factors such as the species cultured, general fish health, stocking density and history of sea lice treatments.

As mentioned above the presence of wild salmonid and non-salmonid hosts may serve as a reservoir of sea lice. Many non-salmonid hosts of *C. elongatus* are often attracted to and present in large numbers in the vicinity of netpen sites. Wild hosts are also an important source of: 1) *L. salmonis* and *C. clemensi* that infect netpen-reared Atlantic salmon and wild juvenile salmon in British Columbia, 2) *C. orientalis* that infected brackish water pen-reared rainbow trout in Japan and 3) *C. rogercresseyi* that infect netpen-reared Atlantic salmon, coho salmon and rainbow trout in Chile.

## D. Disease Signs

### 1. Behavioral Changes Associated with the Disease

Studies on leaping behavior in salmon suggest a relationship between the presence of sea lice and leaping frequency, but the evidence is not conclusive. Badly diseased fish are found swimming slowly at or near the surface.

### 2. External Gross Signs

Copepodids and chalimus larvae are small (<4 mm in length) and can occur on all exterior surfaces of the body and fins as well as in the buccal cavity and occasionally on the gills. Preadult and adult sea lice are visible to the naked eye. They occur on the body surfaces, especially on the head and back and in the perianal region.

When present only in low abundance, *L. salmonis* is responsible for only minor host tissue damage (abrasion, dark coloration, and hemorrhages of the perianal region). However, heavy infestations can successively remove mucus and skin to expose underlying muscle, fin rays and/or bone (Figure 1). Damage by copepodid and chalimus larvae is limited to a small area around their point of attachment. They erode the epidermis and sub-epidermis. Because the preadult and adult parasites are larger and capable of moving on the surface of the fish, damage is more severe and widespread. Heavily infected salmon commonly show grey patches (extensive areas of skin erosion and hemorrhaging) on the head and back, and a distinct area of erosion, dark coloration, and sub-epidermal hemorrhages in the perianal region. Morbidity and death of hosts can be attributed directly to the development of lesions associated with the attachment and feeding activities of the sea lice. These lesions cause osmotic stress, as well as serve as foci for the development of secondary infections and diseases.

Heavy infections of *C. clemensi* on the fins of pink salmon resulted in various stages of fin damage up to complete removal.

3. **Internal Gross Signs**
   None reported.

4. **Histopathological Changes Associated with the Disease**
   Pathological changes that have been reported in the skin of Atlantic salmon around sites of *L. salmonis* attachment and feeding include: erosion and sloughing of cells, edema, hyperplasia and cellular inflammation. Fins of Atlantic and Chinook salmon infected with chalimus larvae of *L. salmonis* show erosion of the dermis and mild inflammation. The skin and fins of coho salmon infected with the chalimus larvae of *L salmonis* show a pronounced epithelial hyperplasia. In many instances chalimus larvae on coho salmon fins are surrounded by epithelial tissue and inflammatory infiltrate. Feeding and attachment sites of chalimus stages of *C. elongatus* on Atlantic salmon skin showed erosion of the epidermis to the basement membrane, with detachment of the epidermal layer form the basement membrane in the surrounding areas. Necrotic cell were present within lesions, while normal epithelial cells occurred immediately adjacent to lesions. There was little evidence for hyperplasia being associated with these lesions.

## E. Disease Diagnostic Procedures

1. **Presumptive Diagnosis**
   A presumptive diagnosis is made by detecting the presence of copepods and determining their specific identity through microscopic examination. Very small fish can be examined without dissection. For larger fish, the fins, opercula and gills may be dissected and examined separately prior to examining the remainder of the fish. The small size of the copepodid and chalimus stages requires the use of a dissecting microscope to detect their presence. Easily recognized features used for distinguishing among the species of sea lice found on netpen-reared salmon and trout include the presence or absence of lunules (Figure 2), body shape, and structure of the first and fourth legs. General body shape can be determined using a dissecting microscope. Determining the structures of the first and fourth legs requires their removal and examination under a compound microscope.

