

**AN INTRODUCTION AND KEY TO THE FRESHWATER CALANOID  
COPEPODS (CRUSTACEA) OF BRITISH COLUMBIA**

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# **AN INTRODUCTION AND KEY TO THE FRESHWATER CALANOID COPEPODS (CRUSTACEA) OF BRITISH COLUMBIA**

## **INTRODUCTION**

Carl (1940) described the distribution of the freshwater calanoid copepods of British Columbia. Since this early work, one of Carl's identifications, as well as early B.C. records of Kincaid (1953, 1956), have been referred to other species by Wilson (1951, 1959). Since these early publications, the B.C. freshwater calanoid copepod fauna has-not been treated systematically. Additional sampling has permitted more comprehensive distributions to be plotted.

The present study gives an introduction to the calanoid copepods and a key to the freshwater calanoid copepods of British Columbia, together with distribution maps based on a checklist of B.C. calanoid copepods (Sandercock and Scudder *unpub* MS). The best reference available to identify the calanoids of British Columbia was, until now, the key to all the calanoid species of North America in *Free-Living Copepoda: Calanoida* (Wilson 1959). Wilson (1959) remains a useful reference which should be consulted to confirm identifications made using the present key or for identifying any new B.C. species not included in the present key. Our key simplifies the identification of B.C. calanoid copepods by restricting the number of identifiable species to the 30 we have reported from B.C. (Sandercock and Scudder *unpub* MS), rather than having to deal with the 100 or more species covered by Wilson's (1959) North American key. Wilson's (1959) key has few drawings of whole animals, and for some species, is lacking drawings of diagnostic key characters, both of which make it difficult to use by someone unfamiliar with the group.

Smith and Fernando (1978) in their keys to the freshwater zooplankton fauna of Ontario pointed out that identification is simplified by having a regional publication with fewer species to deal with, and by having new distribution information. New drawings and new distribution maps are provided.

## THE CALANOID COPEPODS

Freshwater calanoid copepods (Class Crustacea, Order Copepoda, Sub-order Calanoida) are one of three groups of free-living freshwater crustaceans. They are about 1-5mm in total body length and are usually both planktonic and limnetic. They are found in a variety of habitats ranging from freshwater lakes and ponds, to streams or rivers, occasionally in ditches, and some euryhaline species are found in either brackish, salt- or freshwater (Williamson 1991). Copepods make up a major portion of the biomass and secondary productivity of freshwater systems (Bayly and Williams 1973, Williamson 1991). They are important in aquatic food webs both as primary and secondary consumers or as prey items (Williamson 1991).

Descriptions of the three major groups of free-living copepods, the calanoids, the cyclopoids and the harpacticoids, are found in Thorp and Covich (1991), Smith and Fernando (1978), Wilson and Yeatman (1959) and Gurney (1931, 1932, 1933). The shape of the body, position of the body constriction, and length of the 1<sup>st</sup> antennae are some of the characteristics used to separate the groups (Wilson 1959, Smith and Fernando 1978). Appendages of the three groups are compared in Williamson (1991). The major body articulation is behind the segment of the 5th legs in calanoids, but behind the segment of the 4<sup>th</sup> legs in cyclopoids and harpacticoids (Dudley 1986) (Fig. 1) .

The North American calanoids have been classified into four families: Family Clausocalanidae<sup>1</sup> (or Pseudocalanidae) with genus *Senecella* Juday; Family Centropagidae with genera *Limnocalanus*<sup>2</sup> Sars and *Osphranticum*<sup>2</sup> S.A. Forbes; Family Temoridae with genera *Eurytemora* Giesbrecht, *Epischura*

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<sup>1</sup> Family Clausocalanidae was used by Bowman and Abele (1982) to replace Family Pseudocalanidae used by Wilson (1959).

<sup>2</sup> *Limnocalanus* has not been found in B.C., although it was reported from Alaska and Washington State (Wilson 1959, 1972). *Osphranticum* was reported (D. Gordon, *pers. comm.*) from Sooke Lake, Vancouver island but no specimens were available for the record to be confirmed. Wilson reported it from Central and Southern U.S.A., west to Texas (Wilson 1959).

Forbes, *Heterocope* Sars; and Family Diaptomidae with the genera *Acanthodiaptomus* Kiefer and *Diaptomus* Westwood<sup>3</sup> (Wilson 1959). Six of these genera have been found in British Columbia.

The Diaptomidae are the most widely distributed and abundant group of freshwater copepods found in the plankton of North America (Williamson 1991). *Eurytemora affinis* (Pope) is unusual in that it is found in both freshwater and euryhaline lakes, estuaries and ponds in the Pacific, Atlantic and Gulf of Mexico regions (Wilson 1959, Busch and Brenning 1992), as well as in inland saline reservoirs of the Southern Great Plains, from Texas, Oklahoma, Arkansas and Illinois (Saunders 1993). *Acanthodiaptomus denticornis* (Wierzejski) is found in Europe and Asia as well as in North America (Wilson 1959). *Senecella calanoides* Juday and *Limnocalanus macrurus* . Sars have been described as glacial relicts in northeastern North America (Wilson 1972, Carter and Goudie 1986). They are related to marine forms, but are usually found in lakes which were once part of the glacial lakes of the Wisconsin period of glaciation (Hebert and Hann 1986). They also were reported from isolated lakes in western North America, *L. macrurus* from Cedar Lake in the Cascade Mountains of Washington State and *S. calanoides* from Waterton Lake, Alberta/Montana in the Rocky Mountains (Wilson 1972).

*D. (Skistodiaptomus) pallidus* Herrick was reported from Deer Lake, Burnaby, B.C., and other lower mainland lakes (Sandercock and Scudder, *unpub.* MS; Chapman *et al.* 1985). As *D. (Skistodiaptomus) oregonensis* Lilljeborg was reported from Deer Lake by Carl (1940), *D. pallidus* may be a relatively recent arrival in British Columbia (Chapman *et al.* 1985). Byron and Saunders (1981) have demonstrated the recent expansion in range of *D. pallidus* in the western U.S. with new records from Lake Tahoe California/Nevada.

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<sup>3</sup> We have followed the classification and terminology used by Mildred S. Wilson (Wilson 1959). There has been a tendency in the current literature to use the subgenus name assigned by Light (1938,1939) or Wilson (1959) in place of the genus name *Diaptomus* (as in Chapman *et al.* 1985). Wilson (1959) stated that "confusion in the literature is avoided if these groups are considered as subgenera" [and the genus *Diaptomus* is retained]. We have used the genus *Diaptomus* with the subgenus indicated in brackets when a species is mentioned in the text for the first time.

In reports of zooplankton from estuaries in California, there are records of several exotics, one of which is *Pseudodiaptomus forbesi* (Pope and Richard), which probably arrived in ship ballast water from Asia (Cordell, Morgan and Simenstad 1992). *P. forbesi* is an estuarine form and is not to be confused with *D. (Aglaodiaptomus) forbesi* Light, a freshwater calanoid copepod found in ponds or lakes and included in this report from British Columbia.

## **GENERAL BIOLOGY**

### **Developmental Stages of the Egg, Nauplius, Copepodite and Adult**

An introduction to the biology of calanoid copepods has been summarized, including descriptions of their developmental stages, means of reproduction, feeding methods, life cycles and population studies (Williamson 1991, Chapman and Lewis 1976, Wilson 1959).

The fertilized egg is the first developmental stage of a calanoid copepod. Subitaneous (or normal) eggs hatch within 1-5 days of being extruded by the female, or a second kind of egg, a "resting egg", may be produced which may not hatch for months after being extruded. Both types of eggs may be produced at the same time (Williamson 1991). Resting eggs may be produced in the late summer or fail to overwinter (Hairston Jr. and Olds 1984).

### **Variations in Life Cycles**

In the life cycle, on emergence from the egg, the calanoid copepod passes through six naupliar stages (N1-N6) and six copepodite stages (C1-C6) before reaching the adult stage. Life cycles and development times of N1-N6 and C1-C6 vary considerably among different species. Within a species development can vary with environmental factors such as temperature, food availability and predation rate (Williamson 1991). Life cycles of calanoid copepods may be multivoltine, with multiple generations per year. In a study of a lake population of *D. pallidus*, metasome length of adults measured throughout the year for

seasonal changes in the percentage of ovigerous females (Fig. 8a) and the female clutch size showed this species to have probably five generations per year (Chapman *et al.* 1985)(Fig. 8a). It was described as "perennial" with breeding occurring between March and November each year. Probably only subitaneous eggs, which hatch immediately, were produced, with no resting eggs (Chapman *et al.* 1985). Armitage *et al.* (1973) also found the life cycle of *D. pallidus* to be polycyclic in ponds in Kansas. The *D. pallidus* population in Deer Lake, Burnaby, B.C., overwintered in the copepodite stages, with some copepodites surviving to C5 in the spring. Chapman *et al.* (1985) found that mean egg clutch size was largest in March (mean no. eggs/egg sac=39.6).

In Lake Washington, *D. (Leptodiaptomus) ashlandi* Marsh was observed to be univoltine, or monocyclic, with one generation or one distinct breeding period per year (Comita and Anderson 1959). This population overwintered as adults, with a peak in numbers in early December. Pulses in the nauplii and copepodite stages were used to describe the life history (Fig. 9). Clutch size varied from a mean of 5 eggs/egg sac in December to 32 eggs/egg sac in May (Comita and Anderson 1959). *D. (Hesperodiaptomus) arcticus* Marsh also has been described as univoltine (Tash and Armitage 1967, Sawchyn and Hammer 1968) with the population being re-established each year from overwintering resting eggs (Tash 1971). Hebert and Hann (1986) stated that most calanoid copepods in the Arctic were univoltine, producing eggs which overwintered.

*D. (Onychodiaptomus) sanguineus* S.A. Forbes, has a life cycle that varies with environmental conditions. It was found to have only one generation per year in temporary Saskatchewan ponds (Sawchyn and Hammer 1968). Copepodites appeared in May and development to adult stage took 3-4 weeks. The number of eggs/egg sac ranged from 11 -131. Eggs probably overwintered in a state of diapause(Sawchyn and Hammer 1968). in Clarke Lake, a small Ontario lake, *D. sanguineus* also was found to have one generation per year (Sandercock 1967), but Carter *et al.* (1980) found adult specimens

throughout the year in different locations in eastern North American lakes. Hairston Jr. and Olds (1984) studied *D. sanguineus* in a permanent pond, Bullhead Pond, Rhode island, and found that it had two generations per year. *D. sanguineus* eggs hatched into nauplii after diapause under the ice surface and developed into G1 (1<sup>st</sup> generation adults) in February and March. G1 females at first produced subitaneous or normal eggs which produced G2, 2<sup>nd</sup> generation adults, maturing in April or May. By late March, G1 females switched from producing subitaneous eggs to producing resting or diapausing eggs, which stayed on the pond bosom until late fall (Hairston Jr. and Olds 1984). These variable life cycles were described as "bet hedging", *D. sanguineus* having the ability to switch from subitaneous to diapause egg production depending on the environmental circumstances, perhaps using the time of diapause as a coincidental predator-avoidance adaptation (Hairston Jr. *et al.* 1985, Hairston Jr. 1987) (Fig. 10).

### **Population Studies**

A method for estimating population size was developed by Edmondson (1960), Edmondson *et al.* (1962) and modified by Paloheimo (1974) to give a measure of a population's instantaneous birth rate, death rate and growth rate (in Williamson 1991). Methods outlined by Rigler and Cooley (1974) to derive population statistics for freshwater copepods have been Used widely (Hairston Jr. and Twombly 1985) and other modelling approaches to cohort analysis have been developed (Hairston Jr., Braner and Twombly 1987).

### **Copepod Body Size and Coexistence**

The presence of two sizes of adult male calanoid copepods in a plankton sample may indicate the presence of two species. In small lakes or ponds, two or three calanoid species may be found coexisting, often with size differences (Sandercock 1967, Northcote and Clarotto 1975). in the largest of Canadian freshwater lakes multiple calanoid species are found. In Lake Winnipeg, *Limnocalanus macrurus* Sars, *Epischura lacustris* S.A. Forbes and *E. nevadensis* Lilljeborg were recorded together with seven congeneric species of *Diaptomus* (Patalas and Salki 1992) and six species of *Diaptomus* were described from the Great Lakes (Czaika and Robertson 1968). Chow-Fraser and Maly (1992) found a range in diet



overlap between *D. minutes* and *D. oregonensis* in some Quebec lakes and hypothesized that divergence in size and diet may allow the coexistence of the two species when food becomes limiting, or the two sizes of adult males might be two generations, G1 and G2 of the same species. Individuals developing at different times and temperatures often have different lengths, there being a negative correlation between body size and temperature (Sawchyn and Hammer 1968, Green 1974, Warren *et al.* 1986).

An example of a sample with a large range in size (males 1.44-1.98 mm, females 1.41-2.37 mm)<sup>4</sup> was collected in May from a permanent pond south of Penticton, B.C. At first it was not clear whether the large specimens in this collection were of the same species as the small specimens, or a different species. Several large and small males were checked for 5<sup>th</sup> leg and 1<sup>st</sup> antenna characteristics, and all were identified as *D. (Leptodiaptomus) sicilis* S.A. Forbes. The sample size was large, more than 600 specimens: total body length, excluding caudal setae, was measured for 50<sup>+</sup> males, 50<sup>+</sup> females and 50<sup>+</sup> copepodites for each of C1-C4 stages. Plotting histograms showed only one cohort of developing copepodites, but there were two sizes of adults. The larger specimens might have overwintered in the adult stage (J.D. Green and N.T. Johnston pers. comm.).

Within a species, the body size of calanoid copepod females is typically larger than that of males (female/male body size ratio = 1.13) (Gilbert and Williamson 1983) so in any study of size variation it is important to separate adults by sex. Variations in adult body size have been noted during life history studies by Comita (1972), Lai (1977), Hertzog *et al.* (1980) and Carter *et al.* (1983). The length of *D. ashlandi* adults in Lake Michigan changed over a season by a factor of 1.2 (Warren *et al.* 1986). Carter *et al.* (1983) found variation in metasome length for *D. minutes* and *D. oregonensis* collected from over 600 lakes in glaciated North America. It was suggested that *D. minutes* could grow larger in coloured or humic waters (Carter *et al.* 1983).

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<sup>4</sup> Total body length measured, excluding caudal setae.

Brooks and Dodson (1965) and Confer and Blades (1975) have demonstrated that the addition of planktivorous fish to a lake generally results in elimination of the larger-sized zooplankton and a shift to smaller-sized zooplankton. In an experimental fish introductions to some B.C. lakes, the *Chaoborus* population was more affected than the calanoid population (Northcote et al. 1978). O'Brien and Schmidt (1979) suggested that the type of predator feeding on calanoid copepods would determine whether the zooplankton community consists of small or large individuals. Visual-feeding, planktivorous fish select larger sized prey, whereas tactile-feeding invertebrates, like *Chaoborus* select small sized prey.

### **Mating Behaviour**

Most calanoid copepods must mate before each egg clutch is produced (Watras 1983), but there are exceptions. Chow-Fraser and Maly (1988) found that *Epischura lacustris* could produce multiple clutches from a single mating. Copepod eggs are fertilized on extrusion (Williamson 1991). During mating the male calanoid pursues the female from behind with increased swimming speed, and then with coordinated turns and short, quick movements the male grasps the female with the geniculate right 1<sup>st</sup> antenna (Watras 1983). After coupling the animals spin rapidly. The female urosome is grasped by the male's right 5<sup>th</sup> leg and the left 5<sup>th</sup> leg is used to attach a spermatophore, containing sperm, to the genital segment of the female (Watras 1983). The release of a pheromone may trigger mating activity (Watras 1983).

### **Swimming Behaviour**

Swimming behaviour of calanoid copepods is variable and can be altered by environmental stimuli (Wong *et al.* 1985, Williamson 1991). Swimming copepods have been studied using high speed infrared film at 200-300 frames s<sup>-1</sup> (Strickler 1977, 1982) or video tape (Wong *et al.* 1985, Wong and Sprules 1986). Calanoid copepods move by either gliding along slowly or by swimming with a jerky hop and sink motion. Some remain motionless at times, moving only to counter sinking, while others swim vigorously and continually (Wong and Sprules 1986).

Strickler (1977) described two types of propulsion for copepod swimming either propulsion from the vibration of the mouthparts alone, or propulsion from the combination of the vibrating mouthparts together with power-strokes by the swimming legs. A feeding herbivorous *Diaptomus spp.* moves from one position to another with changes in antennal position (Strickler 1977) (Fig. 12) and slow, smooth swimming motions (Anderson 1967).

Wong *et al.* (1985) introduced a predatory, calanoid copepod *Limnocalanus macrurus*, to *D. minutes* in a chamber. Using a video camera, Wong *et al.* (1985) observed that *D. minutes* changed from swimming slowly to jumping motions as the predator swam past. When the *L. macrurus* turned and swam after *D. minutes*, it moved away quickly in a series of jumps (Wong *et al.* 1985). Some herbivorous calanoid copepods have an escape response, in which they detect predators and escape quickly (Lehman 1977, Strickler 1977, Wong and Sprules 1986)(Fig. 13).

*D. (Hesperodiaptomus) shoshone* S.A. Forbes was observed to exhibit rapid bursts of speed when swimming and attacking *D. tyrrelli* in Teardrop Pond, Alberta, alternating with periods of coasting (Anderson 1967). *S. calanoides* and *Epischura lacustris*, both predatory species, were observed to spend most of their time in either slow swimming, sinking motions or gliding motions (Wong and Sprules 1986). In the presence of prey, both *S. calanoides* and *E. lacustris* had longer and slower sinking intervals and shorter, faster gliding intervals; possibly an advantage for a predator (Wong and Sprules 1986)(Fig. 14).

### **Mouthpart Structure and Feeding**

In *Diaptomus spp.* the feeding apparatus consists of the mandibles with mandibular palp, the 1<sup>st</sup> and 2<sup>nd</sup> maxillae and the maxillipeds form the mouthparts (Williamson 1991). The mouthparts of *D. (Hesperodiaptomus) kenai* M.S. Wilson (Chapman 1982)(Fig. 15) are similar to those of other

herbivorous calanoid copepods: *D. (Leptodiaptomus) siciloides* Lilljeborg (Comita and Tommerdahi 1960), *D. sicilis* (Czaika and Robertson 1968), *D. oregonensis* (Comita and McNett 1976) and *D. (Leptodiaptomus) nudus* Marsh (Shih and Maclellan 1977). The mouthparts of *D. (Hesperodiaptomus) kenai* M.S. Wiison are similar to those of other herbivores (Chapman 1982)(Fig. 15).

Wong (1984) compared the mouthparts of *Epischura lacustris*, *L. macrurus*, *S. calanoides*, *D. sicilis* and *D. shoshone*, and found that the 2<sup>nd</sup> antennae, the mandibular palps and the 1<sup>st</sup> maxillae were similar for all five species. Such herbivores have long setae on the 2<sup>nd</sup> antennae, on the mandibular palps and on the 1<sup>st</sup> maxillae, all of which move to produce feeding currents. The mandible has a cutting edge with short teeth for grinding (Wong 1984). The ultrastructural complexity of mouthpart structure in *D. kenai* and *D. (Hesperodiaptomus) caducus* Light has been documented by Chapman (1982) and in *D. ashlandi*, *D. oregonensis*, *D. siciloides*, *D. pallidus* and *Eurytemora affinis* by Friedman (1980).

Maly and Maly (1974) compared the gut contents and the mouthpart morphology of adults and copepodites of *D. shoshone* (an omnivore) and *D. (Leptodiaptomus) coloradensis* Sars (an herbivore) from a Colorado pond. The 2<sup>nd</sup> maxillae of the two species were similar, but the maxillipeds of the adult *D. shoshone* were much longer than those of the adult *D. coloradensis* in relation to body size, and had long spines. The gut contents of *D. shoshone* in late copepodite stages contained large-sized food particles, similar to those eaten by adult *D. shoshone*. The maxillipeds of the late copepodite stages were enlarged and more developed than those of the early copepodite stages and were similar to the adult *D. shoshone* maxilliped. Early copepodite stages of *D. shoshone* had slimmer, less-developed maxillipeds, similar to those of adult *D. coloradensis*, and they consumed small-sized food particles (Maly and Maly 1974).

Wong (1984) studied the mouthparts of *S. calanoides* and *D. sicilis*. Although the mouthparts resembled those of herbivores, a study of *S. calanoides* gut contents revealed that it was an omnivore. Lair and Hilal (1992) examined the mouthparts of *A. denticornis* and found that the mandible had a denticulate cutting edge and that they were consuming rotifers and algae. Revis, Castel and Tackx (1991) examined the mandible plate of *Eurytemora affinis* with both light microscope and scanning electron microscopes (SEM), and classified this species as an omnivore. The mandible structure of *E. affinis* was observed to consist of teeth with molar-like structures. The teeth of males were less sharp than those of the females and the copepodites had smaller, sharper teeth than those of the females (Revis, Castel and Tackx 1991).

### **Feeding Behaviour**

Early studies of feeding behaviour led to the concept that most calanoid copepods were herbivores which fed by sieving water through the 2<sup>nd</sup> maxillae (summarized in Koehl and Strickler 1981). New understanding of the feeding behaviour of calanoid copepods has come from studies with high-speed motion picture filming techniques and using dyes as tracers (Alcaez *et al.* 1980); the 2<sup>nd</sup> maxillae were shown to function as a funnel, not as a sieve (Koehl and Strickler 1981, Vanderploeg and Paffenhoffer 1985, Williamson and Vanderploeg 1988).

### **Herbivores - Suspension Feeding Calanoids**

Two kinds of feeding, passive and active, have been reported for the herbivorous or suspension-feeding calanoid, *D. sicilis* (Vanderploeg and Paffenhoffer 1985).

#### **1. Passive Feeding On Algae**

At first the food is brought to the mouth by currents caused by the rapid vibration of the 2<sup>nd</sup> antennae, the mandibular palps, the 1<sup>st</sup> maxillae and the maxillipeds (Koehl and Strickler 1981, Vanderploeg and Paffenhöffer 1985). Passive capture occurs for particles <5µm when *D. sicilis* moves the alga in a smooth path between the setae of the left and right 2<sup>nd</sup> maxillae, which act as

a funnel; mouthpart vibrations continue uninterrupted during passive capture (Vanderploeg and Paffenhoffer 1985, Price and Paffenhoffer 1986).

## **2. Active Feeding On Algae**

For particles >5µm in size the copepod uses its antennae and swimming legs to orient itself before it pounces on a food item (Williamson 1987, 1991; Williamson and Vanderploeg 1988). In active capture, the copepod moves the maxillipeds above the swimming legs, and the swimming legs are pulled backward or flapped back. The 2<sup>nd</sup> maxillae fling outwards, up to three times in the capture of a single prey item, and then they squeeze inward enclosing the prey (Koehl and Strickler 1981, Vanderploeg and Paffenhoffer 1985).

## **Omnivores**

Most calanoids are now known to be omnivores with a tendency to herbivory; gut analysis of *S. calanoides* and *Epischura lacustris* showed consumption of 84% plant material and the balance, rotifers (Wong and Chow-Fraser 1985). *D. shoshone* was described as omnivorous (Anderson 1967, Wong 1984), as was *D. pallidus* which was observed to orient itself and pounce over short distances to capture rotifers (Williamson and Butler 1986). Other calanoids are omnivorous with a tendency to be carnivorous (Williamson and Butler 1986).

## **Predatory Copepods**

The large calanoids such as species of *Heterocope*, *Epischura*, *Limnocalanus* and the larger diaptomids have predatory tendencies (Williamson 1991). Predators may cruise and then attack with a pounce while grasping the prey with the 1<sup>st</sup> and 2<sup>nd</sup> maxillae; should they fail to capture the prey they may then swim in a loop (Kerfoot 1978). In *L. macrurus* and *Epischura lacustris*, the 2<sup>nd</sup> maxillae are used to capture prey and the long, prehensile maxillipeds are used for reaching forward and pushing prey into the mouth (Wong 1984).

Studying *L. macrurus*, in Gull Lake, Ontario, Wong and Chow-Fraser (1985) observed that the lateral and ventral walls of the feeding basket were formed by the 2<sup>nd</sup> maxillae and the maxillipeds. Copepodite stages of cyclopoid copepods were the most important food item for this species. Wong (1984) described calanoid copepod predators as having prehensile appendages with fewer setae than non-predators; the mandible in predators has a cutting edge with long, sharp teeth, the endopods of the 1<sup>st</sup> maxilla are flexible with dagger-shaped setae and the 2<sup>nd</sup> maxilla has very strong, claw-like setae on the distal segment. Anderson (1967) observed *D. shoshone* to be predatory on the smaller calanoid copepod *D. tyrrelli*, and also described the last maxilliped segments of *D. shoshone* as enlarged and claw-like.

## **ROLE OF CALANOID COPEPODS IN THE AQUATIC HABITAT**

Calanoid and cyclopoid copepods occupy a significant intermediate position in aquatic food chains (Kerfoot and DeMott 1984), are usually omnivorous in habit, and when possible tend to be food selective (Williamson 1991). A wide variety of foods have been found in copepod guts including algae, pollen, detritus, bacteria and rotifers (Maly and Maly 1974, Williamson 1991). It was originally thought that all freshwater calanoid copepods were herbivorous filter-feeders, straining algae through their 2<sup>nd</sup> maxillae (from Wong 1984). Studies of the past 25 years have demonstrated that while some genera are herbivorous, some are omnivorous and some are selective predators (eg. *Epischura* and *Heterocope*), preying on zooplankton such as rotifers, cladocerans and copepodites (Confer and Blades 1975; Kerfoot 1977a, 1977b, 1978; O'Brien and Schmidt 1979; Kerfoot and Peterson 1980; Wong 1981). *Acanthodiaptomus denticornis* and some species of the genus *Diaptomus* are omnivorous; feeding on both zooplankton and algae (Williamson 1991, Lair and Hilal 1992). Other *Diaptomus* spp. are herbivorous, such as *D. (Leptodiaptomus) tyrrelli* Poppe 1888 (Anderson 1967).

Calanoid copepods have been reported to be a food source for cyclopoid copepods (Confer 1971, Confer and Cooley 1977, Peacock and Smyly 1983), for chironomid insect larvae, *Chaoborus* sp. (Swift and Fedorenko 1975, Peacock 1982) and for juvenile fish (Gurney 1931, Wetzel 1983, Williamson 1991).

The Arctic grayling, *Thymallus arcticus* (Pallas), has been reported to be predatory on *Heterocope septentrionalis* Juday and Muttkowski (O'Brien *et al.* 1992, Schmidt and O'Brien 1982). The 3-spined stickleback, *Gasterosteus aculeatus* Linnaeus, was found to feed on *Epischura nevadensis* Lilljeborg (Manzer 1972, 1976). In some of B.C.'s largest lakes, juvenile sockeye salmon, *Oncorhynchus nerka* (Walbaum), have a diet containing calanoid copepods (Narver 1970; Barraclough and Robinson 1971, 1972; Stockner 1977, 1987; Stockner and Shortreed 1978; Morton and Williams 1990). *H. septentrionalis* and *Diaptomus* spp. were consumed by under-yearling sockeye in Babine Lake, B.C. (McDonald 1973).

In a number of nursery lakes for sockeye salmon in British Columbia, lake fertilization has been a major project of the Canada Department of Fisheries and Oceans (DFO). Increasing the production of phytoplankton and indirectly increasing the biomass of zooplankton has resulted in increased fish production (Barraclough and Robinson 1972, Stockner 1977, 1987; Hyatt and Stockner 1985; Stephens . . and Stockner 1983). Fertilization experiments in Salsbury Lake, a small (78.7 ha) mountain lake north of Mission, B.C., have changed the lake from oligotrophic to mesotrophic, and resulted in great increases in zooplankton production without a change in zooplankton species composition (Ashley and Johnson MS 1989).

Other British Columbia fish have calanoid copepods in their diet: Dolly Varden, *Salvelinus malma* (Walbaum) and cutthroat trout, *Salmo clarki* (Richardson) (Northcote and Clarotto 1975, Hume and Northcote 1985); rainbow trout, *Salmo gairdneri* (Richardson) (Irvine and Northcote 1982); and kokanee (*O. nerka*) (Northcote and Lorz 1966).

Changes in the copepod species composition in a lake can be indicative of a habitat change, such as shifts in pH, from the industrial acidification of lakes, or their subsequent recovery (Sprules 1975,



Schindler *et al.* 1991, Marmorek and Korman 1993). Effects of acid rain, first noted in the poorly buffered lakes of Scandinavia, eastern Europe and eastern North America, have also been observed in the past decade or more in western North America, in the Yukon and the Northwest Territories (Schindler 1988).

In poorly buffered lakes in Ontario, with increased acidification the number of zooplankton species decreased and the biomass level of the zooplankton declined (Sprules 1975, Yan and Strus 1980, Carter *et al.* 1986, Schindler 1988 and Keller *et al.* 1992). Keller *et al.* (1992) reported that acid-sensitive species such as *Epischura lacustris* S.A. Forbes and *D. oregonensis* were absent in a highly acidified lake, Bowland Lake near Sudbury, Ontario. Four years after the experimental neutralization of Bowland Lake, *Epischura lacustris* was found to be important in the plankton (Keller *et al.* 1992). In other Ontario lakes, declines in abundance of the acid-sensitive species, such as *Epischura lacustris* and *D. oregonensis* resulted in increases in acid tolerant species (Sprules 1975, Marmorek and Korman 1993). In some of the industrially acidified lakes in the La Cloche Mountains, Ontario, where the pH was below 5.0, *D. minutes* Lilljeborg, was the single zooplankton species found, a very unusual community structure for a temperate lake (Sprules 1975a, 1975b).

Copepods have been used for the bioassay of toxins in water. A life cycle test (an 8-day survival test of nauplii or egg-bearing females) using *Eurytemora affinis* was one of the tests used to measure toxicity levels in estuarine and freshwater areas near Chesapeake Bay (Hall *et al.* 1992). Marmorek and Korman (1993) have suggested a lake monitoring program to detect lake acidification and recovery, with a lake sampling program for copepods, cladocerans and rotifers to detect changes in the abundance of the pH-sensitive species, the pH-tolerant species, changes in the number of species present and the community composition (Marmorek and Korman 1993).

Cyclopoid and calanoid copepods are sometimes intermediate hosts for parasites including flukes, nematodes and tapeworms, which are found in vertebrates as final hosts (Gurney 1931, Smith and

Fernando 1978, Williamson 1991). In a study of Newfoundland lakes, metazoan parasites of salmonid fish which used limnetic copepods as intermediate hosts, were found most often in those fishes inhabiting deeper lakes where the intermediate host was most abundant (Marcogliese and Cone 1991).

Sometimes copepods have small epiparasites attached to them: Evans *et al.* (1986) reported an infestation of *Tokophyra quadripartita* Claparede and Lachmann (Class Suctoria), covering adults of *L. macrurus* in southeast Lake Michigan, with the infestation heaviest in the fall and winter months. Internal parasitism of *D. leptopus* by dinoflagellates was recorded from a bog lake in Montague, Massachusetts, with 20% of the population being infected in early June, and 100% of the diaptomids examined being infected by late August (Winner 1970).

## IDENTIFICATION

Correct identification of freshwater calanoid copepods is needed for studies of freshwater habitats for fishstocking or water pollution control, in determining the role of copepods as food for fishes, from lake fertilization studies, or for monitoring pH change or toxin levels. This report has been prepared to identify male B.C. freshwater calanoid copepods to genus and species. Adult females are more difficult to identify with certainty to species (Wilson 1959), and have not been included in this key, but figures of some females are included. Diagnostic descriptions of the British Columbia species are under preparation<sup>5</sup>, but for now, species identifications can be checked in Wilson (1959).

## Materials and Methods

### Collection Methods

Calanoid copepods have been collected from B.C. freshwater ponds and lakes using a #20 plankton net, with preservation in either 10% formalin or 70% alcohol. A conical throw net, 15cm diameter by 50cm

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<sup>5</sup> (Sandercock and Scudder, *unpub.* MS)

length, was used, with the net rim weighted so that the net would sink when thrown out a distance of up to 8m. The plankters were washed down and concentrated with a water squirt bottle into a screened cup at the conical end which could be removed to wash the animals into a sample bottle. Samples were preserved in 4% formalin or 75% isopropyl alcohol, and were deposited either at Royal British Columbia Museum (RBCM) or the University of British Columbia (UBC). For other collection methods see Wilson (1959), and Smith and Fernando (1978).

## Materials

This study is based in part on the authors' own collections in British Columbia from over a 30 year period. It includes identification of B.C. materials at the RBCM, much of which was studied earlier by M.S. Wilson (MSW, *in litt.*)<sup>6</sup>. These include plankton collections made by other collectors from 60 years ago until the present. Some slide materials and notes of the late G.C. Carl were obtained on loan through the RBCM, courtesy J.L. Hart (Mrs. G.C. Carl). Numerous plankton samples previously identified by the late M.S. Wilson were reexamined<sup>7</sup>. These included samples collected for the British Columbia Ministry of Environment Lands & Parks, Fisheries Branch, Vancouver (formerly British Columbia Fish & Wildlife Branch, [BCFW]), which are now catalogued and housed in the RBCM. Samples were examined of collections made in the interior of British Columbia by G.G.E. Scudder in 1962-63 which are now part of the M.S. Wilson Accession at the Smithsonian institution, National Museum of Natural History (NMNH), Washington, D.C. and were obtained on loan, courtesy T.E. Bowman. Slide materials of *D. (Leptodiaptomus) novamexicanus* Herrick, identified by T. Kincaid from British Columbia locations, were also obtained from the Smithsonian institution, courtesy T.E. Bowman.

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<sup>6</sup> Mildred S. Wilson identified numbers of B.C. specimens in the 1950's (MSW, *in litt.*), but her identifications and B.C. locations were never published. other than that they were included in ranges for her key to the North American species (Wilson 1959). Wilson's B.C. records (MSW, *in litt.*) have been included in the present study and were used to confirm many of the authors' identifications.

<sup>7</sup> An "examined by M.S. Wilson" label was found in many collection jars. M.S. Wilson worked on these samples in Vancouver, B.C. in the laboratory of T.G. Northcote, University of British Columbia (T.G. Northcote *pers. comm.*).

For comparison with B.C. specimens and illustration, type specimens of *D. (Hesperodiaptomus) hirsutus* M.S. Wilson and *D. caducus* as well as sample specimens of *D. (Aglaodiaptomus) forbesi* Light, *D. (Leptodiaptomus) insularis* (Kincaid), *D. siciloides*, *D. sanguineus* and *S. calanoides* were obtained on loan from T.E. Bowman, Smithsonian institution.

The previously unpublished identification records for British Columbia calanoid copepods of the late M.S. Wilson (MSW, *in litt.*) were obtained from T. E. Bowman of the Smithsonian institution and were matched by lake name and date to the RBCM collection. Wilson had planned to publish these records in a monograph of the calanoid copepods of North America (M.S. Wilson, *pers. comm.* to both T.G. Northcote and G.G.E. Scudder), but this work was never completed.

A collection of littoral zone samples from British Columbia lakes and ponds (Chengalath 1982) was obtained from the National Museum of Natural Sciences (NMNS), Ottawa, and examined for calanoid copepods. We have also studied other recent collections from the following British Columbia sources: RBCM, Victoria, B.C.; Ministry of Environment and Parks, Fisheries Branch, Vancouver; international Pacific Salmon Fisheries Commission, New Westminster; Canadian Department of Fisheries and Oceans (DFO), Pacific Biological Station, Nanaimo; University of British Columbia (UBC), Vancouver, and the Westwater Research institute, Vancouver.

Specimens were identified using Wilson's (1959) key to North American calanoid copepods and the original descriptions for each species, genus and subgenus. A checklist was compiled from the author's own records (Sandercock and Scudder *unpub.* MS) and previously published records. Old and new records were plotted to obtain an updated distribution map for each species in B.C.

Geographic co-ordinates and names of collectors for the majority of B.C. lake for the maps and our annotated checklist (in prep.) were obtained from the lake files at B.C. Ministry of Environment and Parks, Fisheries Branch, Vancouver; by reference to Balkwili (1972, 1986), by examination of the appropriate National Topographic Map (1:50,000 series), and by reference to the Gazetteer of Canada for British Columbia (Anon. 1985). Other lake coordinates were obtained from K.I. Ashley and E.A. Parkinson (B.C. Ministry of Environment and Parks, Fisheries Branch, Vancouver, *pers. comm.*), Cannings (1975), Lindsey *et al.* (1981), Rankin *et al.* (1983) and Costella *et al.* (1983). Listings of Wilson's (MSW, *in litt.*) and the authors' British Columbia collection records and topographical map reference numbers are currently on file at the B.C. Ministry of Environment and Parks, Fisheries Branch, UBC.

### **Dissection Methods**

Calanoid copepods were examined using a stereo-zoom dissecting microscope. Two or more males were dissected for each species of calanoid copepod in a given sample. The copepod was placed in a small amount of water at the edge of a water droplet on a glass slide. The 1<sup>st</sup> antennae (A1) and 5<sup>th</sup> legs (S5) were removed from the body using dissecting needles. Total body length was measured for 30-50 adult males and females in each species, when available. Body length was the length of the metasome to the distal end of caudal ramus (excluding caudal setae, Fig. 2). Although tungsten needles mounted on handles have been recommended as dissecting tools (Smith and Fernando 1978; Harding and Smith 1974), fine insect pins mounted on handles were found to be adequate.

The whole animal and dissected parts were examined under a compound microscope, at first without a cover slip. The dissected parts were transferred to another slide with dissecting needles into a drop of permanent mounting medium, Polyvinyl Lactophenol, made by Gurr inc. (Smith and Fernando 1978,

Chapman and Lewis 1976). A coverslip was applied by lowering it gently from the side with a needle. Mounts were ringed with nail polish (as suggested in Smith and Fernando 1978)<sup>8</sup>.

### **Drawing Methods**

Drawings were made with a camera lucida (Wild 1.25x) mounted on a phase compound microscope (10x or 40x objective lens, 10x ocular lens). Whole animals were positioned for drawings on strands of cotton batten in a minimal amount of water in a shallow dish, and drawn without cover-slip. Measurements were made using an ocular micrometer which was calibrated in millimetres.

Figures used in this key include figures redrawn from other publications and original figures drawn by the authors.

### **Identification Methods - Background information**

#### **Identifying calanoid copepod adults from their nauplii and copepodites.**

The present key to British Columbia's freshwater calanoid copepods is for adult males only. In a plankton sample, adult males can be recognized by the right geniculate antenna (except for *Senecella*<sup>9</sup>), by the 5-segmented urosome and by the characteristics of the 5<sup>th</sup> legs (Fig. 2a). Mature females (except for *Senecella*), may be recognized if they are carrying egg sacs, or by the swelling of the genital segment seen in lateral view, whether they have egg sacs or not, or by a 2-4 segmented urosome (Wilson 1959) (Fig. 2b). Adult females can be identified to species occasionally, but with less certainty than adult males (Wilson 1959) and are not included in this key. In a situation where there are 5-6 species present, as in the Great Lakes, once the males are identified, then the corresponding females can be associated with the males and identified to species (Czaika and Robinson 1968).

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<sup>8</sup> There were shrinkage problems using nail polish. J.W. Reid, Smithsonian Institution (*pers. comm.*) recommended that slides be cleaned with 70% alcohol before use, that a period of time such as 2 weeks be allowed for slides to dry, and then slides should be ringed with Glyceel (Gurr Inc.) and dried in a dessicator.

<sup>9</sup> In *Senecella* neither the left nor the right antennae are geniculate in mature males.

In any plankton sample there may be juvenile stages present as well as adults. In calanoid copepods there are six naupliar stages (N1-N6) which may be identified to stage and species in a given lake system by differences in caudal armature and body size (Green and Northcote 1982)(Fig. 3a). Copepodite stages (C1-C6) are recognized by a combination of counting the numbers of pairs of legs and by studying the degree of development of the legs (Ravera 1953, Wilson 1959, Shih and Maclellan 1977, Chapman and Lewis 1978, and Einsele 1989)(Fig. 3b). C1 has 2 pairs of legs, legs 1 and 2 usually having an unsegmented exopod and endopod, and a bud or rudimentary 3rd leg. C2 has 3 pairs of legs and a bud for leg 4. C3 has 4 pairs of legs and a bud for leg 5. Stages C4-C6 have 5 pairs of developed, segmented legs (Wilson 1959). The exact differences in stages vary with different species (Wilson 1959, Comita and Tommerdahl 1960)(Fig. 4). In both stages C4 and C5, the 5<sup>th</sup> pair of legs can be distinguished as to male and female (Wilson 1959, Comita and Tommerdahl 1960)(Fig. 4). The 5<sup>th</sup> leg of C6 has well developed, adult characteristics (Fig. 5a). Detailed descriptions of nauplii and copepodites are found in the literature for only a few species: *D. siciloides* (Comita and Tommerdahl 1960), *D. (Aglaodiaptomus) leptopus* S.A. Forbes (Pinel-Alloul and Lamoureux 1988a, 1988b), *D. nudus* (Shih and Maclellan 1977), and *Eurytemora affinis* (Katona 1971). Copepodites for six species of calanoids in the Great Lakes are described in Czaika and Robinson (1968).

