The life history of a Colorado population of *Kogotus modestus* (Plecoptera: Perlodidae)

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Abstract

The life history of *Kogotus modestus* was studied from July, 1999, to February, 2001, at 3,048 meters elevation in Colorado. Adults emerged in late August. Eggs are "turtle-shaped" and measure 412 to 427, and 323 to 337 micrometers in length and width, respectively. Eggs diapaused for 222-258 days from August, 1999 to April-May, 2000. Hatchlings are described for the first time. Early instar larvae first appeared in October-December and were present until the following March. The life cycle was semivoltine. Larvae developmentally lost their 2nd lacinial tooth, and late instars fed almost exclusively on chironomids.

Keywords: Plecoptera, stonefly, *Kogotus*, life history.

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Introduction

The North American perlodid stonefly genus *Kogotus* RICKER, 1952 contains two western species *Kogotus modestus* (BANKS, 1908) and *Kogotus nonus* (NEEDHAM & CLAASSEN, 1925). They have substantially derived morphological characters in all life stages and greatly specialized, derived drumming signals. The eggs have not been previously described, but we supposed that they might be of the apomorphic Diploperlini type (Stark *et al.*, 1988). The unidentate lacinia of the late instar larvae (Stewart and Stark, 1984, 1988) is apomorphic, and the male epiproct with its short basal sclerite and anterior coiled band, is greatly specialized, constituting an apomorphy, and is shared only with the sister genera *Baumannella* STARK & STEWART and *Osobenus* RICKER (Stark and Stewart, 1985). The grouped, bi-beat drumming calls of *K. modestus* are apobehavioric and have been demonstrated by computer simulation with live females to contain essential informational content for female recognition and response (Stewart and Maketon, 1990).

The life history of *K. nonus* is poorly known (Stewart and Stark, 1988), except that its emergence period is April to September, depending on altitude and latitude (Jewett, 1959; Sheldon and Jewett, 1967; Gaufin *et al.*, 1972; Baumann *et al.*, 1977). Knowledge of the life history and other biological aspects of *K. modestus* is largely anecdotal. Its life cycle was characterized as univoltine in Colorado by Allan (1982), based on presence of uniform-sized late instars in August. Larvae fed predominately at night on chironomids and to a lesser extent in daytime on the mayfly *Baetis* (Walde and Davies, 1984). Allan *et al.* (1987) found experimentally that small *K. modestus* larvae, offered an array of *Baetis* prey sizes, exhibited strong, positive selection for the smallest prey, decreasing progressively to strong avoidance of the largest sizes.

We located an abundant population of *K. modestus* in Gunnison County, Colorado, in 1998, and began this study in 1999, to elucidate its emergence, adult behavior, egg morphology and development, first instar morphology, larval growth phenology and development and food habits, and voltinism.

Study Stream

Sampling and observations were done within 100 m of the confluence of 1st order Hooper Creek and 2nd order Halls Gulch Creek at 3,098 m elevation and 38°38.92'N, 106°29.07'W, in Gunnison County, Colorado. The site is accessed from May to November by Gunnison County Highway 76, then Forest Service Road 766, and is about 8.5 km northwest of the town of Pitkin. The road from Pitkin is closed by gate from about December to May, when access to the stream site is by snowshoes, skies or snowmobile. The watershed has experienced little development and human infringement, except for a few low-occupancy summer cabins, low-level cattle grazing and logging, and abandoned gold and silver mines. Riparian vegetation is dominantly willow (*Salix* sp.) with scattered Engelmann Spruce (*Picea engelmanni*). Stream water is generally clear and unpolluted, except during snowmelt or occasional heavy rainfall, and substrate is gravel-cobble except at beaver ponds.

Material and Methods

The study was carried out from July, 1999, to March 2001. Larvae were qualitatively sampled in May, 2000, June, 2000, July, 1999, 2000, August 1999, October, 1999, December, 1999, 2000, and March, 2001, with a kick net having 0.5-0.8 mm mesh opening. Larvae were preserved in 80% ethanol until measurement of interocular distance (IOD) between the insides of compound eyes with a calibrated ocular micrometer fitted to a Wild M-5 stereomicroscope. The multiple-year July and December samples were pooled for determination of larval growth phenology and voltinism. Late instar larval guts from August, 1999, and July, 2000, samples were examined for identifiable contents.

