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Observations on the life history and ecology of *Clubiona pacifica* Banks in Washington State (Araneae: Clubionidae)

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Abstract. *Clubiona pacifica* Banks, 1896 is a common secondary occupant of lepidopteran leafrolls on alders (*Alnus* spp.). We collected rolled alder leaves at riparian sites in Washington State to determine seasonal phenology of *C. pacifica* and to examine egg laying and predatory activity. All stages of the spider occurred in rolled leaves, and spiders were found in rolled leaves throughout the season. Rolled alder leaves were used by *C. pacifica* as protected sites in which to molt and spend inactive periods and possibly to seek prey. Field observations and greenhouse experiments indicated that *C. pacifica* is capable of preying upon leafroller larvae. Occasionally, lepidopteran leafrolls were used by *C. pacifica* as ready-made chambers in which to oviposit, but more commonly the female spider herself folded an alder leaf to form a protective retreat for oviposition. These egg sac retreats and the associated egg sac are described and illustrated. After eclosion *C. pacifica* passes through a prelarval stage, a larval stage, and six nymphal stages before reaching adulthood. The principal period of reproduction and egg deposition is June and July, and most post-larval stages of *C. pacifica* appear to overwinter. We postulate that some individuals require two years to complete their life cycle although others may do so in a shorter time. Three ichneumonid wasps parasitized *C. pacifica*: *Gelis* sp. attacked the eggs; *Schizopyga frigida* and *Zaglyptus varipes* parasitized immature and adult spiders.

Keywords: Sac spider, alder, leafroll, egg sac retreat

Spiders of the genus *Clubiona* Latreille, 1804 are active, nocturnal hunters, generally pale in color, that spend the day in tubular silken retreats (also referred to as nests or sacs) constructed in protected locations (Edwards 1958; Marc 1990). Approximately 50 species occur in North America north of Mexico (Richman & Ubick 2005), and the genus is worldwide in distribution. *Clubiona* occur in a variety of habitats including coniferous and deciduous forests, bogs, marshes, meadows, and dunes (Edwards 1958; Dondale & Redner 1982). Within these habitats, *Clubiona* may reside in forest canopy (Toft 1978; Jennings & Dimond 1988), under loose bark (Austin 1984), in understory vegetation (Duffey 1969; Turnbull 1960), and in soil surface debris (Duffey 1969; Dondale & Redner 1982). In cultivated areas, *Clubiona* have been found in numerous field crops (Young & Edwards 1990), orchards (Chant 1956), and blueberry fields (Collins et al. 1996).

Clubiona pacifica Banks, 1896 is a common western North American species closely related to *Clubiona canadensis* Emerton, 1890 and synonomized with it by Edwards (1958). Roddy (1973) reinstated *C. pacifica* as a valid species, noting genitalic differences and limited overlap in their geographic distributions. Crawford (1988) retained *C. pacifica* and *C. canadensis* as separate species in his checklist of Washington State spiders, stating that his numerous Washington *C. pacifica* females were readily distinguished from those of *C. canadensis*.

Our interest in *Clubiona pacifica* came about during an investigation of arthropods associated with lepidopteran leafrolls on alders (*Alnus* spp.) and other riparian plants on the eastern slopes of the Cascade Range in Washington State (Miliczky et al. 2014). Alders were found to be heavily infested with leafrolling caterpillars of several species, and the leafrolls were in turn utilized by a diverse array of secondary occupants including herbivorous, carnivorous and parasitoid insects, phytophagous and predatory mites, and spiders. *Clubiona pacifica* was the most common spider in these samples, and examination of rolled leaves proved an efficient way to collect specimens. Here we present observations made between 2002 and 2013 on its life history and phenology, number of instars, structure of egg sac retreats, natural enemies, and its potential as a predator of leafrolling caterpillars.

METHODS

Study sites.—Specimens of *Clubiona pacifica* were collected at 16 sites in Yakima, Kittitas, and Skagit Counties, Washington State (Fig. 1). Of the 14 sites in Yakima and adjacent Kittitas Counties (east of Mount Rainier National Park on Fig. 1), 13 were along State Highway 410 and two subsidiary roads. The roads parallel the American, Bumping, Little Naches, and Naches Rivers. Site elevations ranged from approximately 750 m (easternmost) to 1300 m (westernmost). The fourteenth site was in the Wenas Wildlife Area (Washington Department of Fish and Wildlife), 40 km northwest of Yakima. Lastly, single collections were made at each of two sites north of Lake Chelan in Skagit County along State Highway 20 near Rainy Pass (elevation: 1480 m). Each of the 16 sites was near a river or stream or was in a locally moist area where standing water was often present.

Riparian vegetation, including alders (*Alnus* spp.; Betulaceae), dominated all sites. *Alnus incana* (L.) Moench (mountain alder), a shrub that reaches 10 m in height, was the most common alder at most sites. Red alder, *Alnus rubra* Bong., a tree reaching 25 m in height, was present at several sites, and is the dominant alder species on the west slopes of the Cascade Range. *Alnus viridis* (Vill. Lam. & DC.), green alder, was