#### **Detailed morphology of adult calanoid copepods - male and female**

Adult calanoid copepods have two long 1<sup>st</sup> antennae, (A1) left and right, inserted ventrally at the head end(cephalosome - CS). The anterior part of the body, the cephalosome consists of a head region with a fused complex of appendages: 1<sup>st</sup> antennae (A1), 2<sup>nd</sup> antennae (A2), mandibles with mandibular palp (MP), 1<sup>st</sup> and 2<sup>nd</sup> maxillae (M1 and M2), and maxillipeds (MXP). The cephalosome is fused to the "thorax" region which has 5 pairs of appendages (swimming legs 1 to 4, plus the 5<sup>th</sup> legs)(Fig. 6).

The metasome or prosome is the term for the cephalosome plus "thorax" and it is the part of the body anterior to the major body articulation. We have followed Wilson (1959) in the use of "metasome" to be equivalent to "prosome", as this use is found frequently in the freshwater copepod literature following

Wilson's 1959 publication. In some publications, metasome has been used as a synonym for "thorax", which is closer to the original terminology of Sars (1901) (from Dudley 1986). The posterior part of the body, the urosome, is segmented and is attached to the metasome at a major point of articulation, between the last metasomal segment and the 1<sup>st</sup> urosomal segment. The urosome is 5-segmented in calanoid males and ends in two caudal rami, each of which have 3-5 caudal setae (Fig. 6). The number of caudal setae on the caudal ramus, the characteristics of the inner and outer seta and differences in the 5<sup>th</sup> leg are used in our key to identify specimens to genus. There are a number of variations in the terminology used to describe the copepod body (Dudley 1986).

#### **Methods for identification to species - Characteristics used in the key.**

The male left and right 1<sup>st</sup> antennae usually both have 25 segments (24 segments in *Eurytemora*). To locate a particular antennal segment it is best to start at terminal segment 25 and count backwards. The number of setae on the segments of the left antenna and the size of the spines on the right antennal segments 10, 11 and 13 are both used in the key. Except in the genus *Senecella*, the right antenna of calanoid copepod males, in dorsal view, has a geniculation or point of flex between segment 18 and the fused segment 19-21. Male right antennal segments 14-18 are usually enlarged. The right antennal segments 22-23, referred to as segment 23, may not have an antennal process. The distal end of the antenna may or may not have an outwardly produced process. The left 1<sup>st</sup> antenna in dorsal view is similar in both males and females, and the left and right 1<sup>st</sup> antennae are similar in females with no geniculation or fused segments (Fig. 7).

The 5<sup>th</sup> pair of legs are asymmetrical in males; symmetrical and smaller in females (the 5<sup>th</sup> legs are entirely lacking in *Senecella* females). Differences in the 5<sup>th</sup> legs are used to identify the genera and species, in male *Diaptomus* these include the size and shape of the inner and distal processes of left leg exopod 2, the modification of the right leg segments, the length of the right leg's lateral spine and the claw shape (Figs. 5a).



## CALANOID COPEPOD TAXONOMIC LIST FOR BRITISH COLUMBIA

### Order Copepoda

#### Suborder Calanoida

##### Family Pseudocalanidae Wilson

###### Genus *Senecella* Juday

###### *S. calanoides* Juday

##### Family Tremoridae Sars

###### Genus *Epischura* Forbes

###### *E. nevadensis* Lilljeborg

###### Genus *Eurytemora* Giesbrecht

###### *E. affinis* (Poppe)

###### Genus *Heterocope* Sars

###### *H. septentrionalis* Juday & Muttkowski

##### Family Diaptomidae Sars

###### Genus *Acanthodiaptomus* Kiefer

###### *A. denticornis* (Wierzejski)

###### Genus *Diaptomus* Westwood

###### Subgenus *Aglaodiaptomus* Light

###### *D. (A.) forbesi* Light

###### *D. (A.) leptopus* S.A. Forbes

###### Subgenus *Hesperodiaptomus* Light

###### *D. (H.) arcticus* Marsh

###### *D. (H.) caducus* Light

###### *D. (H.) eiseni* Lilljeborg

###### *D. (H.) franciscanus* Lilljeborg

###### *D. (H.) hirsutus* M.S. Wilson

###### *D. (H.) kenai* M.S. Wilson

###### *D. (H.) kiseri* Kincaid

###### *D. (H.) nevadensis* Light

###### *D. (H.) novemdecimus* M.S. Wilson

###### Subgenus *Leptodiaptomus* Light

###### *D. (L.) ashlandi* Marsh

###### *D. (L.) connexus* Light

###### *D. (L.) insularis* (Kincaid)

###### *D. (L.) novamexicanus* Herrick

###### *D. (L.) nudus* Marsh

###### *D. (L.) pribilofensis* Juday & Muttkowski

###### *D. (L.) sicilis* S.A. Forbes

###### *D. (L.) siciloides* Lilljeborg

###### *D. (L.) signicauda* Lilljeborg

###### *D. (L.) tyrrelli* Poppe

###### Subgenus *Onychodiaptomus* Light

###### *D. (O.) hesperus* M.S. Wilson & Light

###### *D. (O.) sanguineus* S.A. Forbes

###### Subgenus *Skistodiaptomus* Light

###### *D. (S.) oregonensis* Lilljeborg

###### *D. (S.) pallidus* Herrick

## KEY TO THE FRESHWATER CALANOID COPEPODS OF BRITISH COLUMBIA

### Part 1. Illustrated Key to the Genera (males only).

1. Right 5<sup>th</sup> leg, including claw, longer than left 5<sup>th</sup> leg (see Fig. 25); right exopod 2 ending in a long claw (Fig. 25); caudal ramus with 5 short terminal setae, length of setae 1/3 to 1/2 that of the urosome

(Fig. 26) **2**

Right 5<sup>th</sup> leg, including claw if present, either shorter than or the same length as left 5<sup>th</sup> leg; right exopod 2 ending in a reflexed claw, a long claw or no claw; caudal ramus with 3 or 4 long terminal setae, length of setae more than 1/2 the length of the urosome

(Fig. 17) **3**

2. Apex of last segment (segment 25) of right 1<sup>st</sup> antenna with an outwardly produced process

(Fig. 16) ***Acanthodiaptomus*** Kiefer

[1 sp. *A. denticornis* (Wierzejski)(Map 16)]

Apex of last segment (segment 25) of right 1st antenna without an outwardly produced process

(Fig. 41) ***Diaptomus*** Westwood [In B.C. 28 species]

3. Basal segment 2 of left 5<sup>th</sup> leg with a long curved process

(Fig. 19) **4**

Basal segment 2 of left 5th leg without a long curved process

(Fig. 23) **5**

4. Right exopod 2 with only one segment, the distal end with a reflexed claw; distal end of left exopod 2 with 2 short spines

(Figs. 17, 19) ***Epischura*** Forbes

[In B.C. 1 sp. *E. nevadensis* Lilljeborg (Map1)]

Right exopod 2 with two segments, the distal end rounded at tip and without claw; distal end of left exopod 2 with 1 long spine and 1 short spine

(Figs. 18, 20) ***Heterocope*** G.O. Sars

[In B.C. 1 sp. *H. septentrionalis* Juday and Muttkowski]

5. Distal end of exopod 2 on left 5U' leg enlarged with 2 digitiform processes

(Figs. 21, 23) **Eurytemora** Giesbrecht

[In B.C. 1 sp. *E. affinis* (Poppe)(Map 3)]

Distal end of exopod 2 on left 5<sup>th</sup> leg with a cone-shaped process

(Figs. 22, 24) **Senecella** Juday

[1 sp. *S. calanoides* Juday(Map 4)]

## Part 2. Illustrated Key to the Species of *Diaptomus* and *Acanthodiaptomus* (males only).

1. Left 1<sup>st</sup> antenna with 2 setae on segment 11, and either 1 seta(Fig. 34) or 2 setae (Fig. 33) on some or all of segments 13-19

2

Left 1<sup>st</sup> antenna with only 1 seta on segment 11, and only 1 seta on segments 13-19

11

2. Exopod 2 on left 5<sup>th</sup> leg with both inner and distal processes long; inner process of exopod 2 long and curved, approximately equal to exopod 2 in length (Fig. 25)

3

Exopod 2 on left 5<sup>th</sup> leg with both inner and distal processes short; inner process of exopod 2 a short spine, tooth-shaped or pointed, shorter than exopod 2 (Fig. 27)

4

3. Segment 23 of right 1<sup>st</sup> antenna with an antennal process, this process long, out-curved and tapering and reaching past antennal segment 24 (Fig. 25)

**D. (Aglaodiaptomus) forbesi** Light (Map 5)

Segment 23 of right 1 st antenna without an antennal process, but with a hyaline membrane along segment margin, extending slightly past distal end of segment 23 (Fig. 26)

**D. (Aglaodiaptomus) leptopus** S.A. Forbes (Map 6)

4. Inner margin of basal segment 2 on right 5<sup>th</sup> leg with serrate border (Fig. 27), or denticulate border (Fig. 29), or with cuticular outgrowths (Fig. 28)

5

Inner margin of basal segment 2 on right 5<sup>th</sup> leg smooth, without serrate or denticulate border or cuticular outgrowths (Fig. 30)

7

5. Inner process of exopod 2 on left 5<sup>th</sup> leg a short, wide-based curved spine (Fig. 27)

***D. (Hesperodiaptomus) arcticus*** Wilson (Map 7)

Inner process of exopod 2 on left 5<sup>th</sup> leg a short, narrow-based spine (Figs. 28, 29)

6

6. Basal segment 2 of right 5<sup>th</sup> leg with cuticular outgrowths on inner margin; spine on segment 10 of right 1<sup>st</sup> antenna shorter than spine on segment 13 (Fig. 28)

***D. (Hesperodiaptomus) kiseri*** Kincaid (Map 8)

Basal segment 2 of right 5<sup>th</sup> leg with expansion and denticulate surface; spine on segment 10 of right 1<sup>st</sup> antenna the same length as spine on segment 13 (Fig. 29)

***D. (Hesperodiaptomus) eiseni*** Lilljeborg (Map 9)

7. Segment 3 of left 1<sup>st</sup> antenna with 1 unusually long seta, reaching to distal end of antennal segment 8 (Fig. 30)

***D. (Hesperodiaptomus) hirsutus*** M.S. Wilson (Map 10)

Segment 3 of left 1<sup>st</sup> antenna with seta not so elongate, not reaching past distal end of segment 6 (Fig. 31 )

8

8. Segment 2 of left 1<sup>st</sup> antenna with 4 setae, segment 11 with 2 setae and segments 13-19 each with 2 setae (Fig. 31)

***D. (Hesperodiaptomus) caducus*** Light (Map 11)

Segment 2 of left 1<sup>st</sup> antenna with 3 setae, segment 11 with 2 setae and segments 13-19 each with either 1 seta (Fig. 34) or 2 setae (Fig. 33)

9

9. Basal segment 1 of right 5<sup>th</sup> leg with inner protrusion extending between left and right legs (Fig. 32)

**D. (*Hesperodiaptomus*) *nevadensis*** Light (Map 12)

Basal segment 1 of right 5<sup>th</sup> leg without inner protrusion (Fig. 33)

10

10. Claw on right 5<sup>th</sup> leg long, with length equal to combined lengths of basal segments 1 and 2 plus lengths of exopods 1 and 2 (Fig. 33)

**D. (*Hesperodiaptomus*) *novemdecimus*** M.S. Wilson (Map 13)

Claw on right 5<sup>th</sup> leg short, with length about equal to combined lengths of exopods 1 and 2 (Fig. 34)

**D. (*Hesperodiaptomus*) *kenai*** M.S. Wilson (Map 14)

11. Distal pad of exopod 2 on left 5<sup>th</sup> leg with distinctive transparent lobes<sup>10</sup> (Fig. 35)

**D. (*Hesperodiaptomus*) *franciscanus*** Lilljeborg (Map 15)

Distal pad of exopod 2 on left 5<sup>th</sup> leg not lobed or transparent (Figs. 36, 37, 40)

12

12. Inner process of exopod 2 on left 5<sup>th</sup> leg digitiform, inserted distally and directed outwards away from the mid-line of body; distal process digitiform, inserted on outer side of exopod 2 (Fig. 36)

***Acanthodiaptomus denticornis*** (Wierzejski) (Map 16)

Inner process of exopod 2 on left 5<sup>th</sup> leg digitiform or not, inserted on the inside of exopod 2 and directed mesially, toward midline of the body; distal process digitiform or not, but inserted at distal end of exopod 2 (Figs. 37, 40)

13

13. Processes of exopod 2 on left 5<sup>th</sup> leg not similar to one another, either both modified to form a pincer-like structure, or inner process modified into a curved seta with distal process digitiform (Figs. 37, 39)

14

Both processes of exopod 2 on left 5<sup>th</sup> leg similar to one another, digitiform, not modified to form a pincer-like structure, the inner process not modified into a curved seta (Fig. 38)

16

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<sup>10</sup> Lobes may not be visible if left leg is at an angle (Fin. 35). Lobes are most easily seen before cover slip is put on slide

14. Both inner and distal processes of exopod 2 on right 5<sup>th</sup> leg modified to form a pincer-like structure; lateral spine inserted mid-segment (Fig. 37)

***D. (Onychodiaptomus) sanguineus* S.A. Forbes (Map 17)**

Both inner and distal processes of exopod 2 on right 5<sup>th</sup> leg not modified to form a pincer-like structure; inner process either narrow and straight, or a long, curved Beta; distal process digitiform; lateral spine inserted in lower 1/3 of segment (Figs. 38, 39)

15

15. Right 5<sup>th</sup> leg slender, basal segment 2 elongate, its length 3x its width and with inner proximal portion produced Upward (Fig. 38)

***D. (Onychodiaptomus) Hesperus* M.S. Wilson and Light (Map 18)**

Right 5<sup>th</sup> leg not slender, basal segment 2 not elongate, nearly square-shaped and without inner proximal portion produced upward (Fig. 39)

***D. (Skistodiaptomus) pallidus* Herrick (Map 19)**

16. Segment 23 of right 1<sup>st</sup> antenna without antennal process (Fig. 41)

17

Segment 23 of right 1<sup>st</sup> antenna with antennal process (Fig. 43)

19

17. Distal process of exopod 2 on left 5<sup>th</sup> leg almost the same length as inner process (Fig. 40)

***D. (Leptodiaptomus) pribilofensis* Juday and Muttkowski (Map 20)**

Distal process of exopod 2 on left 5<sup>th</sup> leg twice as long as inner process (Fig. 41)

18

18. Lateral spine of exopod 2 on right 5<sup>th</sup> leg inserted in lower 1/3 of segment, just above claw base (Fig. 41)

***D. (Skistodiaptomus) oregonensis* Lilljeborg (Map 21)**

Lateral spine of exopod 2 on right 5<sup>th</sup> leg inserted close to middle of segment, some distance from claw base (Fig. 42)

***D. (Leptodiaptomus) tyrrelli* Poppe (Map 22)**

19. Antennal process on segment 23 of right 1<sup>st</sup> antenna long, reaching beyond distal end of segment 24 (Fig. 43)

20

Antennal process on segment 23 of right 1<sup>st</sup> antenna short, not reaching beyond distal end of segment 24 (Fig. 45)

21

20. Exopod 2 of right 5<sup>th</sup> leg with proximal part of segment distinctly angled at point of insertion of lateral spine (Fig. 43)

***D. (Leptodiaptomus) ashlandi*** Marsh (Map 23)

Exopod 2 of right 5<sup>th</sup> leg with proximal part of segment slightly curved but not angled at point of insertion of lateral spine (Fig. 44)

***D. (Leptodiaptomus) insularis*** (Kincaid) (Map 24)

21. Lateral spine of exopod 2 on right 5<sup>th</sup> leg inserted above middle of segment (Fig. 45)

***D. (Leptodiaptomus) nudus*** Marsh (Map 25)

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22

22. Spine on segment 8 of right. 1<sup>st</sup> antenna unusually large, about 1/2 the size of the spine on segment 11 (Fig. 46)

***D. (Leptodiaptomus) connexus*** Light (Map 26)

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23

23. Segment 23 of right 1<sup>st</sup> antenna with base of antennal process starting in the middle of segment (Fig. 47)

***D. (Leptodiaptomus) novamexicanus*** Herrick (Map 27)

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24

24. Segment 23 of right 1<sup>st</sup> antenna with antennal process slender, reaching distal end of segment 24, and with swollen tip (Fig. 48)

***D. (Leptodiaptomus) sicilis*** S.A. Forbes (Map 28)

Segment 23 of right 1<sup>st</sup> antenna with antennal process broad, only reaching as far as mid-segment 24, and with tip outcurved (Fig. 49)

25

25. Spine on segment 11 of right 1<sup>st</sup> antenna subequal to or longer than spine on segment 13 (Fig. 49)

***D. (Leptodiaptomus) siciloides*** Lilljeborg (Map 29)

Spine on segment 11 of right 1<sup>st</sup> antenna about 1/2 the length of the spine on segment 13<sup>11</sup> (Fig. 50)

***D. (Leptodiaptomus) signicauda*** Lilljeborg (Map 30)

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<sup>11</sup> Based on Wilson's (1959) figure of *D. moorei* M.S. Wilson 1954



## GLOSSARY

[illegible]


- 1st antenna - the first appendage of the head-region in calanoid copepods, usually with 25 segments.
- 5th legs - the 5th pair of swimming legs, in calanoids modified structurally for mating.
- acid rain - rain water with higher pH than normal, due to acidic emissions from industry.
- body articulation - the point of flex, where the copepod body bends.
- brackish - water that is part marine, part freshwater.
- cephalosome - the head region of a calanoid copepod; with 2 pairs of antennae and mouthparts as appendages.
- cohort - a group of individuals in one life-stage of a copepod's life cycle, a cohort can be followed from one stage to the next.
- Diapause - a period of arrested development, often seasonal.
- euryhaline - organisms found in both freshwater and part marine - part freshwater.
- G1, G2, etc.- G1 is the first generation of adults to appear in a year, G2 is the 2nd generation, etc.
- genital segment - in female calanoid copepods, the 1<sup>st</sup> urosome segment, which is often swollen in appearance.
- geniculate - bent or flexed, used in calanoids to refer to the male right antenna. In *Diaptomus* the geniculation of the male right antenna is between segment 18 and the fused segment 19-21 (Wilson 1959).
- herbivorous - animals with a diet wholly of plant material.
- lake fertilization - the experimental addition of fertilizing nutrients to a lake's surface.
- lake neutralization - the experimental addition of buffering agents or neutralizing agents to a lake, in order to return the lake pH to near normal levels.
- limnetic - found in the open-water area of a lake.
- mandible - one of the mouthparts of a copepod, used for biting or crushing.
- mandibular palps - one of the mouthparts, used in feeding.
- metasome - equivalent to prosome, is formed from the fusion of the cephalosome and the "thorax", with
- Wand 2<sup>nd</sup> antennae, the mouthparts and the swimming legs as appendages.

- mesotrophic - term for a lake with an intermediate level of nutrients; intermediate between oligotrophic, of low nutrient levels and eutrophic, with high nutrient levels.
- MSW, *in litt.* - the previously unpublished records of Mildred S. Wilson for British Columbia, obtained courtesy of T.E. Bowman, NMNS.
- multivoltine - more than 1 generation of adults per year.
- NMNH - National Museum of Natural History, Washington ,D.C.
- NMNS - National Museum of Natural Science, Ottawa, Ontario now new name?
- Oligotrophic - a nutrient-poor lake.
- omnivorous - having a diet consisting of both plant and animal materials.
- planktivorous fish - fish which prey on plankton
- planktonic - free-floating in the water column of a lake or pond, yet sometimes exhibiting diurnal migrations.
- polycyclic - having many generations of adults per year.
- primary consumers -an animal which feeds on plant material ( the first level of consumption in a food web).
- productivity - the amount of biomass produced by a body of water, usually expressed, unit area / year.
- prosome - equals metasome.
- RBCM - Royal British Columbia Museum, Victoria, B.C.
- secondary consumers - animals which feed on plant-eating animals (second level of consumption in a food web).
- syntype -
- UBC - University of British Columbia, Vancouver, B.C.
- univoltine - one generation of adults per calendar year.
- urosoma - the segmented posterior of calanoid copepods, the part of the calanoid copepod body posterior to the point of flex. In the female calanoid the 1<sup>st</sup> segment of the urosoma is called the genital segment.

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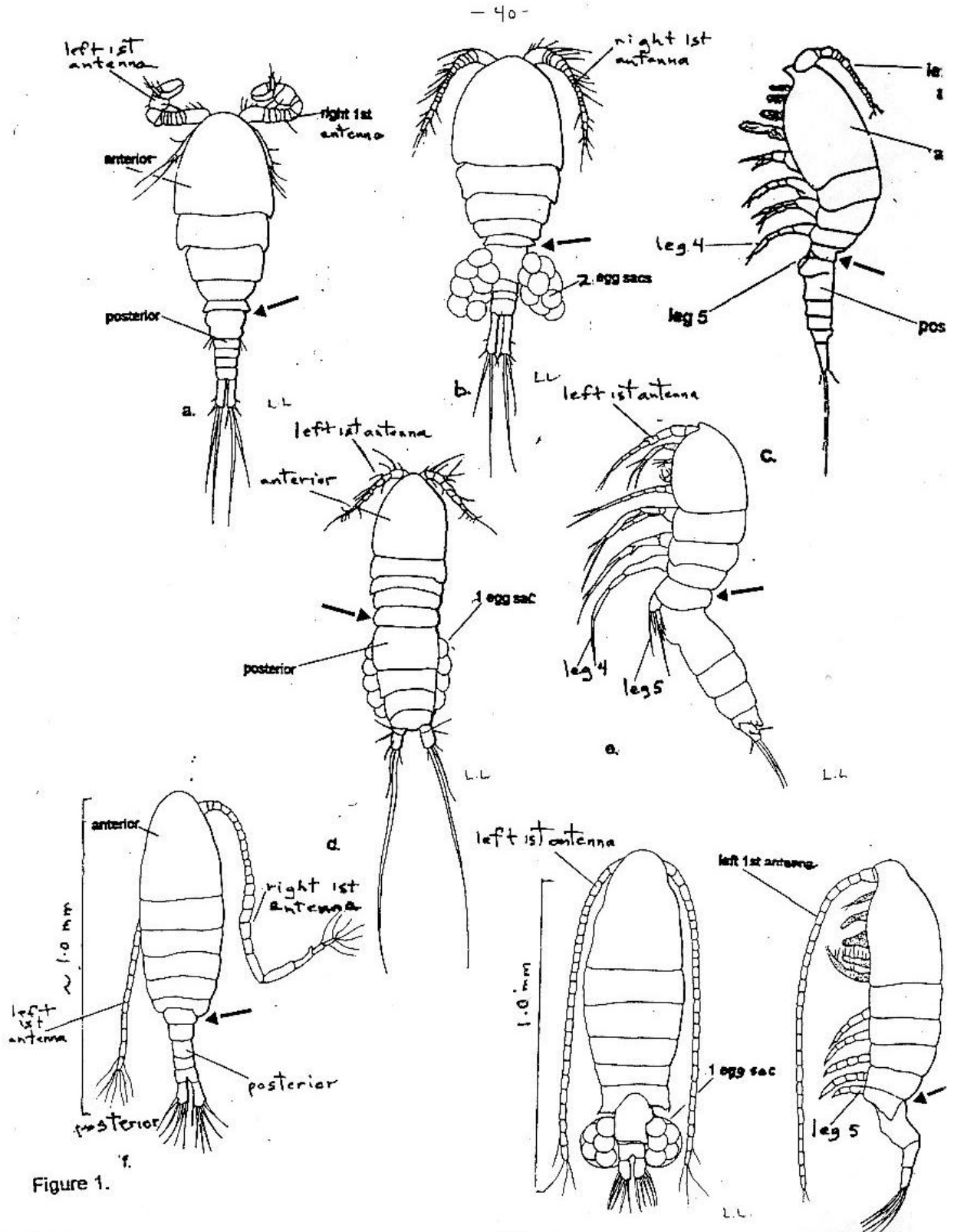


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<i>D. nevadensis</i>	Fig. 32	70
<i>D. novamexicanus</i>	Fig. 47	81
<i>D. novemdecimus</i>	Fig. 33	72
<i>D. nudus</i>	Fig. 45	79
<i>D. oregonensis</i>	Fig. 41	76
<i>D. pallidus</i>	Fig. 39	75
<i>D. pribilofensis</i>	Fig. 40	76
<i>D. sanguineus</i>	Fig. 37	75
<i>D. sicilis</i>	Fig. 48	82
<i>D. siciloides</i>	Fig. 49	83
<i>D. signicauda</i>	Fig. 50	84
<i>D. tyrrelli</i>	Fig. 42	77
<i>Epischura nevadensis</i>	Fig. 19	59
<i>Eurytemora affnis</i>	Fig. 21	60
<i>Eurytemora affnis</i>	Fig. 23	61
<i>Hetercope septentrionalis</i>	Fig. 18	58
<i>Hetercope septentrionalis</i>	Fig. 20	59
<i>Senecella calanoides</i>	Fig. 22	60
<i>Senecella calanoides</i>	Fig. 24	61

Figure 1. Adult Cyclopoida (a.-c.), Harpacticoida (d.-e.) and Calanoida (f.-h.) showing distinguishing features. (a.- b.) *Acanthocyclops vernalis* (Fischer) (after Smith and Fernando 1978). (a.) dorsal view of male (b.) dorsal view of female (c.) Lateral view of female [species not given] (after Harding and Smith 1974). (d.) *Canthocamptus staphylinoides*, dorsal view of female (after Smith and Fernando 1978). [Note: The male body form in harpacticoids is similar to the female, but with both right and left 1st antennae geniculate] (e.) *C. staphylinus*, lateral view of female (modified from Gurney 1932). (f.- h.) *Diaptomus nudes* Marsh (Copp Lake, B.C., drawn with reference to Shih and Maclellan 1977). (f.) dorsal view of male; (g.) dorsal view of female; (h.) lateral view of female



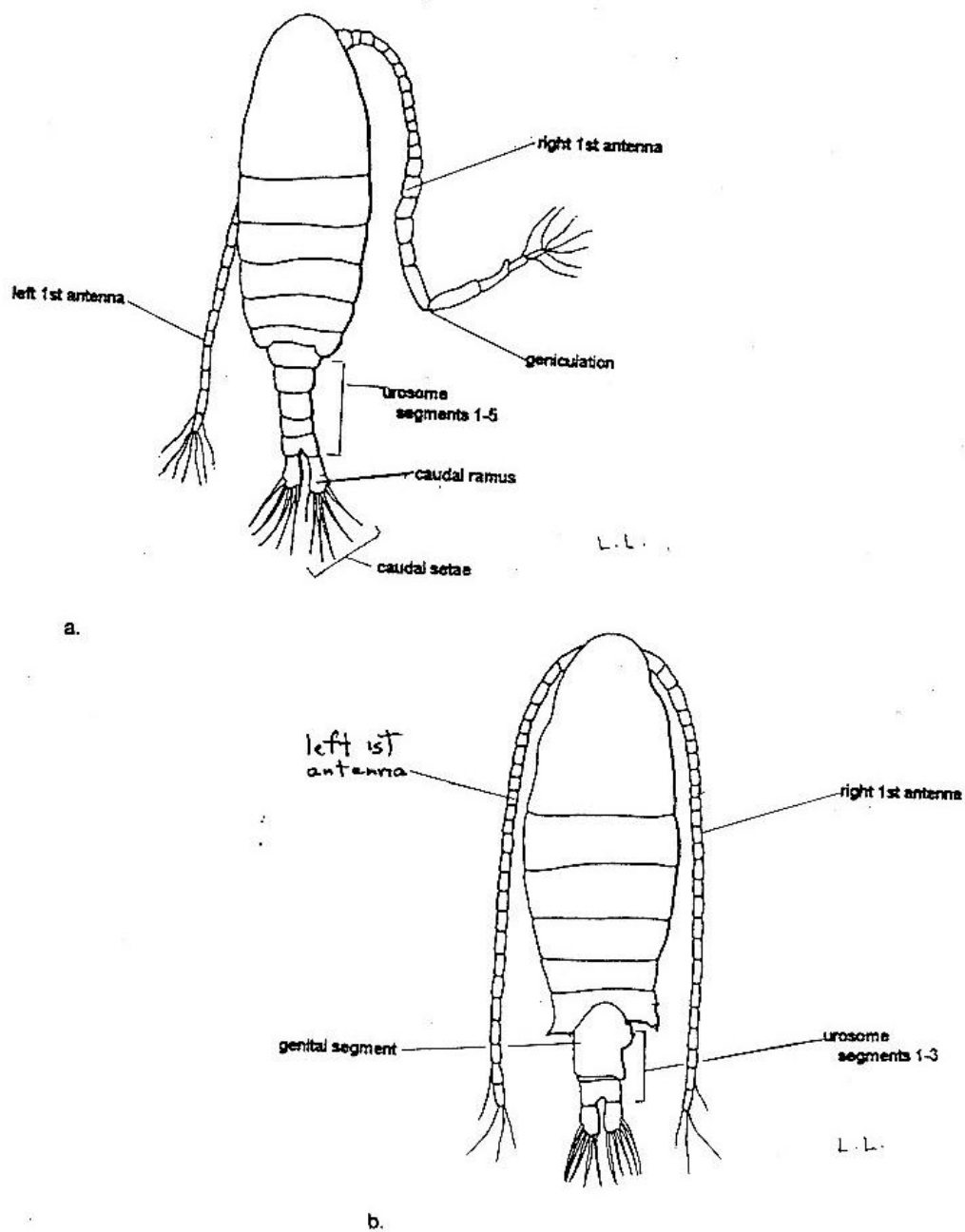


Figure 2. (a.) Adult male and (b.) adult female *Diaptomus nudus* Marsh, dorsal view, showing differences in male and female 1<sup>st</sup> antennae and urosome (Copp L., B.C., drawn with reference to Shih and Maclellan 1977).

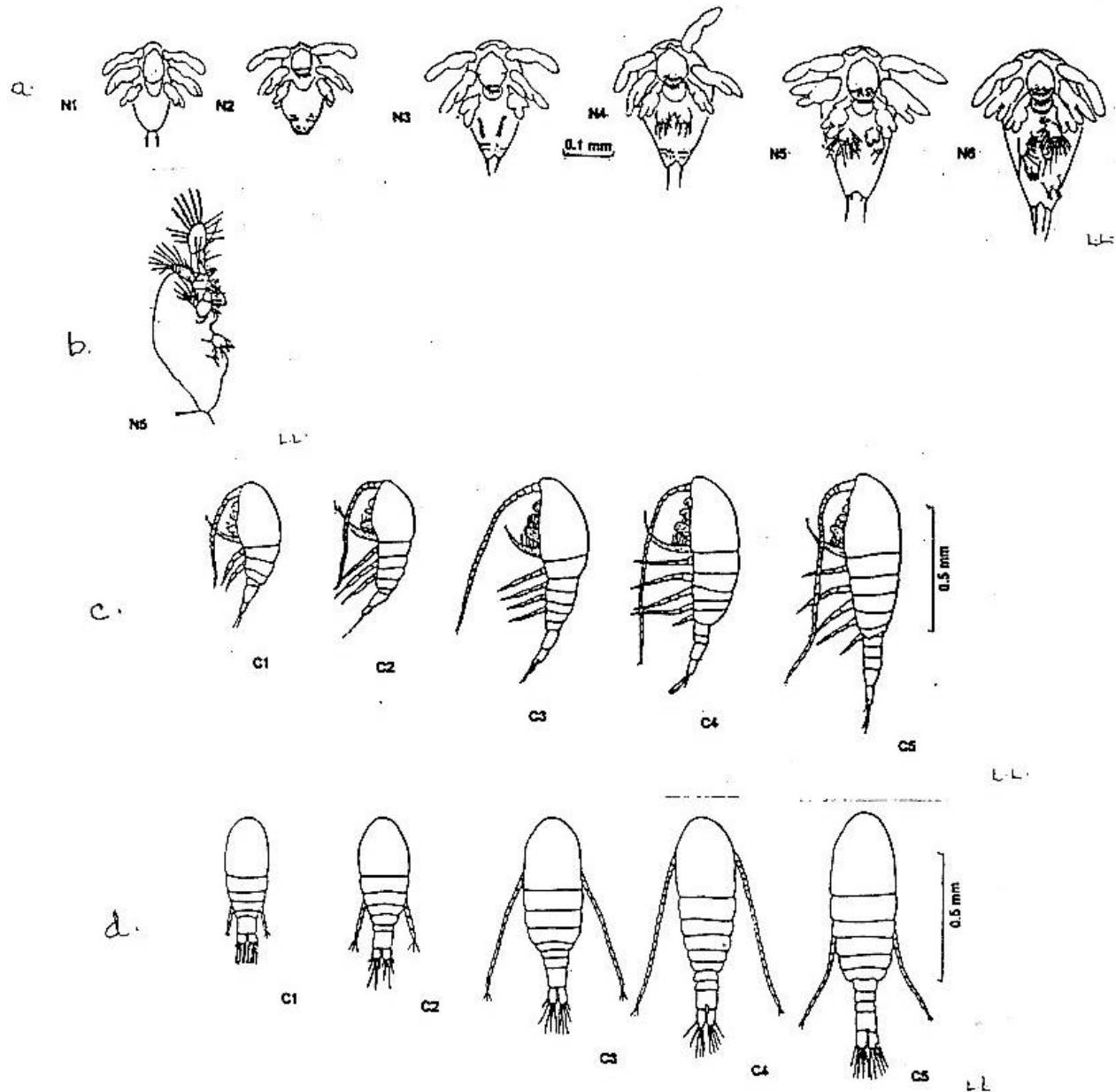


Figure 3. Naupliar and copepodite stages of *Diaptomus* spp. (a.) N1 - N6, naupliar stages of *D. kenai* M.S. Wilson, ventral view (after Green and Northcote 1982). (b.) N5, nauplius stage 5 of *D. gracilis* Sars, lateral view (after Gurney 1931). (c - d.) C1 - C5, copepodite stages of *Diaptomus* sp. (modified from Shih and Maclellan 1977 and Einsele 1989). (c.) lateral view (d.) dorsal view



Figure 4 Development of legs in calanoid copepods, Stages 1-5 (C1- C5).

Copepodite Stage 1 (C1)

(a ) 2<sup>nd</sup> pair of legs, anterior view.

(b ) leg bud (develops into 3<sup>rd</sup> leg of C2)

(c ) lateral view with 2 pairs of legs and showing position of C1 leg bud

Copepodite Stage 2 (C2)

(d ) leg bud (develops into 4<sup>th</sup> leg of C3)

(e ) with 3 pairs of legs and showing position of C2 leg bud

Copepodite Stage 3(C3)

(f ) leg bud (develops into 5<sup>th</sup> leg of C4)

(g ) lateral view with 4 pairs of legs and showing position of C3 leg bud

Copepodite Stage 4(C4)

(h ) 5<sup>th</sup> leg, female, posterior view (develops into 5<sup>th</sup> leg of C5 female)

(i ) 5<sup>th</sup> leg, male, posterior view ( develops into 5<sup>th</sup> leg of C5 male).

(j ) lateral view with 5 pairs of legs showing position of either male or female 5<sup>th</sup> leg

Copepodite Stage 5 (C5)

(k ) 5<sup>th</sup> leg, male, posterior view (develops into 5<sup>th</sup> leg of male C6).

(l ) 5<sup>th</sup> leg, female, posterior view (develops into 5<sup>th</sup> leg of female C6).

(m ) lateral view with 5 pairs of legs and showing position of either male or female 5<sup>th</sup> leg

Figures a, b, d, f, h, i, k, and l, copepodite leg buds and legs of *Diaptomus siciloides* Lilljeborg (after Comita and Tommerdahl 1960)

Figures c, e, g, j, and m, lateral views of copepodites (C1-C5), (modified from Shih and Maclellan 1977 and Einsele 1989)



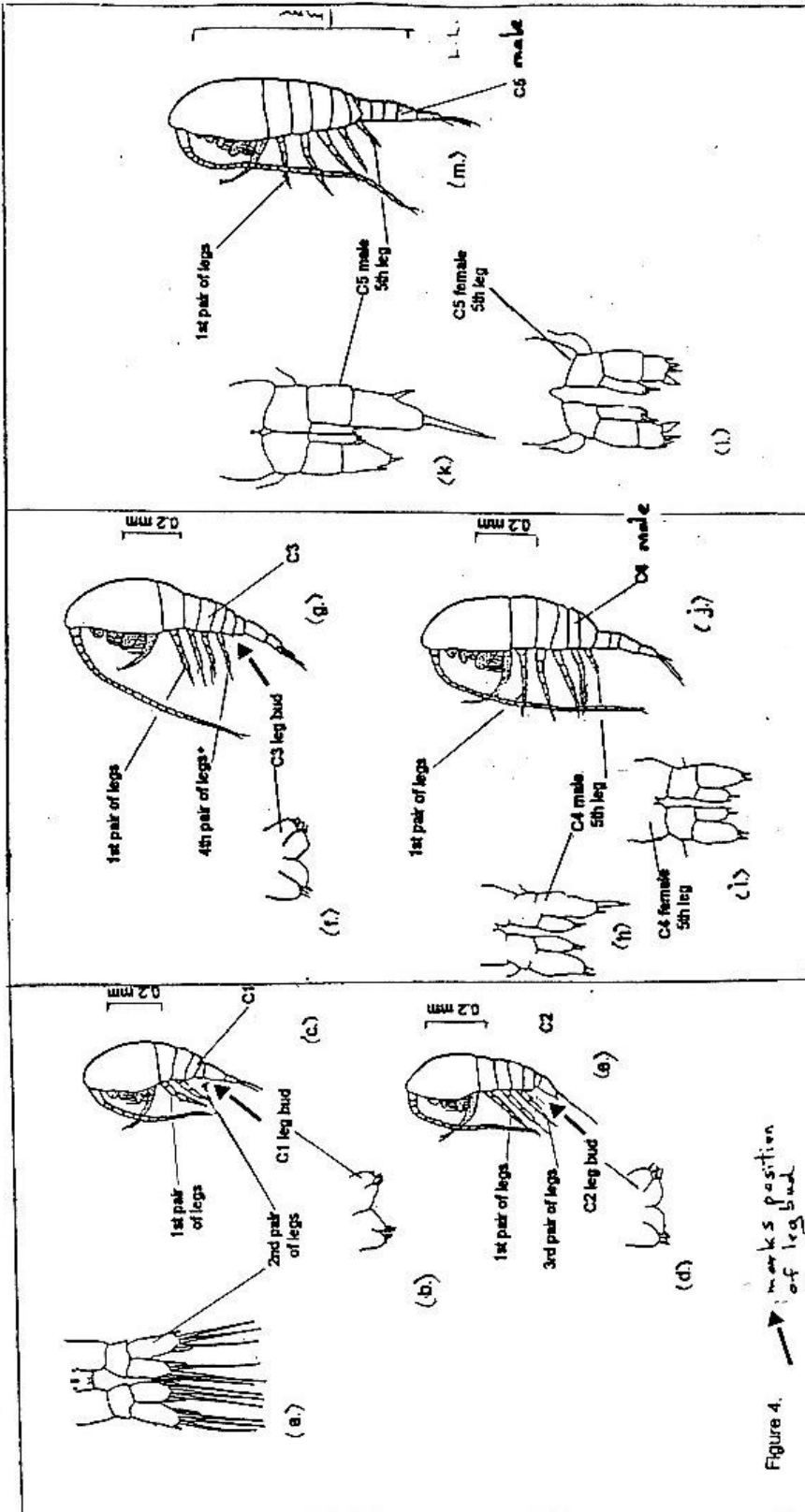




Figure 5 Adult (C6) 5<sup>th</sup> legs with parts identified (a.) Male 5<sup>th</sup> leg, posterior view (after Wilson 1959) (b.) Female 5<sup>th</sup> leg, posterior view (after Shih and Maclellan 1977) (c.) male, lateral view (d.) female, lateral view.