A malaise trap was installed on the site during late July-October, 1999, directly over the confluence; it intercepted the entire width of the 1st order, and part of the 2nd order portion of the confluence, and its inside wings projected down to near the water surface. Adults were collected with a beating sheet along an approximate 50m stretch adjacent to the confluence during peak adult presence in late August, 1999. An intensive search for exuviae was made on the potential transformation substrates of debris, vegetation and rocks at stream margins along this same stretch during the same time. Field collected adults were kept together in ventilated, shaded vials near a stream for insured mating and attempted egg mass collection. Eggs from presumed-mated females were kept in stream water in vials with a 210-µm-mesh cover, and transported on ice to Texas, then incubated in a laboratory stream containing de-ionized water at approximate simulated stream temperatures and photoperiod. Eggs were examined weekly under a stereomicroscope for hatching, and we attempted to retard fungal growth by addition of methyl blue and the anti-fungal treatment MarOxy® (Mardel Laboratories Inc.). Hatchlings (1st instars) were preserved in 80% ethanol and later drawn with a Wild Drawing Attachment. Scanning electron micrographs (SEM) of *K. modestus* were provided by B. P. Stark. Water chemistry in Hooper Creek, and directly upstream of the confluence in Halls Gulch Creek, was measured on June 11, 2001, by K. D. Alexander with a Datasonde 4A Hydrolab.

Results and Discussion

June water chemistry data for Hooper and Halls Gulch Creeks are presented in Table 1; they reflect a low-ion, clean water condition typical of little-impacted streams of this region. Larvae inhabited the gravel-cobble substrate of both creeks.

Table 1 - Water chemistry data for Hooper and Halls Gulch Creeks, Gunnison County, Colorado, June, 2001.

	1st order Hooper Creek	2nd order Halls Gulch Creek
Temperature	6.72°C	7.96°C
Dissolved oxygen	8.29 mg/l	7.52 mg/l
Specific conductance	254.9 mµs/cm	171.8 mµs/cm
Salinity	0.12 ppt	0.08 ppt
Turbidity	17.4 NTU	12.5 NTU
Total Dissolved solids	0.1632 g./l	0.1094 g./l
pH	8.66	8.5
Oxygen saturation	63.5%	62.4%

Adults. – Our previous observations at this site and collections in late August, 1999, indicated a synchronized emergence at this elevation during the last two weeks of August and early September, at daytime stream temperatures of 8.9-10°C. Daily collections Aug. 16 to 21 (Fig. 1) were 1 female, 18 males: 7 females, 29 males: 14 females, 36 males: 13 females and 10 males: 5 females. No adults were collected in the malaise trap from July-October that year; this and beating sheet collections from streamside willows suggest that they fly little horizontally along the streams, and are probably bush-toppers (Stewart, 1994). Six male and one female exuviae collected during a week after mid-August in 1999, were found mostly on wood debris jutting out of, or very close to, the waters edge. Oviposition behavior was not observed in the field.

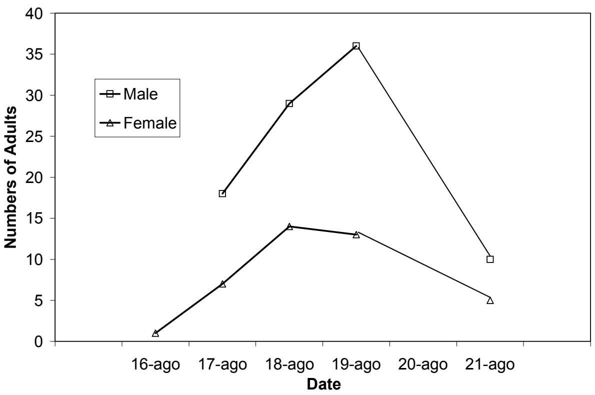

Fig. 1 - Adult presence of *K. modestus*, Aug. 16-21, 1999.