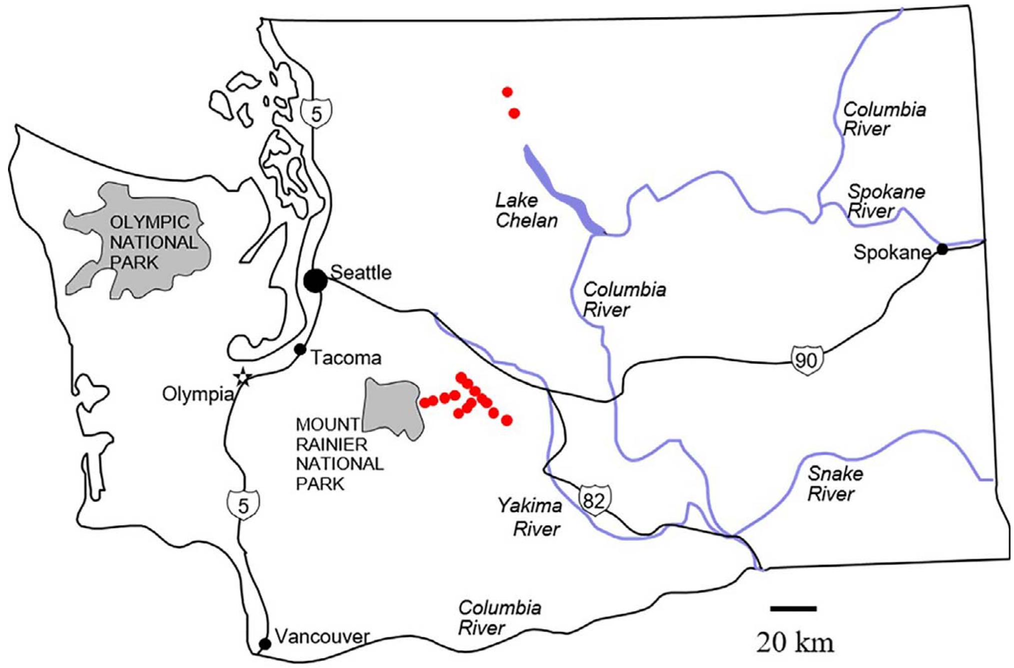


Figure 1.—Washington State map showing sampling sites.

encountered more commonly at higher elevations. Other tree and shrub species that occurred at some sites included willows *Salix* spp., red osier dogwood *Cornus sericea* L., black hawthorn *Crataegus douglasii* Lindl., snowberry *Symphoricarpos albus* (L.) Blake, vine maple *Acer circinatum* Pursh, Wood's rose *Rosa woodsi* Lindl., black cottonwood *Populus trichocarpa* T. and G., big-leaf maple *Acer macrophyllum* Pursh, and ponderosa pine *Pinus ponderosa* Dougl.

Sampling for *Clubiona*.—Specimens of *Clubiona pacifica* were obtained in three ways. (1) Examination of lepidopteran leafrolls. *Clubiona pacifica* was a frequent secondary occupant of alder leaves rolled by lepidopteran larvae (Miliczky et al. 2014). Samples of rolled leaves were collected over six seasons between 2002 and 2012, and observations for *C. pacifica* from those collections are discussed in this paper. Rolled leaves were collected by hand or with a telescoping pole pruner that allowed a maximum sampling height of about 4 m. Sampling began after alder flowering was complete, leaves were well expanded, and rolled leaves had begun to appear. Our earliest sample date was 15 June 2010 and the latest was 29 September 2010. July and August were the most heavily sampled months. Collectively, 101 samples comprising 6101 individual leafrolls were examined. Sample size ranged from eight to 238 leafrolls and depended on leafroll abundance and site accessibility. Not all sites were sampled on a given sample date, and some were sampled more frequently than others. Rolled leaves were placed in self-sealing plastic bags, held in a cooled ice chest for transport to the laboratory, and stored under refrigeration ($\sim$5°C) until examination. Leafrolls were examined under a dissecting microscope. *Clubiona* specimens were either preserved in 70% isopropyl alcohol for measurement or reared for confirmation of identity or use in leafroller predation tests.

(2) Examination of egg sac retreats. An egg sac retreat is a leaf folded by the adult female *C. pacifica* to form an enclosed chamber in which a clutch of eggs is deposited. A retreat's location was often apparent due to the modified appearance of the leaf and its frequent position near the end of a branch. Approximately 300 retreats were collected in 2005 and 2006 from sites at which *C. pacifica* was common. Retreats were collected at one- to two-week intervals between late June and mid-September. The retreats were taken to the laboratory for examination.

(3) Miscellaneous collections. In May and June prior to the appearance of lepidopteran leafrolls, other collecting techniques were employed to gain additional knowledge about *C. pacifica* activity at this time of year. Beating tray samples were taken on alder and neighboring plants. Litter samples were collected beneath alder and extracted with Berlese funnels. Few *Clubiona* were obtained using these techniques. More productive was visual inspection of foliage for the presence of silken retreats or folded leaves in which the spiders sometimes sought refuge.

***Clubiona* identification.**—Genitalia of adult *Clubiona* were examined microscopically and compared with illustrations in Dondale & Redner (1982) and Roddy (1973). Voucher specimens of *Clubiona* and other spiders collected during this study were deposited in the Burke Museum of Natural History and Culture, Seattle, WA. Identifications were confirmed by Rod Crawford of the Burke Museum. All other specimens are housed at the USDA-ARS Temperate Tree Fruit and Vegetable Research Unit, Wapato. WA.

Measurements and rearing.—All *C. pacifica* collected during this study were preserved in 70% isopropyl alcohol. Maximum carapace width of all specimens was measured with a Zeiss Stemi 2000-C stereomicroscope equipped with an ocular micrometer. Carapace width was used to help determine the number of instars and to help elucidate seasonal phenology.

Approximately two dozen first instar nymphs collected from rolled alder leaves on 20 August 2010 were reared to determine the number of instars *C. pacifica* passes through *en route* to adulthood. Occasional immatures were reared to obtain adults for species verification. Individual spiders were reared in 30 ml plastic cups with tight-fitting lids. They were fed weekly with fruit flies (*Drosophila* sp.) collected from rotting fruit and maintained in a laboratory colony. At feeding, spiders were also given 1–2 drops of water.