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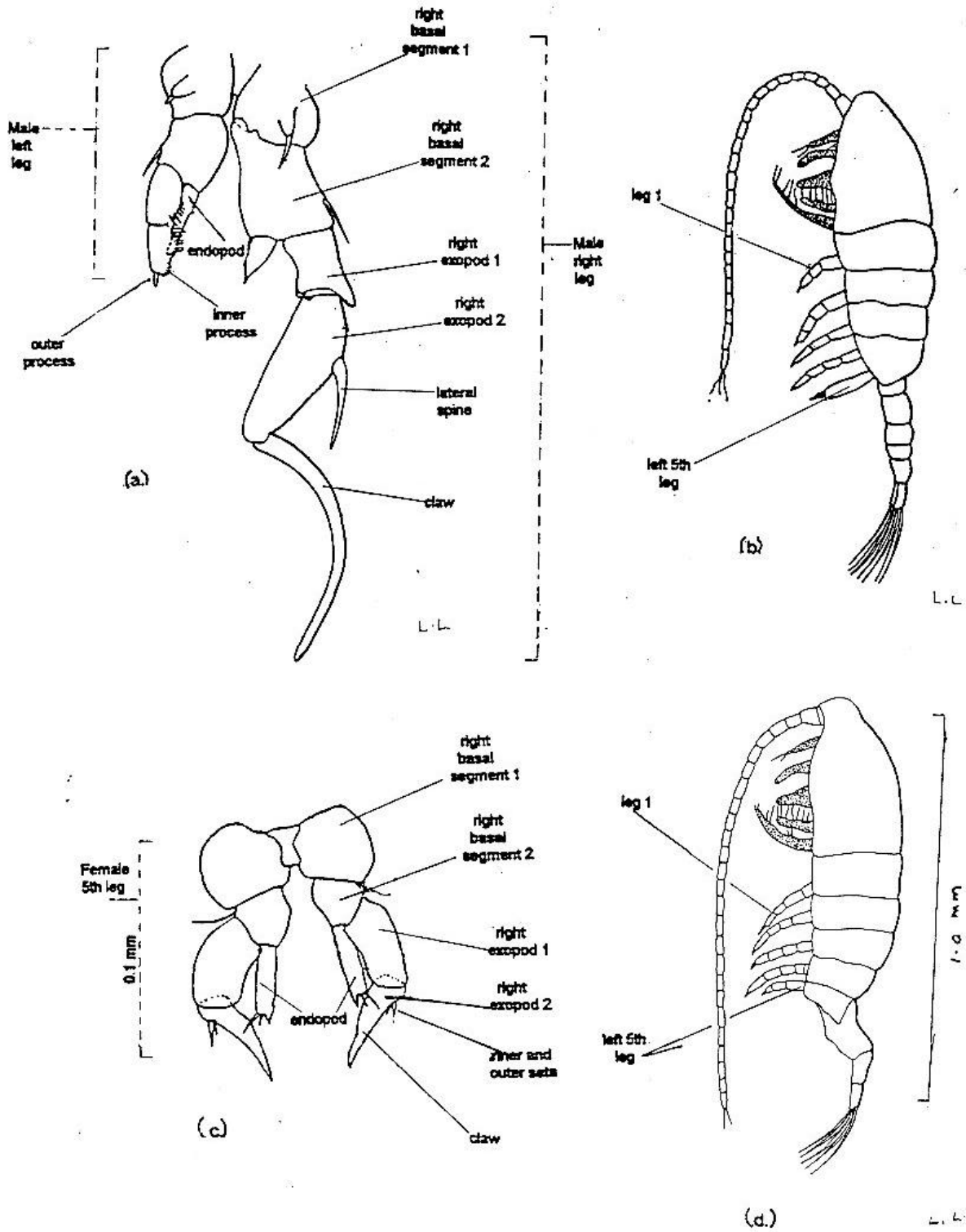


Figure 5.



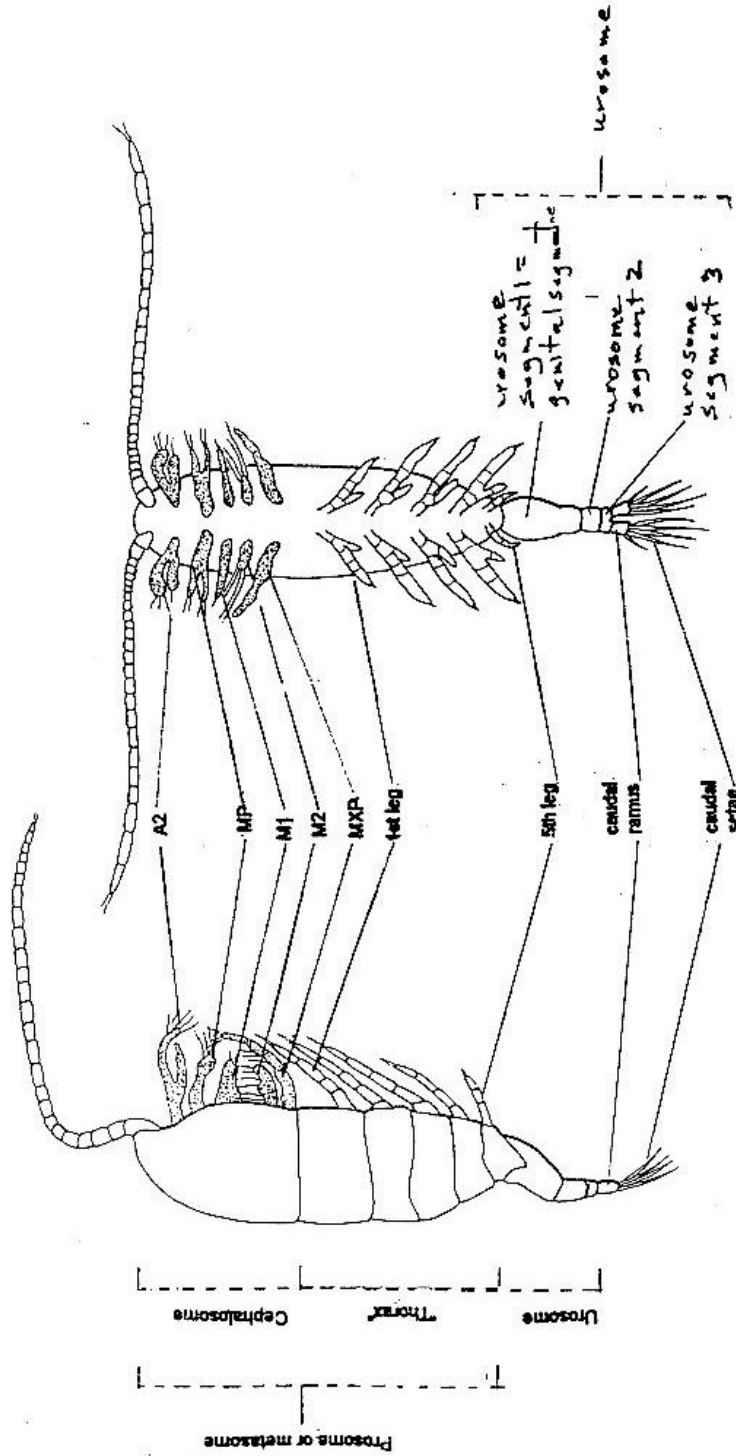


Figure 6. Female calanoid with body parts identified, and diagram of mouthparts. (a.) *Diaptomus nudus* Marsh, lateral view (Copp L., B.C.) Mouthparts, 2<sup>nd</sup> antenna (A2), mandibular palp (MP), 1<sup>st</sup> maxilla (M1), 2<sup>nd</sup> maxilla (M2), and maxilliped (MXP); (modified from Vanderploeg and Paffenhöffer 1985, Lowndes 1935, Sars 1903) (b.) Ventral view, modified from Ilig (1975).

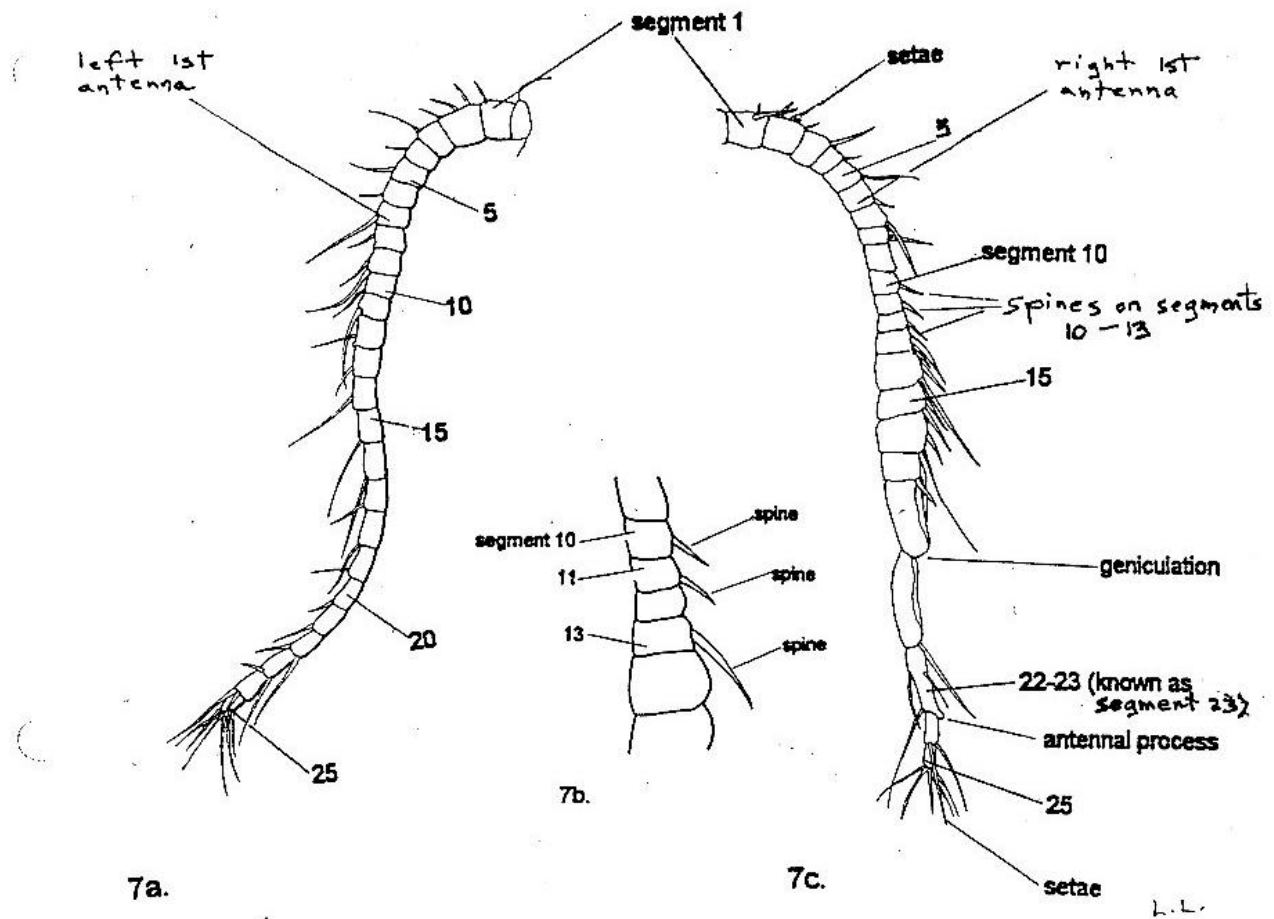


Figure 7. Male 1<sup>st</sup> antennae, *Diaptomus nudus* Marsh (after Shih and Maclellan 1977). (a.) Left antenna, segments 1-25 (b.) Right antenna, spines on segments 10, 11 and 13 (modified from Shih and Maclellan 1977 to show spines only) (c.) Right antenna, segments 1-25 [Note: Scale for a. and c. only].

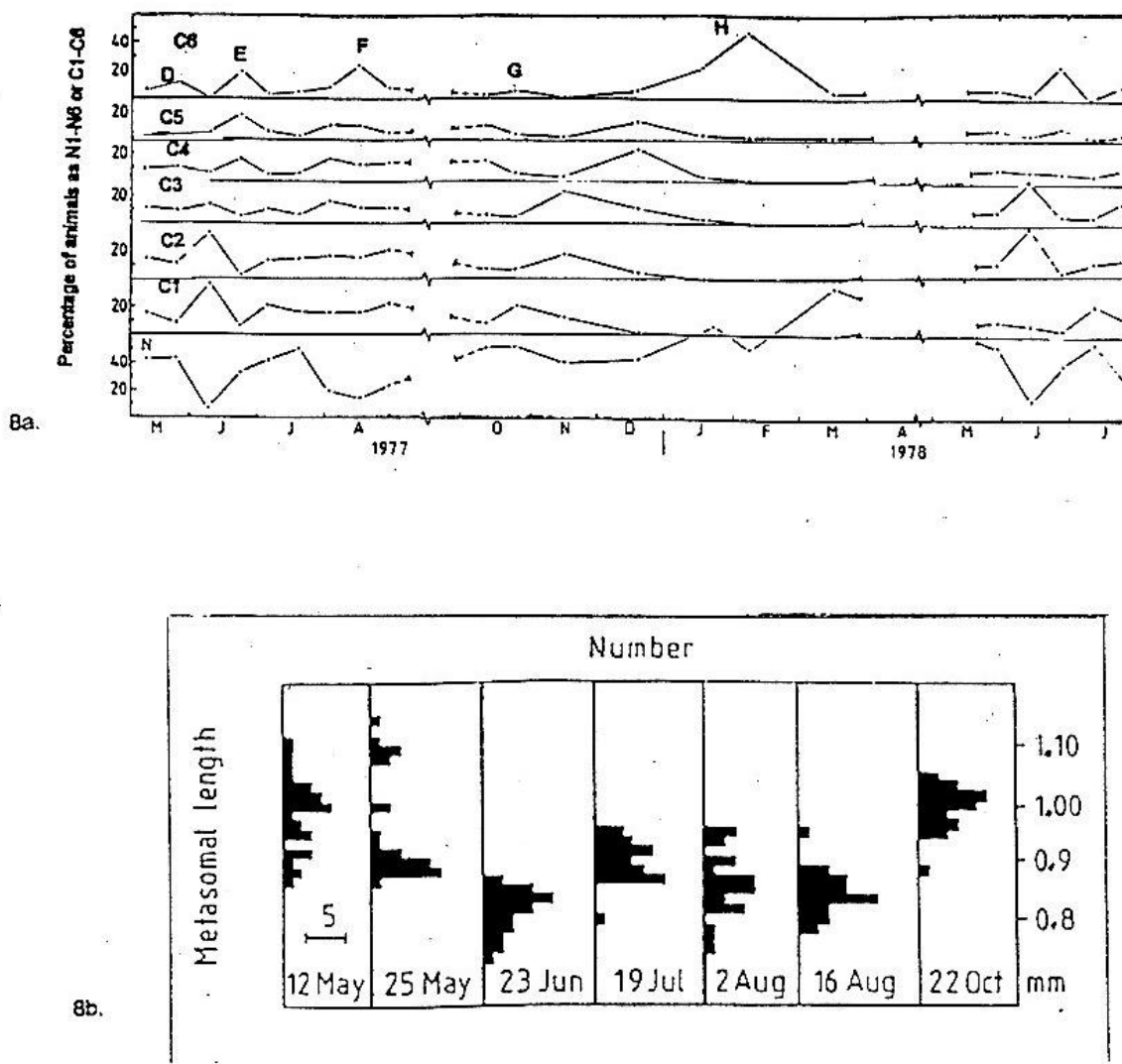


Figure 8. (a.) Seasonal population dynamics of *Diaptomus pallidus* Herrick in Deer Lake, Burnaby, B.C. Percentage of animals as nauplii (N) and copepodite stages (C1-C6), D to H = sequential cohorts of adults (after Chapman *et al.* 1985) (b.) Seasonal changes in adult metasome length of *D. pallidus* (after Chapman *et al.* 1985).



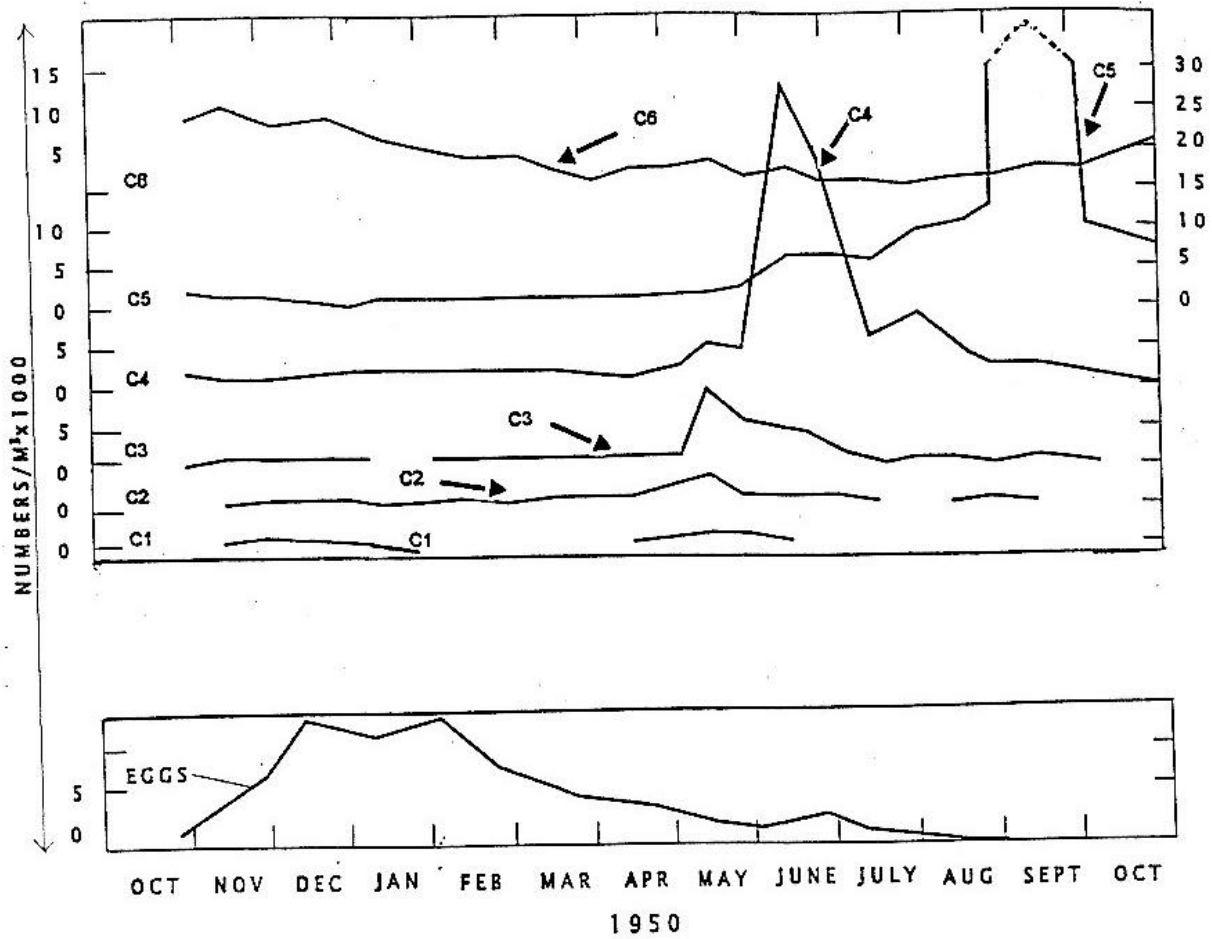
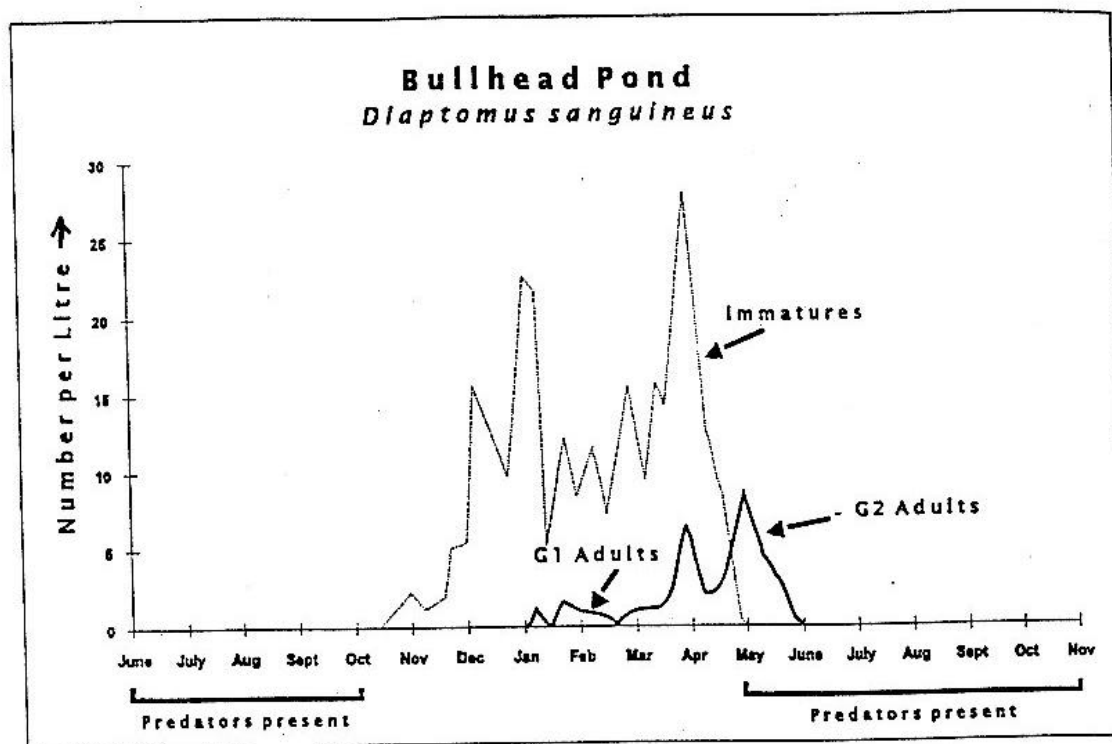


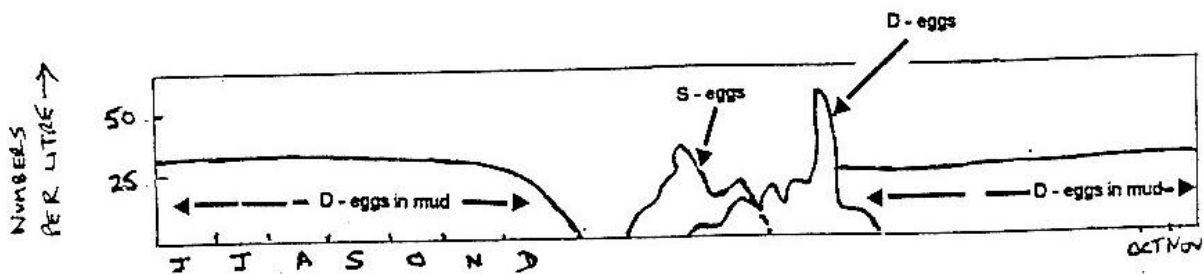
Figure 9. Population changes in the developmental stages of *Diaptomus ashlandi* Marsh in Lake Washington, Washington State. C1-C5 = copepodites 1-5, and C6 adults (modified from Comita and Anderson 1959).



10a.

L.L.

(MS Graph format imported into Corel Draw Document)  
L. Lucas Feb. 16/94



10b.

Figure 10. Life cycle of *Diaptomus sanguineus* S.A. Forbes, in Bullhead Pond, Rhode Island. (a.) Two generations of adults (G1-G2) in one year (b.) Numbers of diapausing eggs in the mud, numbers of subitaneous eggs [S-eggs] carried by females, and numbers of diapausing eggs [D-eggs] carried by females (modified from Hairston Jr., 1987).

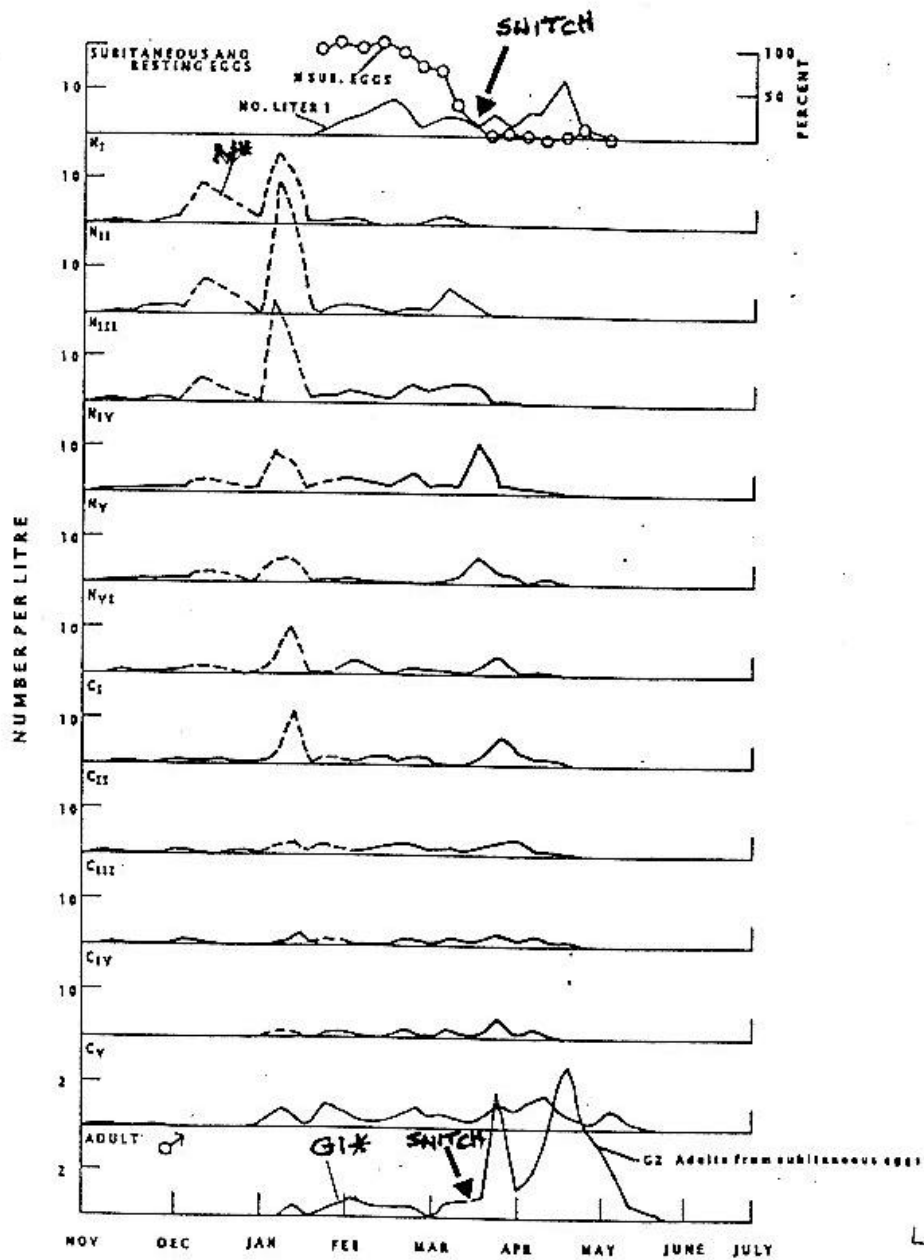


Figure 11. Cohort analysis of *Diaptomus sanguineus* S.A. Forbes, in Bullhead Pond, Rhode Island, showing two discrete generations of nauplii (N1-N6), copepodites (C1-C5), and adults (G1 = generation 1; G2 = generation 2) over a one year period.

N\* = nauplii which have developed from diapausing eggs and which develop into G1.  
 G1\* = females which produce subitaneous eggs which develop into G2.  
 Switch\* = females switch from producing subitaneous eggs to producing diapausing eggs which marks the end of G1 (after Hairston and Olds 1984).

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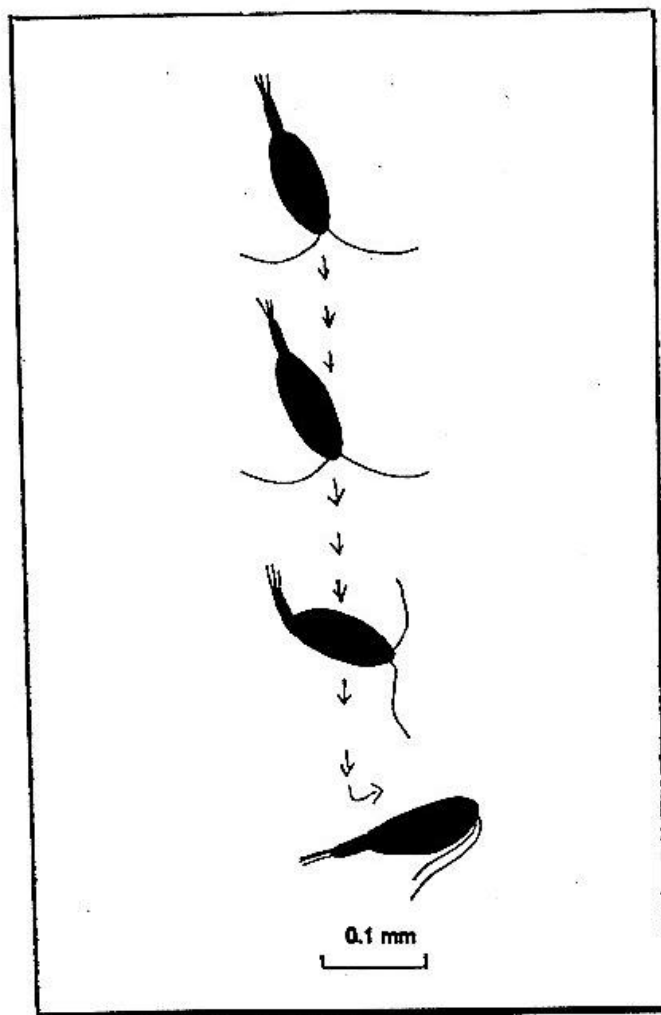


Figure 12. A feeding *Diaptomus* sp. drawn from high-speed film photographs showing changes in antennal position (from Strickler 1977).

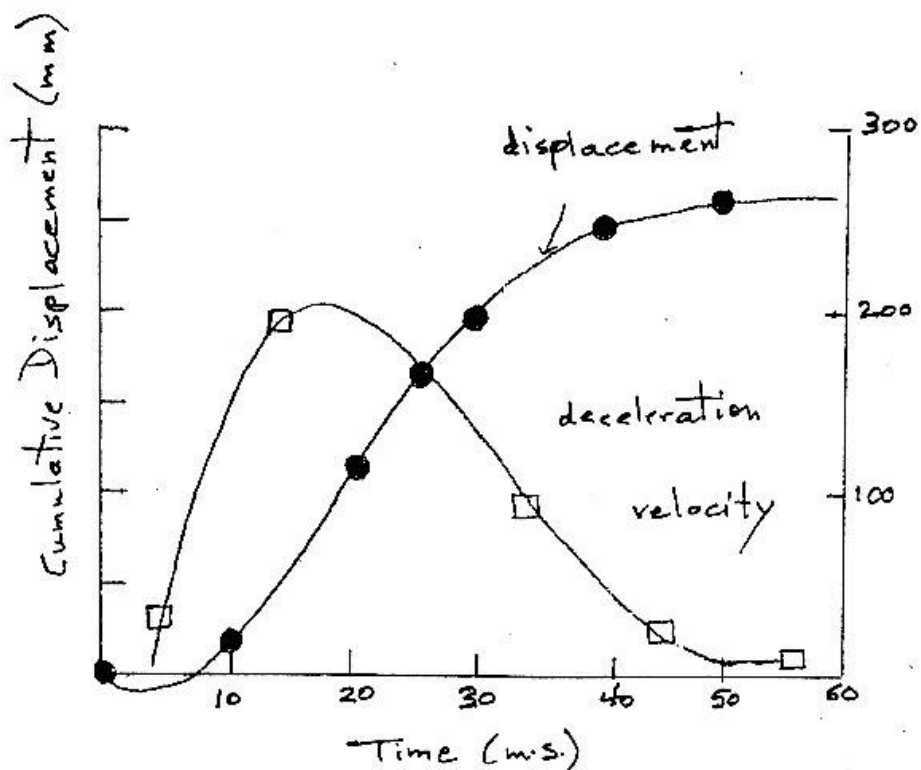


Figure 13. A high velocity escape response of *Diaptomus franciscanus* Lilljeborg, following successive positions (displacement) of the copepod with time (after Lehman 1977). □ - average velocity between frames • - successive positions of *D. franciscanus*.

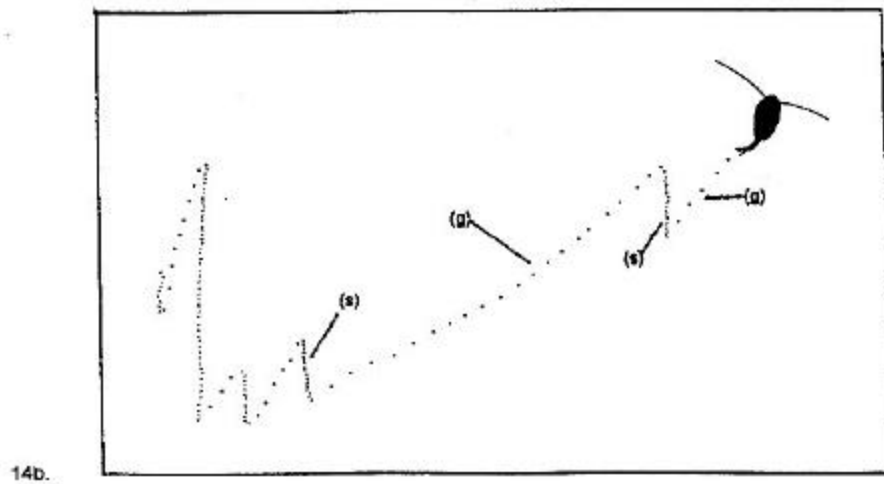
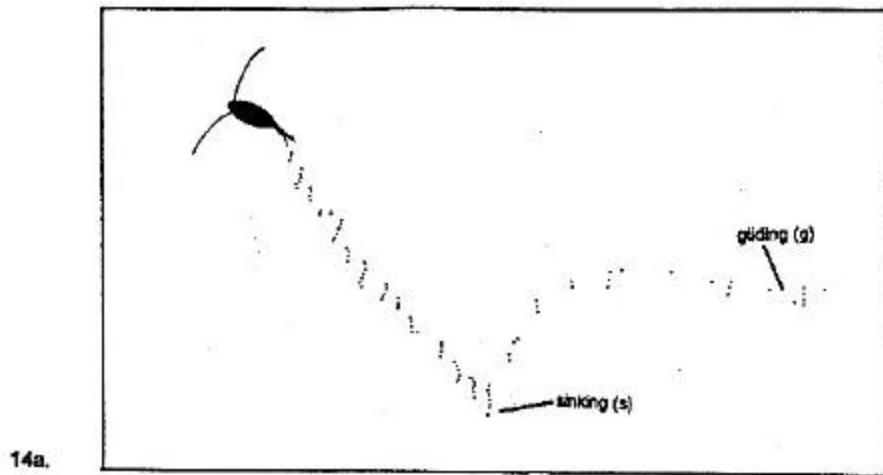


Figure 14. Tracing of swimming paths showing sinking [s] and gliding [g] (after Wang and Sprules 1986).  
(a.) *Senecella calanoides* Juday (b.) *Epischura lacustris* S.A. Forbes.



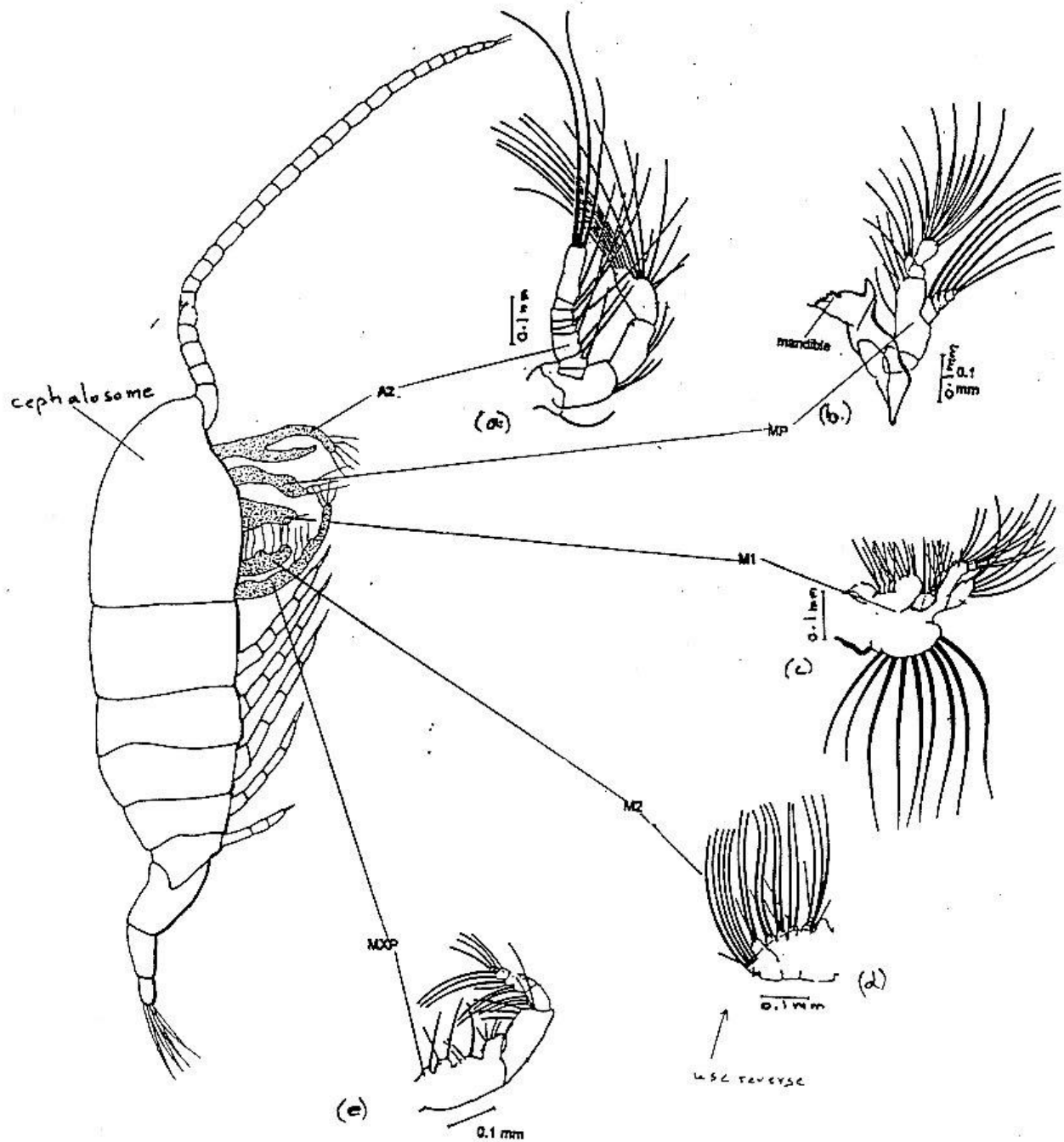


Figure 15. Mouthparts of *Diaptomus kenai* M.S. Wilson (drawn under a light microscope, after Chapman 1982) with diagram of cephalosome and mouthparts (after Vanderploeg and Paffenhöfer 1985).  
 (a.) = A2 = 2<sup>nd</sup> antenna (b.) = MP = mandible and mandibular palp (c.) = M1 = 1<sup>st</sup> maxilla  
 (d.) = M2 = 2<sup>nd</sup> maxilla (e.) = MX = maxilliped.