Eggs. – *K. modestus* eggs (Fig. 2) are "turtle-shaped"; their dorsal surface has an anterior "lid" covering the collar and anchor, and is rounded, and the ventral surface is flat. Four eggs, measured in dorsal orientation, ranged from 412 to 427 and 323 to 337 micrometers in length and width, respectively, and the lid from 69.6 to 75.6 micrometers. The collar diameter of three eggs ranged from 46.8 to 50.3 micrometers. The lid is coarsely reticulate over the entire surface, but the dorsal and ventral surfaces lack distinct cell impressions; there is an irregular, slightly granular character on the dorsal surface and sometimes faint follicle cell impressions on the ventral surface. The micropyles are in an irregular ventral line located midway between the collar and the equator. There is no dorsal keel as is present in some Diploperlini (Stark *et al.*, 1988).

Only one partially viable egg mass was field-collected from a presumably mated female on August 20, 1999. From this mass, 4 eggs hatched on April 2, 2000, requiring approximately 222 days and 2,827 degree days to develop (Table 2). A second hatch occurred on May 6, 2000, producing 9 more hatchlings, requiring approximately 258 days and 3,086 degree days to develop. These data proved at least one over-winter egg diapause of approximate 7.5 - 8.5 month duration, similar in duration but not season to the perlodid *Hydroperla crosbyi* (Needham & Claassen) (Oberndorfer and Stewart, 1977). Further research is needed to determine if direct hatching and/or longer than one winters diapause are possibilities.

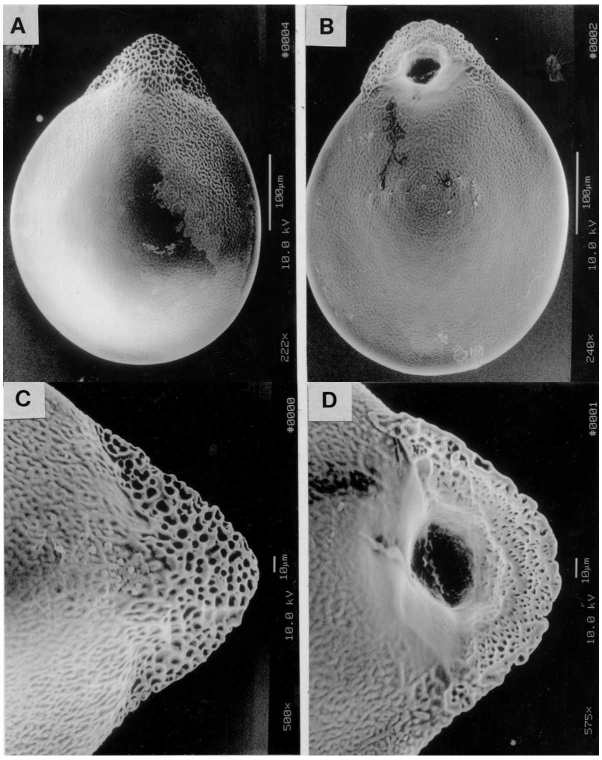

Fig. 2 - Scanning electron micrographs of *K. modestus* egg. A. Dorsal; B. Ventral, showing micropyles; C. Dorsal hood; D. Ventral hood.

Table 2 - Laboratory stream incubation conditions and hatching results of one *K. modestus* egg batch, 1999-2000.

Date	Number of days	Temp. °C	Degree days	Accumulated degree days	Eggs hatched
22 Aug.-15 Feb.	175	13	2,275	2,275	—
15 Feb.-15 Mar.	30	15	450	2,725	—
15 Mar.-02 Apr.	17	6	102	2,827	4
02 Apr.-15 Apr.	14	6	84	2,911	—
15 Apr.-30 Apr.	15	7	105	3,061	—
30 Apr.-01 Jun.	7	10	70	3,086	9

First instars. – The 13 first instars hatching from the above egg incubation experiment (Fig. 3) were unpigmented, had 9 antennal and 3 cercal segments, and their mean interocular distance was 0.172 mm. These characters are similar in segmentation, and generally in setation, to the first instars of *Isoperla lata* Frison (Sandberg and Szczytko, 1997); *K. modestus* first instars differ from those of *H. crosbyi* (Oberndorfer and Stewart, 1977) in having one less cercal segment, possessing additional pairs of setae along the dorso-mesal anterior margins of the meso- and metanota, and slight differences in the number and arrangement of anterior labral setae.