Leafroller predation experiments.—Frequent occupancy of alder leafrolls by *C. pacifica* prompted greenhouse experiments to evaluate the spider as a predator of lepidopteran leafrollers. Spiders were collected from rolled alder leaves and maintained in 30 ml plastic cups until use. Adult females and immatures of various sizes were tested. Estimated instar numbers of immatures were: small immatures – first and second instars; medium immatures – third and fourth instars; large immatures – fifth and sixth instars. Spiders were provided leafrollers that were somewhat smaller to somewhat larger than the spider itself. Leafrollers included *Pandemis pyrusana* Kearfott and *Choristoneura rosaceana* (Harris) (both Tortricidae), collected in local orchards and maintained in laboratory colonies and *Caloptilia alnicolella* (Chambers) (Gracillariidae) obtained in the field from rolled alder leaves. Fresh alder cuttings with the cut ends immersed in water, apple and pear seedlings in 10 cm pots, and small apple trees in 15-liter pots were provided to leafrollers for feeding and construction of leafrolls. Seedlings and cuttings were held in cylindrical cages 17.5 cm in diameter by 43 cm tall made of colorless, transparent, plastic sheeting with a tight-fitting gauze cover for ventilation. Since alder is also a host for *P. pyrusana* and *C. rosaceana* (Miliczky et al. 2014), all three leafrollers are potential prey for *C. pacifica* in the field. Leafroller larvae were placed on host plants and given 24 – 72 hours to establish leafrolls prior to spider introduction. Cages were monitored regularly during an experiment for evidence of predation following criteria developed by Miliczky & Calkins (2002). Eight experiments were conducted using different combinations of host plants, leafroller species, and stages of *Clubiona*. An experiment was terminated when all leafrollers had been consumed or otherwise disappeared or if no predation occurred. Test duration ranged from six to 18 days.

Predation on *Pandemis pyrusana* egg masses was also examined. Test spiders were held individually in ventilated plastic vials (4.5 cm in diameter by 9.5 cm long) and were provided with egg masses that had been deposited either on a wax paper substrate or the side of the vial. Tests were run until eggs were consumed or had begun to hatch.

RESULTS

***Clubiona* fauna.**—*Clubiona pacifica* was the most abundant spider collected during the study. *Clubiona moesta* Banks, 1896, occurred at 10 of 16 study sites on some of the same plant species as *C. pacifica* and was occasionally found in rolled alder leaves. It was a far less common spider than *C. pacifica*. The two belong to different species groups and are readily separable in both sexes by genitalic differences. *Clubiona moesta* is a smaller spider than *C. pacifica*. The only other *Clubiona* found were three unidentified females from rolled alder leaves.

Egg sac retreats.—*Clubiona pacifica* females usually construct egg sacs within chambers formed from leaves that they fold themselves, referred to here as egg sac retreats (use of a lepidopteran leafroll as a ready-made chamber for egg sac construction is discussed below). Most egg sac retreats that we examined were on *Alnus*: 170 on *A. incana,* 105 on *A. viridis,* eight on *A. rubra*, and 12 on unspecified *Alnus*. Because each separate site tended to be dominated by one species of alder (usually *A. incana*) it was not possible to determine if *C. pacifica* showed a preference among *Alnus* species for retreat construction. Other riparian plants utilized for egg sac retreat construction included: *Cornus sericea* (eight retreats), *Crataegus douglasii* (1), *Salix* sp. (9), *Symphoricarpos albus* (1), and one on an unidentified herbaceous mint (Lamiaceae). These other plant species were generally far less common than alder at our study sites and received far less effort in terms of discovering egg sac retreats.