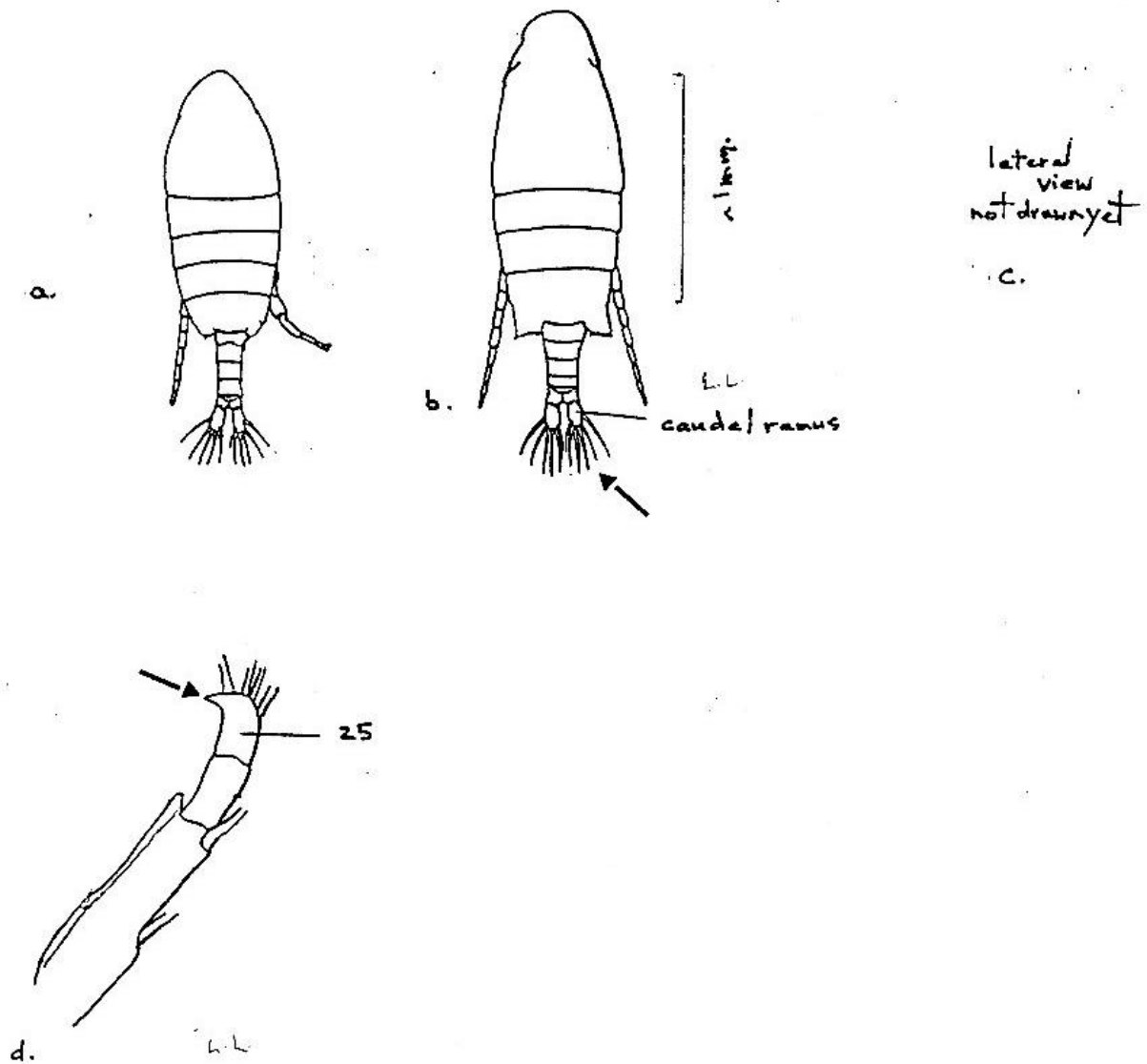


Figure 16. *Acanthodiaptomus denticornis* (Wierzejski). (a.) Male, dorsal view (b.) Female, dorsal view (c.) Female, lateral view (a.- c.) Bickle L., B.C., after Einsele 1989 (d.) Male, right 1<sup>st</sup> antenna, segments 23-25 with outwardly produced process at distal end of segment 25 (e.- f.) Detail of male, 5<sup>th</sup> leg, posterior view (after Wilson 1959) (e.) left (f.) right.

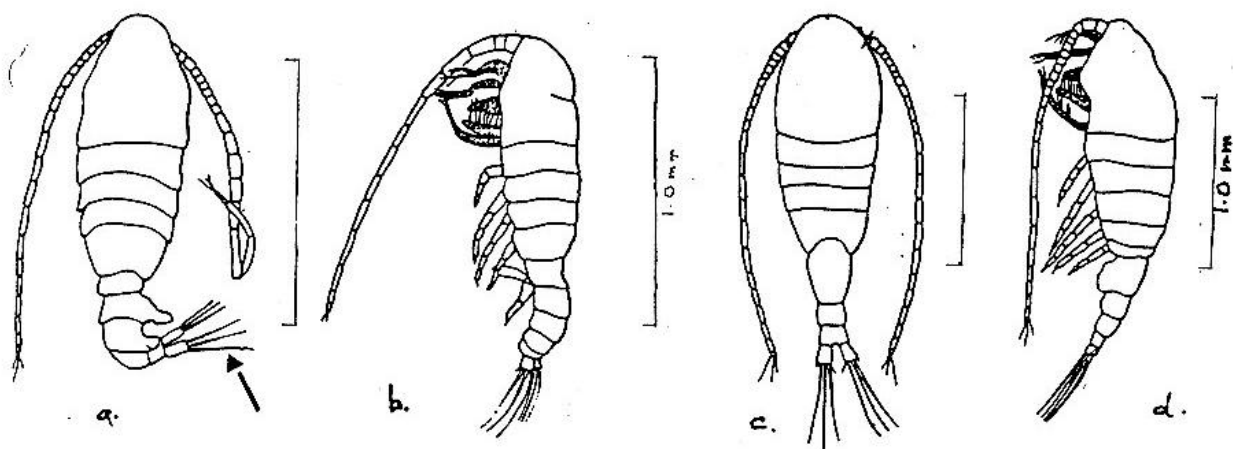


Figure 17. *Epischura nevadensis* Lilljeborg. (a.) Male, dorsal view (b.) Male, lateral view (c.) Female, dorsal view (d.) Female, lateral view (a.- d.) body; Shuswap L., B.C.; antennal segments; Cheslatta L., B.C..

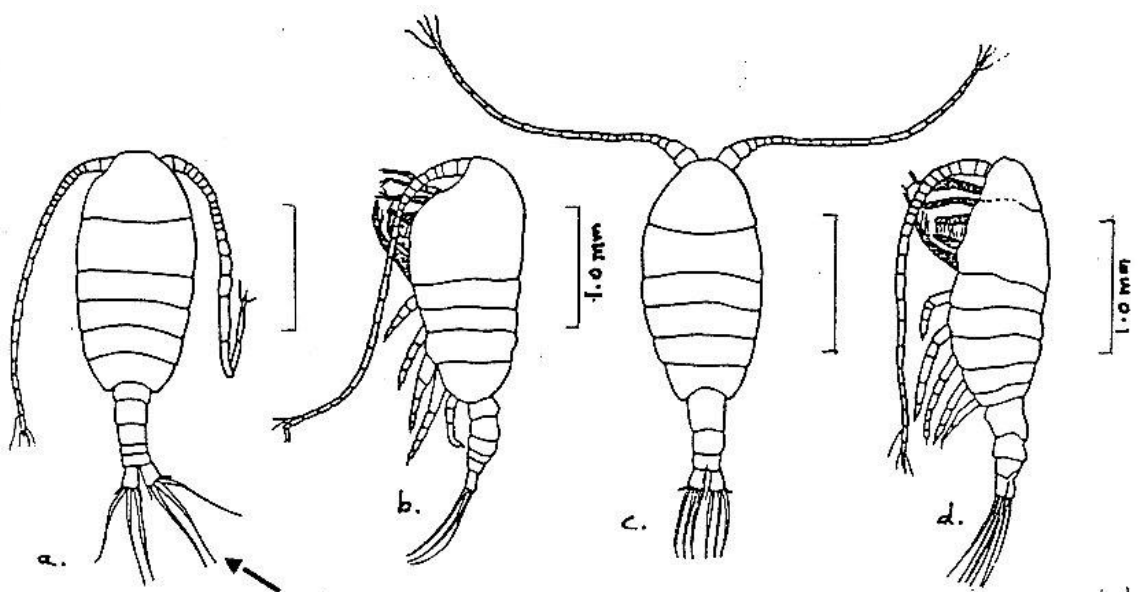


Figure 18. *Heterocope septentrionalis* Juday and Muttkowski. (a.) Male, dorsal view (b.) Female, dorsal view (c.) Male, lateral view (d.) Female, lateral view (a.- d.) body; Fraser L., B.C.; antennal segments; Chief L., B.C..

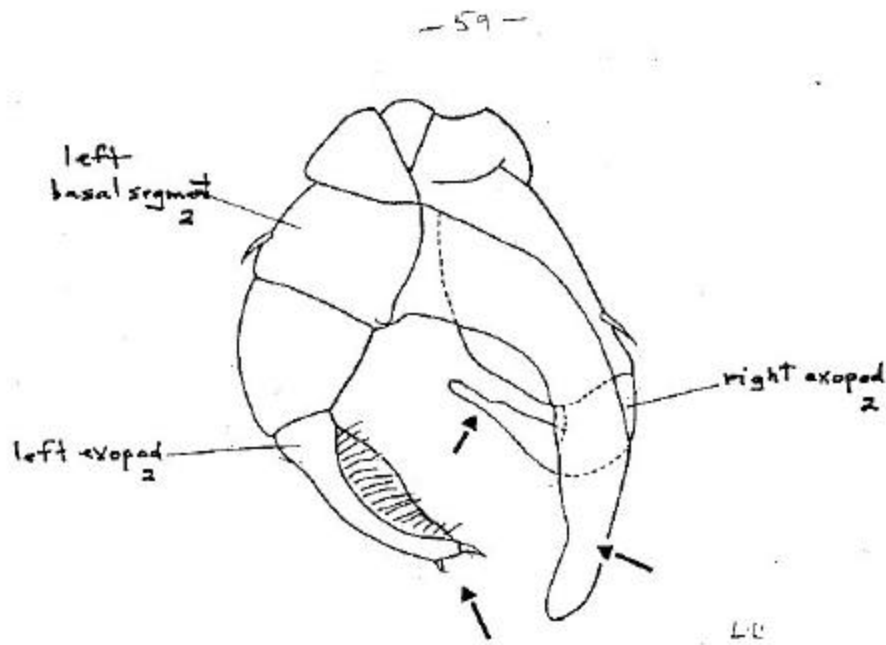


Figure 19. *Epischnra nevadensis* Lilljeborg, male 5<sup>th</sup> leg, posterior view (after Wilson 1959) [no scale given].

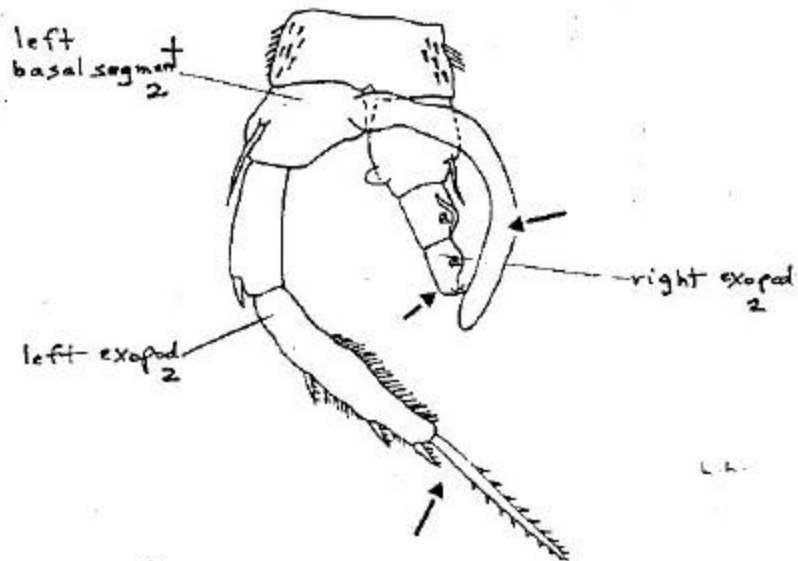


Figure 20. *Heterocope septentrionalis* Juday and Muttkowski, male 5<sup>th</sup> leg, posterior view (after Wilson 1959) [no scale given].

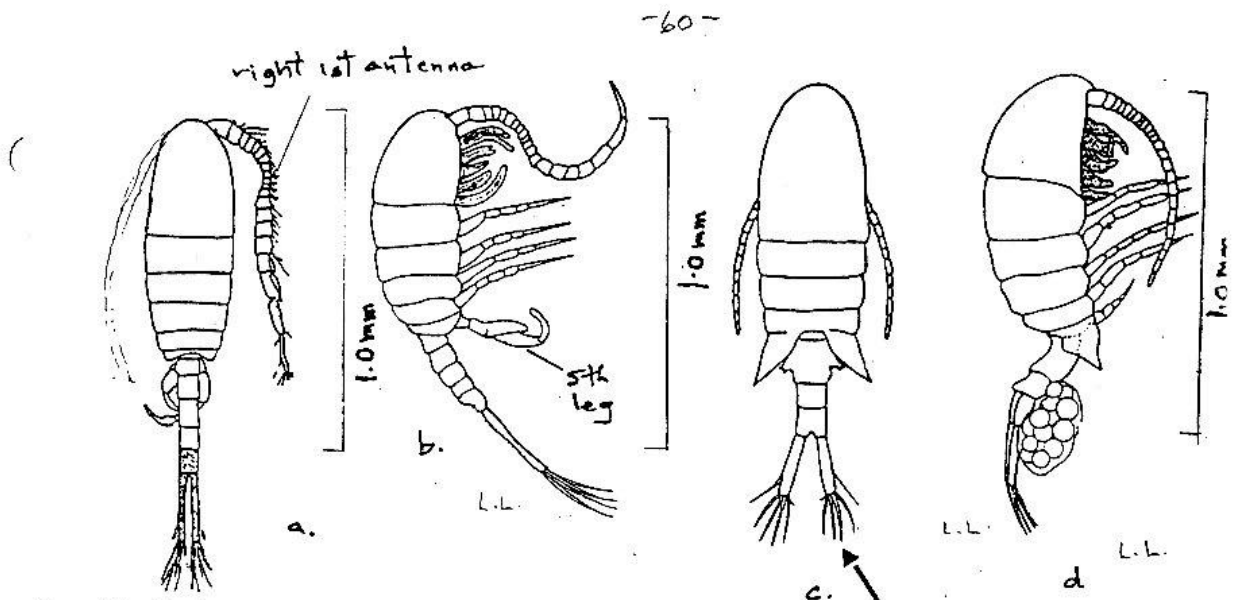


Figure 21. *Eurytemora affinis* (Poppe). (a.) Male, dorsal view (with reference to Gardner and Szabo 1982) (b.) Male, lateral view (after Katona 1971 and Gurney 1931) (c.) Female, dorsal view (after Gurney 1931) (d) Female, lateral view (after Katona 1971) (b.-d.) Nitinat L., B.C.

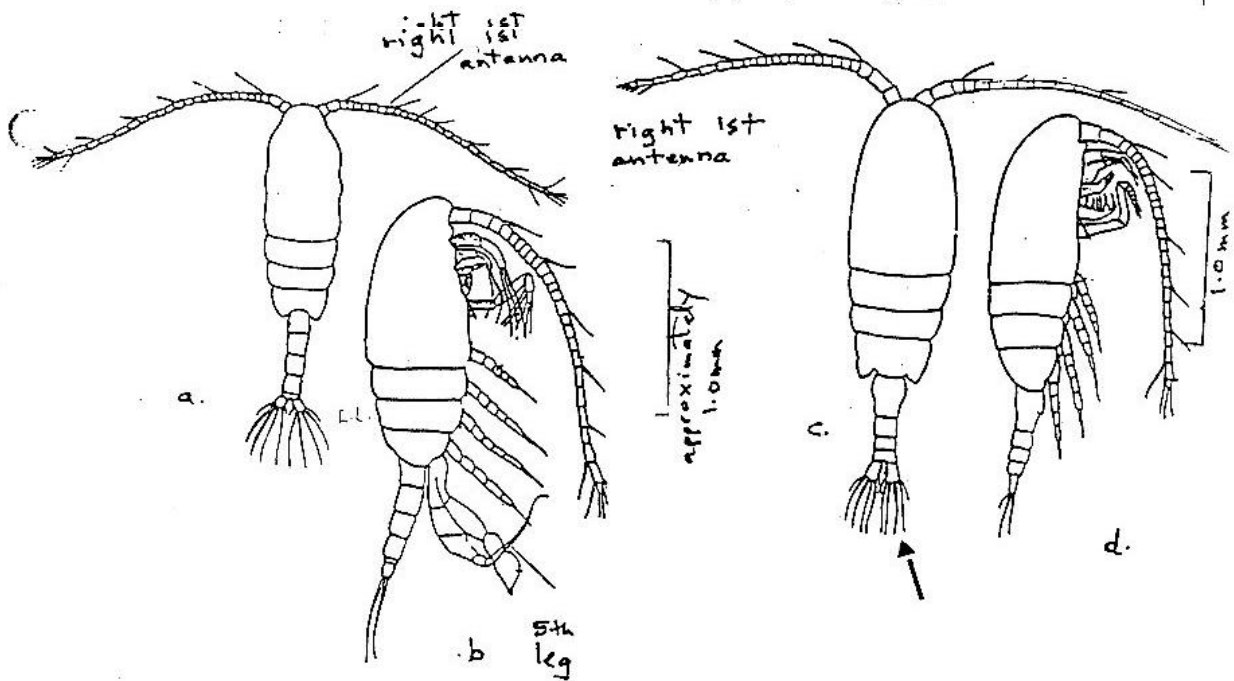


Figure 22. *Senecella calanoides* Juday (from Juday 1923). (a.) Male, dorsal view (b.) Male, lateral view (c.) Female, dorsal view (d.) Female, lateral view.

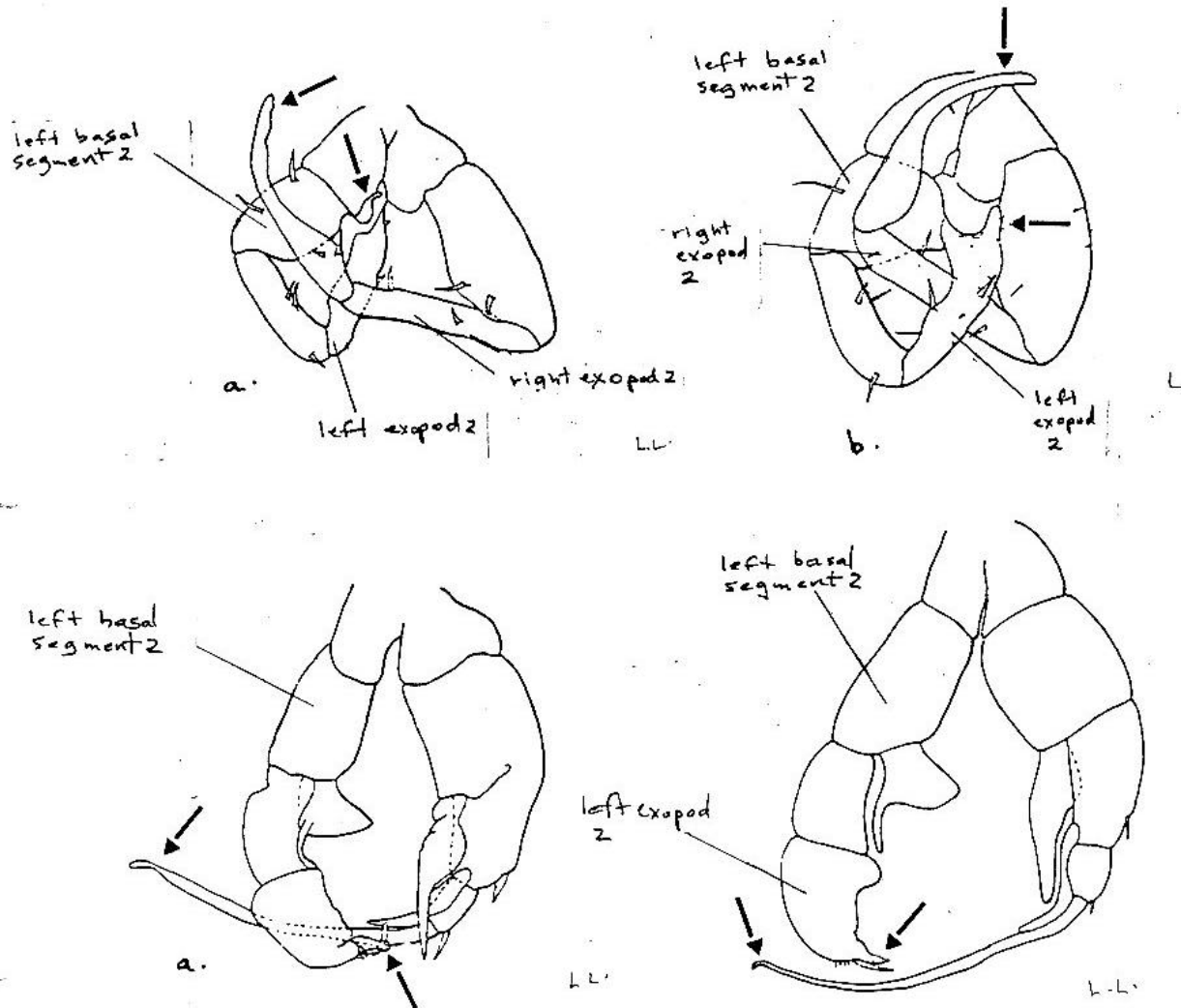


Figure 24. *Senecella calanoides* Juday male 5<sup>th</sup> leg, posterior view. (a.) after Wilson 1959 (b.) after Juday 1923.

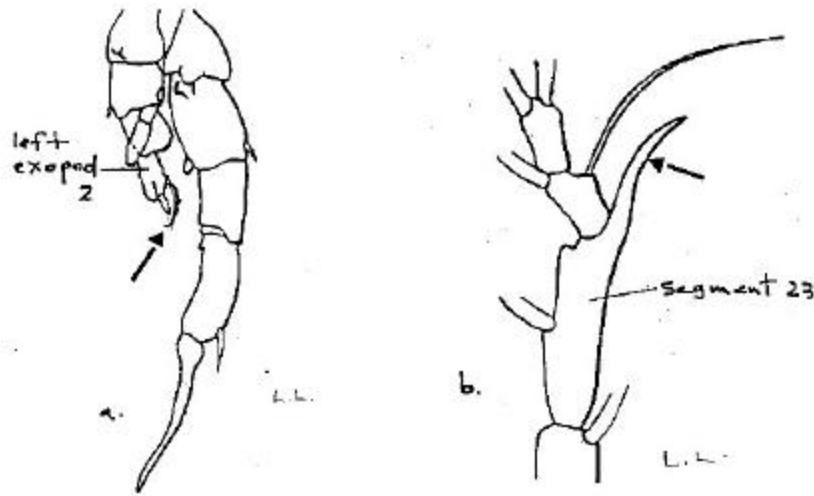


Figure 25. *Diaptomus forbesi* Light. (a.) Male, 5<sup>th</sup> leg (after Wilson 1959) (b.) Male, right 1<sup>st</sup> antenna, segments 23-25 (after Light 1938).

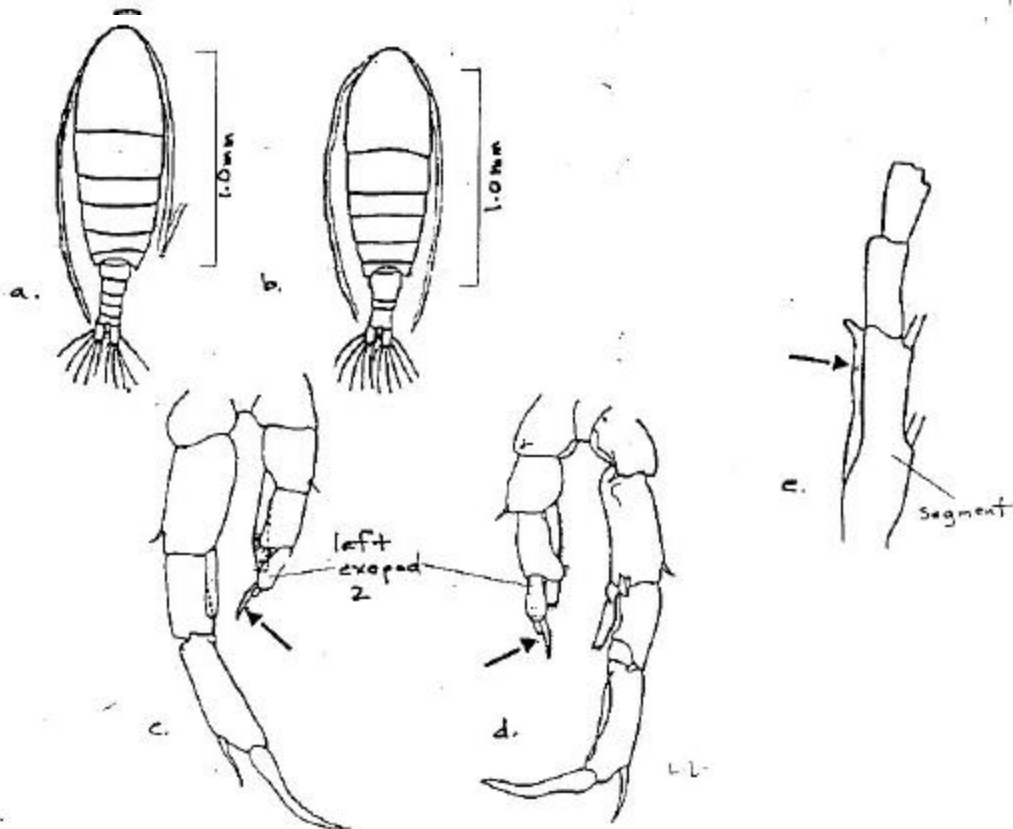


Figure 26. *Diaptomus leptopus* S.A. Forbes. (a.) Male, dorsal view (b.) Female, dorsal view (c.) Male, 5<sup>th</sup> leg, anterior view (a,c.) after Pinel-Aloul and Lamoureux 1988b (d.) Male, 5<sup>th</sup> leg, posterior view (e.) Male, right 1<sup>st</sup> antenna, segment 23.

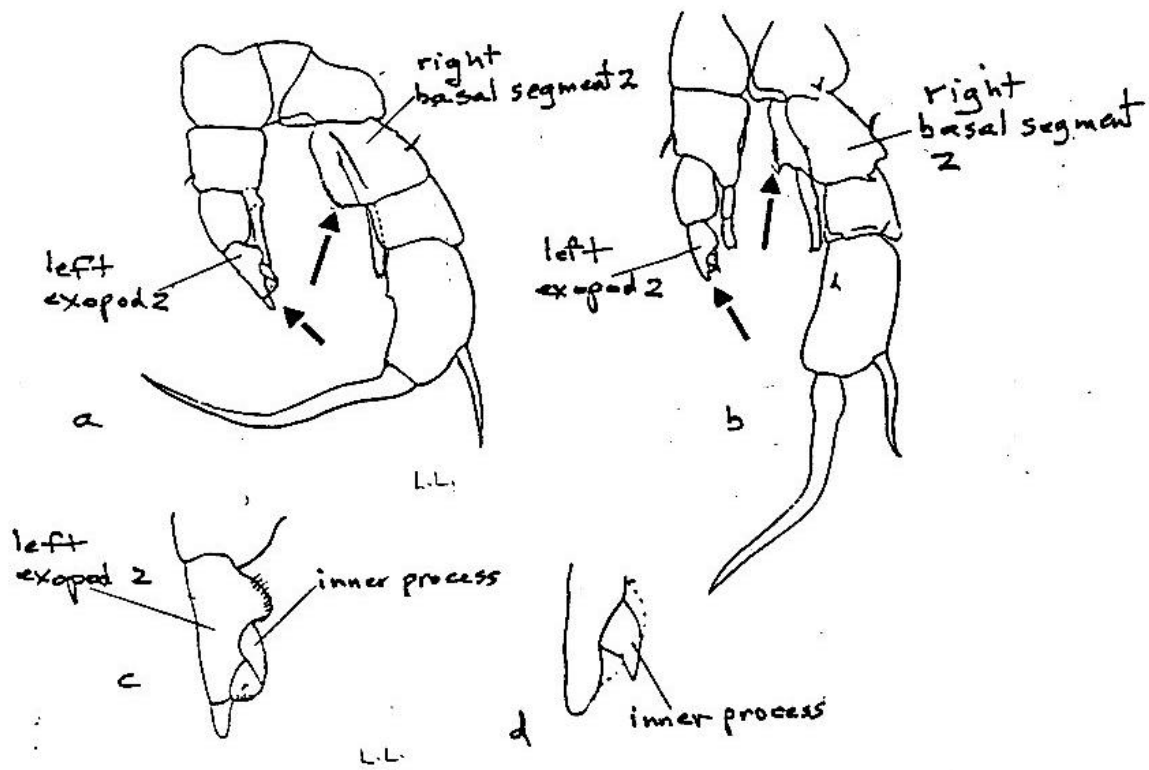


Figure 27. *Diaptomus arcticus* Marsh. (a.- d.) Male, 5<sup>th</sup> leg, posterior view (a., d.) right leg (b.- c.) detail of left leg. (a.- b.) Clearwater L., B.C. (c.- d.) after Wilson 1959 (e.) Male, right 1<sup>st</sup> antenna, segments 10-14 with spines (Conkle L., B.C.).

Figure 28. *Diaptomus kiseri* Kincaid. (a.-b.) Male, 5<sup>th</sup> leg, posterior view (a.) right leg (b.) detail of left leg (a.-b.) after Wilson 1959) (c.-e.) *D. kiseri* male, right 1<sup>st</sup> antenna (c.) segments 7-14 (after Kincaid 1953). (d.) segments 8-14 (e.) segments 10-14 (d.-e. Boitano Ph. Pond, B.C.

Figure 29. *Diaptomus eiseni* Lilljeborg. (a.) Male, right 5<sup>th</sup> leg, posterior view (after Wilson 1959) (b.-c.) Male, right 1<sup>st</sup> antenna (b.) segments 10-13 (Lake Lagunita, Calif.) (c.) segments 10-16 (after Wilson 1959).



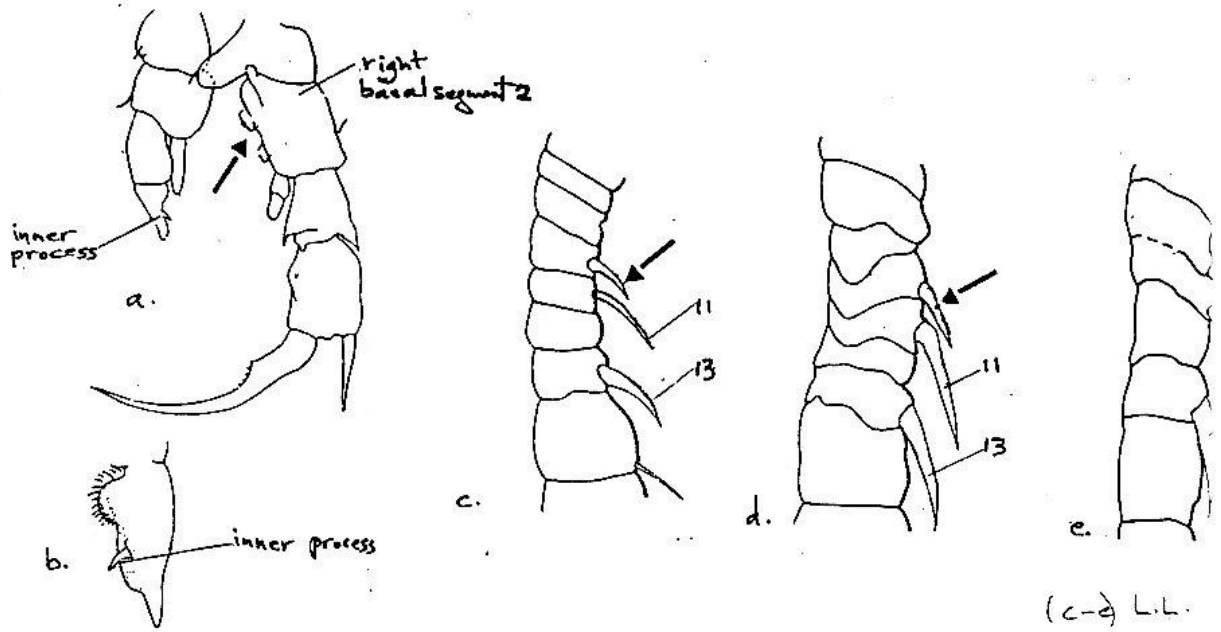


Fig. 28. *Diaptomus (Hesperodiaptomus) kiseri* Kincaid

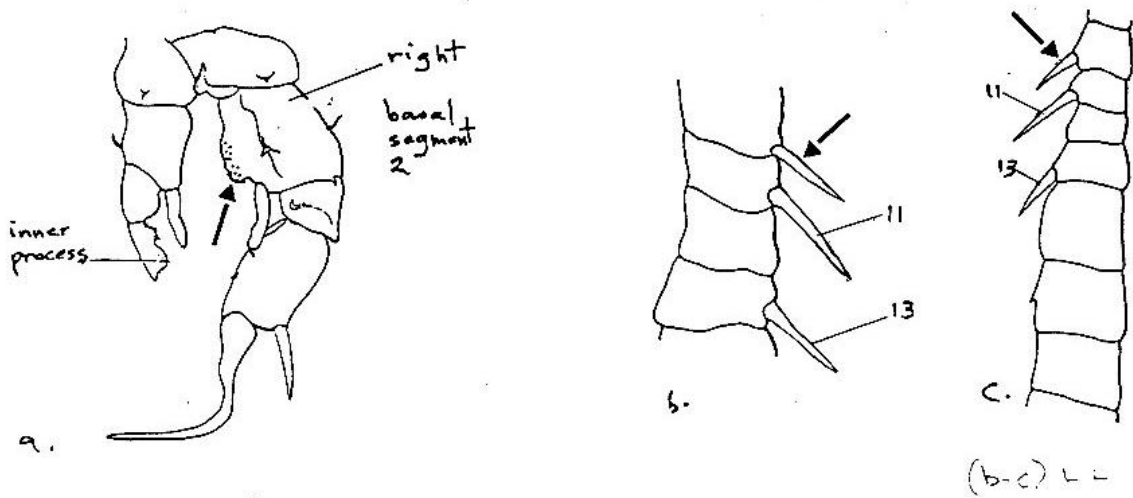


Fig. 29. *Diaptomus (Hesperodiaptomus) eiseni* Lilljeborg

Figure 30. *Diaptomus hirsutus* M.S. Wilson. (a.-c.) Male, 5<sup>th</sup> leg (a.) right leg, anterior view (Westwick 1 Pond, B.C.) (b.) detail of left leg, anterior view (after Wilson 1959) (c.) right leg, posterior view (after Wilson 1959) (d.) Male, left 1<sup>st</sup> antenna, segments 1-14 (Westwick 1 Pond B.C.) (e.) Male, dorsal view (f.) Male, lateral view (g.) Female, dorsal view (h.) Female, lateral view (e.-h.) Granite Lake, Amador, Calif.

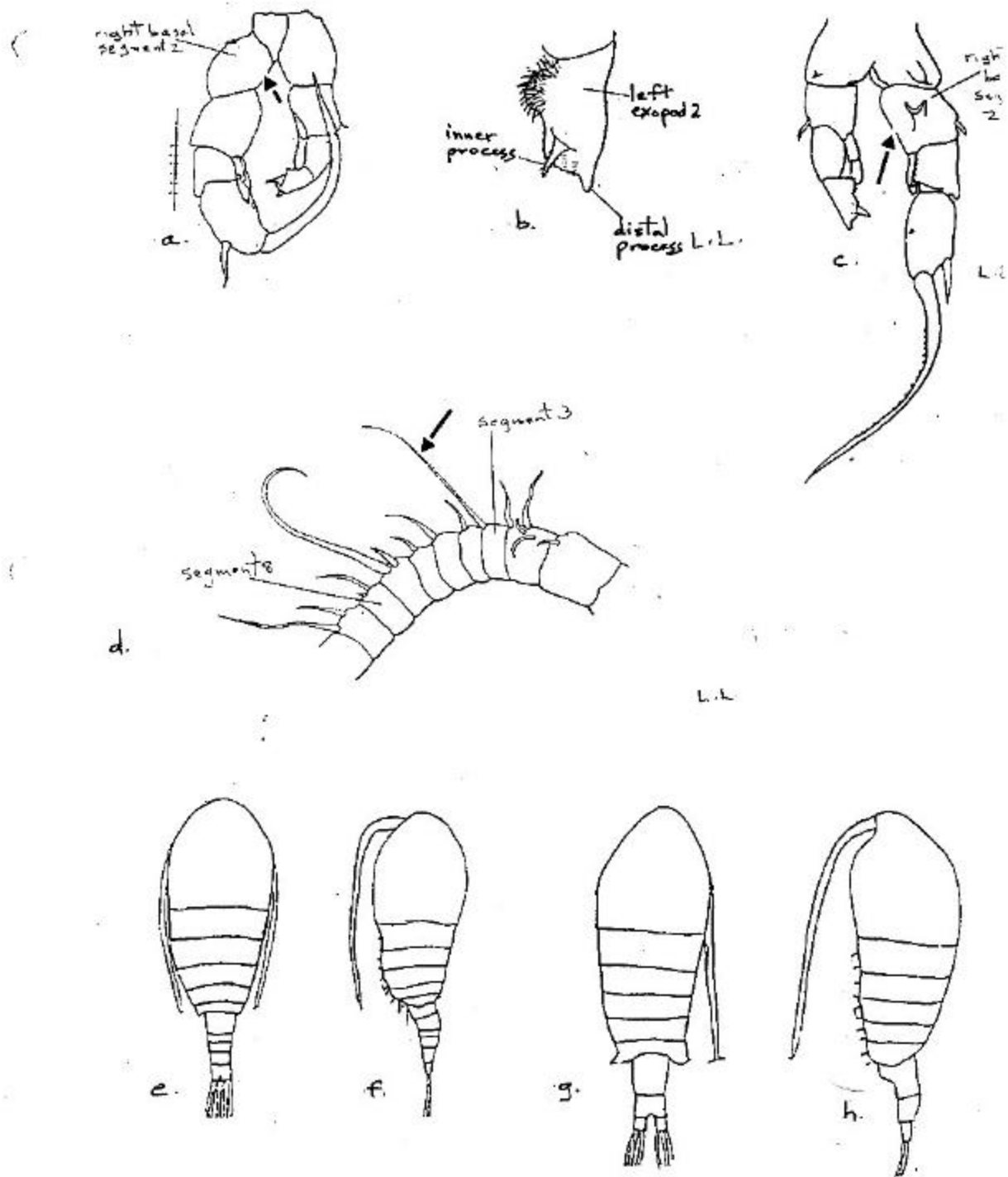


Fig. 30. *Diaptomus (Hesperodiaptomus) hirsutus* M.S. Wilson

Figure 31. *Diaptomus caducus* Light. (a.-d.) Male, 5<sup>th</sup> leg (a.) right leg, anterior view (b.) right leg, posterior view (c.) left leg, anterior view (d.) right leg, posterior view (a.-b. St. Anselm's Pond B.C.) (c.-d. after Wilson 1959) (e.) Male, left 1<sup>st</sup> antenna segments 1-14 (after Wilson 1959) (f.-g.) Adult male (f.) dorsal view (Lake Lagunita, Calif.) (g.) lateral view (St. Anselm's Pond, B.C.) (h.-i.) Adult female (h.) dorsal view (i.) lateral view (h.-i.) Lake Lagunita Calif.