2. **Confirmatory Diagnosis**

Features such as size, color, position on host, and species of host cannot be used to differentiate species of sea lice. Identification must be based on morphological features such as overall body shape and appendage structure. These features vary between species as well as between the different developmental stages.

On the Pacific coast of North America, the preadult and adult stages of *C. clemensi* can be distinguished from those of *Lepeophtheirus* spp. by the presence of lunules (Figure 1). Preadult and adult stages of *L. salmonis* can be distinguished from *L. cuneifer* by the position of the large spine on the exopod of the third leg (Figure 3). There are two ways to identify *C. clemensi* chalimus stages from those of *Lepeophtheirus* spp. All of the chalimus stages can be identified to genus by examination of the anterior margin of the cephalothorax and the structure of the frontal filament. In *Lepeophtheirus* spp. the frontal filament is replaced at each of the molts and it appears to be continuous with the anterior margin of the cephalothorax. In *Caligus* spp. additional material is added to the frontal filament at each of the molts resulting in a series of segment-like sections where the filament meets the cephalothorax. In *Caligus* spp. the filament does not appear as continuous with the anterior margin of the cephalothorax. In the chalimus III and IV stages of *C. clemensi* rudimentary lunules are present. A detailed key for identifying the early developmental stages of *L. salmonis* from *C. clemensi* is given in Galbraith (2005).

Identification of preadult and adult *C. clemensi* can be confirmed by reference to Kabata (1972; 1988) and Parker and Margolis (1964). Earlier developmental stages of *C. clemensi* can be identified by reference to Kabata (1972). Identification of adult *L. salmonis* can be confirmed by reference to Kabata (1973; 1979; 1988). Earlier developmental stages of *L. salmonis* can be identified by reference to Johnson and Albright (1991a), Schram (1993; 2004) and Galbraith (2005). Identification of adult *L. cuneifer* can be confirmed by reference to Kabata (1974). There are no descriptions of the earlier developmental stages of *L. cuneifer.*

In Atlantic waters and adjacent seas, the preadult and adult stages of *C. curtus* and *C. elongatus* can be distinguished from *L. salmonis* by the presence of lunules (Figure 2). Adult *C. curtus* can be distinguished from *C. elongatus* by differences in the shape of the genital complex and abdomen as well as differences in the number of setae on the exopod of the fourth leg (Figures 2 and 4). The fourth leg has four setae in *C. curtus* and five setae in *C. elongatus*. Species identification can be confirmed by reference to Parker et al. (1968) Kabata (1979; 1988) and Piasecki (1996). Earlier developmental stages of *C. elongatus* can be identified by reference to Piasecki (1996). The earlier developmental stages of *C. curtus* have not been described.

The identification of chalimus, preadult and adult stages of *C. rogercresseyi* can be confirmed by reference to Boxshall and Bravo (2000) and González and Carvajal (2003). Confirmation of identification of *C. orientalis* can be made by reference to Urawa et al. (1979).

## F. Procedures for Detecting Subclinical Infections

Same as Disease Diagnostic Procedures above.

## G. Procedures for Determining Prior Exposure to the Etiological Agent

There are no procedures available at present.

## H. Procedures for Transport and Storage of Samples to Ensure Maximum Viability and Survival of the Etiological Agent

Samples of sea lice can be preserved in 10% formalin or 70% ethyl alcohol. If not available, any other histological preservative (e.g., Bouin's or Davidson's) can be used.

For long-term storage, fix for two weeks in 10% formalin and then transfer to 10% glycerine alcohol (10 ml glycerine in 90 ml of 70% ethyl alcohol).

## I. Key to Adult Sea Lice of Salmon and Trout

The following key serves to distinguish the adults of the five species of sea lice reported from pen-reared salmon and trout in North America.