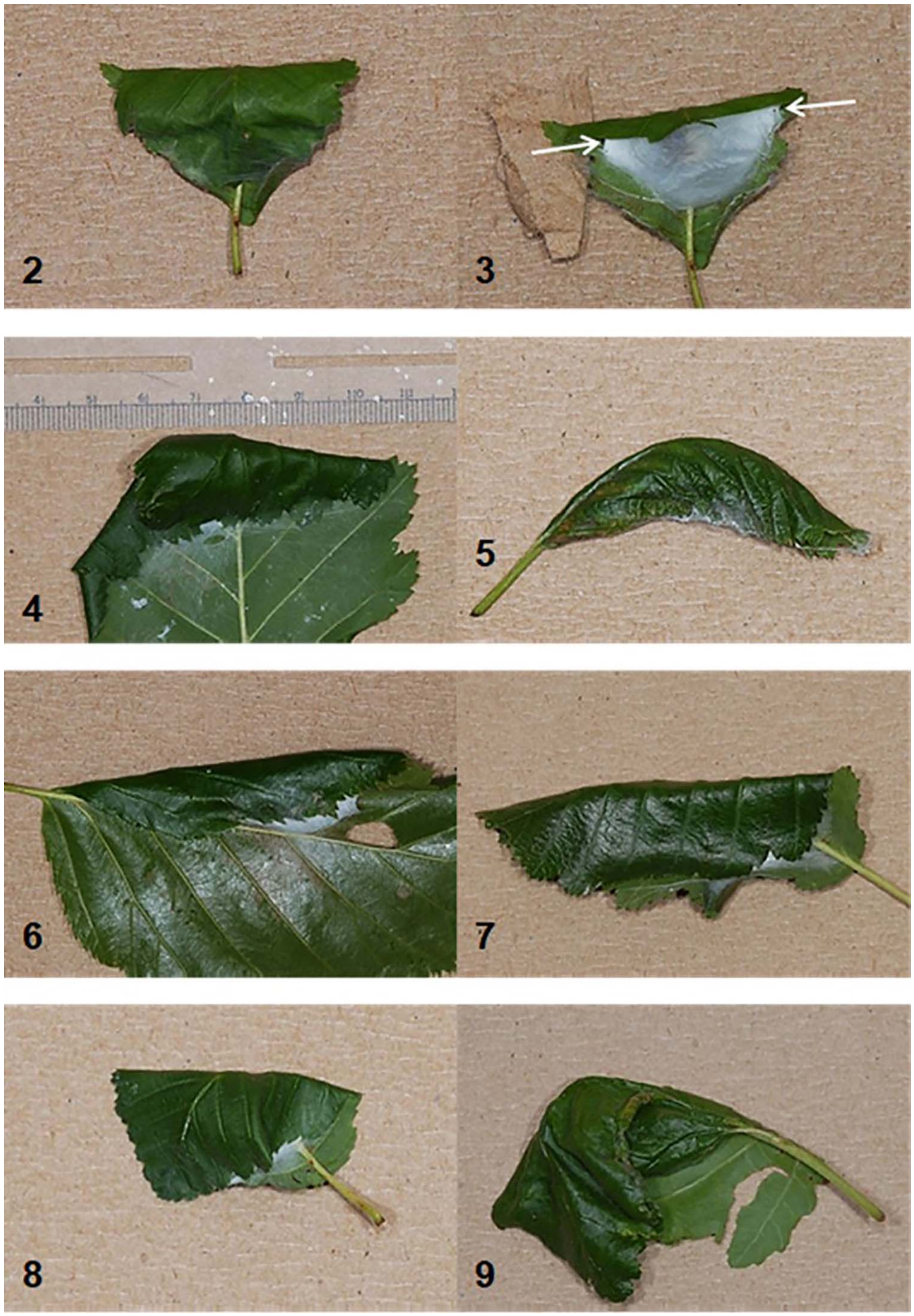
Construction of egg sac retreats was not observed. Retreats varied in form (Figs. 2–9), but almost without exception a leaf was folded so that its lower surface formed the interior of the retreat. Retreat variability may represent a continuum with leaves folded perpendicular to the long axis (Figs. 2–4) at one end and those folded parallel to the long axis (Figs. 5, 6) at the other. Leaves folded at angles between perpendicular and parallel (Figs. 7, 8) make up the middle part of the continuum, while some retreats are not readily categorized (Fig. 9). Neither leaf species nor leaf size appeared to influence the pattern of folding. Silk applied to the outer surface of the retreat (where the edges of the leaf come together) presumably helps maintain retreat integrity. Most retreats were formed from a single leaf, but on occasion two or three leaves were irregularly joined together to form a retreat chamber between their opposing surfaces.

Dimensions of egg sac retreats varied according to the size of the leaf and how it was folded. Outside dimensions of smaller retreats were as little as 2 cm x 3 cm. Larger retreats included long, narrow examples up to 7.5 cm x 2.5 cm and those whose major axes were more equal, 7 cm x 6.5 cm for example. Top to bottom thickness of a retreat was on the order of 1 cm.

The interior of the egg sac retreat was lined with silk (Fig. 3). The egg sac itself (Figs. 10–13) was constructed within this silk-lined chamber. Access to the outside was maintained via one or more narrow, slit-like openings in the silk-lined chamber (Fig 3). These openings presumably allow young spiderlings to exit the retreat when it is time to disperse. The egg sac was constructed upon, or incorporated into, a bridge-like layer of silk that partially spanned the interior of the retreat chamber (Figs. 10–13). The bridge was incorporated into the silken lining of the retreat at two or three locations. The egg sac was located near the center of the bridge, suspended within the retreat chamber out of direct contact with the leaf (Fig. 12). This may allow air to circulate around the egg sac.

The dome-shaped egg sac has a circular to oblong footprint. Circular egg sacs ranged from 5 mm to 8 mm in diameter ($n = 9$), while oblong sacs ranged from 2.6 mm x 4 mm to 4.5 mm x 9.5 mm ($n = 5$). Eggs were usually arranged in three or four layers ($n = 22$) (Fig. 12). Mean clutch size was 73.8 ($n = 49$; range: 25–129; SD = 25.1). Eggs were subspherical in shape with diameters from just under to just over 1 mm ($n = 5$).

Female *C. pacifica* remain in the egg sac retreat for some time after oviposition, typically resting atop or beneath the egg



Figures 2–9.—Variability in form of *Clubiona pacifica* egg sac retreats. Figures not all to same scale. 2, Leaf folded perpendicular to its long axis; 3, Same retreat as Fig. 2 with apical half of leaf removed to show silk lining of retreat. Female spider and egg sac are just visible through the silk lining. Arrows indicate exits from silk lined chamber; 4, Leaf folded perpendicular to its long axis and with a small, secondary fold (measurement scale is in cm); 5, 6, Leaves folded parallel or nearly parallel to the long axis; 7, 8, Leaves folded at an angle to the long axis; 9, Irregularly folded leaf.

sac with the ventral surface of the body appressed to it (Fig. 13). The female was present in 127 of 130 (98%) retreats with unhatched eggs, all 17 retreats with prelarvae, and 44 of 45 (98%) retreats containing larvae. She was present in 16 of 24 (67%) retreats with first instar nymphs and only six of 82 (7%) retreats from which all spiderlings had dispersed. The female quickly investigates disturbances such as human-made breaches in the leaf or the silken lining and will persistently bite at pins or forceps inserted through such an opening. Tears or cuts in the silken lining are quickly repaired.