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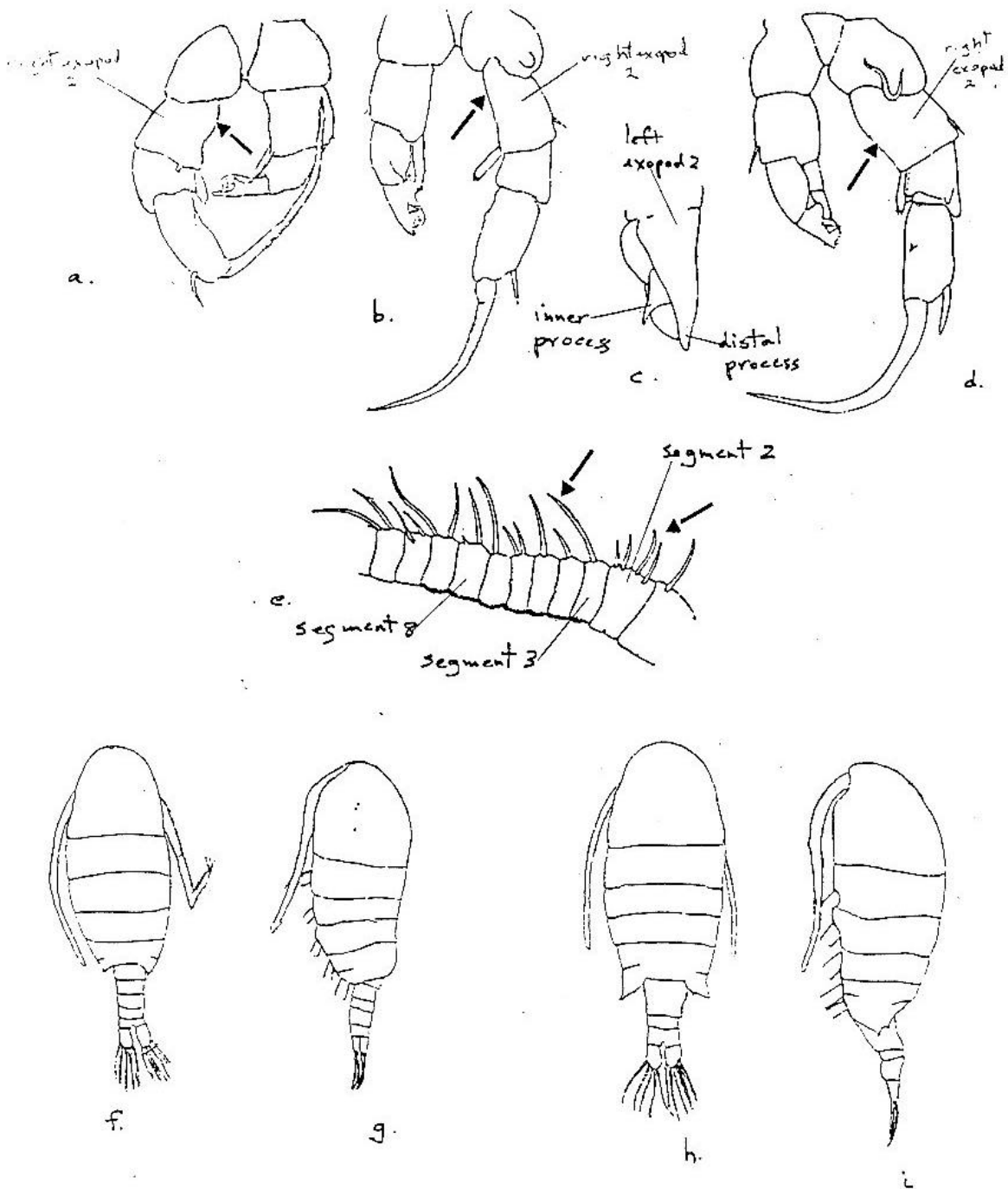
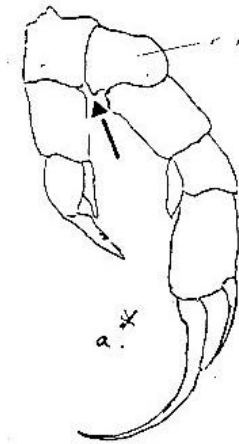


Fig. 31. *Diaptomus* (*Hesperodiaptomus*) *caducus* Light

left antenna  
2 setae on II  
1 on 13-19  
as in D. Kona  
Fig. 34a.



\* (Need to redraw)

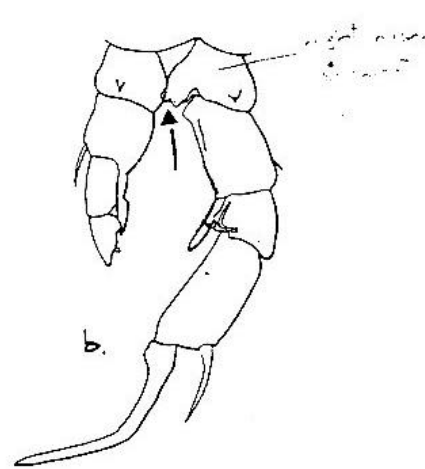


Figure 32. *Diaptomus nevadensis* Light, male, right 5<sup>th</sup> leg, posterior view. (a.) (White L., B.C.) (b.) (after Wilson 1959).

Figure 33. *Diaptomus novemdecimus* M.S. Wilson. (a.) Male, left 1<sup>st</sup> antenna, segments 13-20 (Springhouse Pond, B.C.) (b.- d.) Male, 5th leg (b. ) anterior view (after Wilson 1953) (c.) detail of left leg, (after Wilson 1959) (d.) posterior view (after Wilson 1953).

Figure 34. *Diaptomus kenai* M.S. Wilson. (a.) Male, left 1<sup>st</sup> antenna, segments 10-20 (Sumas L., B.C.) (b. e.) Male, 5<sup>th</sup> leg (d.) anterior view (c.) posterior view (d.) detail of left leg (e.) posterior view (b.- c.) ( Sumas L., B.C.) (d.- e.) (after Wilson 1959).

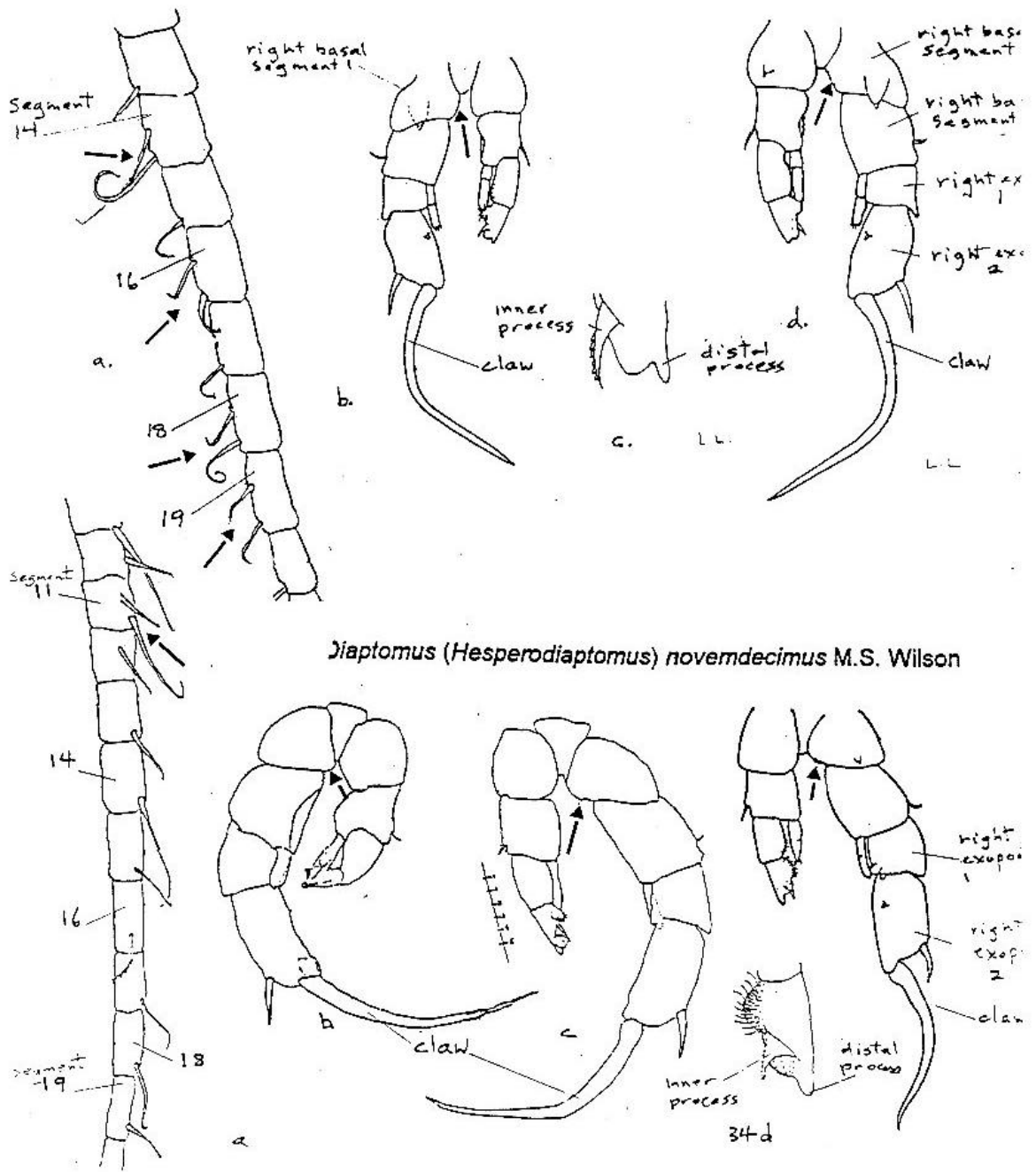


Fig. 34. *Diaptomus (Hesperodiaptomus) kenai* M.S. Wilson



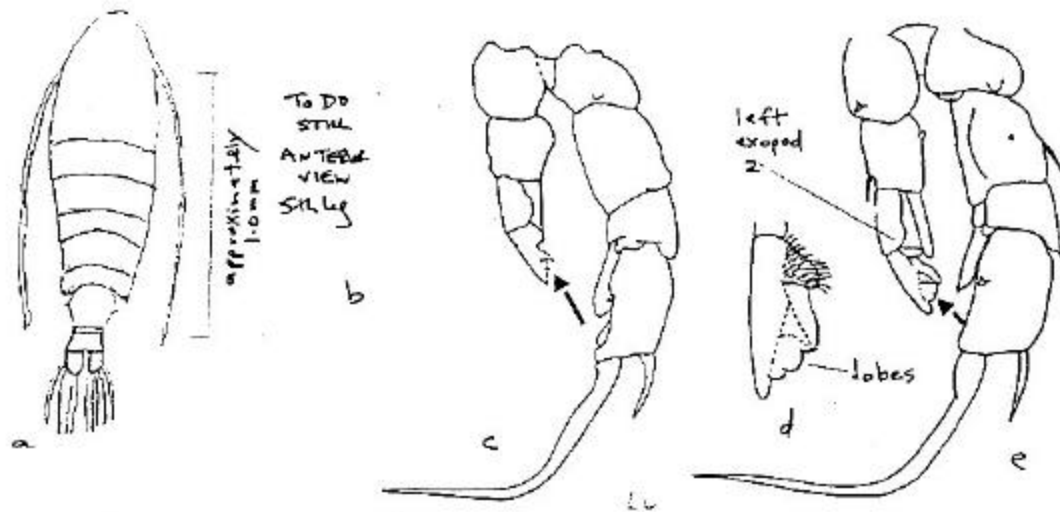


Figure 35. *Diaptomus franciscanus* Lilljeborg. (a.) Adult female (Glinz L., B.C. and Petworth Crescent Pond, B.C.) (b.-e.) Male, 5<sup>th</sup> leg (b.) anterior view (c.) posterior view (Council L., B.C.) (d.) detail of male, left leg, posterior view (after Wilson 1959) (e.) posterior view (after Wilson 1959).

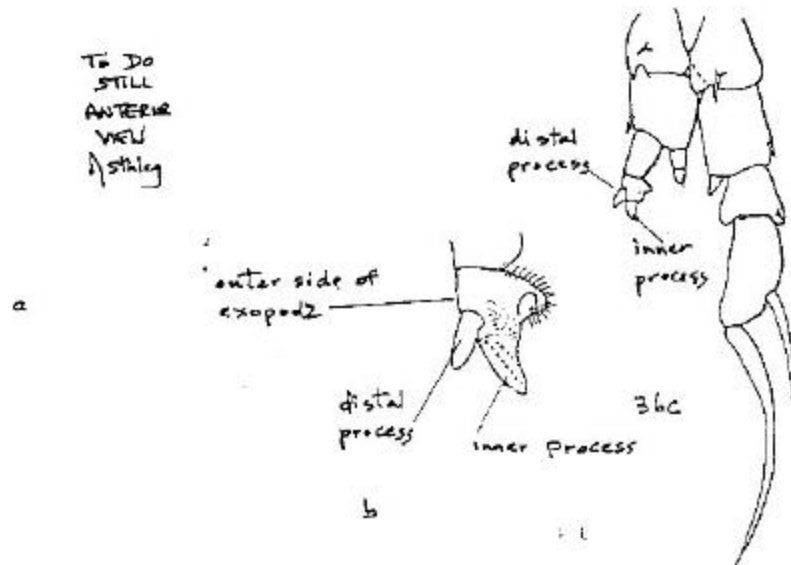


Figure 36. *Acanthodiaptomus denticornis* (Wierzejski). (a - c.) Male, 5<sup>th</sup> leg (a.) anterior view (b.) detail of left leg, posterior view (after Wilson 1959) (c.) posterior view (after Wilson 1959).

Figure 37. *Diaptomus sanguineus* S.A. Forbes, male, 5th leg. (a.) anterior view (after Humes and Wilson 1951) (l.) detail of left leg, posterior view (after Wilson 1959) (c.) posterior view (after Wilson 1959).

Figure 38. *Diaptomus hesperus* Wilson and Light, male, 5th leg. (a.) detail of left leg, posterior view (after Wilson 1959) (b.) posterior view (after Wilson 1959).

Figure 39. *Diaptomus pallidus* Herrick. (a.) Female, dorsal view (modified from Wilson 1959) (b.- c.) Male, 5<sup>th</sup> leg (b.) detail of left leg, posterior view (after Wilson 1959) (c.) posterior view (after Wilson 1959)

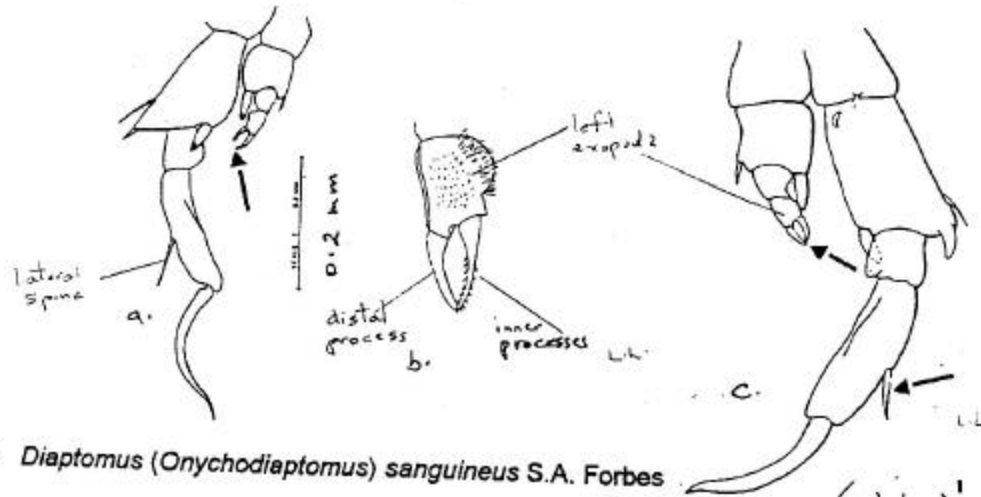


Fig. 37. *Diaptomus (Onychodiaptomus) sanguineus* S.A. Forbes

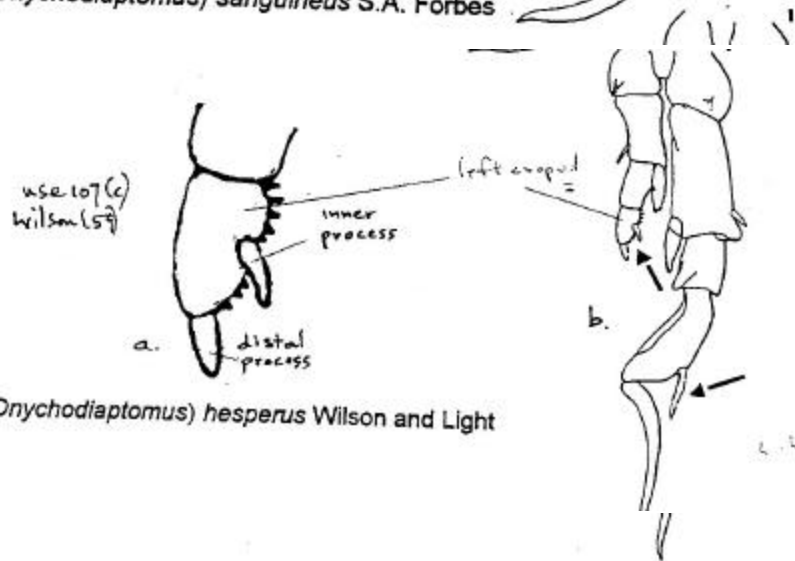


Fig. 38. *Diaptomus (Onychodiaptomus) hesperus* Wilson and Light

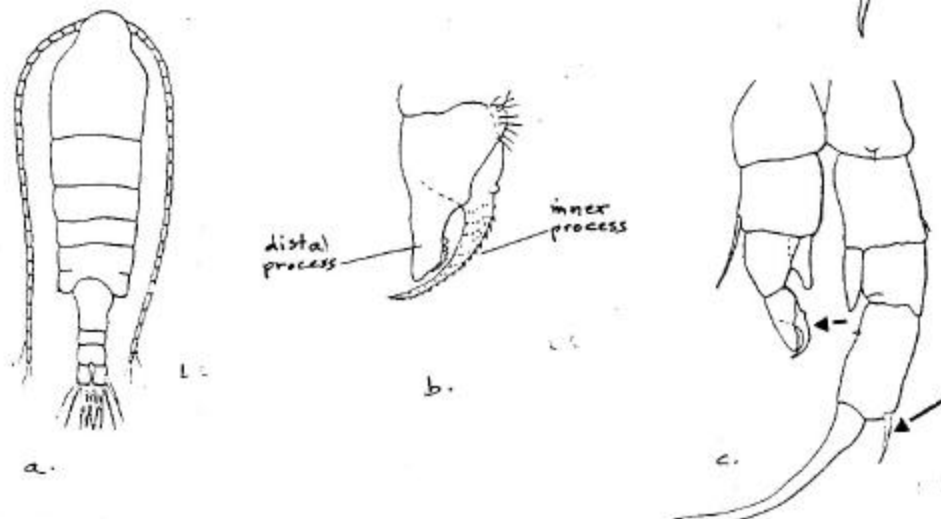


Fig. 39. *Diaptomus (Skistodiaptomus) pallidus* Herrick

STILL  
TO DO  
LATERAL  
SPINE  
IN  
DIFFERENT  
POSITIONS  
5-431-2

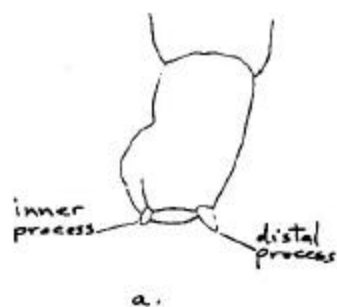


Figure 40.

*Diaptomus pribilofensis* Juday and Muttkowski, male, 5<sup>th</sup> leg. (a.) detail of left leg, anterior view (b.) posterior view (a.-b.) (after Wilson 1959).

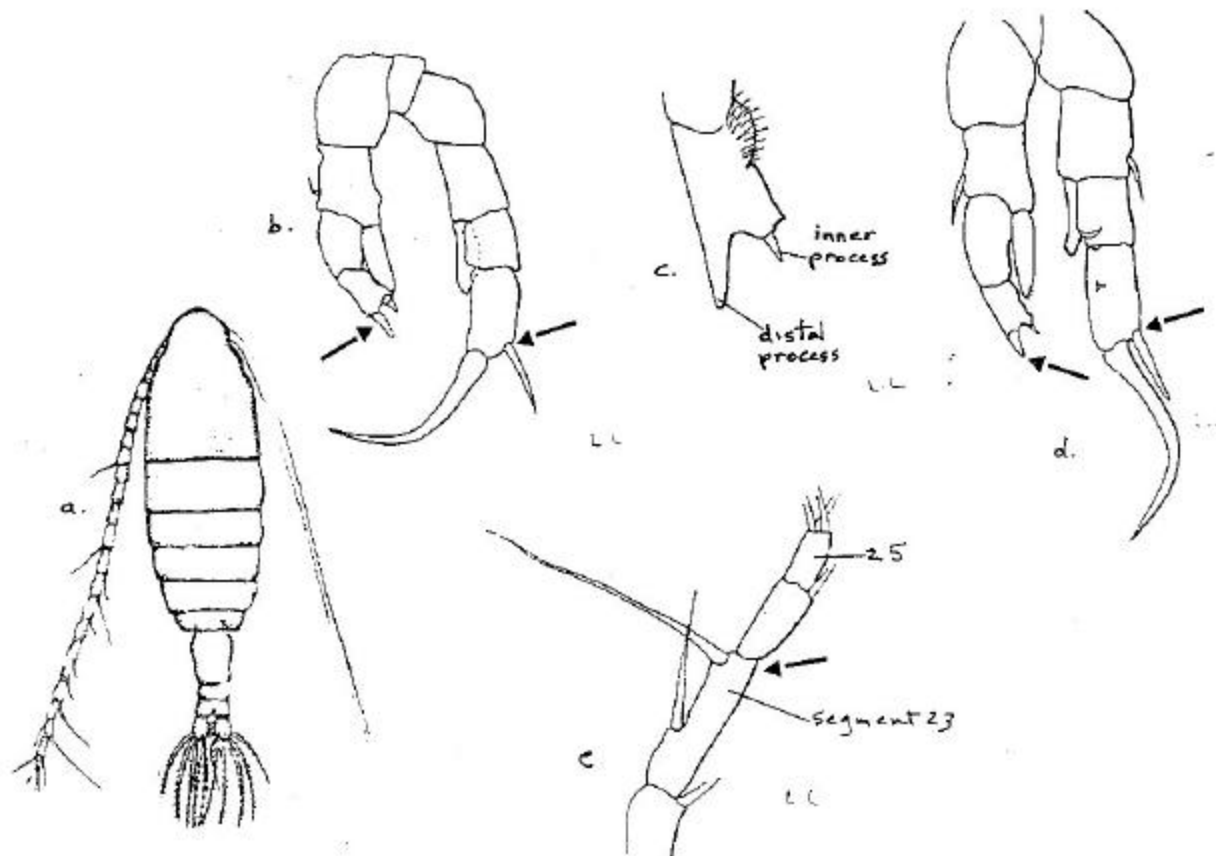


Figure 41. *Diaptomus oregonensis* Lilljeborg: (a.) Adult female, dorsal view (after Smith and Fernando 1978) (b.-c.) Male, 5<sup>th</sup> leg, posterior view (b.) (Como L., B.C.) (c.) (after Wilson 1959) (d.) Male, right 1<sup>st</sup> antenna, segments 23-25 (from Smith and Fernando 1978).

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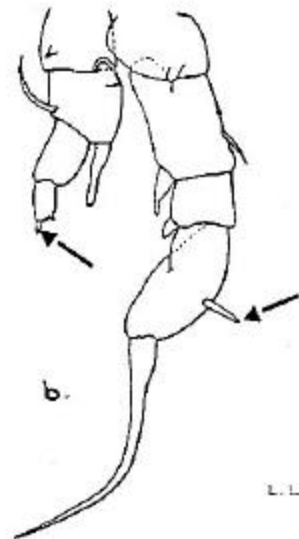
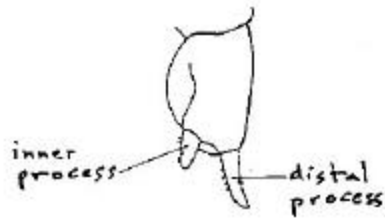


Figure 42. *Diaptomus tyrrelli* Poppe, male, 5<sup>th</sup> leg. (a.) detail of left leg, anterior view (after Wilson 1959)  
(b.) posterior view (after Wilson 1959).

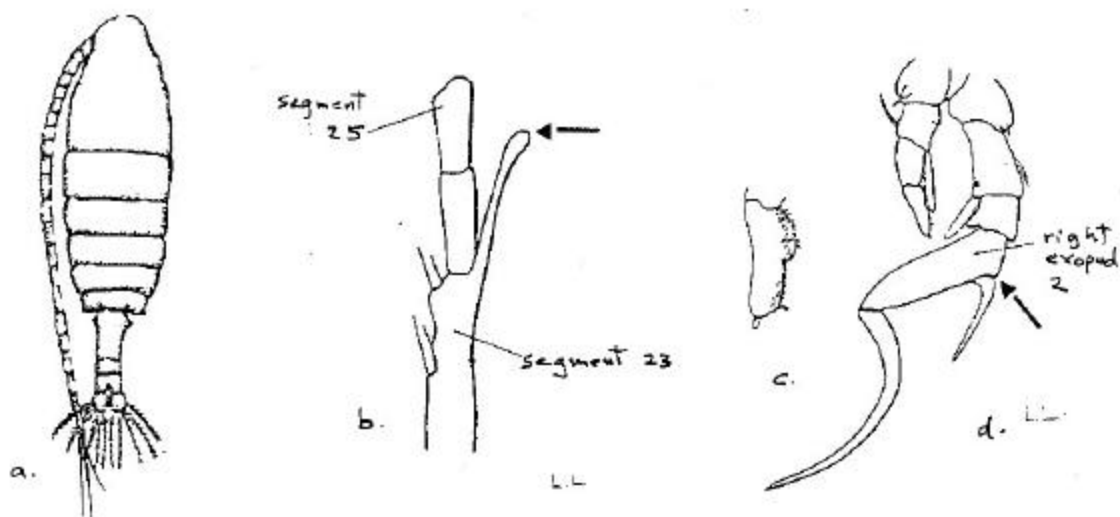


Figure 43. *Diaptomus ashlandi* Marsh. (a.) Female, dorsal view (after Smith and Fernando 1978) (b.) Male, right 1<sup>st</sup> antenna, segments 23-25 (after Wilson 1959) (c.-d.) Male, 5<sup>th</sup> leg (c.) detail of left leg, anterior view (after Wilson 1959) (d.) posterior view (after Wilson 1959).

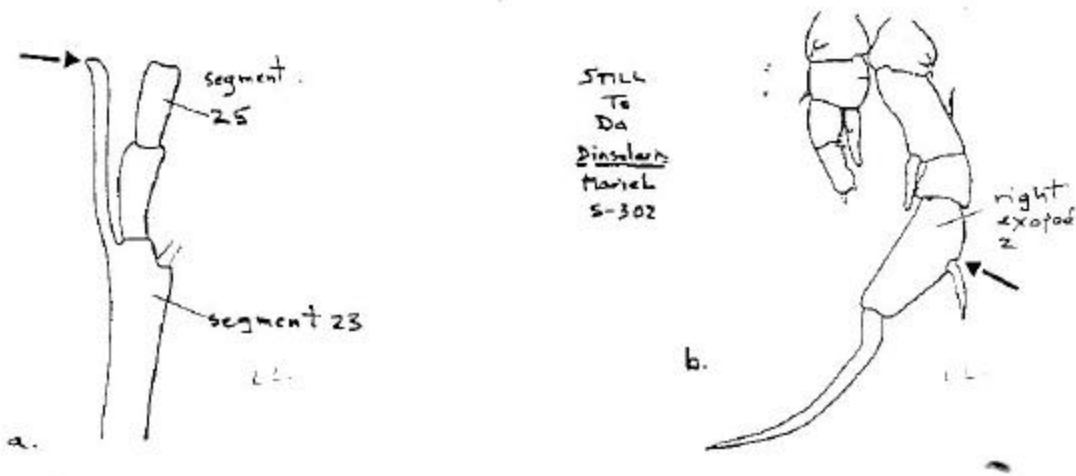


Figure 44. *Diaptomus insularis* (Kincaid). (a.) Male, right 1<sup>st</sup> antenna, segments 23-25 (after Wilson 1959). (b.-c.) Male, 5<sup>th</sup> leg (b.) anterior view (Marie L., B.C.) (c.) posterior view (after Wilson 1959).

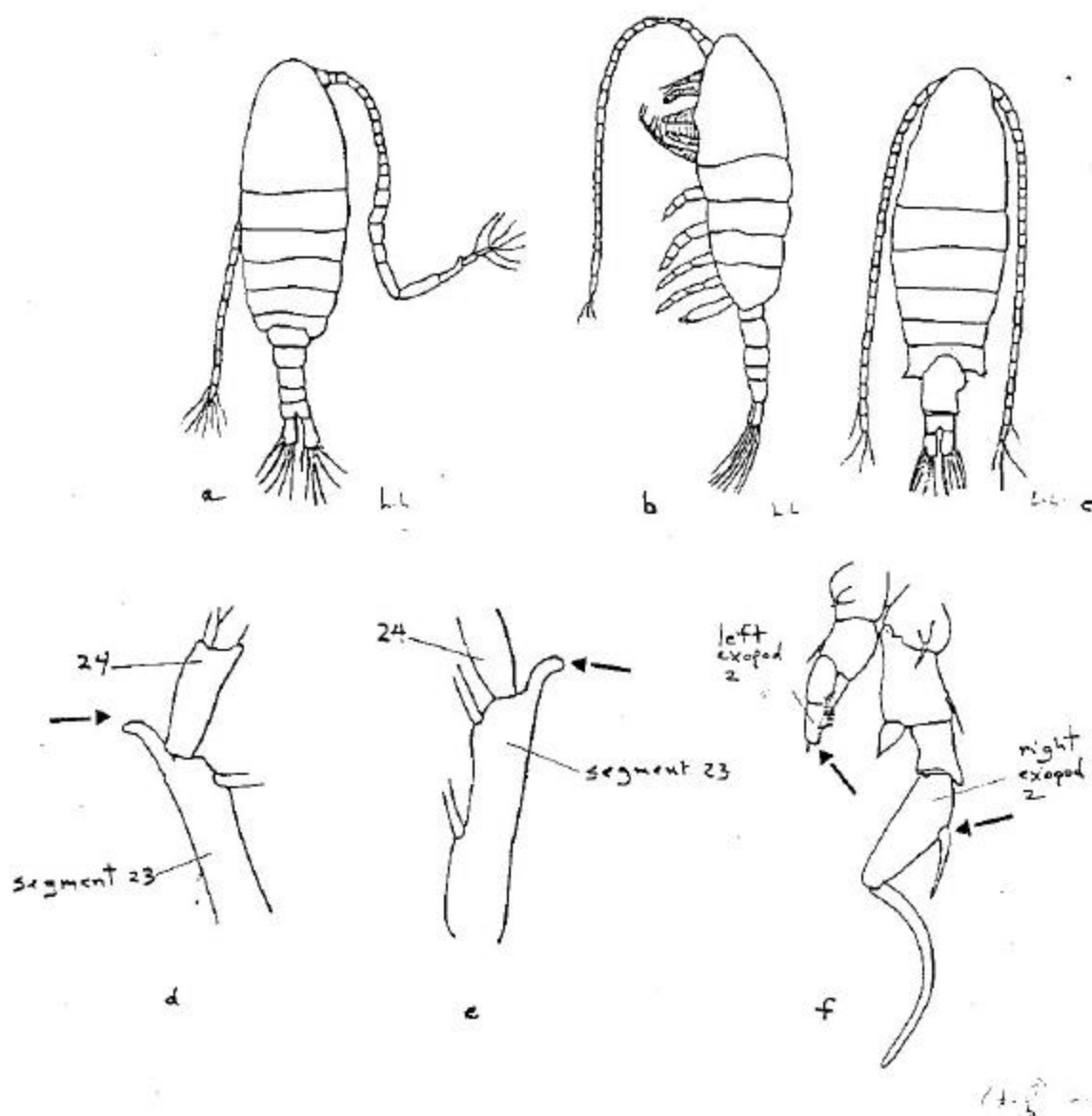


Figure 45. *Diaptomus nudus* Marsh. (a.- b.) Adult male. (a.) dorsal view (b.) lateral view (c.) Adult female, dorsal view (a.- c.) (Copp Lake, B.C., with reference to Shin and Maclellan 1977) (d.- e.) Male, right 1<sup>st</sup> antennal process, segments 23-24 (d.) (after Smith and Fernando 1978) (e.) (after Wilson 1959) (f.) Male, 5<sup>th</sup> leg, posterior view (after Wilson 1959).

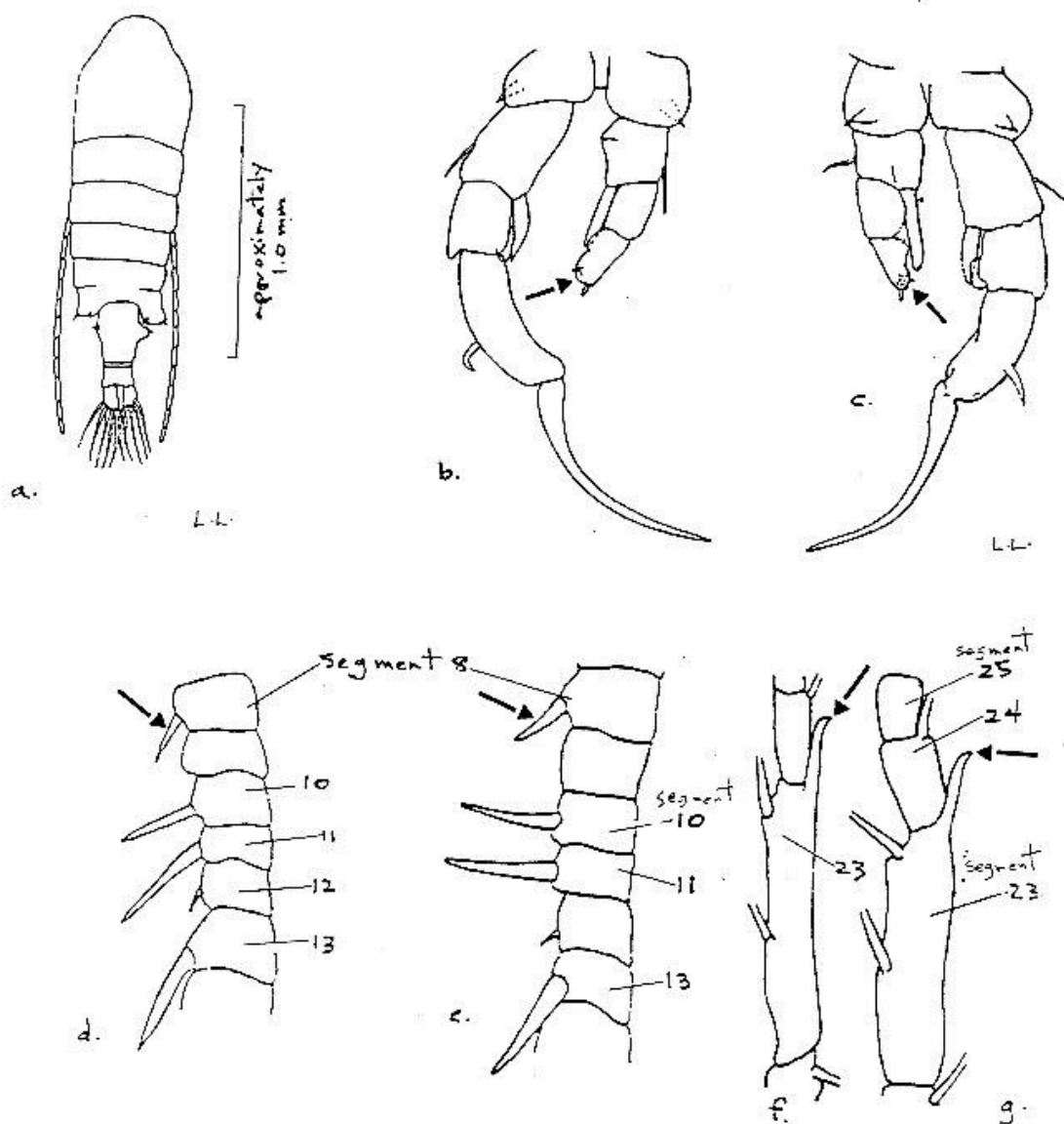


Figure 46. *Diaptomus connexus* Light. (a.) Adult female, dorsal view (after Anderson 1970 and Wilson 1959) (b - c.) Male, 5<sup>th</sup> leg (b.) anterior view (after Wilson 1959) (c.) posterior view (after Anderson 1970) (d - e.) Male, right 1<sup>st</sup> antenna, segments 8-13 (d. after Wilson 1959) (e.) after Anderson 1970) (f - g.) Male, right 1<sup>st</sup> antenna (f.) segments 23-24 (g.) segments 23-25 (f - g. after Anderson 1970).



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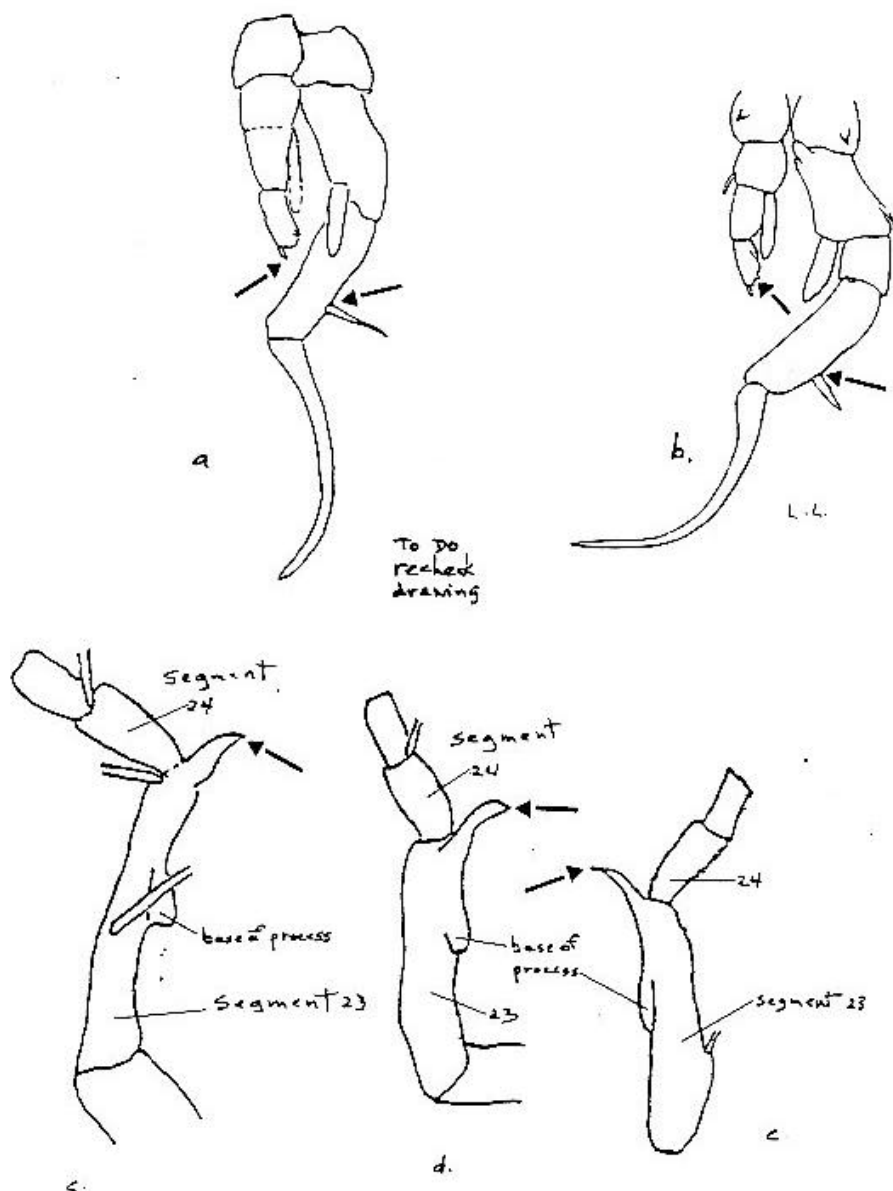


Figure 47. *Diaptomus novamexicanus* Herrick. (a.- b.) Male, 5<sup>th</sup> leg, posterior view (a.) (unknown lake, B.C.) (b.) (after Wilson 1959) (c.- e.) Male, right 1<sup>st</sup> antenna, segments 23-25 (c.- d.) (Kootenay Lake, B.C.) (e.) (after Wilson 1959 [Note spines of male right 1<sup>st</sup> antenna, segments 8 and 12 not seen in USNM 371158, Kincaid collection]).