1. Lunules absent……………………………………………………………………………..2
   Lunules present….……………………………………………………………………………3
2. Large spine of the basal segment of the exopod of the third leg inserts at the distal tip of the segments outgrowth (Figure 3A) *Lepeophtheirus salmonis* ……….……..(Figures 2A and 2B) (Atlantic and Pacific)
   Large spine of the basal segment of the exopod of the third leg inserts at the midpoint of the segment's outgrowth (Figure 3B). *Lepeophtheirus cuneifer*……...(Figures 2C and 2D) (Pacific)
3. Exopod of fourth leg with 4 setae……………………………………………………(Figure 4A)
   Distal margin of exopod of first leg with 4 undivided setae, seta 4 longer than others (Figure 5A) ………………………………………………*Caligus curtus* (Figures 1E and 1F) (Atlantic)
   Exopod of fourth leg with 5 setae (Figures 4B and 4C)………………………………………3
4. Distal margin of exopod of first leg with setae 1 and 4 undivided and unarmed, setae 2 and 3 bifid (Figure 5B) ………………………………………*Caligus clemensi*.(Figures 2I and 2J) (Pacific)
   Distal margin of exopod of first leg with setae 1 and 4 undivided and armed, setae 2 and 3 appearing chelate due to presence of secondary process arising near midlength (Figure 5C) *Caligus elongatus*……………………………………………….….(Figures 2G and 2H) (Atlantic)

**Figure 1.** Disease caused by the feeding activities of *Lepeophthirus salmonis* on adult sockeye salmon. These lesions are identical to those seen on heavily infected farmed salmon. Note the presence of numerous adult female *L. salmonis* associated with the open dorsal lesion. [Photos taken by S. Johnson, previously published in Johnson et al. (1996)]