Number of instars.—Development of *Clubiona pacifica* proceeds as follows. A non-mobile prelarva hatches from the

Figures 10–13.—Egg sacs of *Clubiona pacifica*. Figures not all to same scale. 10, Top view of an egg sac with arrows indicating the bridge-like layer of silk. Some eggs have hatched yielding prelarvae (shed chorions are bright white); 11, Top view of egg sac with unhatched eggs. Bridge of silk on which egg sac rests indicated by arrows; 12, Side view of egg sac showing layered arrangement of eggs. Air spaces above and below egg sac indicated by arrows; 13, Female *C. pacifica* resting atop her egg sac in "guarding" position. Bridge-like layer of silk supporting the egg sac indicated by arrows.

egg and in turn molts to a larva, a non-self-sufficient stage with limited mobility. The first instar nymph that follows is self-sufficient, has complete mobility and functional spinnerets, and is capable of prey capture (see Foelix 1996). First instar nymphs disperse from the egg sac retreat, and many take up temporary residence in lepidopteran-rolled alder leaves. Three females and one male *C. pacifica* reared to adulthood from first instars had each passed through six nymphal stages. A spider with markedly swollen pedipalps that died as a sixth instar nymph was presumably a sub-adult male, while three spiders with slender pedipalps that also died as sixth instars were presumably sub-adult females. Although the number of nymphal instars is variable in some spider species, results for this small sample showed that some *C. pacifica* develop through six nymphal instars and reach adulthood as seventh instars.

Maximum carapace width was measured for 31 larvae and 1268 specimens of all later stages. Carapace width of larvae averaged 0.55 mm (range: 0.51 – 0.66 mm). Distribution of carapace widths for all other individuals is shown in Fig. 14. First instar nymphs (collected from egg sacs prior to dispersal) averaged 0.61 mm in width ($n = 47$; range: 0.53 – 0.66 mm). An additional 481 spiderlings with carapace widths of 0.66 mm or less were likely first instars for an overall mean width of 0.60 mm. First instars in Fig. 14 are centered on the tall peak at 0.61 mm. The modest peak centered on 0.73 mm likely represents second instars. An estimated width range for second instars of 0.68 to 0.83 mm included 194 individuals with a mean width of 0.74 mm. The frequency distribution of

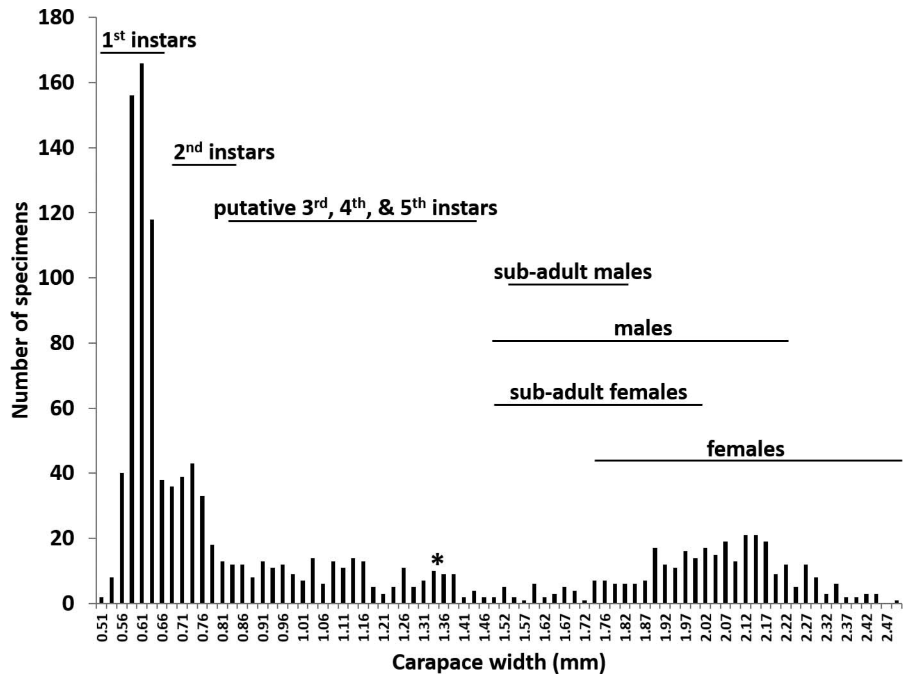


Figure 14.—Distribution of maximum carapace widths and size ranges for the different instars in *Clubiona pacifica* (1268 specimens measured). Sub-adults are 6th instars; adults are 7th instars. Asterisk indicates size of a reared 5th instar nymph. See text for further explanation.

carapace widths was of less use in assigning size limits to later instars (Fig. 14).

The range in carapace widths of sub-adults and adults in Fig. 14 is based on known and presumed representatives of these stages. Sub-adult males averaged 1.67 mm in width ($n =$ 6; range: 1.54 – 1.84 mm), and while adult males were larger (mean = 1.90 mm; $n = 61$; range: 1.44 – 2.20 mm), some fell within the size range of sub-adults. Three reared sub-adult females measured 1.59, 1.69, and 1.74 mm, and the largest presumed sub-adult female was 1.99 mm. Assuming a lower size limit for sub-adult females of 1.44 mm, 42 specimens fell within the range 1.44 – 1.99 mm for a mean width of 1.65 mm. Adult females averaged 2.12 mm in width ($n = 228$; range: 1.74 – 2.5 mm) and again overlapped with sub-adults.

Third, fourth, and fifth instar *C. pacifica* could not be assigned definitive size ranges but must largely fall within the 0.83 mm to 1.44 mm range. A reared fifth instar measured 1.34 mm (Fig. 14, asterisk). Some overlap in size between the three instars seems likely given the overlap between adults and sub-adults.