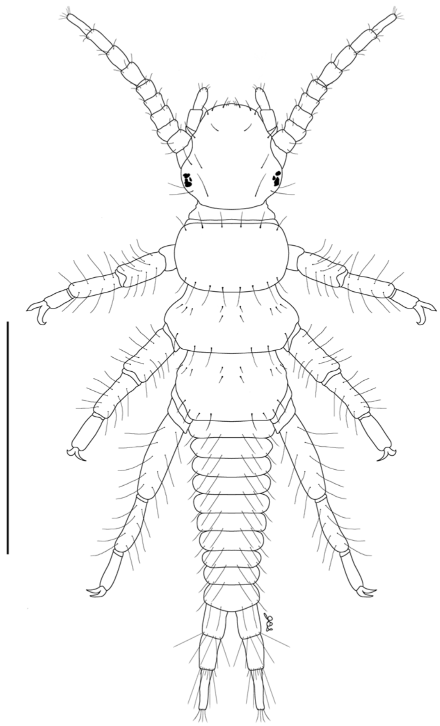

Fig. 3 - *K. modestus* first instar larva. (bar=0.5mm).

Larvae and voltinism. – First instars (laboratory IOD 0.193) were not detected in the field, in part due to mesh size of the kick net. Therefore, growth phenology from that size in about April-May (laboratory hatch period) to the first detected larvae in October-December at mean IOD of 0.69 mm (Fig. 4) remains unknown. The continued presence of early instars into March suggests that breaking of diapause and recruitment of hatchlings might continue through the second winter. Only a single larval year class was evident May-August, until emergence in late August. This, and the approximate 7.5-9.5 month diapause, demonstrated by laboratory incubation, results in interpretation that the life cycle of this population was semivoltine. The gaps in early instar sampling and data in Fig. 4 leave open the possibility of cohort splitting into semivoltine slow and semivoltine fast cycles.

An interesting developmental change, not previously reported in Plecoptera, was gradual loss of the second lacinial tooth and inner marginal setae, present in hatchlings and early instars (Fig. 5) to about 1.41mm (range 0.48-1.41) IOD, resulting in the typical unidentate lacinia of late instars illustrated by Stewart and Stark (1988). This lacinial character is shared in North American Perlodidae only with some *Isoperla* Banks species and the two sister Diploperlini genera *Remenus* RICKER and *Rickera* JEWETT.