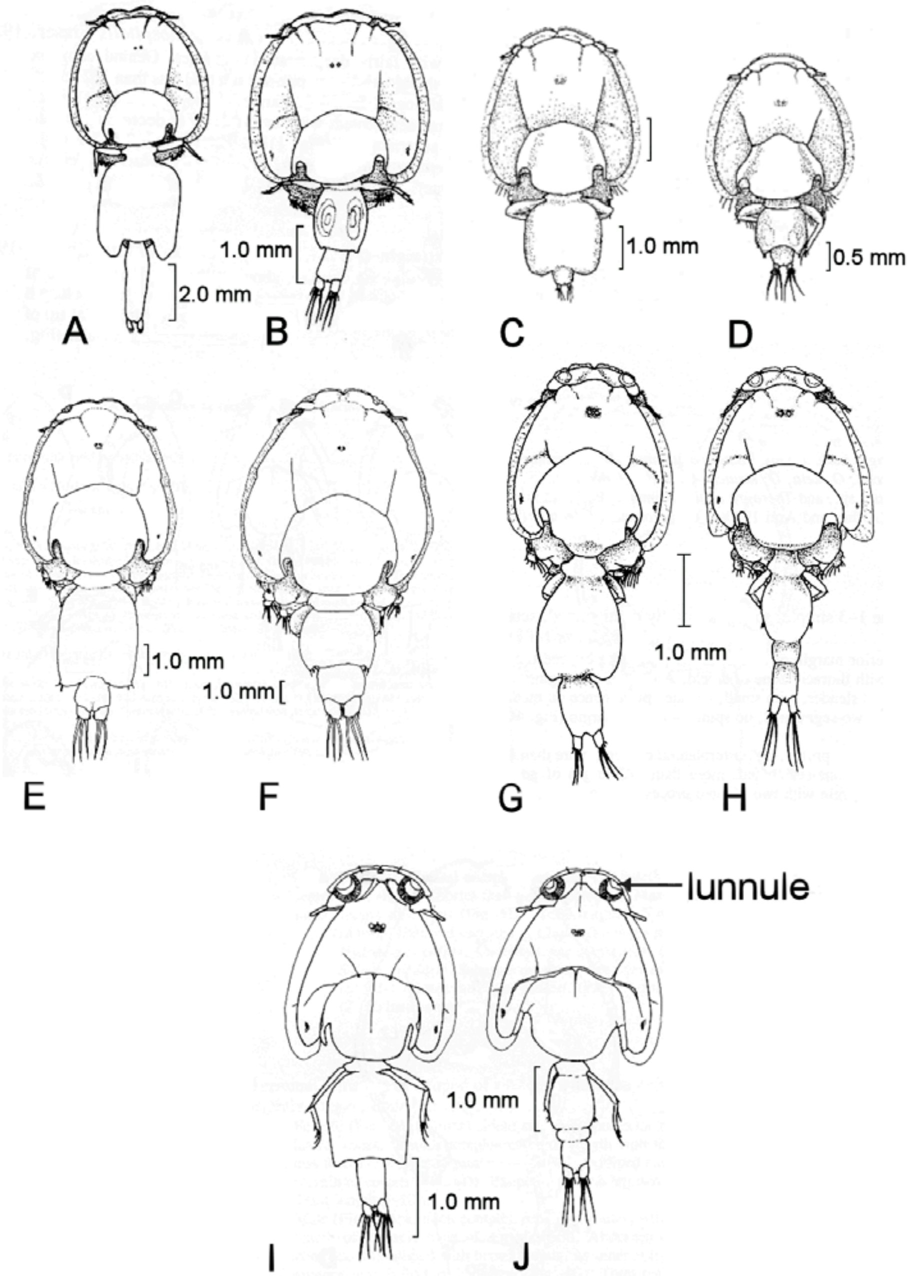


**Figure 2.** Adult stages of sea lice sea lice reported from pen-reared salmon and trout in North America: (A) *Lepeophtheirus salmonis*, female; (B) same, male; (C) *Lepeophtheirus cuneifer*, female, (D) same, male, (E) *Caligus curtus*, female; (F) same, male; (G) *Caligus elongatus*, female; (H) same, male. (I) *Caligus clemensi*, female; (J) same, male. (A,B,E,F,G,H,I and J adapted from Kabata (1988); C and D adapted from Johnson and Albright (1991b))

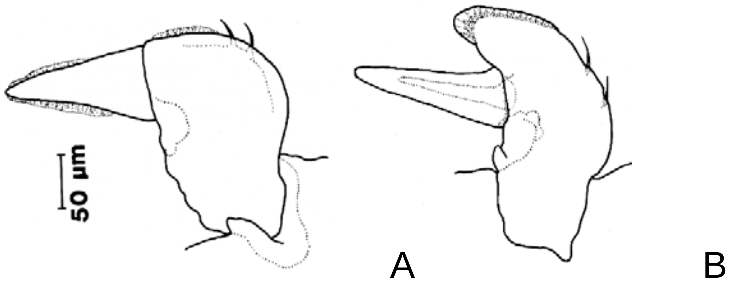


**Figure 3.** Basal spine of exopod of third leg of *Lepeophtheirus salmonis* (A) and *Lepeophtheirus cuneifer* (B) (adapted from Johnson and Albright 1991b).