Seasonal Phenology.—Table 1 presents a bi-weekly summary of the contents of 325 egg sac retreats. Retreats were found from 22 June (2005) to 21 September (2006). Age-composition of the immature stages in retreats changed as the season progressed. From late June to late July, the egg was the most frequently encountered stage. Prelarvae were infrequently encountered, perhaps because this stage is short-lived. Larvae were abundant during the second half of July, and first instar nymphs were common during late July and early August. Throughout August and September retreats containing only shed exoskeletons were common, the first instar nymphs having dispersed. Also, by this time, alder leaves were senescing, and egg sac retreats were deteriorating.

The earliest first instar nymphs in rolled alder leaf samples were singletons on 7 June (2006) and 21 June (2006), presumably overwintered individuals. On both dates older spiders were more common than first instars. From mid-July to late September first instars were often found in rolled alder leaves. A 210 leafroll sample from 11 August (2003), for example, included 41 leafrolls (19.5%) with one or more first instars. Twenty-two larger *Clubiona* were also found. The number of first instars in rolled leaves declined from the latter half of August (257) to the first half of September (14).

The earliest second instar nymph was extracted from old alder catkins on 11 May (2006) when alder was beginning to leaf out. Two second instars were found in rolled leaves on 7 June (2006), as was a single specimen on 21 June (2006). All were likely overwintered individuals. Second instar numbers in rolled alder leaves increased in late July, peaked during August, then declined during September. However, second instars outnumbered firsts in both bi-weekly September collection periods. Putative third, fourth, and fifth instar nymphs were found from late May through late September. Presence of first through fifth instar nymphs in September suggests that all five stages overwinter.

Fewer spiders were collected as sub-adult males (21) than any other stage. Sub-adult males were found as late as 28 August and these late season individuals presumably overwinter in this stage. Putative sub-adult females were collected in larger numbers (64) than their sub-adult male counterparts and were found during all bi-weekly sampling periods except the first half of May. They were most abundant from late July to late August. Late season sub-adult females likely overwinter and reproduce the following year.

Male *C. pacifica* were found from late June to late September. It is not known if September males were old spiders, already mated and destined to die soon, or if they were

Table 1.—Contents of *Clubiona pacifica* egg sac retreats for the seven consecutive, bi-monthly intervals during which retreats were found. Data for all years of the study are included. Occasional retreats containing more than one immature stage were included in the category of the most numerous stage.

Date	No. of retreats	Female spider	no immatures[1]	Eggs	Prelarvae	Larvae	N1s[2]	Exuviae	Parasitoid
6/16 – 6/30	29	29	4	23	1	0	1	0	0
7/1 – 7/15	76	74	3	62	7	2	0	1	1
7/16 – 7/31	108	97(3)[3]	1	37	8	34	12	8	8
8/1 – 8/15	46	14(1)	1	2	1	6	7	26	3
8/16 – 8/31	43	11(2)	0	6	0	1	3	28	5
9/1 – 9/15	11	4	1	0	0	2	1	7	0
9/16 – 9/30	12	0	0	0	0	0	0	12	0
Totals	**325**	**229(6)**	**10**	**130**	**17**	**45**	**24**	**82**	**17**

[1] Retreats in which the female *C. pacifica* was present but had not yet laid eggs.
[2] First instar nymphs.
[3] Number in parenthesis is the number of egg sac retreats, out of the total, in which the female spider was present but was dead or moribund.

young spiders which then overwintered and mated the following year. Females occurred in all sampling periods in at least low numbers and were found in rolled leaves as late as 29 September (2010). Like adult males from the same time period, it is not known if these were post-reproductive individuals, soon to die, or if some were young and would overwinter and reproduce the following year.

Our data indicate that all nymphal instars of *C. pacifica*, with the possible exception of sub-adult males, as well as adult males and females can be found in rolled alder leaves as late as the second half of September. Presumably, all these stages overwinter, and specimens of most of them were found in early season samples (May and first half of June) prior to the species' reproductive period. Unfortunately, we know little of the fate of the spiders once alder and other host plants lose their leaves in the fall. Some individuals apparently make their way to the ground, as evidenced by a single female extracted from a litter sample collected beneath alder trees on 11 May (2006). Other possible overwintering sites are unknown.

Based on the contents of egg sac retreats, the reproductive period of *C. pacifica* is primarily June and July since 124 of the 132 (94%) egg sacs containing eggs were found during the six-week period from mid-June to the end of July (Table 1). It seems unlikely that spiders that overwinter as first and second instars can reach adulthood in time to reproduce during the June-July time period. These individuals may overwinter a second time, this time as late stage nymphs, completing development and reproducing the following year, thus exhibiting a two-year life cycle. On the other hand, more successful foragers or spiders that develop from eggs laid early in the season might reach later nymphal stages in time to overwinter. The following year, such individuals might then be able to complete development in time for the June/July reproductive period, exhibiting an annual life cycle. Our current lack of knowledge as to the whereabouts and activity of *C. pacifica* from October to April makes it impossible to decide if one or both scenarios is correct.

Male – female interactions.—Mating by *C. pacifica* was not observed, but on three similar occasions an adult male was found in association with one, or in one case two, sub-adult females. In each case (one on 13 August 2009, two on 28 July 2010) the spiders were found in association with an alder leaf that had been folded into an apparent egg sac retreat of typical form (see above), although no eggs were present.

Use of rolled alder leaves by *Clubiona pacifica*.—Alder leaves rolled by lepidopteran larvae were frequently occupied by *C. pacifica* and used for a variety of purposes. Lepidopteran leafrolls were occasionally used by female *C. pacifica* as ready-made shelters in which to construct egg sacs, and 20 (0.3%) of the 6101 rolled *Alnus* leaves examined contained a female *C. pacifica* and her egg sac.