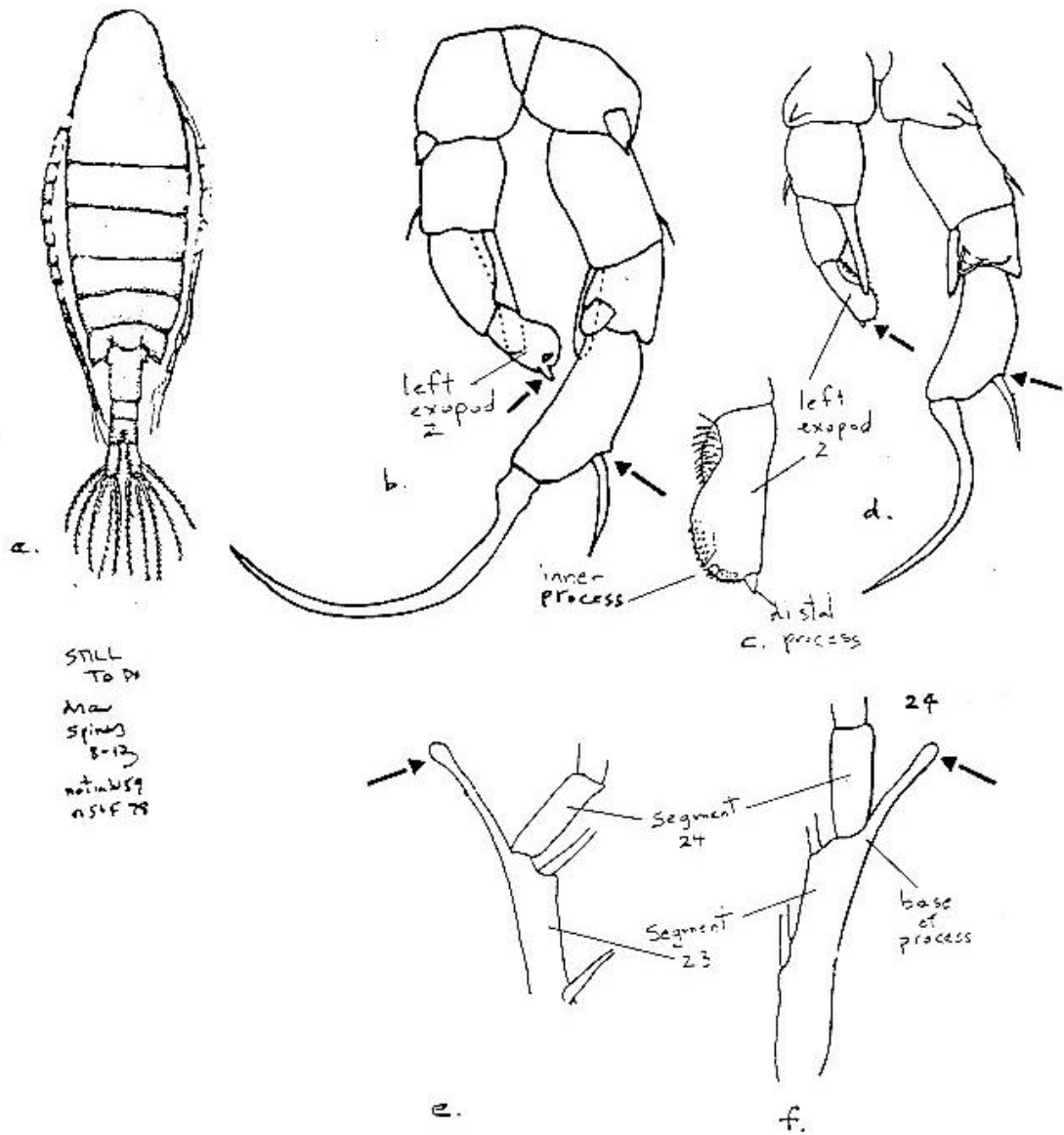


Figure 48. *Diaptomus sicilis* S.A. Forbes. (a.) Adult female, dorsal view (modified from Smith and Fernando 1978) (b.-d.) Male, 5<sup>th</sup> leg (b.) posterior view (after Smith and Fernando 1978) (c.) detail of left leg, anterior view (after Wilson 1959) (d.) posterior view (after Wilson 1959) (e.-f.) Male, right 1<sup>st</sup> antennal process, segments 23-24 (e.) (after Smith and Fernando 1978) (f.) (after Wilson 1959).

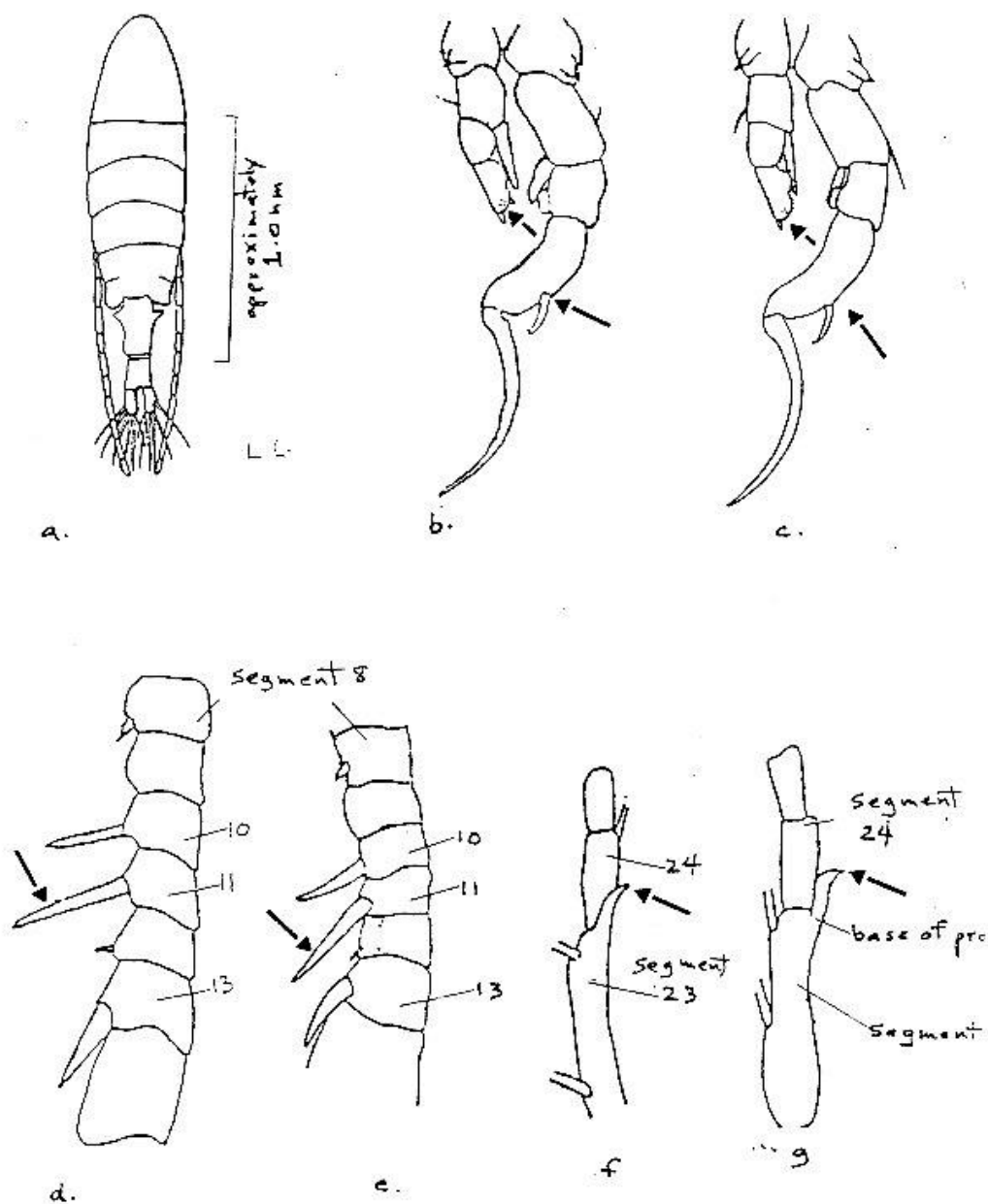


Figure 49. *Diaptomus siciloides* Lilljeborg. (a.) Adult female, dorsal view (after Anderson 1970) (b - c.) Male, 5<sup>th</sup> leg, posterior view (b.) (after Anderson 1970) (c.) (after Wilson 1959) (d - e.) Male, right 1<sup>st</sup> antenna (d.) segments 8-14 (after Wilson 1959 and Anderson 1970) (e.) segments 8-13 (after Anderson 1970) (f.) segments 23-25 (after Anderson 1970) (g.) segments 23-25 (after Wilson 1959).

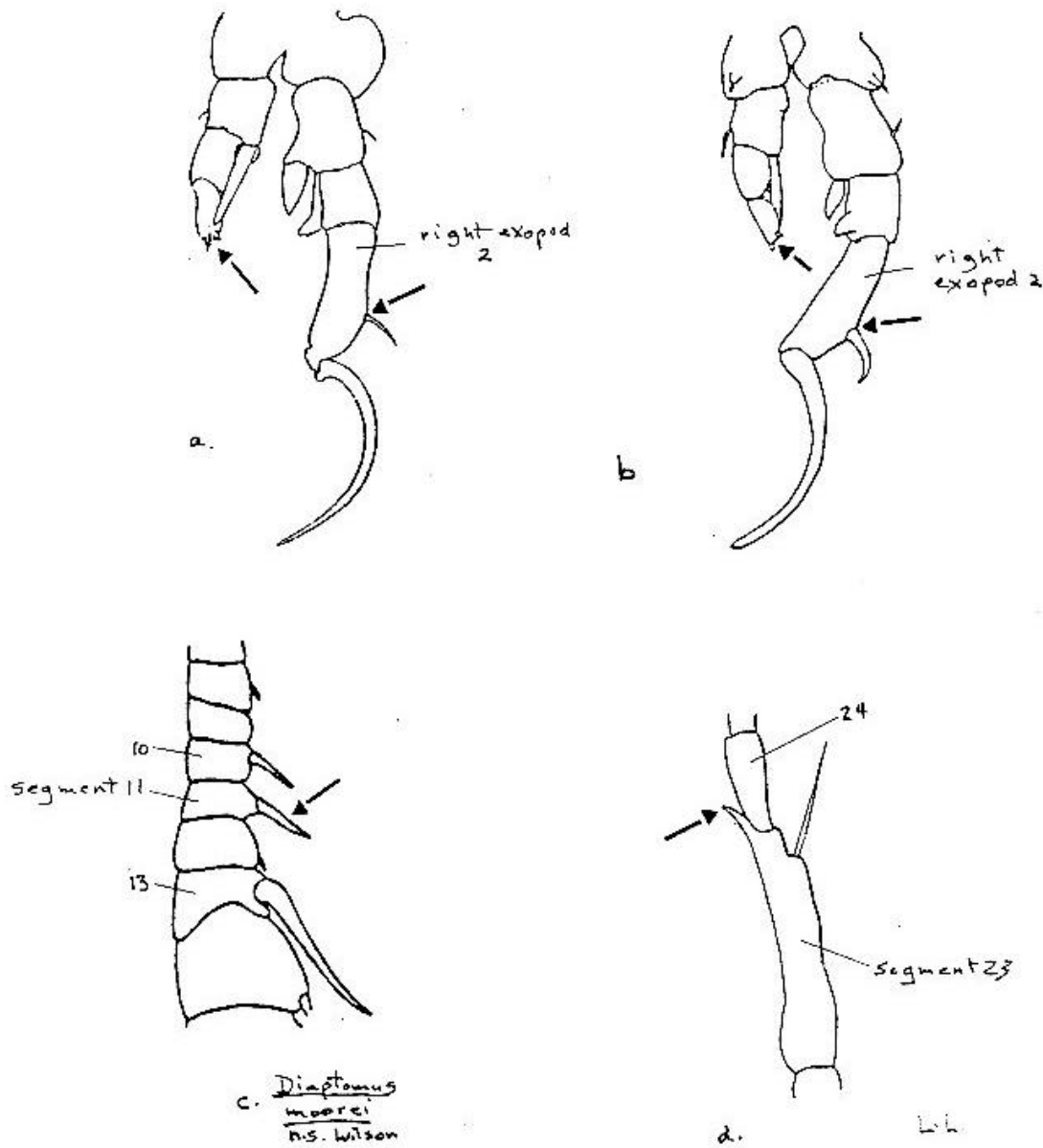


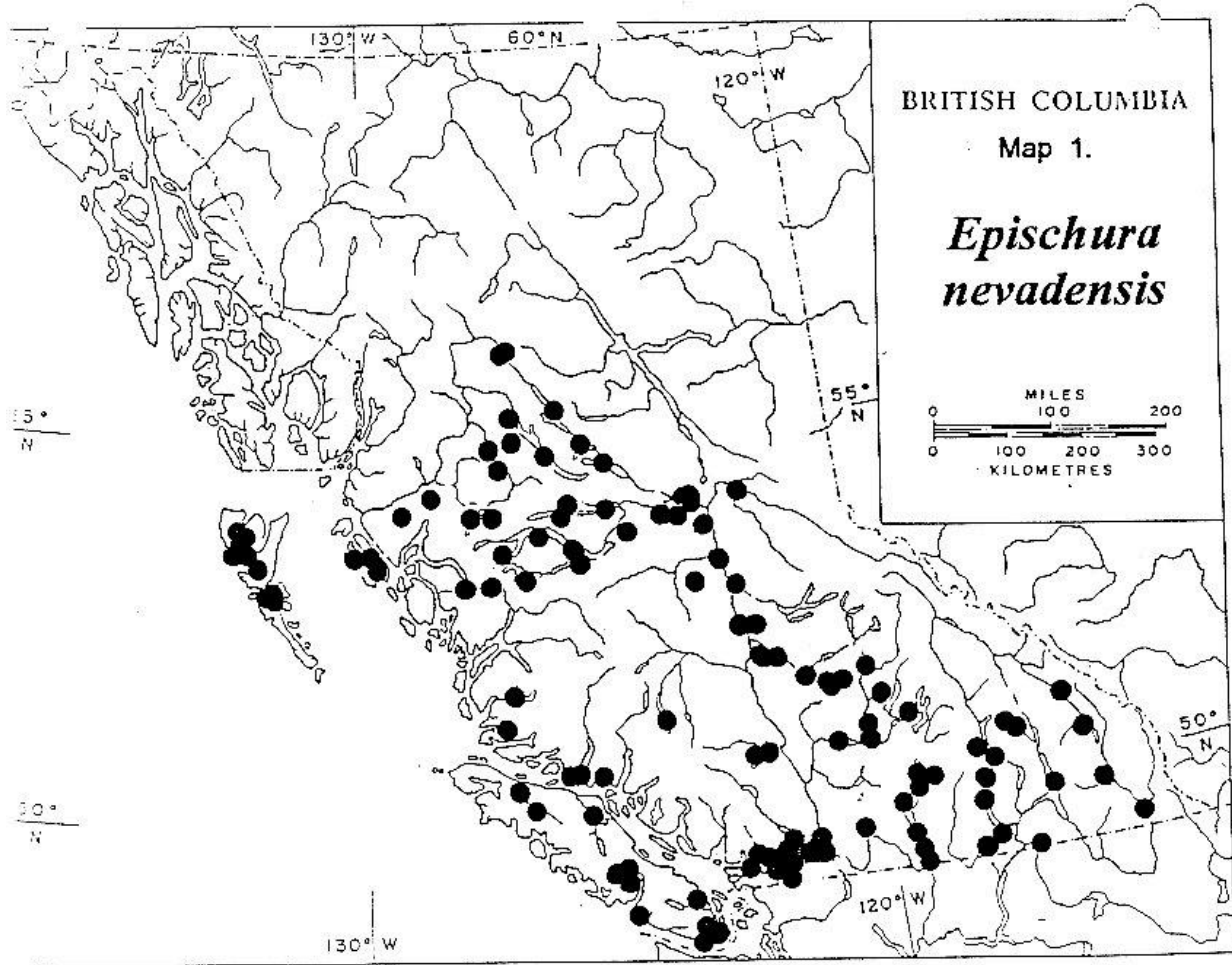
Figure 50. *Diaptomus signicauda* Lilljeborg. Key characters for *D. signicauda* are based on Wilson (1959) and Lilljeborg (1889). No B.C. specimens were available for study. *D. signicauda* is recorded in B.C. in "Old Records" of the Checklist only. (a.-b.) Male, 5<sup>th</sup> leg, posterior view (a.) (after Lilljeborg 1889) (b.) (after Wilson 1959) (c.) *D. moorei* M.S. Wilson, male right 1<sup>st</sup> antenna, segments 8-14 (after Wilson 1959) (given as an example of male, right 1<sup>st</sup> antenna with spine of segment 11 shorter than that of segment 13) (d.) Male, right 1<sup>st</sup> antenna, segments 23-24 (after Lilljeborg 1889).

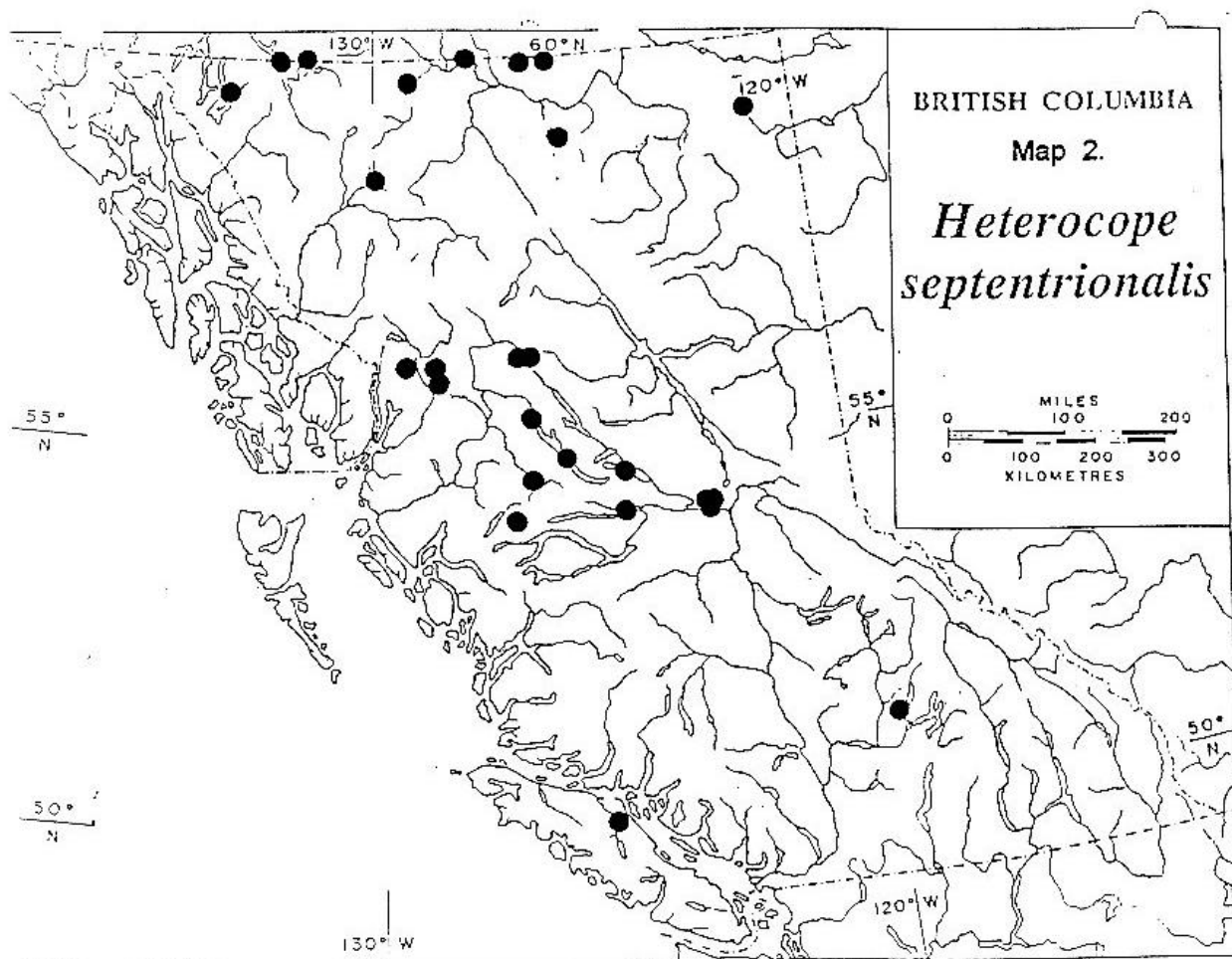
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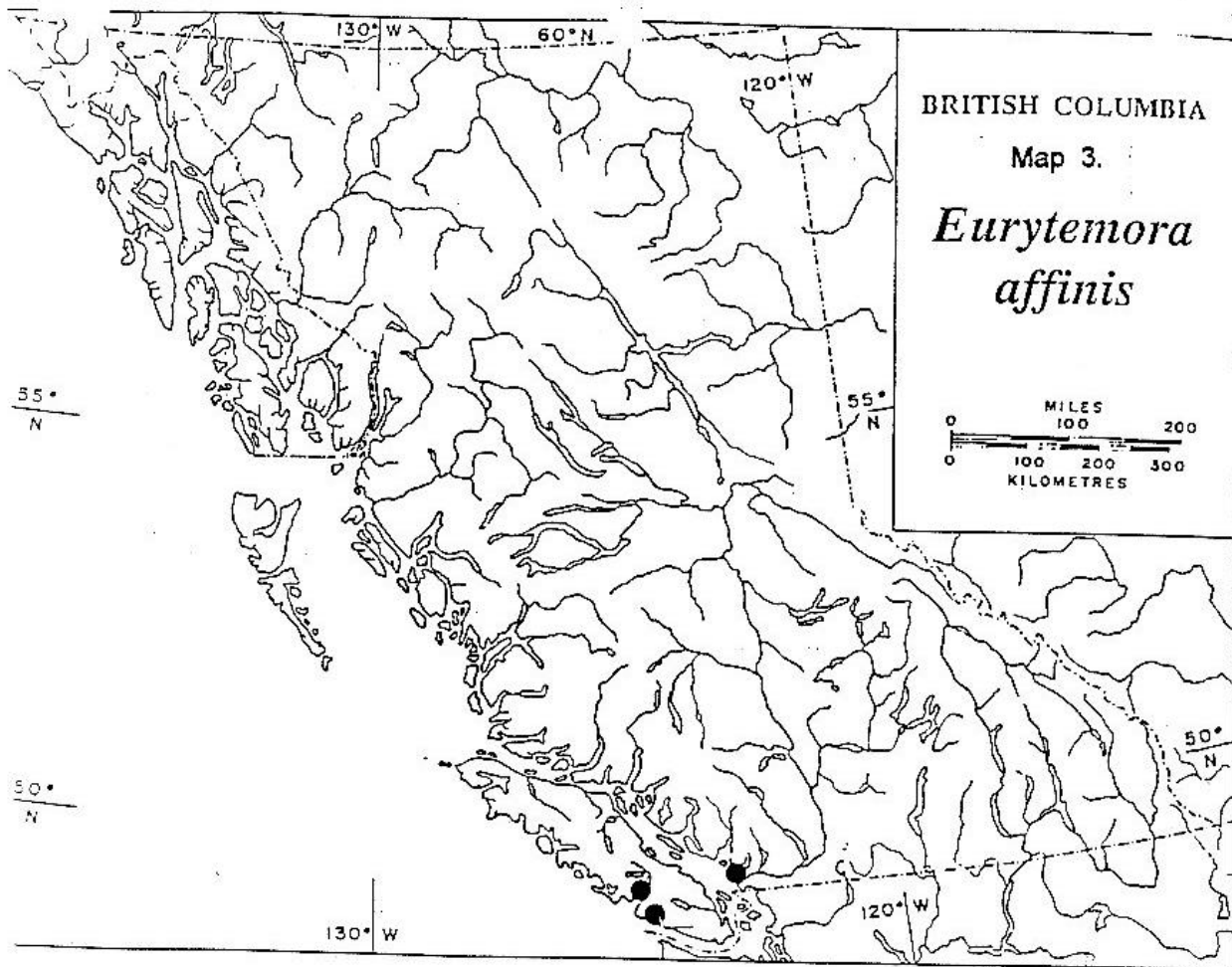
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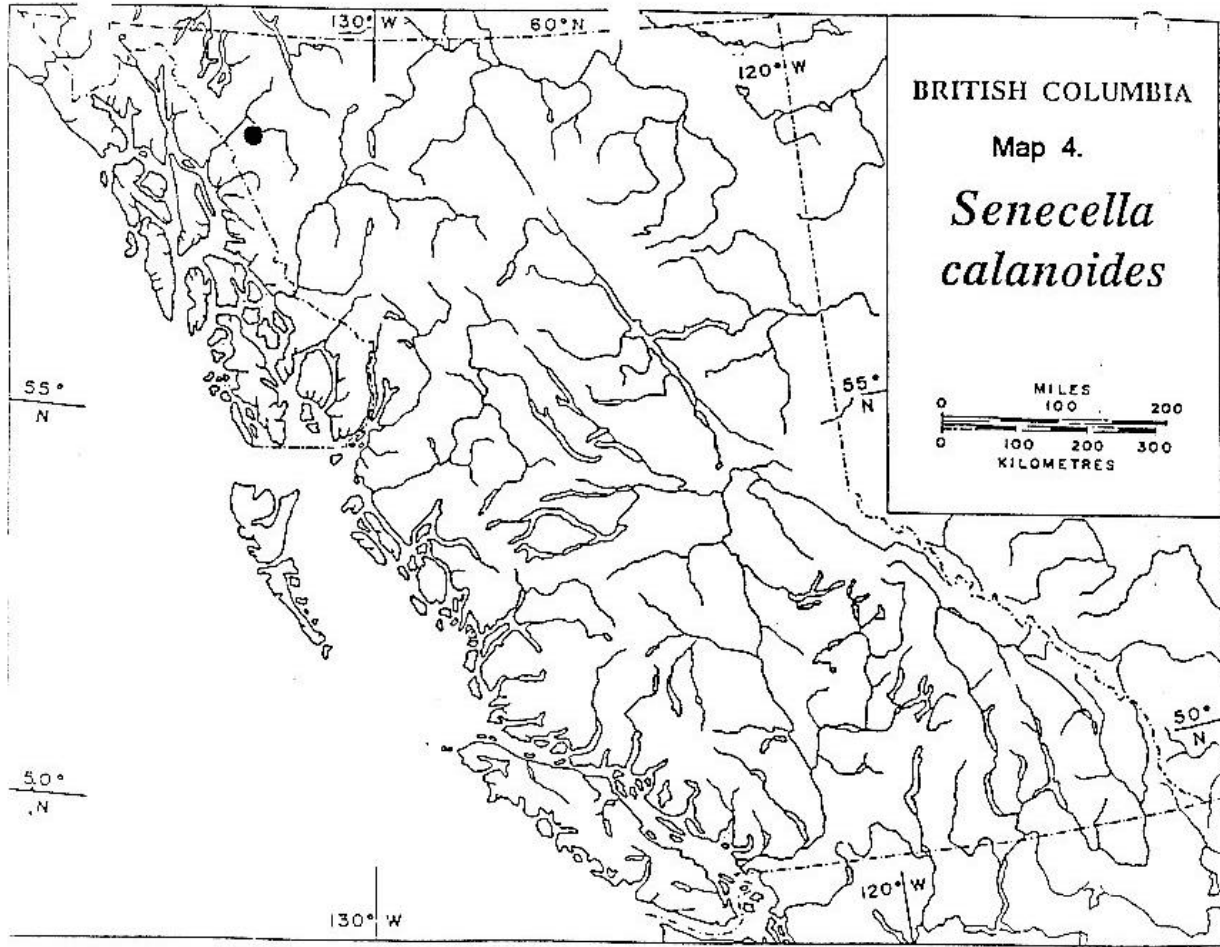
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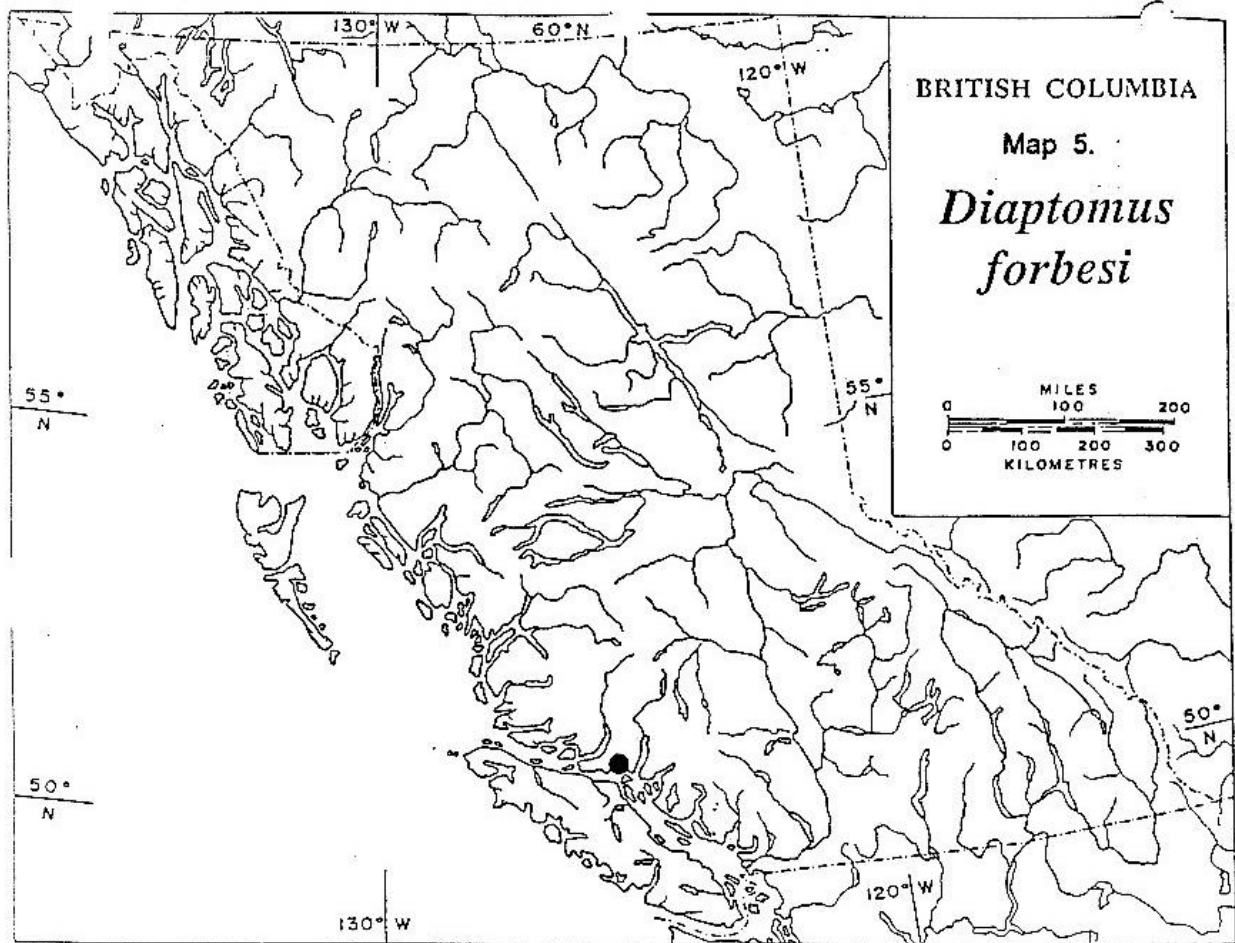