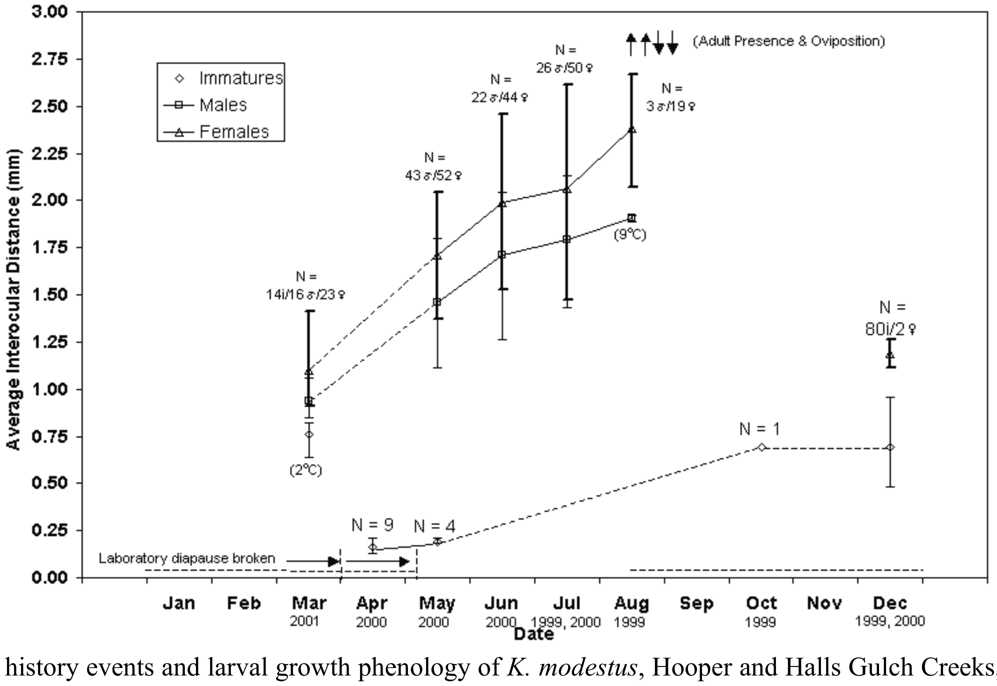

Fig. 4 - Life history events and larval growth phenology of *K. modestus*, Hooper and Halls Gulch Creeks, Colorado, 1999-2000. Vertical bar = IOD range; numbers above each vertical bar represents n sampled and measured, and temperature parenthetically if measured.

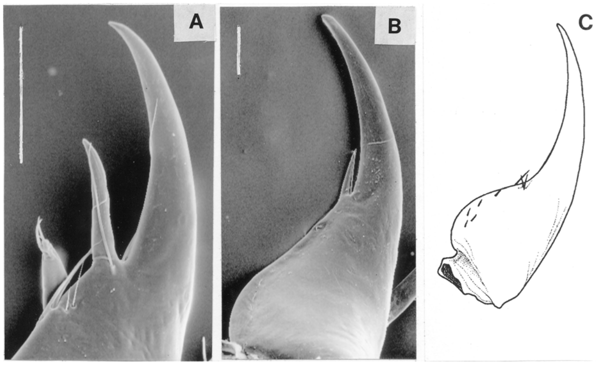

Fig. 5 - Scanning electron micrographs of early and mid-instar *K. modestus* lacinia and drawing of late instar lacinia of *K. nonus* (after Stewart and Stark, 1988). A. Lacinia of 0.66mm IOD larva (bar=100µm); B. Lacinia of 1.25mm IOD larva (bar=100µm); C. *K. nonus* mature lacinia (similar to *K. modestus*).

Late instar larval food habits. – Analysis of 30 late instar larval guts from August, 1999 and July, 2000, samples (Table 3) indicated an almost exclusive propensity to feed on multiple-sized chironomid larvae. There appeared to be a strong election for small larvae, since large numbers were ingested, up to 40 in a single male gut and up to 63 in a single female gut. Allan *et al.* (1987) found experimentally a strong positive election in small *K. modestus* for small *Baetis* prey. The total lack of identifiable prey in the guts of male larvae in mid-August, 1999, indicated that as pre-emergers, they had stopped feeding; some females at that time were still actively ingesting prey. The small amounts of sand in guts (Table 3) was possibly residual from the guts of digested chironomids.

Table 3 - Gut contents of 30 late-instar *K. modestus* larvae, Halls Gulch Creek, Colorado, 1999-2000.

August 16, 1999			July 30, 2000	
Sex	Prey by numbers	Matter by average % volume	Prey by numbers	Matter by average % volume
Males [1.]	None	Amorphous organic- in 5 guts (50%)	Chironomidae larvae- 68 in 2 guts (ave. 34%)	Amorphous organic- in 5 guts (62.4%) Inorganic- in 1 gut (1.75%)
Females [2.]	Chironomidae larvae- 125 in 4 guts (ave. 31.3%) Ephemeroptera - 1 each in 2 guts Plecoptera- 1 each in 2 guts Ancylidae- 1 in 1 gut Unidentifiable insect parts- in 2 guts	Amorphous organic- in 3 guts (71.6%) Inorganic- in 1 gut (1%)	Chironomidae larvae- 79 in 5 guts (ave. 15.8%) Ephemeroptera- 1 in 1 gut Trichoptera- 1 in 1 gut Simuliidae pupa- 1 in 1 gut Unidentifiable insect parts- in 1 gut	

1. 1999 males- n=5 guts examined; 2000 males- n=8 guts examined (3 empty)
2. 1999 females- n=9 guts examined (5 empty); 2000 females- n=8 guts examined (2 empty)

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