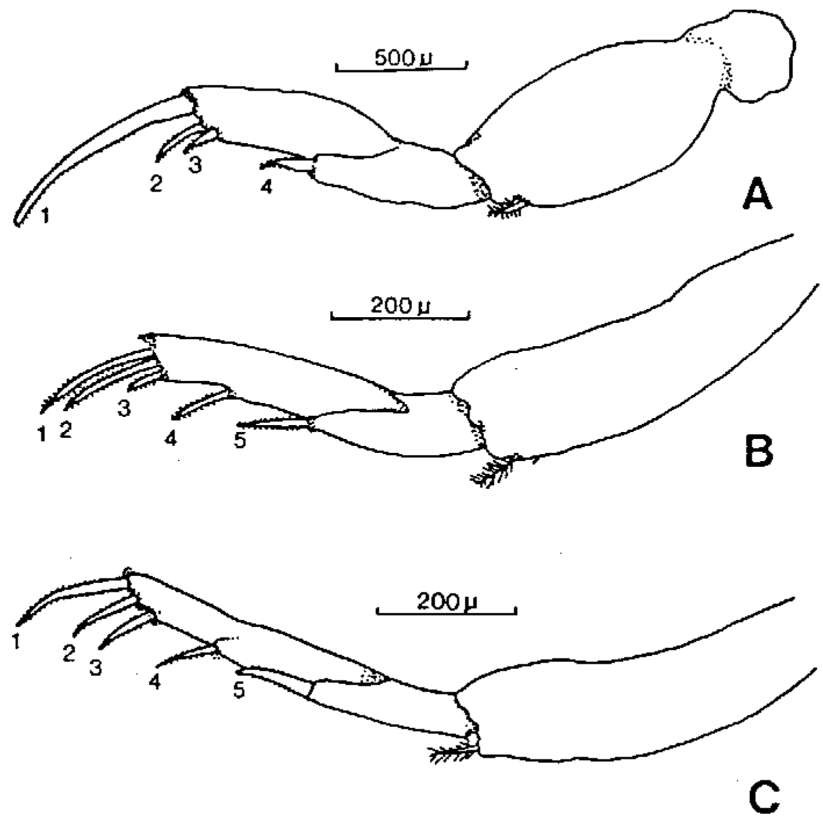


**Figure 4.** Structure of the fourth leg: (A) *Caligus curtus*; (B) *Caligus clemensi*; (C) *Caligus elongatus* (A, redrawn from Kabata 1979; B, redrawn from Kabata 1972; C, original).

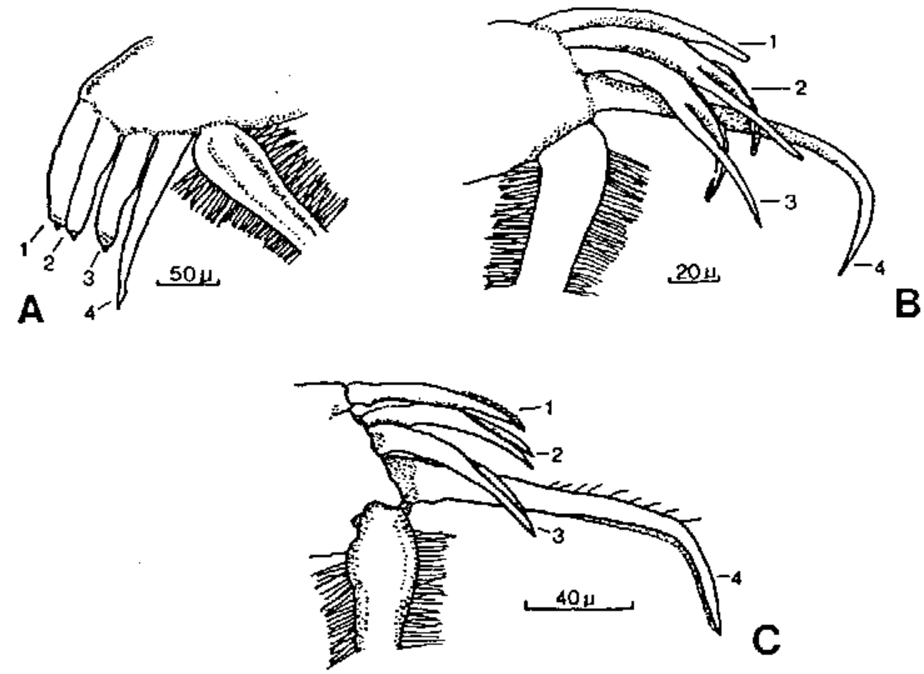


**Figure 5.** Distal margin of the exopod of the first leg: (A) *Caligus curtus*; (B) *Caligus clemensi*; (C) *Caligus elongatus* (A, C, modified from Kabata 1979).

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