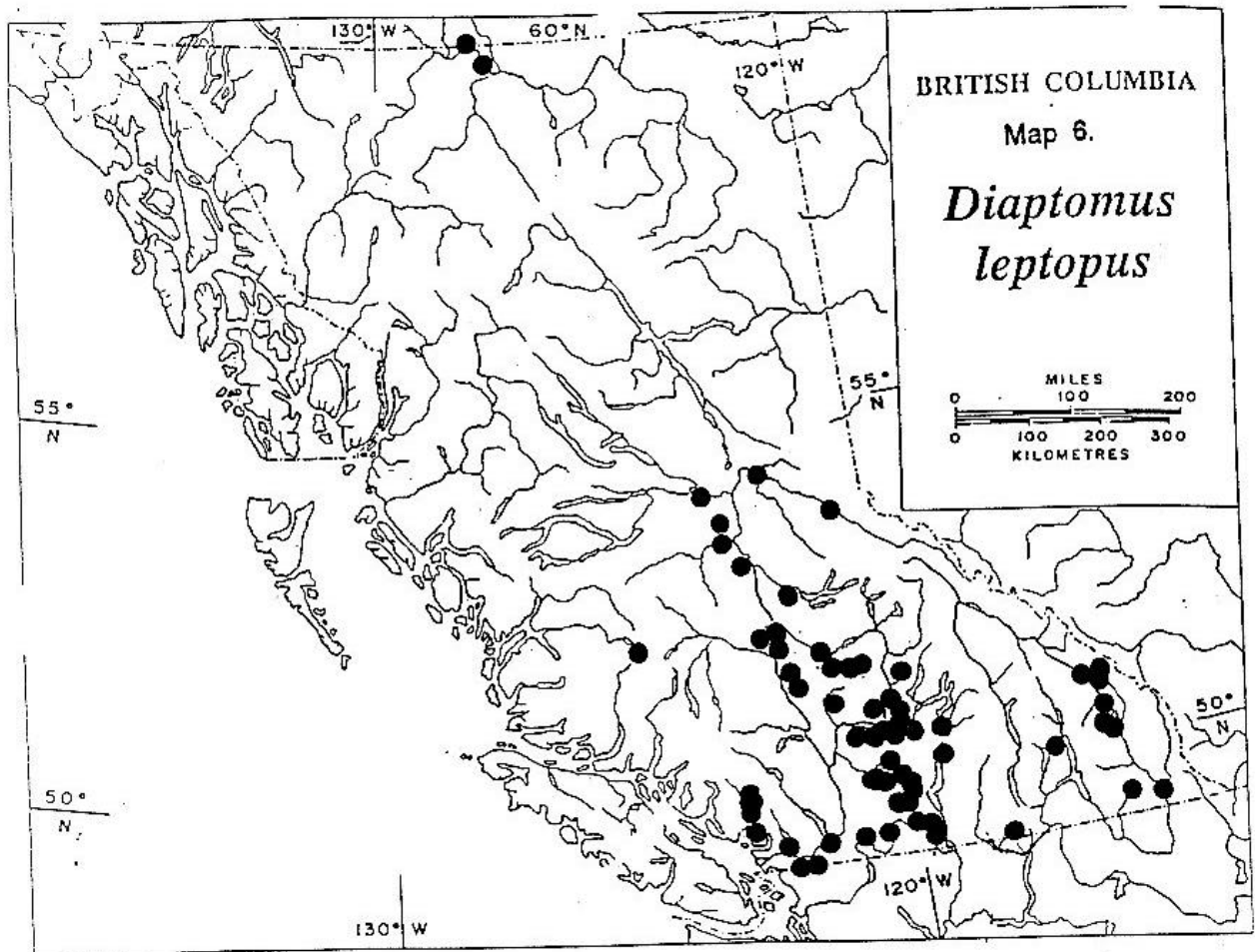


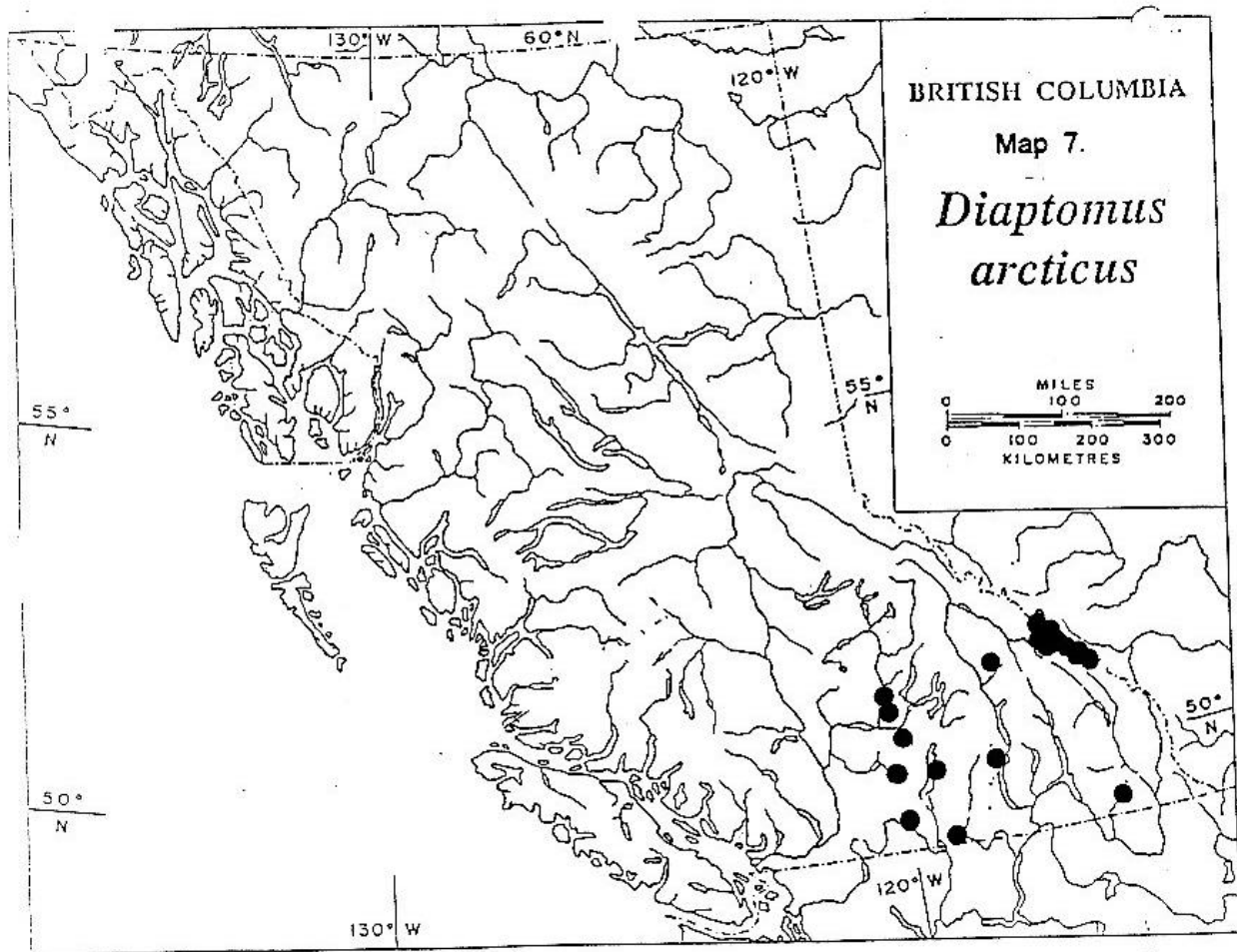


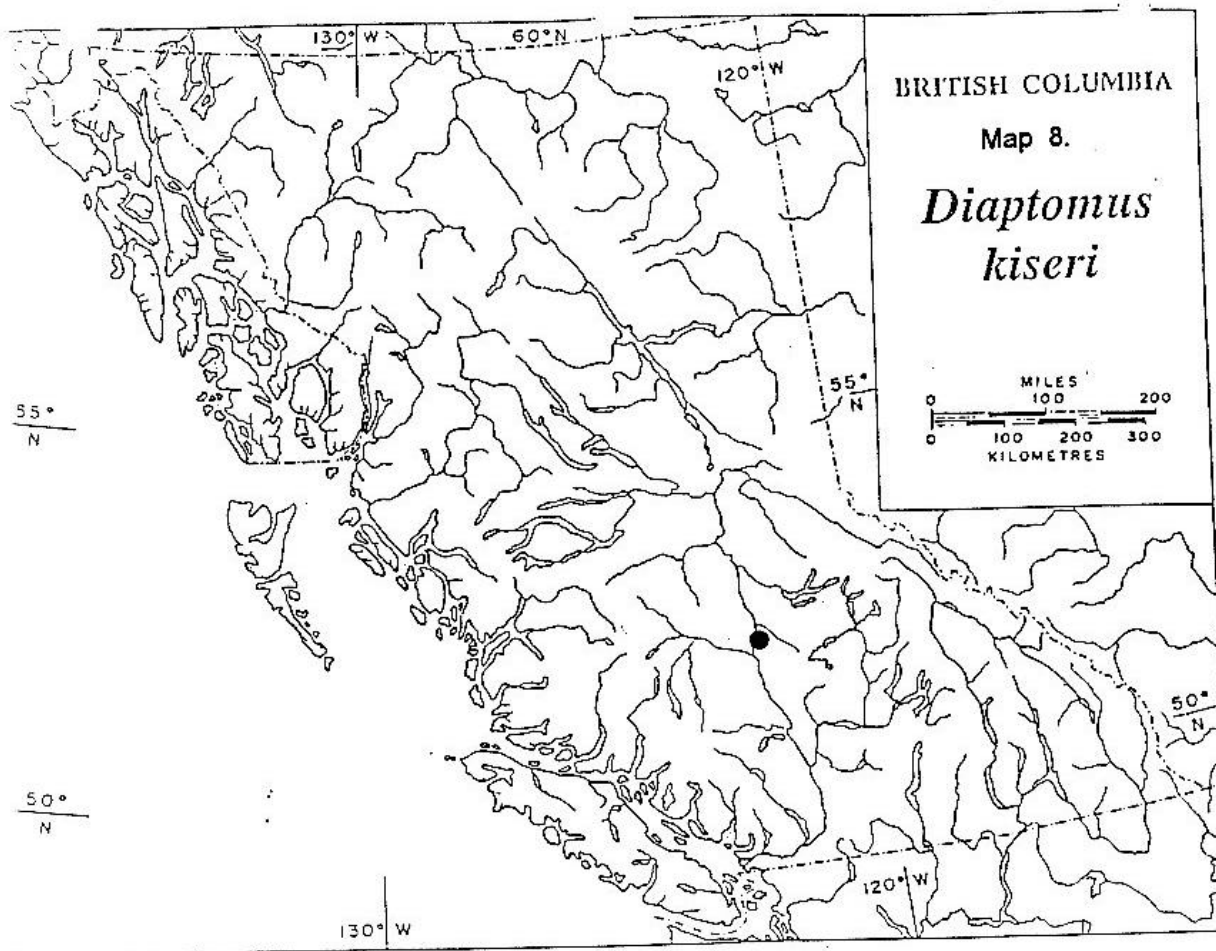


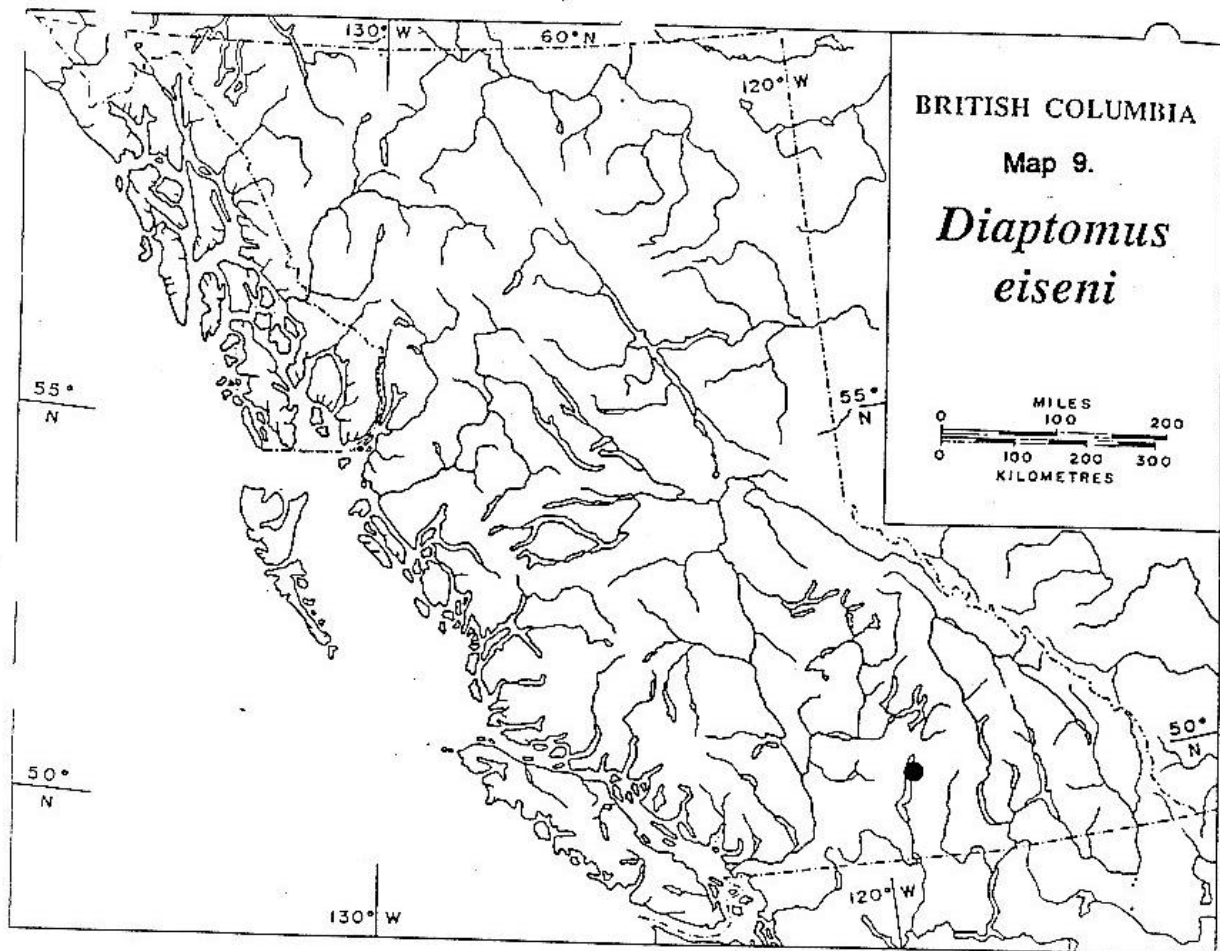


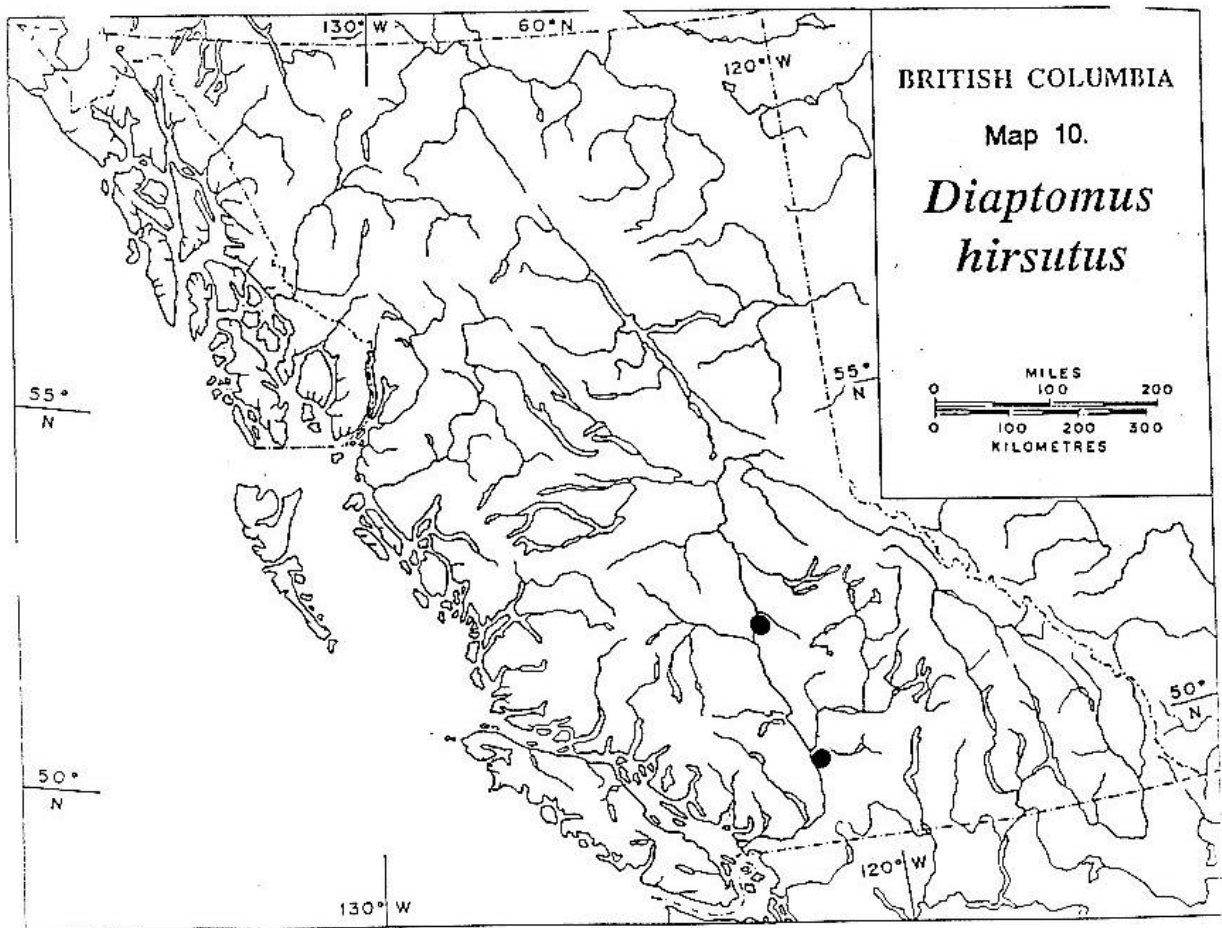




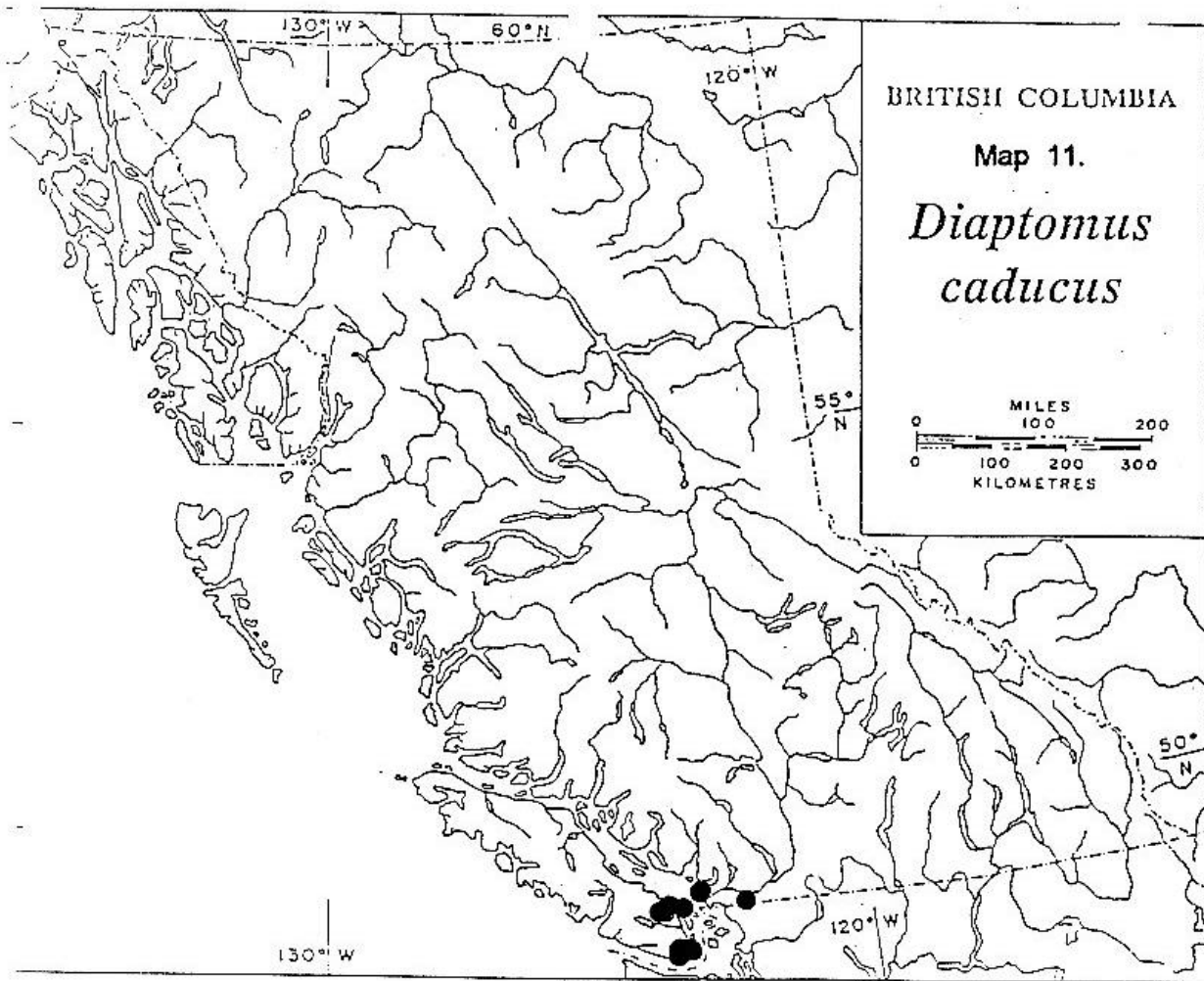


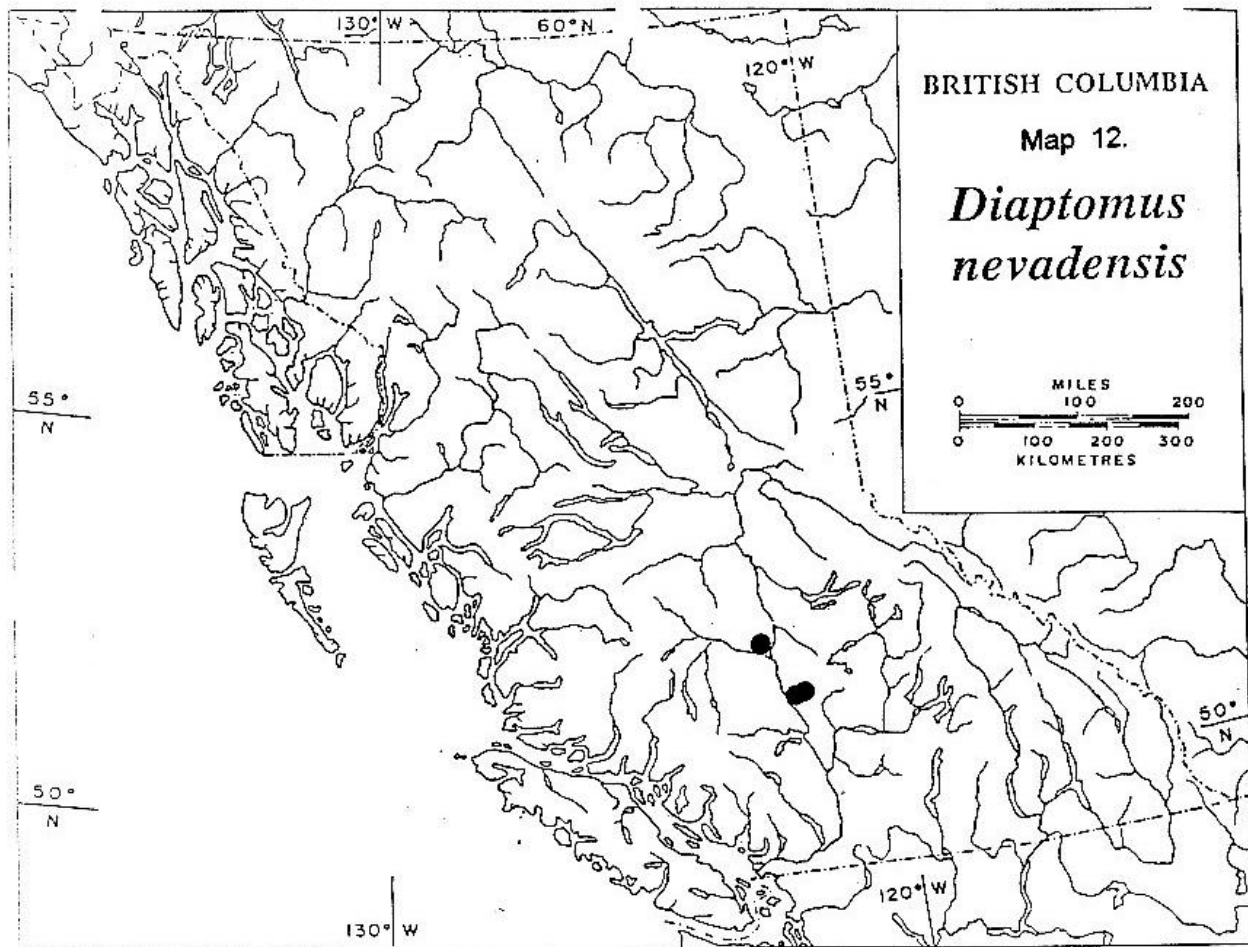


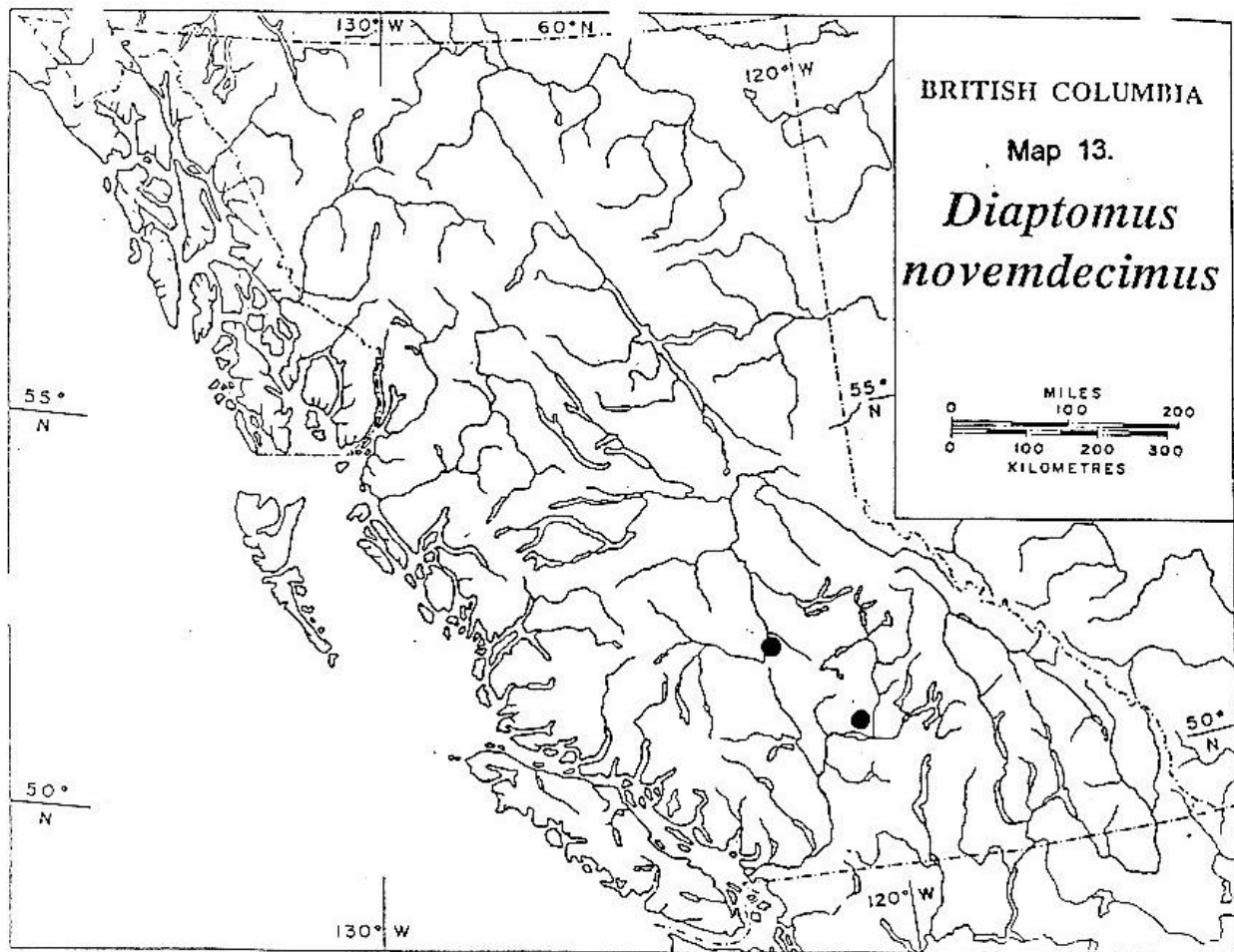


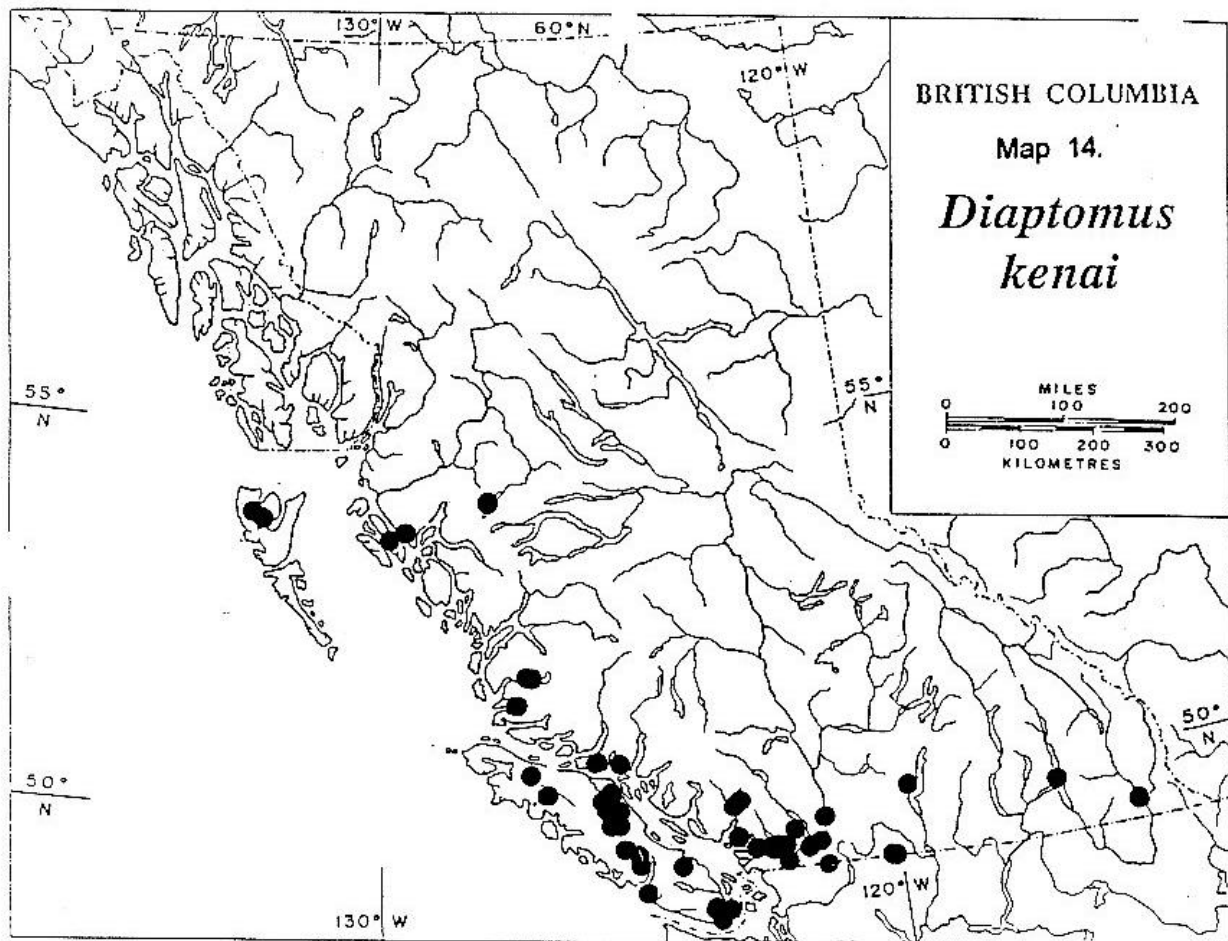


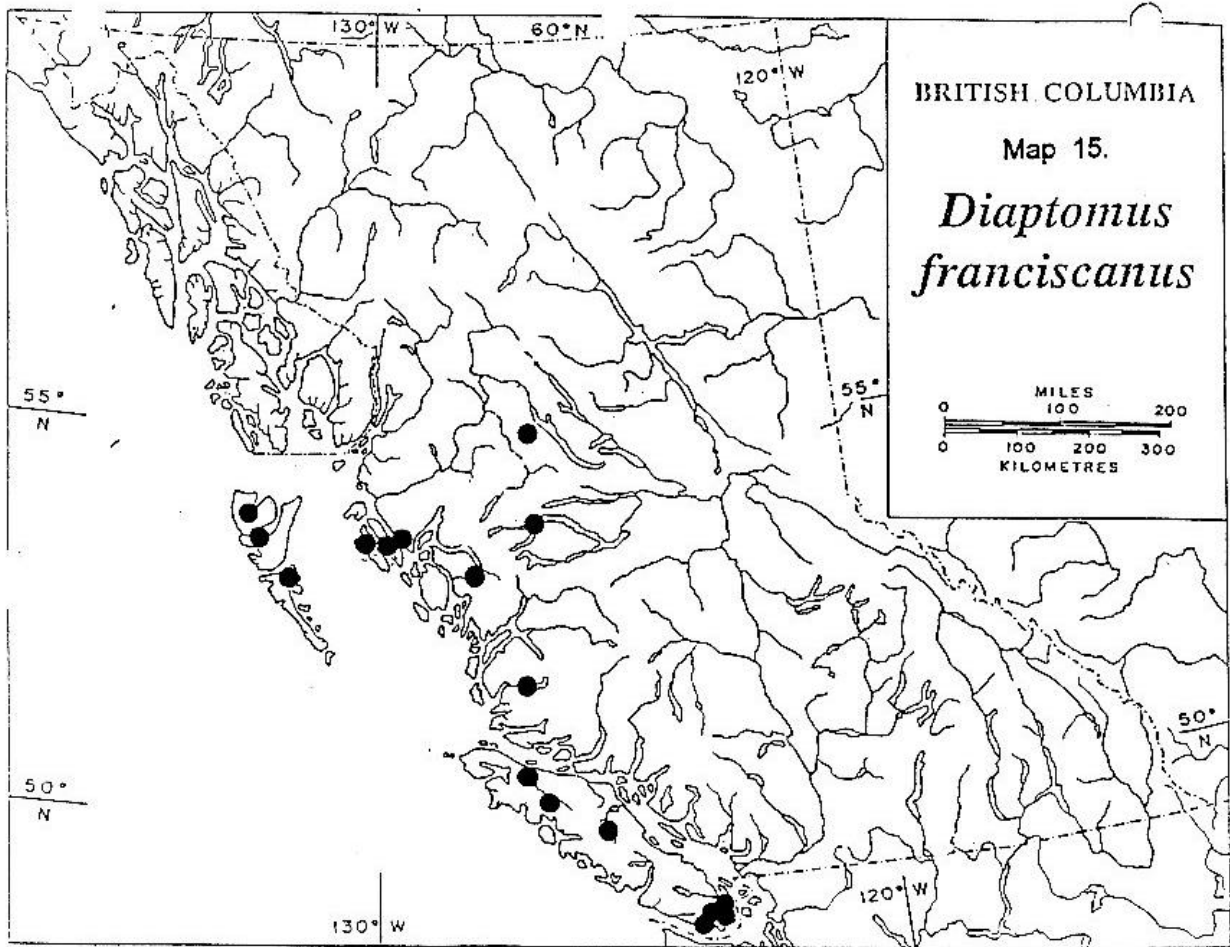


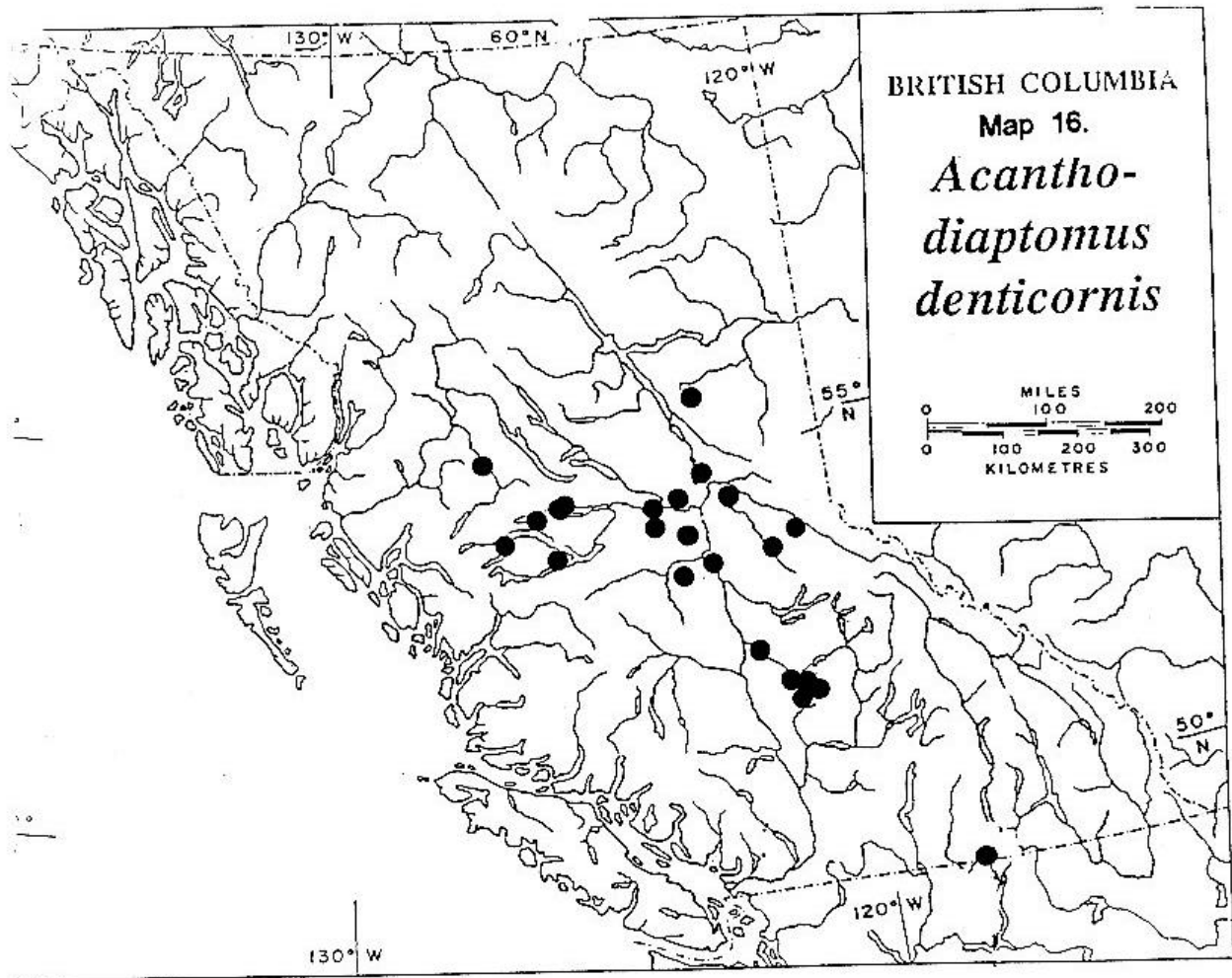


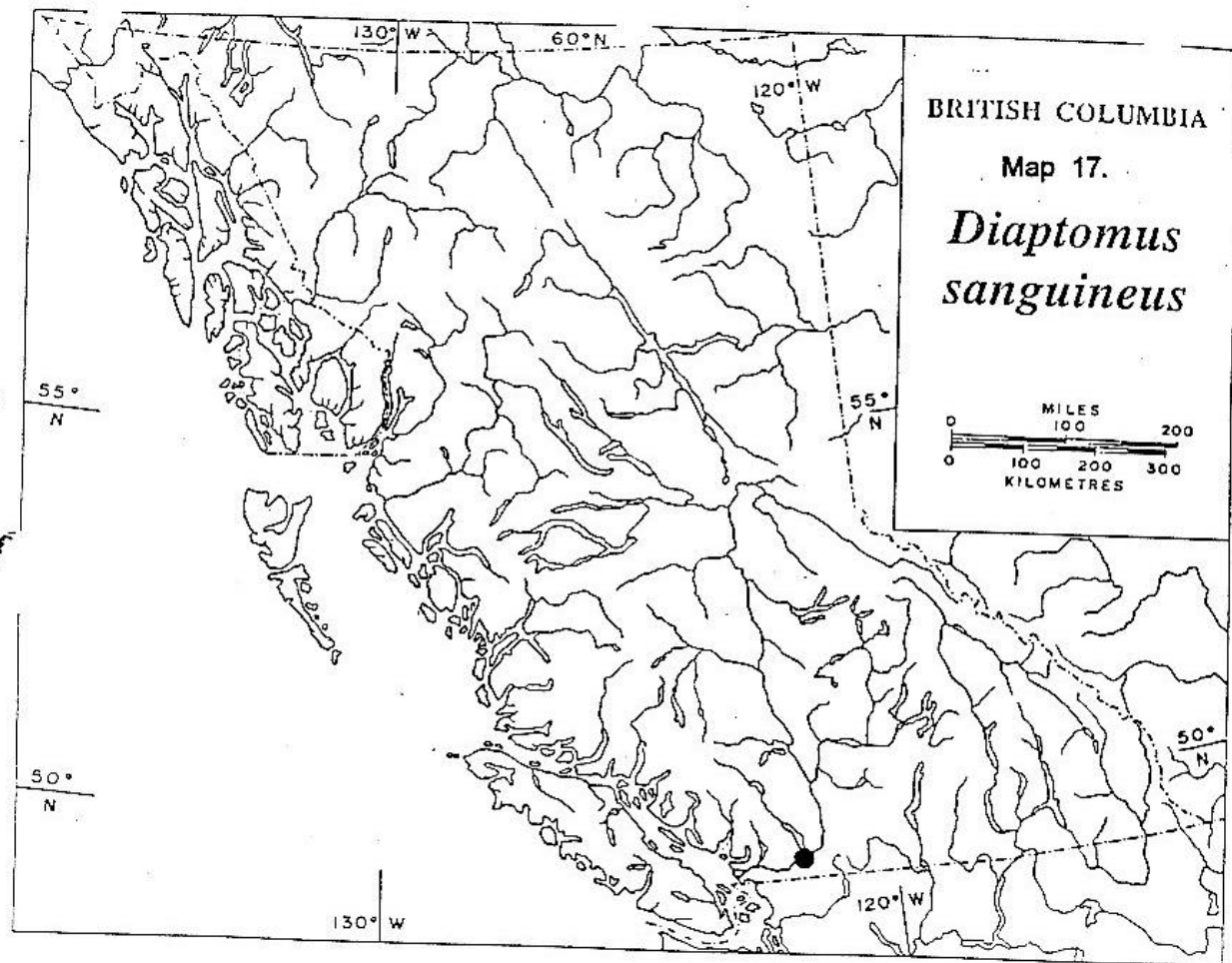


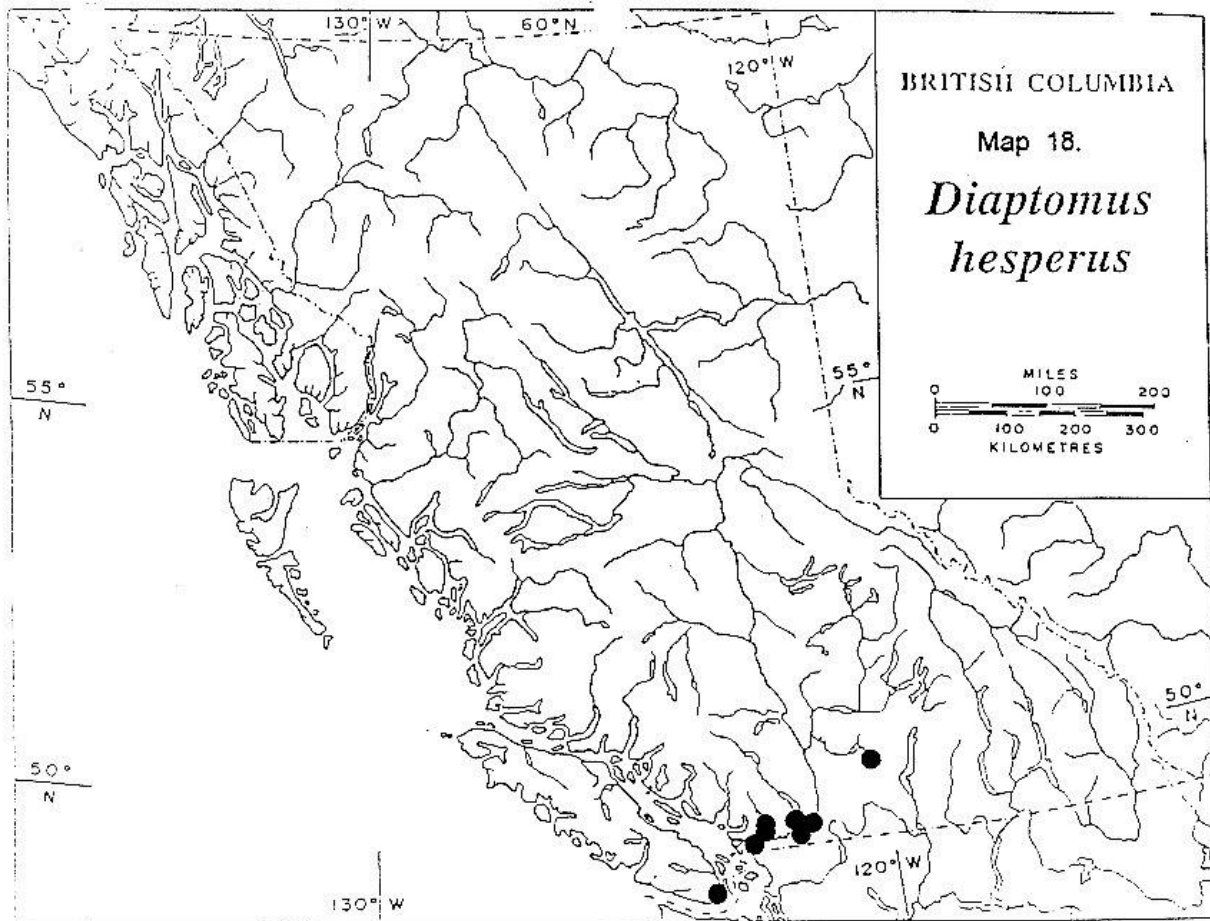