Rolled alder leaves were frequently used as protected sites for molting and passing inactive periods, as evidenced by the presence of tubular silken retreats. Such retreats were common in some rolled leaf samples. For example, 64 leafrolls in a 210 leafroll sample (30%) collected on 11 August 2003 contained one or more tubular silken retreats. Fifteen contained a live *Clubiona*, 18 contained a shed *Clubiona* exoskeleton, three contained a shed salticid exoskeleton, and 33 were empty.

Among the spiders and predatory insects found in rolled alder leaves, *Clubiona pacifica* was the most common. It occurred in nearly twice as many rolled leaves as the minute pirate bug *Anthocoris antevolens* White, the next most common predator (Miliczky et al. 2014). A third use of rolled alder leaves is as a hunting site, and at least two instances of possible predation on leafroller larvae were found. In both cases the *C. pacifica* was found in a leafroll with a dead leafroller larva that showed signs of spider predation according to criteria used by Miliczky & Calkins (2002): larva flaccid, discolored, and leaking bodily fluid. A wide variety of other arthropods occurred in the rolled leaves as secondary occupants and were potential prey (Miliczky et al. 2014).

Predation experiments.—Nineteen of 32 (59%) spiders assayed preyed upon leafrollers in the cage studies (Table 2). Most leafrollers were attacked as larvae, and a vigorous attack on a *Ca. alnicolella* larva was observed. Two pupae and an emerged adult were also preyed upon. All sizes of spiders, except small immatures, attacked leafroller larvae. In one test, six females collectively consumed 25 of 27 (93%) larvae that had been offered. Of 18 *C. pacifica* exposed to *Pandemis pyrusana* egg masses, only two adult females fed on eggs, but nine other individuals fed on neonate larvae that hatched during the tests.

Natural enemies.—Three species of parasitoid wasps in the family Ichneumonidae were reared from *C. pacifica*. *Gelis* sp. [Cryptinae: Phygadeuontini] attacked the eggs, and wasp cocoons were found in 17 of 325 (5.2%) egg sac retreats. The number of parasitoids per egg sac ranged from one to four. In

Table 2.—Results of eight experiments examining predation of leafroller larvae by *Clubiona pacifica*. See also Miliczky & Calkins (2002) for criteria used to define predation. Host plants of *Pandemis pyrusana* and *Choristoneura rosaceana* include apple and pear (in addition to alder), on which they are secondary pests in central Washington orchards. Hosts of *Caloptilia alnicolella* are *Alnus* spp.

Host Plant	Leafroller	*Clubiona* tested[2]	LRs[3] available	LRs consumed	*Clubiona* that fed
Pear seedling (2)[1]	*Pandemis*	3 f; 3 m; 3 s	28	11 (39%)	2 f; 3 m
Pear seedling (1)	*Choristoneura*	2 f; 1 l; 1 m	20	4 (20%)	1 f
Apple seedling (2)	*Pandemis*	6 f; 2 l	34	31 (91%)	6 f; 2 l
Small apple tree (2)	*Choristoneura*	5 f; 1 l; 2 m	36	11 (31%)	3 f
Alder cutting (1)	*Caloptilia*	2 m	13	8 (62%)	2 m

[1] Number of experiments using this host plant and leafroller combination
[2] f -adult female; l – large immature; m – medium immature; s – small immature
[3] Leafrollers

eight of the 17 (47%) parasitized egg sacs the female *Clubiona* was still present in the retreat. One to 56 eggs escaped consumption in each of 12 parasitized egg sacs, and some of these produced first instar *Clubiona* nymphs. The *Gelis* larva spins a tough, reddish brown cocoon within the egg sac or elsewhere in the egg sac retreat. The cocoon is elongate oval, about 5.5 mm long ($n = 8$), and the adult wasp emerges from the side of the cocoon near one end. A hyperparasitoid (Hymenoptera: Eulophidae) emerged from one *Gelis* cocoon.

Two female and one male *Schizopyga frigida* (Cresson) [Ichneumonidae: Pimplinae: Ephialtini] were reared from *Clubiona pacifica*: two from female spiders found in egg sac retreats and one from an immature spider found in a rolled leaf. The *S. frigida* larva feeds externally, usually near the host's petiole, and spins an elongate cocoon of open mesh silk upon completion of feeding. The parasitized spiders were found between 13 July and 23 August and the adult wasps emerged within a month of discovery.

A single *Zaglyptus varipes* (Gravenhorst) (or a new species near *varipes*) [Ichneumonidae: Pimplinae: Ephialtini] was reared from a sub-adult male *C. pacifica* found in a rolled alder leaf on 14 August 2006. The spider appeared dead or paralyzed when found. The parasitoid larva fed externally on the host's abdomen, developed rapidly at ambient temperature, and the adult male wasp emerged on 1 September 2006.

DISCUSSION

Clubiona spiders occur in a wide variety of habitats including forests, beaches, dunes, montane areas, meadows, prairies, and bogs (Edwards 1958; Dondale & Redner 1982). In North American coniferous forests, they often occur in the canopy (Renault & Miller 1972; Jennings & Collins 1987; Jennings & Dimond 1988; Jennings et al. 1990; Halaj et al. 1998) but have also been taken in pitfall traps (Jennings et al. 1988) and malaise traps (Jennings & Hilburn 1988). Several species inhabit the space beneath loose bark of eucalyptus trees in Australia (Austin 1984).