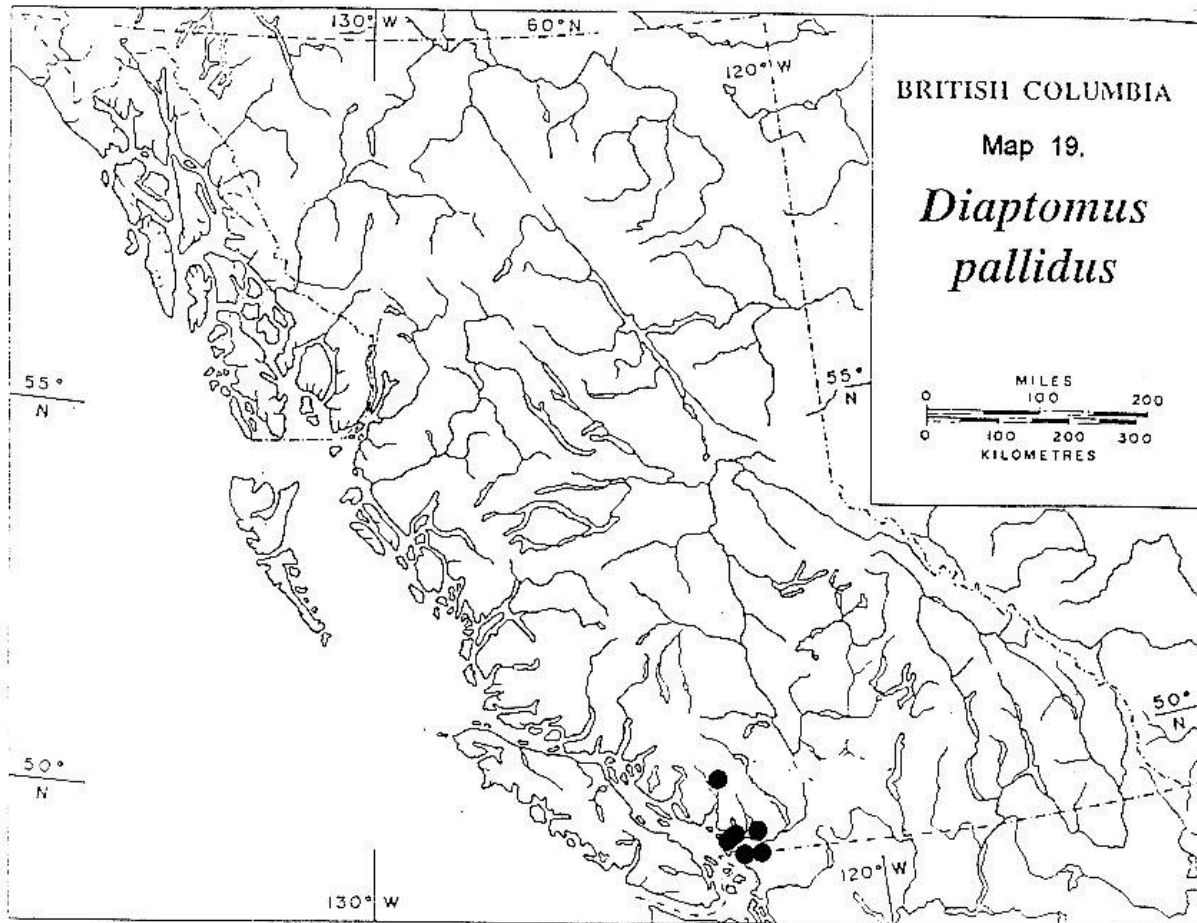


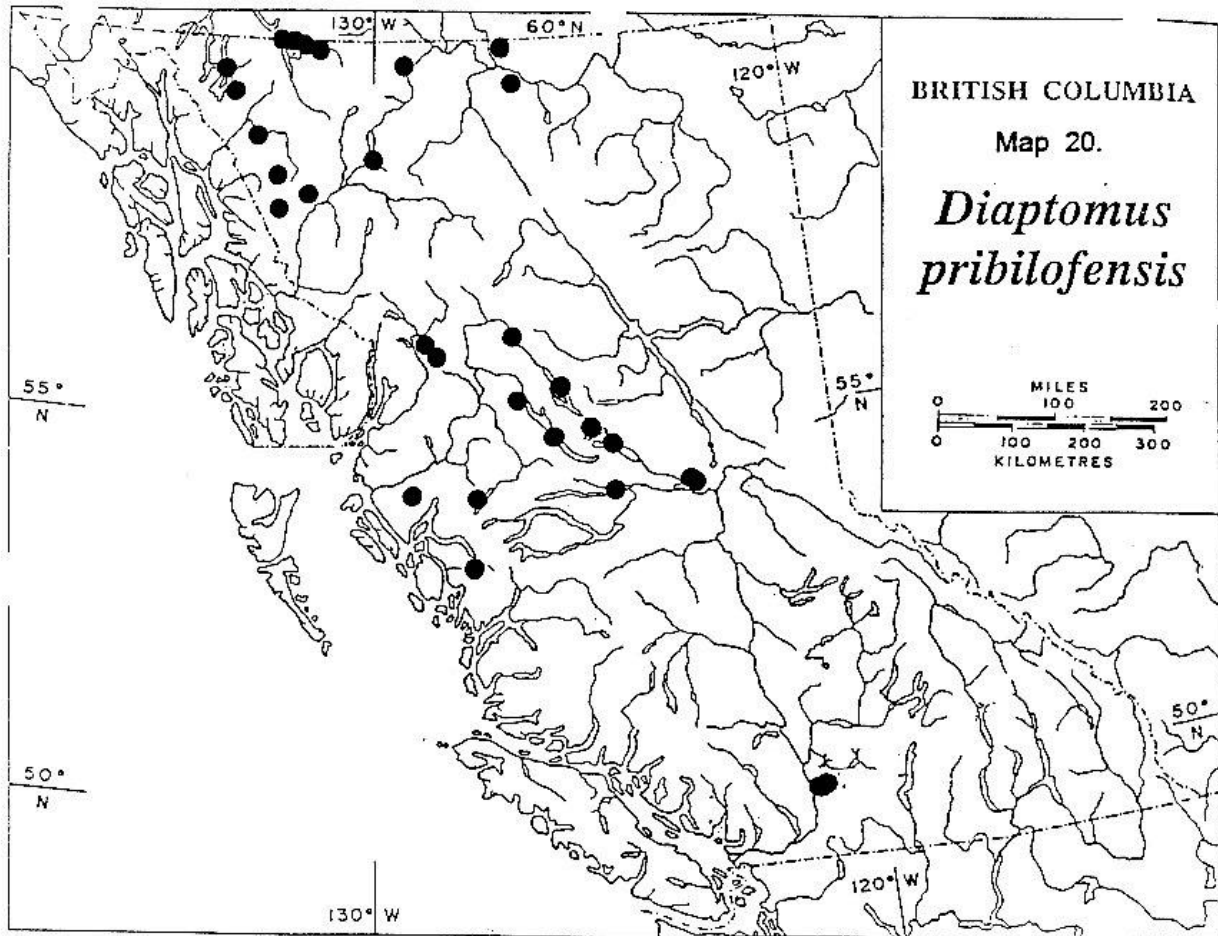


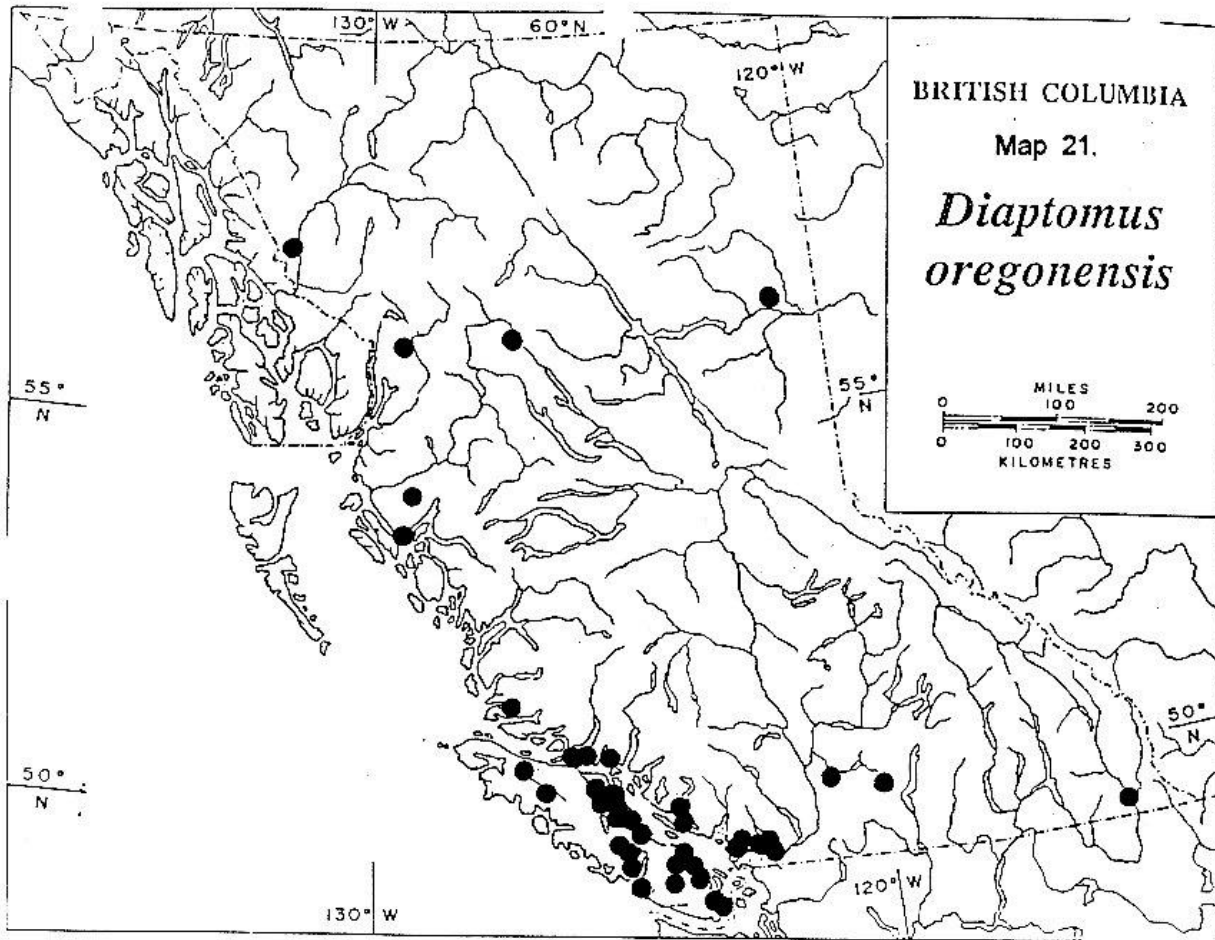


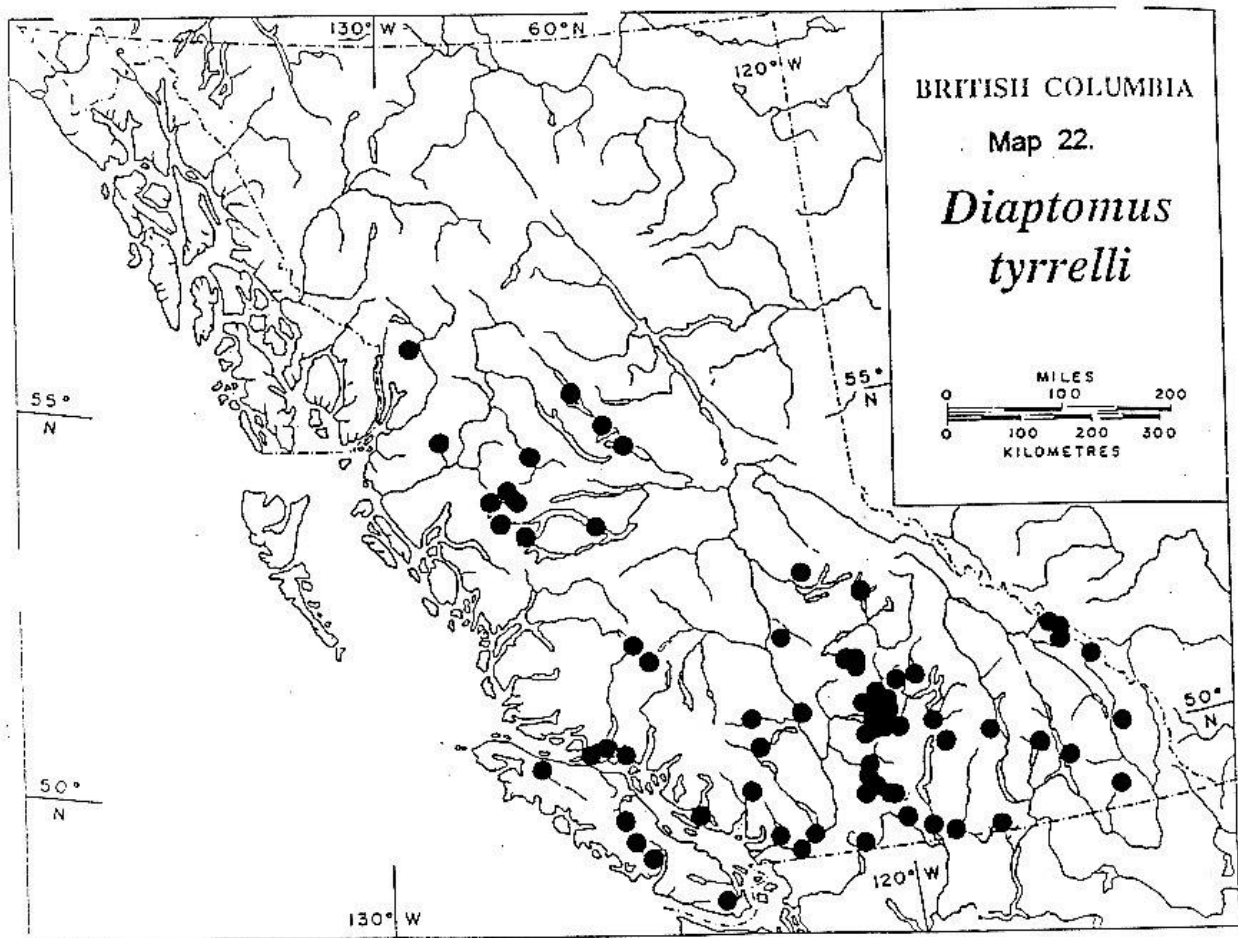


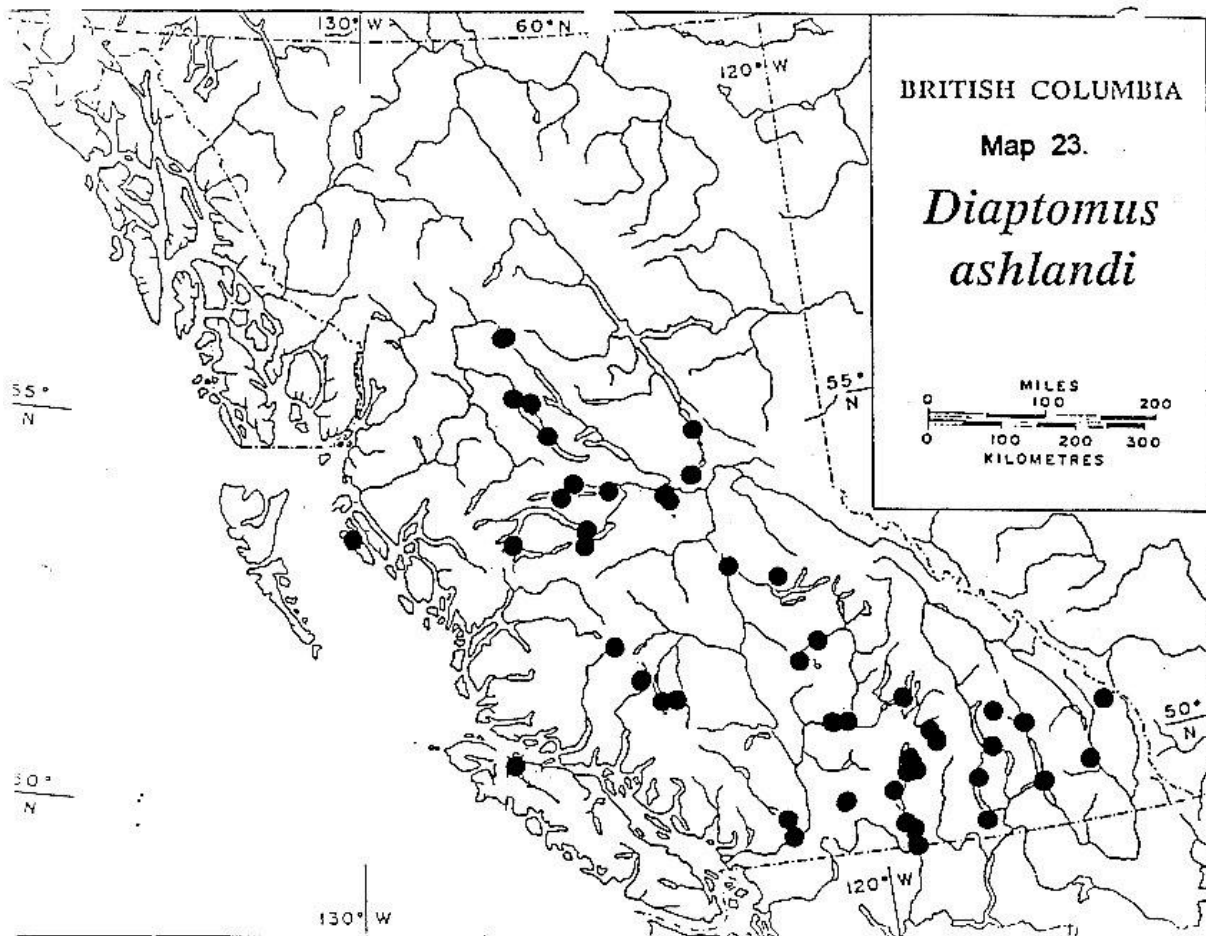


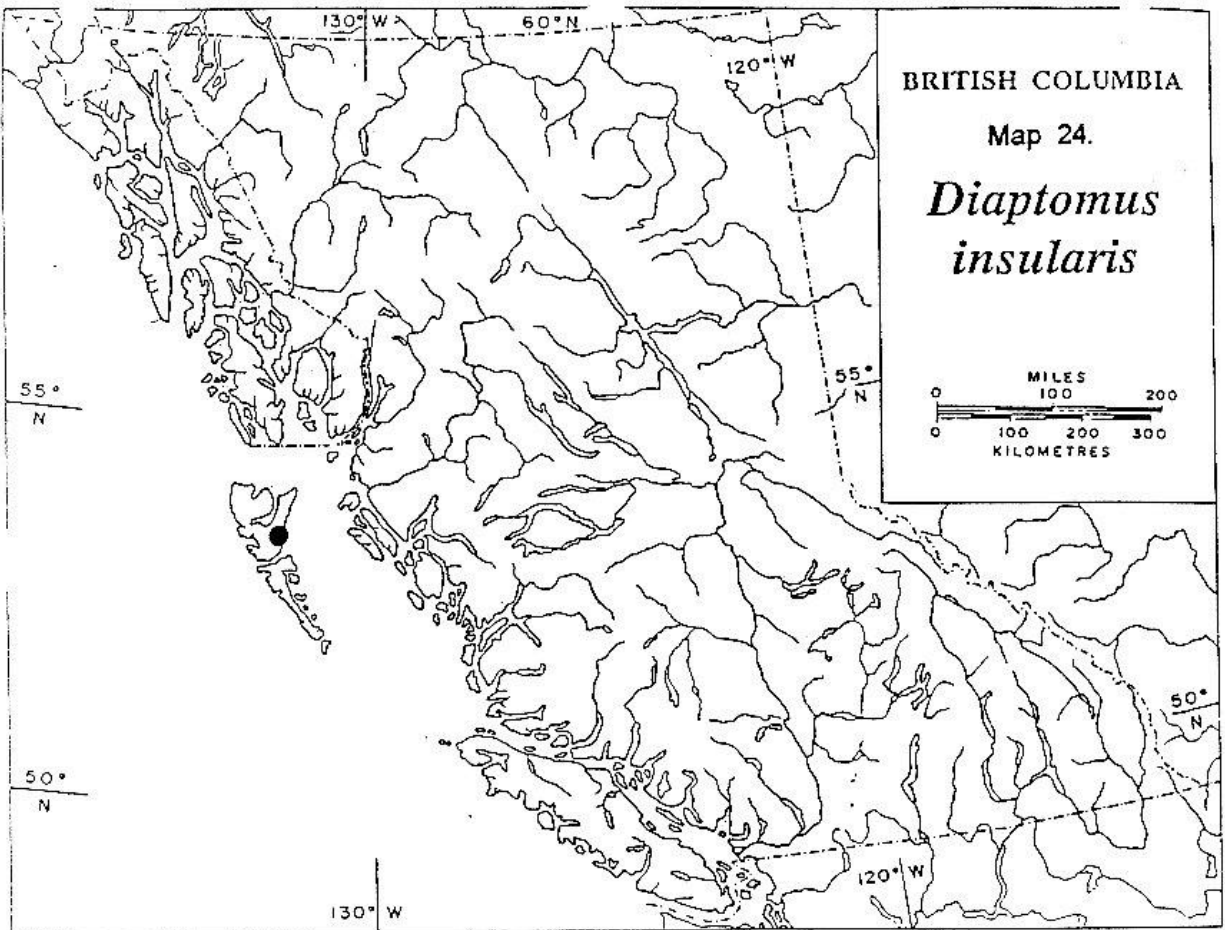


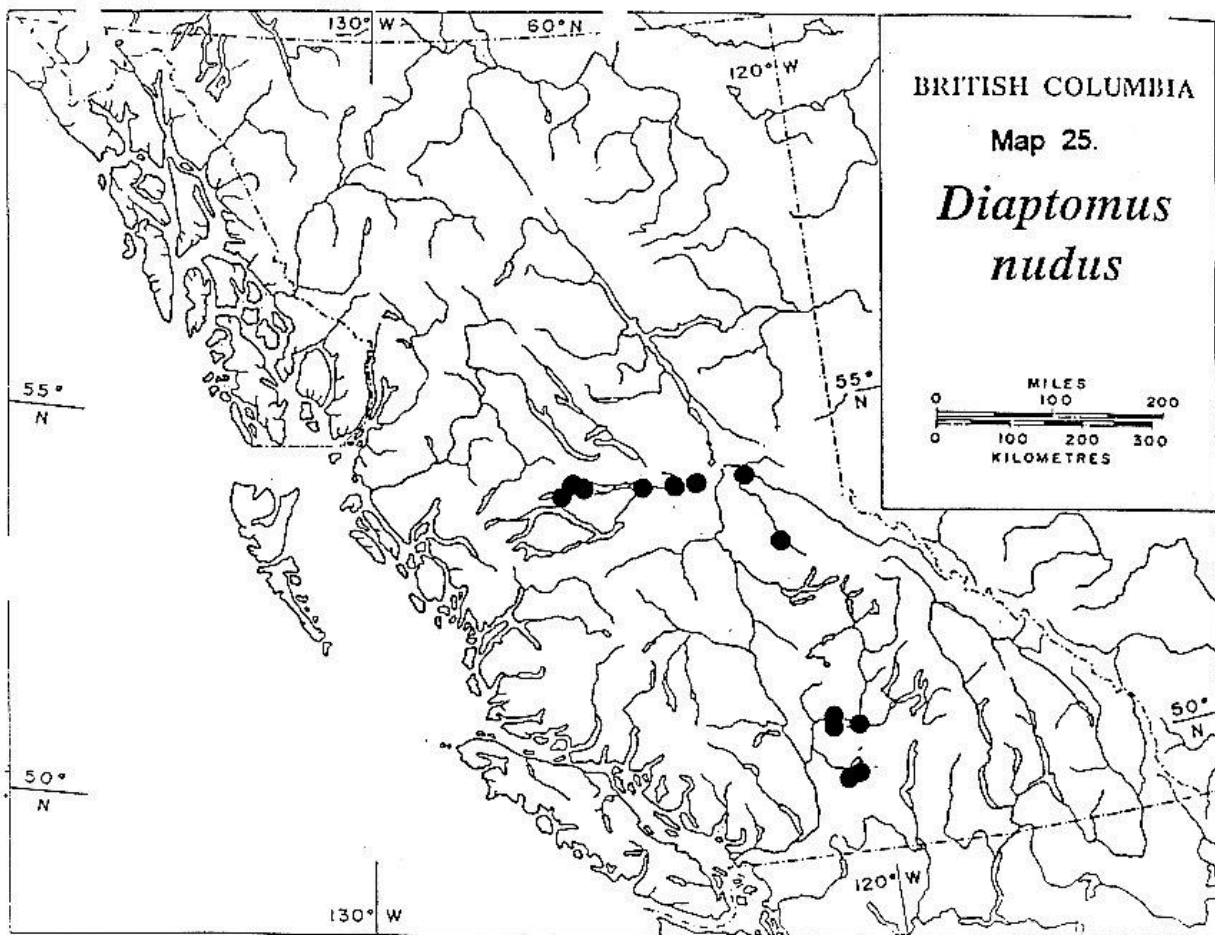


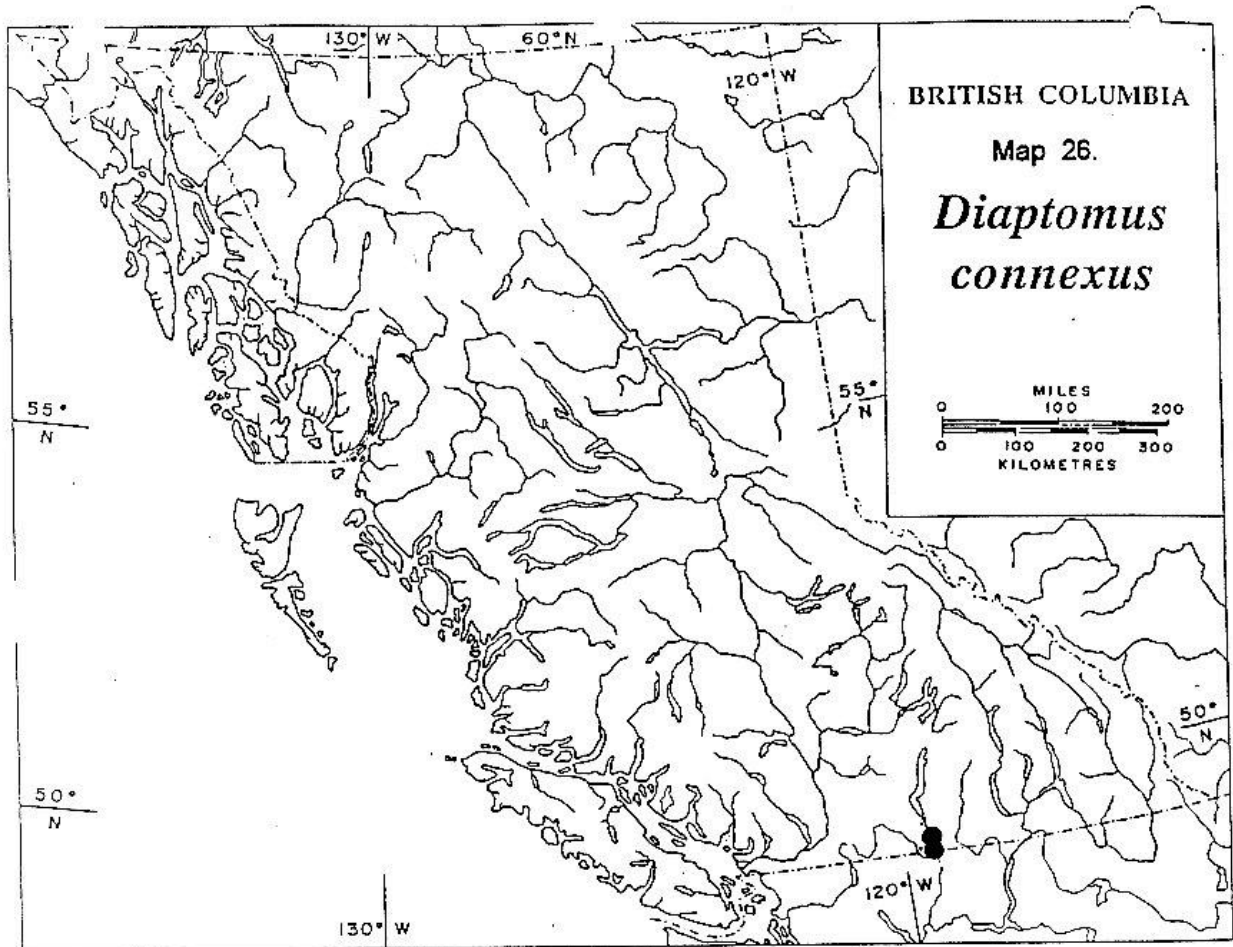




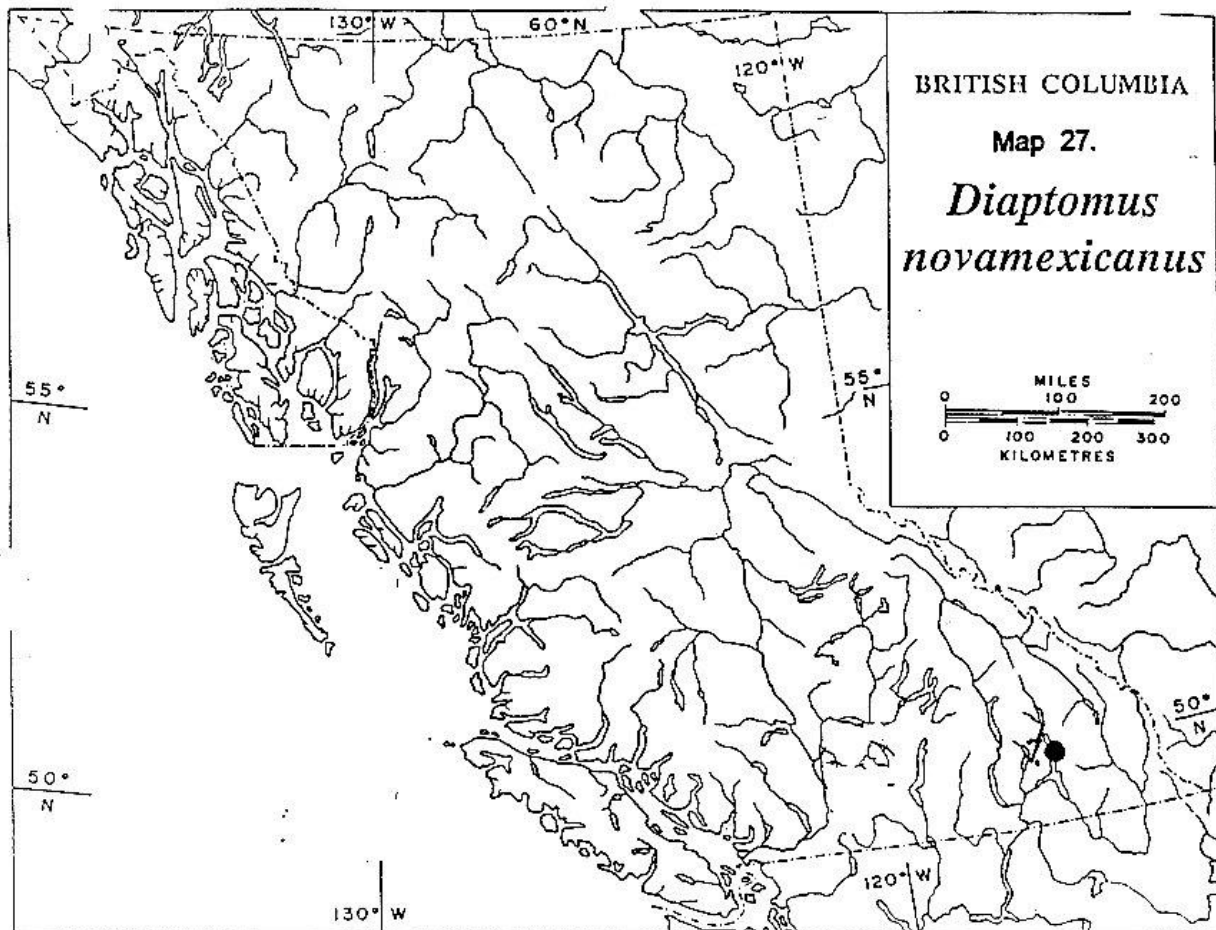


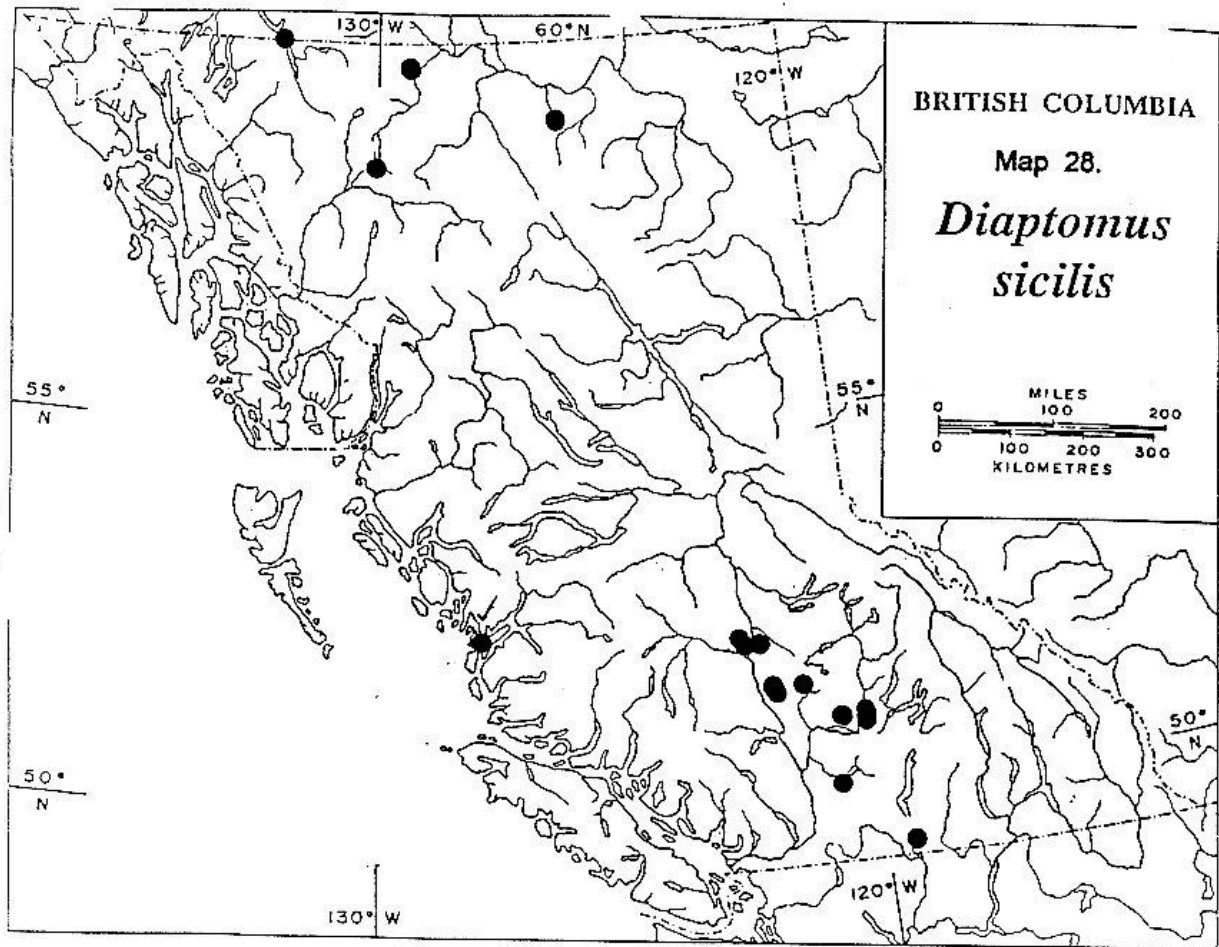


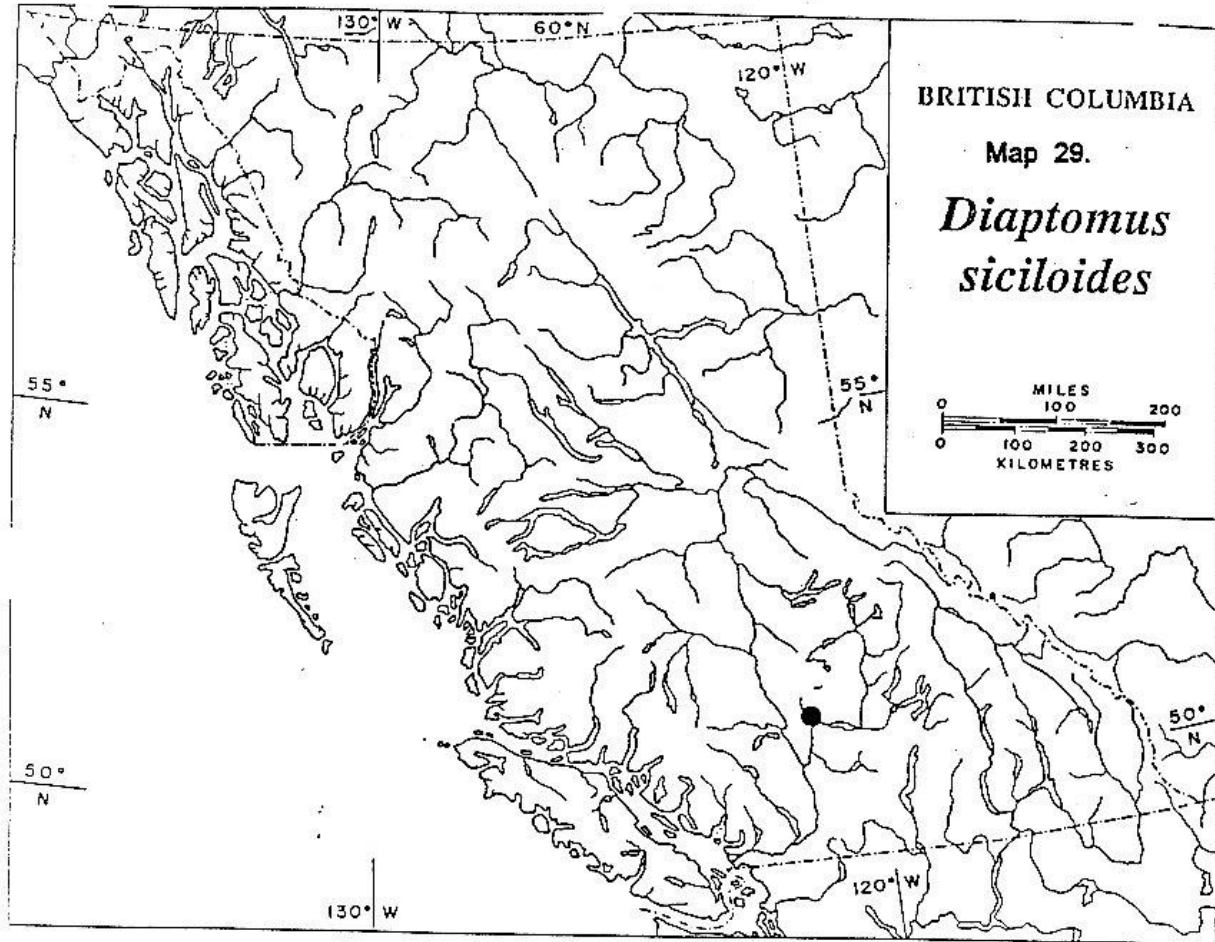


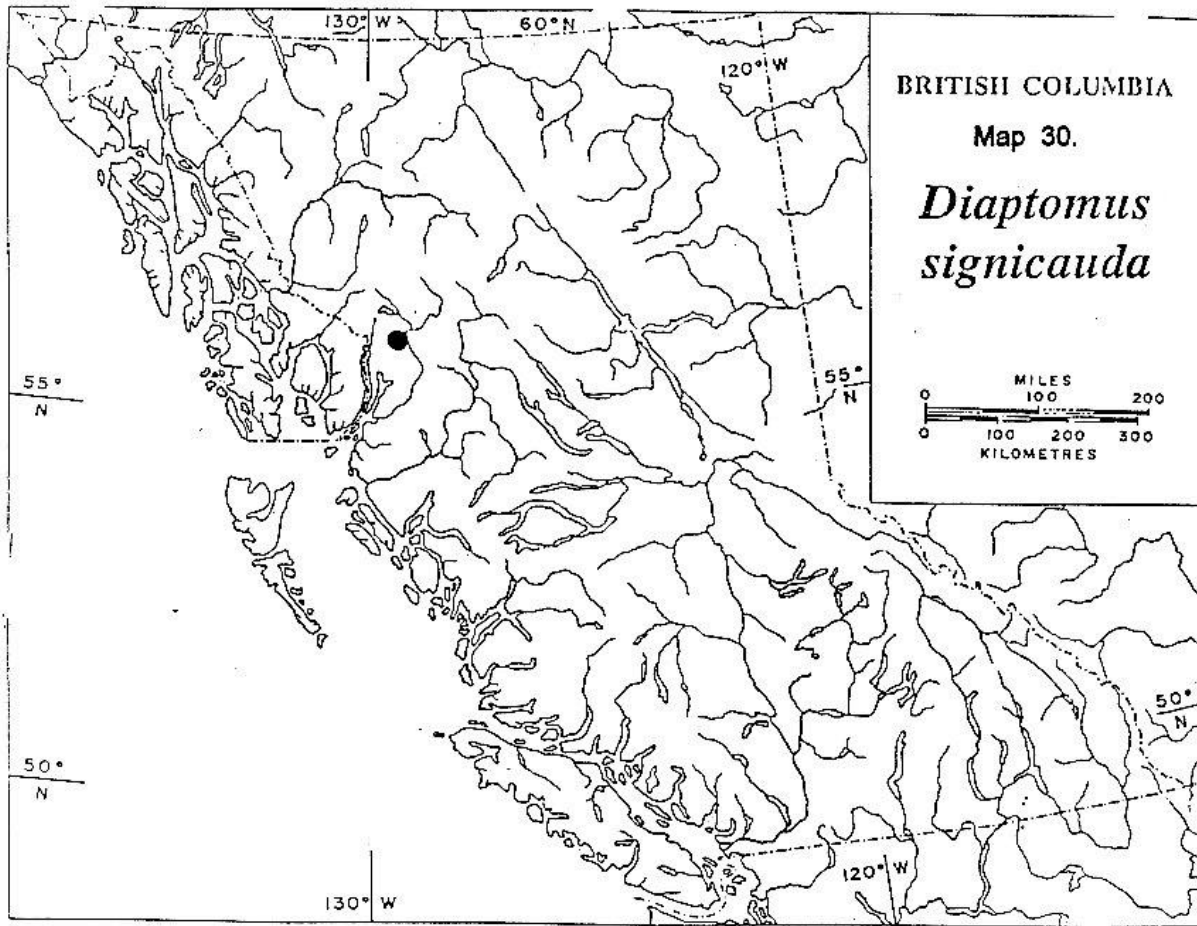












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