Clubiona pacifica has previously been recorded from fir forests, subalpine meadows, salt marshes, and lake shores (Dondale & Redner 1982). Within our study area *C. pacifica* occurred in riparian habitat where it was common on species of *Alnus* but was also found on other shrubs and trees including *Salix*, *Crataegus*, and *Cornus*. Since we did little sampling of herbaceous riparian vegetation or in habitats distant from water, we can say little about its occurrence in such locations. Because maximum sampling height was about 4 m, the species' presence at greater heights, such as in tall *Alnus rubra* trees, is also unknown. A single male spider was found overwintering in a cardboard band in a pear orchard on 29 January 2002 (unpublished data). This orchard, near the town of Sunnyside, was well to the east of our study area but was near extensive riparian habitat along the Yakima River.

A review of spiders in United States agroecosystems found that *Clubiona abboti* L. Koch, 1866 was one of the 42 most frequently occurring spiders in those systems (Young & Edwards 1990). This species is known to prey on eggs of *Helicoverpa zea* (Boddie) (Noctuidae) in corn and soybean (Pfannenstiel & Yeargan 2002). Pfannenstiel (2008) also observed predation on lepidopteran eggs by *Clubiona kiowa* Gertsch, 1941 and *Clubiona maritima* L. Koch, 1867, and felt that predation by *Clubiona* spiders may be under-appreciated because of their primarily nocturnal habits. *Clubiona pikei* Gertsch, 1941 was abundant in Quebec corn fields where it may feed on aphids (Provencher & Coderre 1987). *Clubiona canadensis* and *Clubiona trivialis* C.L. Koch, 1843 prey on the eastern spruce budworm *Choristoneura fumiferana* (Clemens) (Tortricidae), a major forest defoliator (Loughton et al. 1963). Our greenhouse tests indicate that *C. pacifica* readily attacks and feeds on leafrolling Lepidoptera.

Many temperate zone spiders have annual life cycles and complete a single generation per year (Gertsch 1979; Foelix 1996). Four species of *Clubiona* studied in South Australia, for example, had annual life cycles (Austin 1984). Within the temperate zones, however, spiders encounter a vast range of latitudes and great differences in elevation, and their life cycles may be more variable. More than half of the 52 species monitored in a Danish beech woodland, including four species of *Clubiona*, had biennial life cycles (Toft 1976, 1978), and at a similar latitude in Sweden three dune inhabiting *Clubiona* were likewise biennial (Almquist 1969). Almquist (1969) also noted that the species he studied tended to have life cycles that were twice as long as the same or related species in southwestern Europe. The elevation at our study sites (750 m to 1480 m) leads to a relatively short growing season, with snow present on the ground at some sites as late as May some years. Based upon our finding of overwintered first and second instar spiderlings early in the season, prior to *C. pacifica*'s June/July reproductive period, we believe at least some *Clubiona pacifica* individuals in our study population require two years to complete development.

The number of molts needed to reach maturity varies among spider species (Gertsch 1979; Foelix 1996). Even within a species total molts may vary, and the often-smaller male may require fewer than the female (Gertsch 1979). Toft (1978) noted maturity at the sixth instar in four species of *Clubiona*. Female *Clubiona robusta* L. Koch, 1873 reached maturity in the seventh or eighth instar while males did so at instars five, six, or seven (Austin 1984). Laboratory reared *Clubiona phragmitis* C. L. Koch, 1843 yielded adults at the fifth, sixth, and seventh instars (Schaefer 1977). Both sexes of *C. pacifica* reached adulthood at the seventh instar in our laboratory rearings, but the range in carapace width of field-collected adults suggests that maturity may be obtained in more than one instar in both sexes.

Spiders enclose their eggs in silken sacs that vary widely in form. These egg sacs may provide protection against opportunistic predators such as ants, but co-evolution between spiders and specialized natural enemies may be responsible for their great diversity in form (Austin 1985). Some *Clubiona* may gain extra protection for their eggs by concealing them. *Clubiona cambridgei* L. Koch, 1873 constructed egg sacs within dead, curled leaves of New Zealand flax (Pollard 1984), and Austin (1984) found *Clubiona* egg sacs beneath loose *Eucalyptus* bark. Like *C. pacifica*, *Clubiona riparia* L. Koch, 1866 places its egg sac within a chamber formed by the precise folding of a leaf, and a number of different plant species are utilized (Suter et al. 2011).

Passive protection afforded the eggs by the egg sac and associated structures may be supplemented by active female care (Gertsch 1979; Foelix 1996). *Clubiona* females frequently remain with their egg sacs until the young spiderlings have dispersed (Austin 1984; Suter et al. 2011), as was true for *C. pacifica*. *Clubiona pacifica* females also grabbed at probing insect pins with their chelicerae and quickly closed tears in the silken lining of the retreat. Pollard (1984) noted predation by *C. cambridgei* on unattended eggs of conspecifics whereas eggs with the female in attendance were largely immune from such attacks.

The presence of *C. pacifica* adult males in close association with sub-adult females suggests that males can locate soon-to-be-adult females. Cohabitation of adult males with immature females is a common mating tactic of spiders, including species of *Clubiona* (Jackson 1986). Pollard & Jackson (1982) noted that adult male *C. cambridgei* spin a silken chamber next to that of a sub-adult female and mate with her after her final molt.

Our study of *Clubiona pacifica* addressed several life history questions, but many gaps in our understanding of this species remain. Verification of a two-year life cycle at our higher elevation sites would require additional sampling and determination of overwintering stages. If a biennial cycle is confirmed at these higher elevation sites, might the species exhibit an annual cycle at lower elevations? Our interest in *C. pacifica* arose initially from the idea that this species might have potential as a predator of pest leafrollers in orchards. Greenhouse feeding trials showed that *C. pacifica* had an often-considerable appetite for leafrollers. Given that species of *Clubiona* frequently occur in agroecosystems and are known to prey on a variety of pest insects, further study of their natural history as well as their biocontrol potential in agricultural systems is warranted.

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